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Greenhouse Gas Accounting for Sustainable Land Management

Quick Guidance for Users

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Abstract

Agriculture, and the patterns of land use change that are associated with it, have a high environmental footprint and contribute to climate change, as the sector accounts for about one-quarter of anthropogenic greenhouse gas (GHG) emissions globally. However, improved land management practices can play an important role in mitigating GHG emissions by removing substantial volumes of carbon from the atmosphere and sequestering them in soils and plant tissues.

We can't fix what we do not measure, which is why quantifying greenhouse gas emissions is a necessary step for climate-smart agriculture and sustainable land management. Greenhouse gas accounting can provide the numbers and data that are important to decision making in adopting less carbon-intensive practices, guiding low-emissions development, assessing product supply chains, certifying sustainable agriculture practices, and informing consumers on the carbon footprint of their choices.

This *Quick Guidance* on Greenhouse Gas Accounting for Sustainable Land Management provides an overview of SLM activities subject to greenhouse gas appraisal, guidance in the selection of tools, data needs for the application and final use of the greenhouse gas accounting tools. It complements the more comprehensive *Carbon Accounting Tools for Sustainable Land Management* report, and it is targeted at leading resource managers and project developers to proficiency in the independent use of greenhouse gas accounting tools.

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1. Introduction

Agriculture, and the patterns of land use change that are associated with it, have a high environmental footprint and contribute to climate change, as the sector accounts for about one-quarter of anthropogenic greenhouse gas (GHG) emissions globally. At the same time, agriculture is strongly influenced by weather and climate (Battisti and Naylor 2009; IPCC 2001; Lobell et al. 2008).

However, climate change can offer new opportunities for productive and sustainable land management (SLM) practices, such as reforestation, improved water management, integrated soil fertility management, conservation agriculture, agroforestry, improved rangeland management, and others because of changing biophysical or market conditions. Improved land management practices can play an important role in mitigating GHG emissions by removing substantial volumes of carbon from the atmosphere and sequestering them in soils and plant tissues.

We cannot fix what we do not measure. Systematic assessments are required to make targeted decisions and, therefore, ensure food security. The quantification of GHG emissions and carbon sequestration is a necessary step for SLM. GHG accounting can provide the numbers and data that are key for informed decision making. It can help identify management practices and opportunities that reduce GHG emissions while also providing improved food security, more resilient production systems, and better rural livelihoods. In practical terms, GHG emissions data can support farmers in adopting less carbon-intensive practices, guiding low-emissions development, assessing product supply chains, certifying sustainable agriculture practices, and informing consumers on the carbon footprint of their choices (Olander et al. 2013).

Many tools have been developed for assessing GHG emissions from SLM in the last few years. Deneff et al. (2012) classify these tools as calculators, protocols, guidelines, and models.¹ This document provides users with helpful information for choosing the most appropriate tool for a given project. It complements the full report on comparative analysis of Carbon Accounting Tools for Sustainable Land Management.²

The primary use of this guidance note is in project design. Development practitioners who need to estimate the GHG-balance of SLM investment proposals in the agriculture, forestry and land use sector are therefore the principal intended audience. The main target users should be involved during the project design stage and pursue the objective of aligning ex-ante program and project documents in accordance with the results obtained from the GHG appraisal.

This guidance note is divided into 5 sections, including this introduction. Section 2 briefly explains SLM activities which are the prime subject of GHG analysis. Section 3 provides guidance on the selection of GHG accounting tools and how to utilize them as part of the project document design process. Section 4 discusses data types and collection and scenario

¹ In this guidance note, the terms ‘tools’ and ‘calculators’ are used interchangeably.

² For more detailed information, a glossary of terms and the complete bibliography, please refer to the full report Carbon Accounting Tools for Sustainable Land Management

building, while Section 5 concludes with carbon-balance appraisal and how using GHG accounting tools serves this purpose.

2. SLM and their Activity Categories for GHG Assessment

According to the UN Earth Summit of 1992, SLM is “the use of land resources, including soils, water, animals, and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions.” It entails the implementation of land use systems and management practices that enable humans to maximize the economic and social benefits from land (soil, water, and air) while maintaining or enhancing the ecosystem services that land resources provide.

SLM practices include technologies and approaches that aim to increase land quality to enhance productivity and, at the same time, protect the natural resource base through economically viable and socially acceptable solutions. These technologies include agronomic, vegetative, structural, and management measures, such as new seed varieties, terracing, forestation, reduced tillage, micro-irrigation, fertilizer placement approaches, and livestock-feeding schedules.

Databases such as the World Overview of Conservation Approaches and Technologies (WOCAT), TerrAfrica, the World Bank SLM Sourcebook, and the Voluntary Guidelines for Sustainable Soil Management (VGSSM) provide comprehensive recommendations and examples of SLM practices. A non-exhaustive list of SLM practices can be found in table 1.

Table 1: SLM approaches and technologies

SLM practices		
SLM approaches	SLM technologies	
Land use regimes	Agronomic and vegetative measures	Structural measures
<ul style="list-style-type: none"> • Watershed plans • Community land use plans • Grazing agreements, closures, and so on • Soil and water conservation zones • Vegetation corridors 	<ul style="list-style-type: none"> • Intercropping • Natural regeneration of trees or other vegetation • Agroforestry • Afforestation and reforestation • No tillage • Mulching and crop residue • Crop rotation • Fallowing • Composting/green manure • Integrated pest management • Vegetative strip cover • Contour planting • Revegetation of rangelands • Integrated crop-livestock systems • Woodlots • Live fencing • Alternatives to wood fuel • Sand dune stabilization 	<ul style="list-style-type: none"> • Terraces and other physical measures (for example, soil bunds, stone bunds, and bench terraces) • Flood control and drainage measures (for example, rock catchments' water harvesting, cut-off drains, vegetative waterways, stone-paved waterways, flood water diversion, and so on) • Water harvesting, runoff management, and small-scale irrigation (for example, shallow wells/boreholes, micro ponds, underground cisterns, percolation pits, ponds, spring development, roof water harvesting, river bed dams, stream diversion weir, farm dam, tie ridges, inter-row water harvesting, half-moon structures, and so on) • Gully control measures (for example, stone check dams, brushwood check dams, gully cut/reshaping and filling, gully revegetation, and so on)

The first step in GHG accounting for SLM is to determine the activity categories of agriculture, forestry and other land use sectors affected by the project (Table 2). The activity categories in turn will allow the user to select the appropriate GHG accounting tool and modules within the tool.

Table 2: Definition of activity-categories in line with IPCC's and FAO's definitions

Activities	Definition
Afforestation/reforestation	Refers to the artificial establishment of forest on lands that previously did not carry forest within living memory, while reforestation is defined as the artificial establishment and natural regeneration of forest on lands that carried forest before.
Deforestation	Refers to the change of land cover with depletion of tree crown cover to less than 10 percent. Changes within the forest class (for example, from closed to open forest) that negatively affect the stand or site—and, in particular, lower the production capacity—are termed forest degradation.
Forest management	Refers to the reductions in the productive capacity of the forest. For each activity, the initial state of the forest and its expected final states (without project and with project) were identified. It includes directly human-induced change (for example, because of improved silviculture), indirect influences (for example, nitrogen or CO ₂ fertilization), and natural causes (including natural successional processes). Within this study, two main categories of forest management were identified: fire forest management and forest management and degradation (biomass loss).
Annual cropland	Refers to lands covered with temporary broadleaf or grass-type crops that are harvested at the completion of the growing season, then remain idle until replanted. Two categories were identified for annual crops: newly implemented systems after land conversion of other land use systems and annual systems that remain annual systems.
Perennial cropland	Refers to lands covered with temporary broadleaf or grass-type crops that are harvested at the completion of the growing season, then remain idle until replanted. Two categories were identified for perennial crops: newly implemented systems after land conversion of other land use systems and perennial systems that remain perennial systems.
Grassland management	Refers to lands with herbaceous types of cover, typically graminoids. Tree and shrub cover is less than 10 percent. Two categories were identified for grassland systems: newly implemented systems after land conversion of other land use systems and grassland systems that remain grassland systems.
Livestock	Refers to a broad sense to cover all grown animals regardless of age, location, or purpose of breeding. Six main categories of livestock are fixed: dairy cattle, other cattle, buffalo, sheep, swine (market), swine (breeding), goats, camels, horses, mules, asses, poultry, deer, and alpacas.
Inputs	Refers to the use of agricultural chemicals, N fertilizer in non-upland rice systems (that is, flooded rice systems), sewage, and organic fertilizers in farm operations and based on projects activities.
Investments	Refers to electricity consumption, fuel consumption, installation of irrigation systems, and building of infrastructure.

3. Selection of tools

GHG calculators have been developed through different approaches, targets, and objectives, suitable for a defined geographic coverage. To facilitate the different activities of targeting climate change mitigation in agriculture, decision makers can today choose from a wide range of available GHG tools. These tools differ in their main objectives—reflected in different data needs, geographical scope, and coverage along the value chain as well as their regional and subsector specificity. To facilitate a more informed tool selection, six prescreening criteria are usually applied (Colomb et al. 2012, 2013):³

- 1) **Availability.** This criterion allows users to evaluate whether the tool and its technical guidelines are freely accessible online (see Annex 1).
- 2) **Geographical coverage.** This criterion allows users to evaluate the geographical context, that is, the continental regions where the tools are mostly applicable.
- 3) **Activities scope.** This allows users to evaluate to what extent the tools can handle a wide range of SLM activities.
- 4) **Data requirements.** This refers to the data that the GHG analysis is based on. This may be data available to the user before the evaluation begins, or intermediate data that are generated during the analysis. Data requirements are assessed in terms of qualitative and quantitative information (for example, state of degraded forests) and the relative accessibility of the data, especially in the context of low income countries.
- 5) **Time requirements.** This refers to the time it takes for the user to successfully conduct an analysis. Note, however, that it may be difficult to precisely estimate the amount of time necessary for each tool or assessment, as this depends on the skills of the evaluator, level of accuracy, reliability, and data availability.
- 6) **Skills requirements.** This indicates the extent to which skills needed for the analysis exceed what is considered basic evaluation skills. Such basic skills include the ability to reason logically and conduct basic GHG analysis, gather information through interviews and other qualitative methods, and write reports and present results. Without appropriate skills, impractical or inappropriate methodology may be selected, resulting in misleading conclusions. The special skills needed for conducting the different types of efficiency analyses are agronomic, forestry, or SLM skills.

Application of the prescreening criteria to ten commonly used GHG calculators (Annex 2) indicates that seven out of the 10 tools have moderately low data requirements, one (CAT-AR) requires high amounts of data, while CAT-SFM and DNDC are notably extreme in their very high data requirements. The time required for analysis given the availability of data varies from “very short” for CCAFS mitigation tool to “very long” for DNDC, CBP, EX-ACT and TARAM. There is close correlation between time and skill requirements for GHG analysis using the tools. Tools that are relatively highly skill-demanding, that is, require more than the basic skills, correspondingly require more time to perform GHG appraisals.

³ For more information on how the criteria were applied to ten commonly used GHG calculators, please refer to the full report Carbon Accounting Tools for Sustainable Land Management

Following prescreening, the suggested process for selecting a suitable GHG tool(s) is based on the characteristics of each calculator (Annex 3). These characteristics include the ability of the calculator to account for the range of SLM activities, changes in land use, different GHGs, the need for spatially explicit results, uncertainties, and leakages associated with the project. Users should select tools according to these more specific criteria, helped by the tables provided in Annexes 4 and 5.

4. Data collection and scenario building

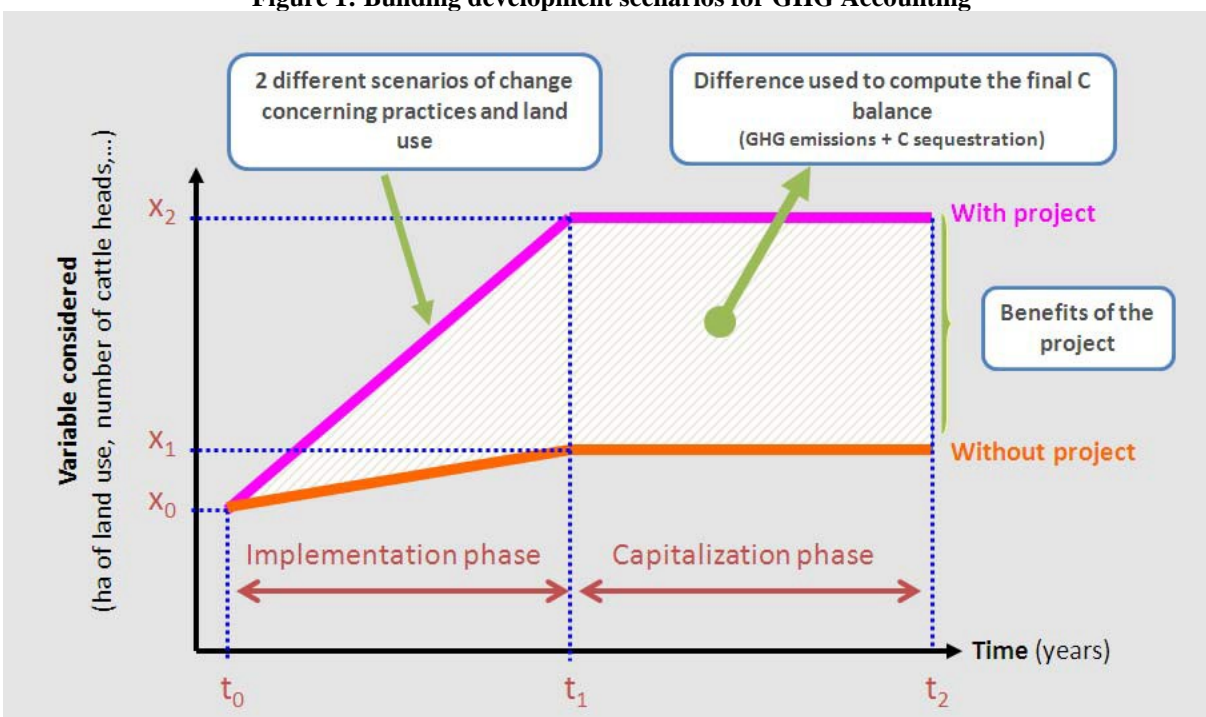
Depending on the specific project, data collection and GHG analysis is only necessary in the modules relevant to the project. The main data needs occur only in the focal areas of the project. Rather than choosing modules according to project type, the modules are chosen with respect to project impacts, that is, what is affected by the project.

This flexibility allows for the adequate consideration of multi-segment projects and leads the project designer to think of possible indirect impacts on in-directly impacted areas, e.g. increased pressure for deforestation or grassland degradation.

Scenario building enables designers to make projections about the impacts that a prospective project or intervention is most likely to have, and to compare this **With-Project Scenario** to the alternative business-as-usual **Without-Project Scenario** in which the project never took place. This ex-ante evaluation of two alternative theoretical scenarios requires data on a real-world baseline situation – something which is very familiar to ex-ante economic analysis in general.

Baseline scenario building begins with the **Initial Situation** of land use and management practices in the project area, given in the following figure as x_0 , using the example of a project that is designed to increase the amount of cropland that is cultivated using improved nutrient management. Developing the alternative scenarios over two time periods, the **With-Project Scenario** projects an increase in the improved fertilized area to x_2 hectares, while the Without-Project Scenario forecasts a proportionately smaller increase in area to x_1 hectares

Figure 1: Building development scenarios for GHG Accounting



GHG accounting typically differentiates between two time periods. The **implementation phase** defines the period in which active project activities are carried out and lasts from t_0 until t_1 (Figure 1). Thereby the period covered by the analysis does not necessarily end with the termination of the active project intervention. Even after the point that a new equilibrium in land use and practices is reached in t_1 further changes may occur, for instance changes in soil carbon content or in biomass, that are extended results of the intervention following the lifespan of the intervention itself. This period defines the **capitalization phase** which lasts from t_1 until t_2 .

The difference in activity data between With- and Without-Project scenarios serves then later as the input data for calculating the carbon-balance of the project.

Data are needed concerning all those areas **in which change is observed between project start and end of the capitalization phase** due to project implementation as well as in those areas **where such alterations are actively prevented because of** project implementation, for instance through prevented deforestation. In addition to more generic Tier 1 data (table 3), more detailed Tier 2 data can be selectively applied to increase resolution and the confidence level of projected results.

A tier level of analysis represents a level of methodological complexity to estimate greenhouse gas emissions following the definition in NGGI-IPCC-2006. Tier 1 methods rely on default values and require a lower level of detail, while Tier 2 methods require regional specific carbon stock values and emission coefficients, implying higher precision and the need for more sophisticated data.

Table 3: Examples of Tier 1 activity data

	Description module	
	Obligatory	
Only if project related		<ul style="list-style-type: none"> - Sub-continent - Type of climate - Moisture regime - Dominant regional soil type - Project duration
		Land use change module
	Deforestation	<ul style="list-style-type: none"> - Forest type and size - Area deforested - Final land use after conversion - Burning during conversion?
	Afforestation & reforestation	<ul style="list-style-type: none"> - Type of current land use - Type of future forest - Burning during conversion?
	Other land use change	<ul style="list-style-type: none"> - Type of current land use - Type of future land use - Burning during conversion?
		Crop production module
	Annual systems	<ul style="list-style-type: none"> - Current and future planted crop area (by type of crop) - Crop management practices - Practices of residue burning?
	Perennial systems	<ul style="list-style-type: none"> - Current and future planted crop area (by type of crop) - Practices of residue burning?
	Irrigated rice	<ul style="list-style-type: none"> - Specifications of water management practices
		Grassland and livestock module
	Grassland	<ul style="list-style-type: none"> - Current and future grassland area by state of degradation - Practices of grassland burning?
	Livestock	<ul style="list-style-type: none"> - Type and number of livestock - Feeding and breeding practices
		Land degradation module
	Forest degradation	<ul style="list-style-type: none"> - Dynamic of forest degradation / rehabilitation by forest type and size - Occurrence of forest fires?
	Degradation of organic soils (peatland)	<ul style="list-style-type: none"> - Vegetation type and size concerned by drainage of organic soils - Area affected by peat extraction
		Input an investment module
	Agricultural inputs	<ul style="list-style-type: none"> - Weight of agricultural inputs by type
	Energy consumption	<ul style="list-style-type: none"> - Quantity of electricity, liquid and gaseous fuel, and wood consumed
	Building of infrastructure	<ul style="list-style-type: none"> - Size of area with newly established irrigation infrastructure or buildings (by type)

Besides offering the option to use Tier 1 default values, some GHG accounting tools encourage users to substitute default values with more location-specific Tier 2 data that lead to lower uncertainty levels in the estimation. Tier 2 data involves location-specific variables that offer specifications on the carbon content and stock changes in all five carbon pools as well as the emission factors for selected practices. Some examples of Tier 2 data include:

- Above and below ground biomass levels and changes for forestland
- Soil carbon content
- Rates of soil carbon sequestration on various land uses
- Amount of biomass burnt during land conversion and crop residue management
- Nitrous oxide and methane emissions from manure management
- Emissions from enteric fermentation
- Emissions associated with the construction of agricultural, road and building infrastructure

The collection of Tier 2 data is especially advised for core project components that are expected to be larger sources or sinks of GHGs. This logic may be understood as a good practice leading to a reasonable combination of Tier 2 and Tier 1 data.

The checklist in Table 4 allows users determine the modules that apply to their project.

Table 4: Checklist for identifying project relevant modules

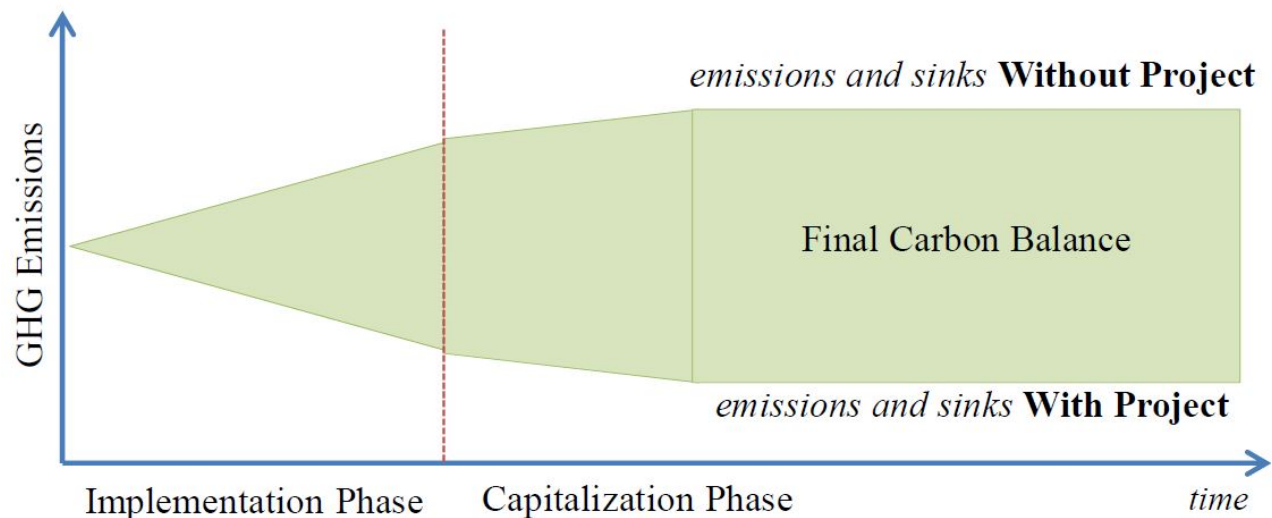
Carbon-balance Impact Main Impact Area		Relevant Module(s) to fill	Project intervention	
			YES	NO
POSITIVE (SINK)	A Reduced emissions of carbon dioxide			
	A1 Reduction in rate of deforestation	Land use change		
	A2 Reduction in forest degradation	Land degradation		
	A3 Adoption of improved cropland management	Crop production		
	A4 Introduction of renewable energy and energy-saving technologies	Investments		
	B Reduced emissions of methane and nitrous oxide			
	B1 Improved animal production	Livestock		
	B2 Improved management of livestock waste	Livestock		
	B3 More efficient management of irrigation water in rice	Crop production		
	B4 Improved nutrient management	Crop production, Livestock		
	C Carbon sequestration			
	C1 Conservation farming practices	Crop production		
	C2 Improved forest management practices	Land use change		
	C3 Afforestation and reforestation	Land use change		
	C4 Adoption of agroforestry	Crop production		
	C5 Improved grassland management	Grassland		
C6 Restoration of degraded land	Land use change			
NEGATIVE (SOURCE)	D Increased emissions of methane, nitrous oxide and carbon dioxide			
	D1 Increased livestock production	Livestock		
	D2 Increased irrigated rice production	Crop production		
	D3 Increased fertilizer use and over-fertilization	Inputs		
	D4 Production, transportation, storage and transfer of agricultural chemicals	Inputs		
		Investments		
	D5 Increased electricity consumption	Investments		
	D6 Increased fuel consumption	Investments		
	D7 Installation of irrigation systems	Investments		
	D8 Building of infrastructure	Investments		
	E Decreased carbon stocks			
	E1 Increased deforestation & timber logging	Land use change		
	E2 Increased land degradation (forests, croplands, grassland)	Land degradation, Grassland		
	E3 Cropland expansion	Land use change		
E4 Residue burning, deep tillage, ...	Crop production			

5. The final carbon balance

In estimating the final carbon balance, only the modules that are directly impacted by project activities should be filled. The main data needs occur only in the focal areas of the project and project team should ensure that sufficient data required by the tool is collected. It is normal that many data entry cells will not be used if some modules do not apply to the project. It is also essential that information is entered on changes occurring With-Project vis-a-vis Without-Project situation.

The specific agro-ecological conditions and activity data in the GHG accounting tool modules lead to the calculation of GHG emissions and carbon stock changes. The comparison of the net emissions from With-Project and Without-Project scenarios constitutes the marginal difference in GHG emissions and carbon sequestration due to project implementation which defines the overall carbon balance.

Figure 2: The Final Carbon Balance



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Annexes

Annex 1: Availability and geographical coverage of 10 commonly used GHG calculators

No.	Tool	Website	Developer	Geographical zone/application
1	AFD-CFT	http://www.afd.fr/lang/en/home/projets_afd/changement_climatique/Liens_utiles_climat/4861736956	Agence Française de Développement (France)	World <i>All climates</i>
2	AFOLU Carb	http://www.afolucarbon.org/	USAID, Winrock International (United States)	World <i>All climates</i>
3	CAT-AR	http://www.worldbank.org/en/search?q=CAT-AR+percent28Carbon+Assessment+Tool+for+Aforestation+and+Reforestation+percent29	World Bank	World <i>All climates</i>
4	CAT-SFM	http://documents.worldbank.org/curated/en/392001468331049999/pdf/903680WP0Box380tingguidanceforestry.pdf	World Bank	World <i>All climates</i>
5	CBP	www.carbonbenefitsproject.org	GEF/United Nations Environment Programme/CSU	World <i>All climates</i>
6	CCAFS-MOT	https://ccafs.cgiar.org/mitigation-option-tool-agriculture#.V717mU19670	CGIAR CCAFS	World <i>All climates</i>
7	CFT	https://www.coolfarmtool.org	Unilever and researchers at the University of Aberdeen	World <i>All climates</i>
8	DNDC	http://www.dndc.sr.unh.edu	Institute for the Study of Earth, Oceans, and Space, University of New Hampshire (United States)	United States, but has been adapted to other parts of the world <i>Temperate climate to a large extent</i>
9	EX-ACT	http://www.fao.org/tc/exact/ex-act-home/en	FAO	World <i>All climates</i>
10	TARAM	https://wbcarbonfinance.org/Router.cfm?Page=BioCF&FID=9708&ItemID=9708&ft=DocLib&CatalogID=44969	World Bank Carbon Finance Unit	World <i>All climates</i>

Annex 2: Data, Time and Skills requirement of the tools

No.	Tool	Data requirements	Time requirements	Skills requirements
1	CBP	+++	+	++
2	AFD-CFT	+++	++	+
3	AFOLU	+++	+++	+++
4	CAT-AR	++	+++	++
5	CAT-SFM	+	++	+
6	CCAFS	+++	++++	++++
7	CFT	+++	+++	+++
8	DNDC	+	+	+
9	EX-ACT	+++	++	++
10	TARAM	+++	+	+
Legend (modified from Colomb, 2013) ⁴		++++ to +; from low data requirements to medium/ high/ very high data requirements	0 min <Time necessary ≤ 10 min → ++++ 10 min <Time necessary ≤ 20 min → +++ 20 min <Time necessary ≤ 30 min → ++ Time necessary > 30 min → +	++++ to +; from basic skills requirements to /medium/high/very high skills requirements

⁴ Colomb V, Touchemoulin O, Bockel L, Chotte J L, Martin S, Tinlot M and Bernoux M 2013 Selection of appropriate calculators for landscape-scale greenhouse gas assessment for agriculture and forestry Environ. Res. Lett. submitted

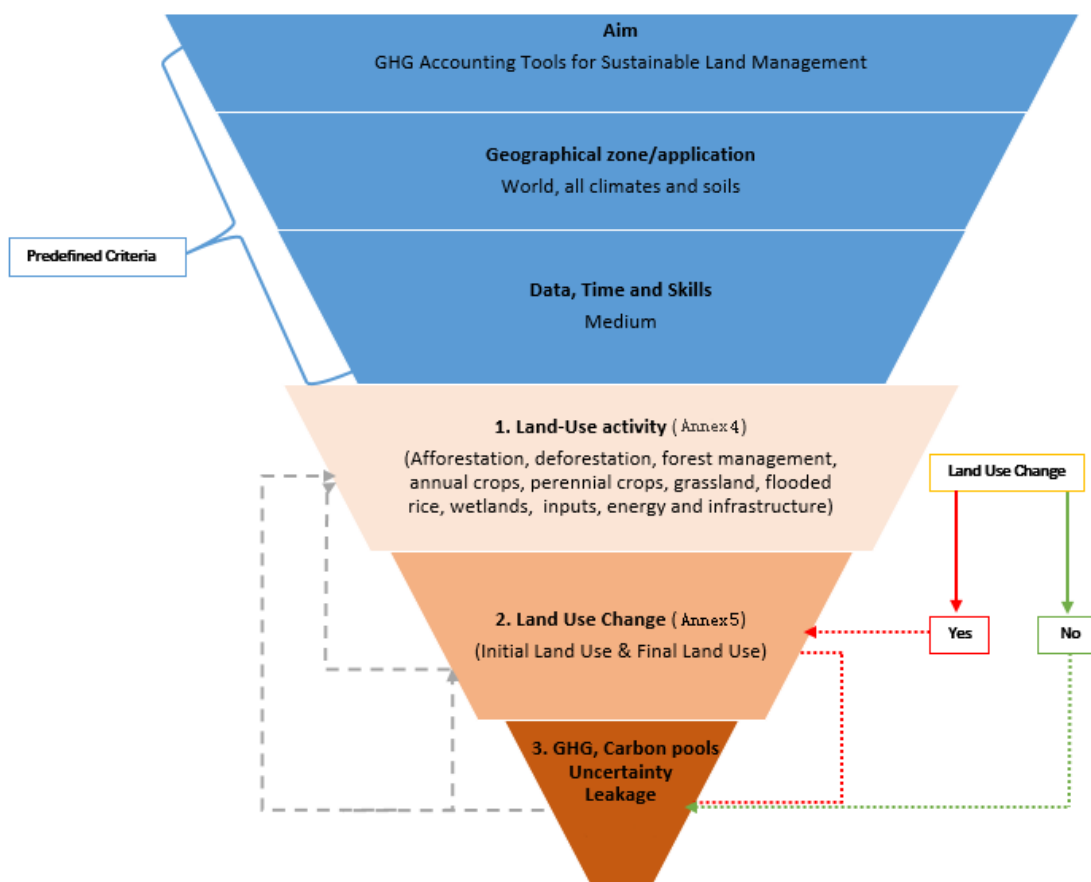
Annex 3: Multicriteria GHG tool selector for SLM projects

The Carbon Accounting Tools for Sustainable Land Management Report documents the performance of GHG calculators in the assessment of GHG emissions from a broad range of SLM activities. The assessment included running the tools on real datasets from 18 GEF projects to determine under what conditions they are best applicable for assessing SLM GHG emissions. The empirical assessment enabled the report authors to develop criteria for selecting tools for SLM operations.

The following three-step process based on the characteristics of each calculator (Figure A2.1) was recommended for selecting a suitable calculator(s) for SLM operations:

- Step 1: Choose the land use activity (afforestation, deforestation, forest management, annual cropland, perennial cropland, grassland, flooded rice, wetlands, inputs, energy, and infrastructure). (Annex 3)
- Step 2: If any land use change activity is foreseen, choose the initial land use (ILU) and the final land use (FLU). (Annex 4)
- Step 3: Consider other criteria as needed to recommend the appropriate GHG calculator(s) (for example, different GHGs (CO₂, N₂O, and CH₄), the IPCC GHG accounting approaches, the need for multiple areas to be analyzed simultaneously, the need for spatially explicit results, uncertainties, and the leakages and so on). Note that additional requirements can be used to reduce the selection to one or two calculators.

Figure A2.3: Step-by-step process for selecting a GHG calculator



Annex 4: Recommended tools per land use activity

No.	Tool	SLM activities														
		Afforestation/reforestation	Deforestation	Forest management		Annual crops		Perennial crops		Grassland		Inputs, energy and infrastructure				
				Fire forest management	Forest management and degradation	Annual crops development	Annual crops improvement	Perennial crops development	Perennial crops improvement	Grassland development	Grassland improvement	Inputs (fertilizers and pesticides)	Electricity consumption	Fuel consumption	Irrigation systems	Infrastructure
1	AFD-CFT	x	x	no	no	x	no	x	x	x	x	no	x	no	no	x
2	AFOLU Carb	no	no	x	no	no	no	no	no	no	x	no	no	no	no	no
3	CAT-AR	x	no	no	no	no	no	no	no	no	no	no	no	no	no	no
4	CBP	x	x	x	x	x	x	x	x	x	x	no	no	no	no	no
5	EX-ACT	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

x means the tool is recommended for the SLM activity, no means the tool is not recommended. For detailed information on the suitability assessment of the tools, please refer to the full report Carbon Accounting Tools for Sustainable Land Management

Annex 5: Recommended tools when considering Land Use Change scenarios ⁵

Initial Land Use Final Land Use	Forestland	Annual crops	Perennial crops	Grassland	Flooded rice	Set aside land	Degraded land	Other land	Settlements
Forestland		AFD-CFT CAT-AR CBP EX-ACT	AFD-CFT CAT-AR CBP EX-ACT	AFD-CFT CAT-AR CBP EX-ACT	EX-ACT	AFD-CFT CAT-AR EX-ACT	EX-ACT	EX-ACT	CBP EX-ACT
Annual crops	AFD-CFT CBP EX-ACT		AFD-CFT CBP EX-ACT	AFD-CFT CBP EX-ACT	EX-ACT	AFD-CFT EX-ACT	EX-ACT	EX-ACT	CBP EX-ACT
Perennial crops	AFD-CFT CBP EX-ACT	AFD-CFT CBP EX-ACT		AFD-CFT CBP EX-ACT	EX-ACT	AFD-CFT EX-ACT	EX-ACT	EX-ACT	CBP EX-ACT
Grassland	AFD-CFT CBP EX-ACT	AFD-CFT CBP EX-ACT	AFD-CFT CBP EX-ACT		EX-ACT	AFD-CFT EX-ACT	EX-ACT	EX-ACT	CBP EX-ACT
Flooded rice	EX-ACT	EX-ACT	EX-ACT	EX-ACT		EX-ACT	EX-ACT	EX-ACT	EX-ACT
Set aside land	AFD-CFT EX-ACT	AFD-CFT EX-ACT	AFD-CFT EX-ACT	AFD-CFT EX-ACT	EX-ACT		EX-ACT	EX-ACT	EX-ACT
Degraded land	EX-ACT	EX-ACT	EX-ACT	EX-ACT	EX-ACT	EX-ACT		EX-ACT	EX-ACT
Other land	CBP EX-ACT	CBP EX-ACT	CBP EX-ACT	CBP EX-ACT	EX-ACT	EX-ACT	EX-ACT		EX-ACT
Settlements	CBP EX-ACT	CBP EX-ACT	CBP EX-ACT	CBP EX-ACT	EX-ACT	EX-ACT	EX-ACT	EX-ACT	

⁵ For detailed comparison of the tools, please refer to the full report Carbon Accounting Tools for Sustainable Land Management

Annex 6: Detailed description of the tools most suitable for SLM project

The carbon accounting tools that are short-listed for evaluation of real project datasets are described in terms of how they can be used, types of activities considered, GHG assessment boundary, carbon pools, sources, and sinks, associated GHG emissions, and other relevant criteria.

Carbon Benefits Project Modeling Tools

The CBP modelling tools were developed by Colorado State University (CSU) with several partners and were released in March 2012. The tools are applicable to any land use/management project and can be applied globally for ex ante and ex post analysis and project tracking. The system has three options:

- The Simple Assessment (SA) is an online tool based on the IPCC method. It requires users to choose land management information from prepopulated menus and uses default IPCC factors.
- The Detailed Assessment (DA), also an online tool, is based on the IPCC method, but it allows users to enter their own project-specific information and emission factors.
- The Dynamic Modeling option, which is the Century Ecosystem Model linked to a GIS, has to be downloaded from the web. Expertise in GIS and ecosystem modeling is needed to use this option.

The SA and DA are designed to work on areas from a few hectares to approximately 10 million hectares. The Dynamic Modeling option has been used at the landscape to subnational scale but can be applied at any scale if data are available.

The CBP SA and DA were specifically designed for project accounting in GEF projects. GEF projects tend to be at landscape scale, often including multiple land uses, land management systems, and smallholdings that can have a mix of livestock and cropping systems. The CBP SA and DA were also specifically designed to deal with heterogeneous situations where an overall GHG balance is required. This is achieved by allowing the user to define multiple points or polygons in the system and then describe land cover, use, and management for ‘baseline’ and ‘project’ scenarios. Furthermore, due to the landscape scope of the tools, they can also work to operate at a transboundary level, targeting projects and activities in more than one country.

In terms of relevance to smallholder farmer groups, the SA can be used with the sort of activity data that a land management project is likely to have and, as an online tool, only requires an Internet connection. Users choose land management options from prepopulated lists. For the DA (also an online tool), users can build their own crop/forest/grass management systems. Local datasets and measurements can be used to improve estimates, so that costs and expertise associated with field sampling can apply, although users are encouraged to use existing local data if available (for example, from journal publications and PhD thesis). Both the SA and the DA tools are available in English, Spanish, French, Russian, Portuguese, and Chinese, with Amharic to be added.

The toolkit covers all ecosystems classified in the IPCC GHG Inventory Methods for Agriculture, Forestry, and other Land Use (IPCC 2006). It covers emissions of all three major GHGs (CO₂, CH₄, and N₂O) from all sources covered by the IPCC method and carbon stock changes associated with all carbon pools. Non-land-use emissions are not dealt with.

The output of the assessment is a spatially explicit net GHG balance expressed in CO₂ equivalents. The system produces a PDF summary report and detailed Excel file reports that can be used in a GIS. Results are broken down by land use, land management, climate region, soil type, source, and sub-source categories for each geographic area that the user defines, in addition to giving a total for the entire area. Results are therefore spatially explicit, allowing multiple land use and management situations across heterogeneous landscapes to be analyzed at the same time. All results are accompanied by an estimate of uncertainty made using the IPCC error propagation method. In the DA, users can modify the model emission or carbon stock factors and adjust the uncertainty associated with their own project-specific factors.

The tools are focused on use in mixed landscapes where net GHG accounting is required for a range of land use and land management situations. They cover all of the land use categories given by the IPCC (forests, agroforestry, trees - outside of forests, in settlements and savannas), croplands (including agroforestry integrated with croplands and perennial/woody crops, such as tree fruits and nuts), grasslands, and wetlands. Carbon stocks covered include SOC and above- and below-ground woody biomass (litter and dead wood are not covered but are in the process of being added to the tool).

The system can be used to address issues of leakage by defining additional 'leakage' polygons or points and adjusting the final total to account for emissions from these areas.

The CBP DA has the flexibility to be used in a way that is compatible with regulatory markets and voluntary market standards. It has not yet been reviewed or directly approved by any market or standard, but there are plans to do so under the ongoing GEF project (SLM-CCMC).

Agence Française de Développement Carbon Footprint Tool

The AFD-CFT was developed by the AFD in 2007 and has been used since for ex ante GHG assessments of all its operations. The AFD-CFT's accounting method uses a project's or an activity's operational data to estimate its GHG emissions. A carbon footprint calculation is created by making an inventory of a project's activities. The quantities are entered into a spreadsheet that directly computes each item's emissions in CO₂ equivalents (CO₂eq) through a scientifically determined 'emission factor' embedded in the spreadsheet. As it multiplies the activity's 'observable' physical data values by this emission factor, the spreadsheet instantly converts each physical value into its CO₂eq using tons as a unit of measure. Tools can be used by any land use/ management project and are freely available from the website.

The outputs of the assessment include emission estimates for CO₂, which results primarily from combusting fossil fuels and from producing aluminum, steel, cement, and glass; CH₄, which results from burning and/or decomposing biomass (organic material) and from producing and/or refining gasoline and natural gas; N₂O, which results from incinerating solid waste, spreading fertilizers, and/or various transportation means; hydrofluorocarbons (HFCs), which occur as a

byproduct of industrial processes making insulation, refrigeration and air conditioning; perfluorocarbons (PFCs), which occur as a byproduct of aluminum production; and sulphur hexafluoride (SF₆), which is used for insulation and current interruption in electricity transmission and distribution equipment and electronic systems.

The emissions are separated into two distinct categories according to the project's phase—construction versus operation—and further sub-categories, as follows:

Project 'Construction Phase' emission sources:

- Clearing: deforestation
- Construction materials: production of cement, steel, metals, and so on
- Construction energy consumption: fuel and electricity used during construction

Project 'Operating Phase' emission sources:

- Fuel consumption: Combustion of fossil fuels.
- Electricity/heat consumption.
- Other process emissions: Includes non-energy-producing processes, especially decarbonation from cement clinker production, CH₄ released from mining and dam reservoirs, mechanization of organic waste and wastewater, N₂O released by spreading fertilizer or from industrial gases, particularly coolants.
- Purchase of goods and services: Includes the production of products consumed due to the project's activity, especially metals, plastics, glass, paper and cardboard, and chemical and agricultural products.
- Freight: Moving commodities, inputs and/or finished products by road, rail, air, or ocean.
- Passenger transport.
- Waste and wastewater.
- Land use: Changing how land is used, resulting in emissions from biomass and soil.
- Utilization: People's use of utilities and infrastructure and/or factories or other buildings. This includes the mix of their use of transportation, electricity, fuels, products, and so on, and their waste-end of life: disposing of built or produced objects

The AFD-CFT calculation is compatible with the definition of 'Scopes' 1, 2, and 3 in the GHG Protocol.

- **Scope 1. Direct sources.** GHG emissions, from sources directly related to a project's activity, for example, combustion
- **Scope 2. Electricity.** Indirect GHG emissions, from the generation of purchased electricity and/or heat needed for the project's activity
- **Scope 3. Other indirect sources.** GHG emissions, from the production of materials purchased from other parties and used in the project's activity, for example, production and/or extraction of purchased materials, waste disposal, and use of sold products and services

The calculation of GHG emissions resulting from a project covers the project's entire lifetime, which is determined by the AFD-CFT. The project lifetime includes both the construction and operating phases. If building the project will generate negligible emissions, its construction phase is not included in the accounting. If the project's construction proves emissive, by default, the

AFD-CFT uses one-year durations. In the operating phase, for ease of comparison, standardized lifetimes for each type of project are suggested depending on the type of activities; the AFD-CFT user can change them on a case-by-case basis as needed and the annual GHG emissions are determined by dividing the project's total lifetime (construction + operation) emissions by the total lifetime of the project.

A project's carbon footprint calculation is presented in terms of emissions generated during the construction phase in tCO₂eq and emissions generated or abated annually during the operating phase in tCO₂eq per year. To aggregate data and compare different projects, the values for the construction and/or operating phases are added to show the average annual emissions over the project's lifetime. No discount rate is applied to annual emissions.

Agriculture, Forestry and Other Land Use Carbon Calculator

AFOLU Carb was developed by Winrock International, in collaboration with the USAID Global Climate Change team, to give USAID an easy way to mainstream its agency wide results indicator of CO₂ emission reductions and removals into its work.

The tool, developed in 2007 and updated since, was designed to estimate emission reductions and removals from agriculture/forestry related USAID project activities that directly have an impact on how land is used or managed. The tool comprises six online and freely available calculators that cover forest protection, forest management, afforestation/reforestation, agroforestry, cropland management, and grazing land management. The calculators can also produce reports on above-ground forest biomass carbon, peat carbon, and soil carbon.

The tool uses a tiered approach (Tier 1 and 2) where data requirements are minimal, but if more detailed information is available, it allows users to override default data to produce more refined estimates.

Under the Tier 1 approach, the generation of CO₂ impact estimates generally only requires that users enter the area of the activity and the geographic location of the project activity. Under the Tier 2 approach, data input options allow users to generate more refined estimates by overriding defaults and entering project-specific information.

The calculators use different methods with an underlying database derived from extensive literature reviews and the IPCC 2006 Guidelines for AFOLU (IPCC 2006). In terms of application at the landscape scale, the database also houses information at the administrative level, which can vary greatly depending on the country and region you are working in.

An estimate of uncertainty is not given with the output, and the developers are very clear in saying that the calculators are not designed to produce the level of accuracy needed for carbon financing. The AFOLU Carb provides a management effectiveness rating that is used as a measure of the success of project activities in terms of preventing GHG emissions or increasing removals from land use change activities, which could be used to predicate carbon leakage. The output gives the carbon change in CO₂eq per activity type, administrative unit, and project.

Carbon Assessment Tool for Afforestation and Reforestation

The CAT-AR was developed by the Tropical Agricultural Research and Higher Education Center (under Spanish acronym, *Centro Agronómico Tropical de Investigación y Enseñanza* (CATIE)) (Costa Rica) for the World Bank as part of the ‘Pilot Program for Assessment of GHG Intensity of Core Development Activities.’ The tool consists of an Excel file and is free to download from the World Bank website.

The CAT-AR is a simplified version of the ‘Tool for ex-ante estimation of forestry CERs’, or TARAM, an Excel-based tool developed jointly by the Bio Carbon Fund (World Bank) and CATIE to facilitate the application of the approved methodologies for afforestation and reforestation CDM project activities. CAT-AR therefore closely follows the CDM approach for GHG accounting of afforestation and reforestation projects. In situations where there is a lack of project-specific data, CAT-AR can provide indicative results by applying default values (Tier 1) from the 2003 Intergovernmental Panel on Climate Change Good Practice Guidance for Land Use, Land Use Change and Forestry (IPCC-GPG LULUCF) and the 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories (IPCC-GNGGI).

The CAT-AR tool considers afforestation and reforestation activities. Afforestation is defined as the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources. Reforestation is defined as the direct human-induced conversion of non-forested land to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources on land that was forested but that has been converted to non-forested land.

The GHG assessment boundary includes four components: the geographic area where the project activities take place, the time frame of the assessment, the carbon pools considered, and the sources and sinks and associated GHG.

With the CAT-AR tool, the GHG emissions/removals are assessed within both the discrete site(s) where the afforestation and reforestation project is located and the site(s) of the project boundary where GHG emissions/removals increase/decrease due to the project activity. The tool allows the user to monitor ex ante annual carbon stocks, changes in carbon stocks, and GHG emissions/removals up to a maximum of 30 years. It also takes four carbon pools: above-ground and below-ground trees and woody biomass, as well as above-ground and below-ground non-woody biomass. SOC and wood products are not included.

The tool outputs include calculations of the CO₂ removals from biomass growth, CO₂ emissions from consumption of fossil fuels (diesel or gasoline) for management purposes and from liming (CaCO₃ and CaMg(CO₃)₂), CH₄ released by burning of pre-existing trees and woody vegetation as well as non-woody vegetation for site preparation, N₂O emissions from the use of organic and synthetic fertilizers and from the burning of pre-existing trees and woody vegetation as well as non-woody vegetation for site preparation.

In addition to emissions/removals of GHGs, the CAT-AR considers two sources of leakage: fuel consumption out of the project boundary (transport of inputs and of staff for plantation and

management, and of products) and emissions due to activity displacement outside the project boundary. The net anthropogenic GHG removals from the AR project are defined as the project net GHG removals by sinks minus the baseline net GHG removals by sinks minus the leakage. Both cumulative and yearly increments are shown in CAT-AR results.

Ex-Ante Carbon-Balance Tool

EX-ACT was developed by the FAO to provide anyone developing agriculture and forestry projects (more particularly, program officers, funding agencies, and ministries) with a tool to estimate the impact of projects on GHG emissions and carbon sequestration (Bernoux et al. 2010). The tool consists of an Excel file and is free to download from the FAO website.

The tool was developed using the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) in conjunction with other methodologies and reviews of default coefficients (Lal 2006; Smith et al. 2008). This makes it globally applicable. The tool assesses the impact of agriculture and forestry activities on carbon stock changes per unit of land and CH₄ and N₂O emissions in tCO₂eq per hectare per year. The tool covers all GHG emissions linked with LULUCF activities covered by the 2006 IPCC Guidelines (IPCC 2006) plus some additional sources.

EX-ACT is applicable to development projects in the areas of crop management, SLM, agroforestry, grassland restoration, production intensification, and livestock management. The tool covers the following sources and activities:

- Deforestation/afforestation/reforestation
- Annual and perennial cropland management
- Flooded rice management practices
- Livestock and dairy (enteric CH₄ and CH₄ from manure)
- Nutrient management (liming, fertilizers, pesticides, and herbicides)
- Energy consumption inputs and farm machinery (electricity and fuel)

Furthermore, the tool covers emissions associated with carbon stock changes during land use conversion; biomass or residue burning; flooded rice cultivation; organic soils; livestock production; and inputs of lime, fertilizer, and manure. The tool also provides comprehensive coverage of non-land-use emissions associated with agriculture, such as those from the production, transport, storage, and transfer of agricultural chemicals and emissions from energy use and infrastructure (electricity and fuel consumption associated with buildings and irrigation system construction and maintenance).

The output is not spatially explicit, but it provides a carbon balance resulting from project activities (for example, what would happen above a baseline scenario). This is accompanied by a rough estimate of uncertainty (rounded up to the nearest 10 percent), which is calculated using the method given in the IPCC 2006 Guidance (IPCC 2006).

Issues of leakage are not addressed specifically, but they could be addressed by adjusting input information. Permanence is not addressed, but the uncertainty results could be used to highlight categories where problems of permanence might arise. No analysis of social or economic

impacts is included, although the tool output has been used to feed into an economic analysis using the Marginal Abatement Cost Curves (Bockel et al. 2012). Tier 1 emission factors are supplied, with the option for users to input their own data. Overall, the tool requires a fair amount of detailed information.