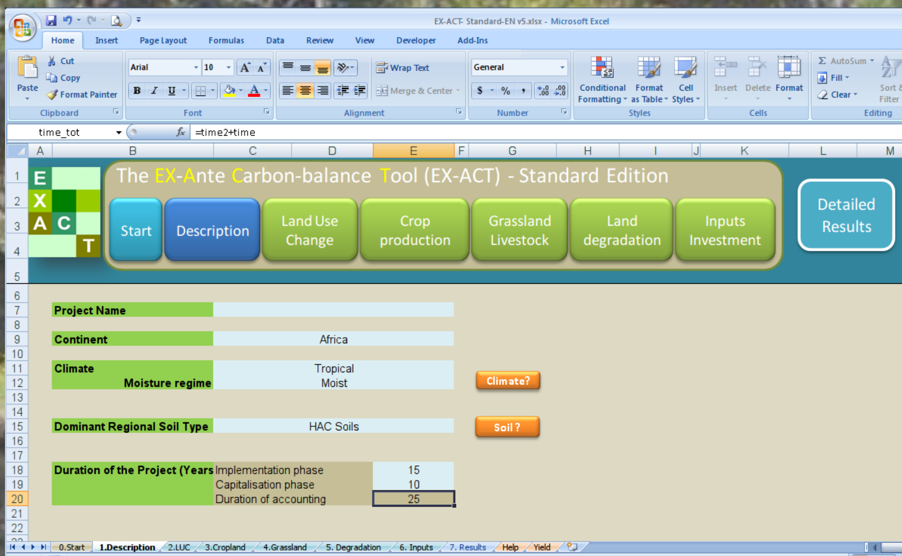
User Friendly Manual of the EX-Ante Carbon-balance Tool (EX-ACT)

Estimating and Targeting Greenhouse Gas Mitigation in Agriculture, Livestock, Forestry and Land Use Projects



FINAL DRAFT

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Abstract

The Ex-Ante Carbon-balance Tool (EX-ACT) is an appraisal system developed by FAO providing ex-ante estimates of the impact of agriculture and forestry development projects, programmes and policies on the carbon-balance. The carbon-balance is defined as the net balance from all GHGs expressed in CO_2 equivalent that were emitted or sequestered due to project implementation as compared to a business-as-usual scenario.

EX-ACT is a land-based accounting system, estimating C stock changes (i.e. emissions or sinks of CO_2) as well as GHG emissions per unit of land, expressed in equivalent tonnes of CO_2 per hectare and year. The tool helps project designers to estimate and prioritize project activities with high benefits in economic and climate change mitigation terms. The amount of GHG mitigation may also be used as part of economic analysis as well as for the application for funding additional project components.

EX-ACT can be applied on a wide range of development projects from all AFOLU sub-sectors, including besides others projects on climate change mitigation, watershed development, production intensification, food security, livestock, forest management or land use change. Further, it is cost effective, requires a compared small amount of data, and has resources (tables, maps) which can help finding the required information. While EX-ACT is mostly used at project level it may easily be up-scaled to the programme/sector level and can also be used for policy analysis.

This manual provides all central information on methodology, application and utilization of EX-ACT and prepares the reader to its independent use. A shorter *Quick Guidance* is also available. EX-ACT is based on Microsoft Excel (without macros) and freely available from the FAO website.

- EX-ACT Website:
  www.fao.org/tc/exact
- Free Tool Access:
  www.fao.org/tc/exact/carbon-balance-tool-ex-act
- EX-ACT User Manual & EX-ACT Quick Guidance:
  www.fao.org/tc/exact/user-guidelines

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Contents

Part A: Introduction and Rationale

Chapter 1: Introduction

This manual describes in a practical oriented way the use of the EX-Ante Carbon-balance Tool (EX-ACT) and leads readers to independently estimate the impact of agricultural and forestry investment projects and programmes on the GHG-balance. EX-ACT provides investment planners with the main functionality to design project and programme activities with high and targeted benefits for climate change mitigation, complementing the usual ex-ante economic analysis.

The introduction at hand provides in the following firstly an overview of the manual structure, gives short advice on how to use the manual and specifies central terminology as well as the main target audience.
In the subsequent step readers are provided with the main rationale that explains why it is important to structurally include active targeting of GHG benefits as part of investment planning and why agriculture and forestry are main important sectors for GHG mitigation efforts.

A. Manual structure

This manual consists of a series of practical steps. It is subdivided into the three bigger report parts A) Introduction and Rationale, B) Step-by-Step Guide to the Tool Use, and C) Making Effective Use of EX-ACT Results.

- **Part A: Introduction and Rationale**
  In the first part readers are presented with the main facts on why it is relevant to include GHG-balance appraisals into planning and design of investment projects and are provided with a brief overview of EX-ACT technical components and analytical results. Part A also gives central information on the methodology behind the tool as well as information on how to develop a baseline scenario.

- **Part B: Step-by-Step Guide to Use EX-ACT**
  Part B then leads the reader step-by-step through the analysis process, specifies how to procure the necessary data, and enter all required information into each topic module of EX-ACT.

- **Part C: Making Effective Use of EX-ACT Results**
  The third part then shows how to interpret the EX-ACT results, comparing the multidimensional performance of different project options and using the results of EX-ACT for economic analyses.

Taking a more detailed look at the manual content, it is subdivided into short, easy digestible steps that allow reading in non-sequential order, for selective reading as well as to skip sections in case of less relevance to the reader. Since specific manual sections are nevertheless of central importance, the reader is provided in the following with a guided overview of content and degree of general or selective importance of each section:

Part A (chapters 1 to 3)

The introduction (chapter 1) offers useful background information on climate change mitigation in general and specifically in the AFOLU sector. It should be consulted by readers that want to clarify whether climate change mitigation is from a public perspective, an important aspect of investment

planning. It also provides the most central information on major emission sources from the Agriculture, Forestry and Other Land Use (AFOLU) sector and identifies where the biggest mitigation potentials are expected. Finally, definitions of central terminology are provided which are of major importance to the understanding of the entire manual.
Chapter 2 subsequently provides an overview of the EX-ACT tool, from brief presentation, to structure, main reasons for using the tool and finally an overview of other carbon appraisal tools.

Chapter 3 presents then the methodological background of EX-ACT. It specifies how it was developed based on the IPCC guidelines for national GHG inventories (NGGI-IPCC), but also clarifies questions of analysis boundaries and differences between pure ex-ante analyses and monitoring as well as evaluation approaches. Finally it introduces the concept of baseline scenarios and their importance for the analysis process.

Part B (Chapters 4 to 10)

Part B then starts on how to use EX-ACT, which is the core of this manual. Chapter 4 presents the main data needs and guides the reader in the process of data procurement.
Chapters 5 to 10 present the different topic modules of EX-ACT that are centered around main climatic and geographical information (chapter 5), information on forestry and land use change (chapter 6), specifications on annual and perennial crop production as well as irrigated rice (chapter 7), livestock production and grassland management (chapter 8), land degradation (chapter 9), as well as inputs and further investments (chapter 10) A good understanding of these chapters is central for the methodological adequate use of EX-ACT, though every project analysis will only involve the use of a smaller sub-set of these topic modules. Readers might thus concentrate on those topic modules of clear relevance to their project first.

Part C (Chapters 11 and 12)

The third part then guides the reader in interpreting the EX-ACT results and shows the reader how to develop different scenarios and evaluate them for their GHG-balance as well as socio-economic performance. This step is the central mechanism for the identification of project designs that are rationalized towards and deliver multi-purpose objectives (chapter 11). The subsequent chapter 12 shows how to use obtained results as part of economic analyses.

Annexes

While the core parts of the *User Manual* focus on the central elements of adequate tool understanding and the practical capacity of using it, there are a wide range of further issues that are closely related to the EX-ACT analysis.
These elements are covered by numerous appendixes that also try to keep a strong practical orientation and focus e.g. on the sub-issues of central used terminology, the use of Marginal Abatement Cost Curves (MACC) or EX-ACT as a tool for accounting the Carbon Footprint per product unit.

For more specific questions that do not directly concern the core understanding and mastering of the tool, it is furthermore frequently referred to the accompanying and free available material on our website www.fao.org/tc/exact.

B. Key concepts and terminology

For the understanding of this manual selected terminology is of central importance and will be shortly explained in the following. For a more comprehensive definition of terms please consult the Glossary in Annex 2.

Carbon-balance **or** ***GHG-balance***

The carbon-balance is defined as the net balance from all GHGs expressed in CO_2 equivalents that were emitted or sequestered due to project implementation as compared to a business-as-usual scenario. It thus accounts for the emissions from all GHGs as well as all kind of carbon pools concerned by the AFOLU sector.

The carbon-balance can thereby be realized at different scales: for an investment project, the resource impact of an organization, a region, a value chain, a country, the planet. Within a dynamic process, it is also possible to appraise the carbon-balance effect of a strategy or policy. The expressions carbon-balance and GHG-balance are used synonymously (Bockel, et al., 2011).

Baseline scenario **or** ***without-project scenario***

The baseline scenario portrays the hypothetical development of land use and activity data as well as GHG emissions that would have occurred in absence of an implemented project, programme or policy intervention. It serves as the assumed counterfactual scenario to which a projects impact on GHGs can be compared in order to appraise its marginal impact.

Global Warming Potential (GWP)

The Global Warming Potential is the factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GHG relative to one unit of CO_2 over a specific time period. It thus allows expressing all sources and sinks of GHGs in CO_2 equivalents, which leads to the evaluation of the combined climate impact of a project.

Following the Clean Development Mechanism (CDM) the official values for methane (CH_4) are set for instance to 21 (meaning that 1 kg of CH_4 is as effective, in terms of radiative forcing, as 21 kg of CO_2) and to 310 for nitrous oxide (N_2O). EX-ACT allows users to choose either the GWP standards of the CDM or the last IPCC update.

IPCC Tier levels (cf. (IPCC, 2006))

A Tier represents a level of methodological complexity to estimate greenhouse gas emissions following the definition in NGGI-IPCC-2006. EX-ACT can accommodate two of these precision levels: Tier 1 and Tier 2.

Tier 1 methods are designed to be the simplest to use, for which equations and default parameter values (e.g., emission and stock change factors) are provided in NGGI-IPCC-2006. While users need to furnish project specific activity data, the IPCC based emission coefficients are mostly applicable globally or at regional level.

Tier 2 can use the same methodological approach as Tier 1 but applies emission and stock change factors that are based on country- or region-specific data. Country-defined emission factors are characterized by more specificity for the climatic regions, land-use systems and livestock categories in the given country. Higher temporal and spatial resolution and more disaggregated activity data are typically used in Tier 2 to correspond with country-defined coefficients for specific regions and specialized land-use or livestock categories.

Tier 3 refers instead to the use of more complex methodologies, including GHG modelling techniques. They are tailored to address national circumstances and are driven by high-resolution activity data and disaggregated at sub-national level. Their strong data requirements make an application time and resource intensive.

EX-ACT version 5

EX-ACT version 5 is released in the two editions "***Standard***" and "***Tier One***". The "Standard" edition comprises the full functionality of EX-ACT and is the focus of this manual. It allows users to either use Tier 1 or Tier 2 level of complexity, following the IPCC definition.

The edition "Tier One" is a simplified version that is reduced to the exclusive use of the Tier 1 level, not allowing for the specification of regional specific Tier 2 data. Since it is in all other aspects identical to the standard edition this User Manual may equally guide users of the "Tier One" edition.

C. Targeted users

International Financial Institutions (IFIs) increasingly commit themselves to structurally consider the impact of projects and programmes on the GHG-balance as one directly targeted objective of their investment decisions. The identification of investments that are climate smart while leading to equally high socio-economic outcomes, requires an accepted methodology and practical tools for project and programme level GHG accounting.

This EX-ACT *User Manual* targets investment planners and project designers in IFIs and national planning institutions that aim at estimating the GHG-balance of any investment proposals in the agriculture, forestry and land use sector (AFOLU). The main target users should be involved during the project design stage and pursue the objective of aligning ex-ante programme and project documents in accordance with the results obtained from the EX-ACT appraisal. The flexible tool can be used to appraise the GHG-balance for any type of AFOLU project, but also for any project that that includes various domains and impacted areas e.g. livestock projects with activities on grassland and forest rehabilitation.

D. Why targeting GHG mitigation in AFOLU investment planning?

Climate change poses a major risk for leading to serious and irreversible impacts on economic activity and the ecosystem. It thus has the potential of being a major impediment to economic development, environmental sustainability and overall human well-being (Stern, 2007).

Changing food production systems, altered landscapes, rising sea levels, increased risks of drought, fire and floods, stronger storms and increased storm damage, more heat-related illness and disease as well as biodiversity and species loss are main expected direct impacts of climate change. Besides these direct effects, climate change has indirect and mediated welfare impacts by altering resource availability and functioning of economic production systems and thus leading to economic losses of high significance in scope and scale as especially in agriculture (Aggarwal, et al., 2007), (Stern, 2007).

GHG Mitigation: A Central Component of Investment Planning

As shown by the precedent paragraph there is thus growing evidence for the in scope and scale severe and irreversible impacts of a business-as-usual path of GHG emissions for overall economic development. This evidence base provides the rationale for the structural integration of climate change mitigation aspects in project and programme design as well as lending behavior of International Financial Institutions (IFIs). Climate change is global in its causes and consequences and requires international coordinated action. The joint commitment of nine IFIs (World Bank , 2012) to structurally account for the GHG emissions during project and programme appraisal is thus an important complementary step to other international efforts.

AFOLU: A Priority Area for Climate Change Mitigation

While the former provides the rationale of why it is essential to strengthen efforts of climate change mitigation, there are several reasons for prioritizing AFOLU as one of the core sectors of these efforts:

- **The agriculture and land use change sector is one of the main contributors to anthropogenic GHG emissions.**
- **Surpassing its share in current emissions, agriculture and land use change is characterized by a huge technical mitigation potential, offering comparably more cost effective mitigation options than other sectors of the economy.**
- **When adequately targeted, GHG mitigation in agriculture is closely linked to benefits for climate change adaptation and food security that are further priority areas for sustainable development.**

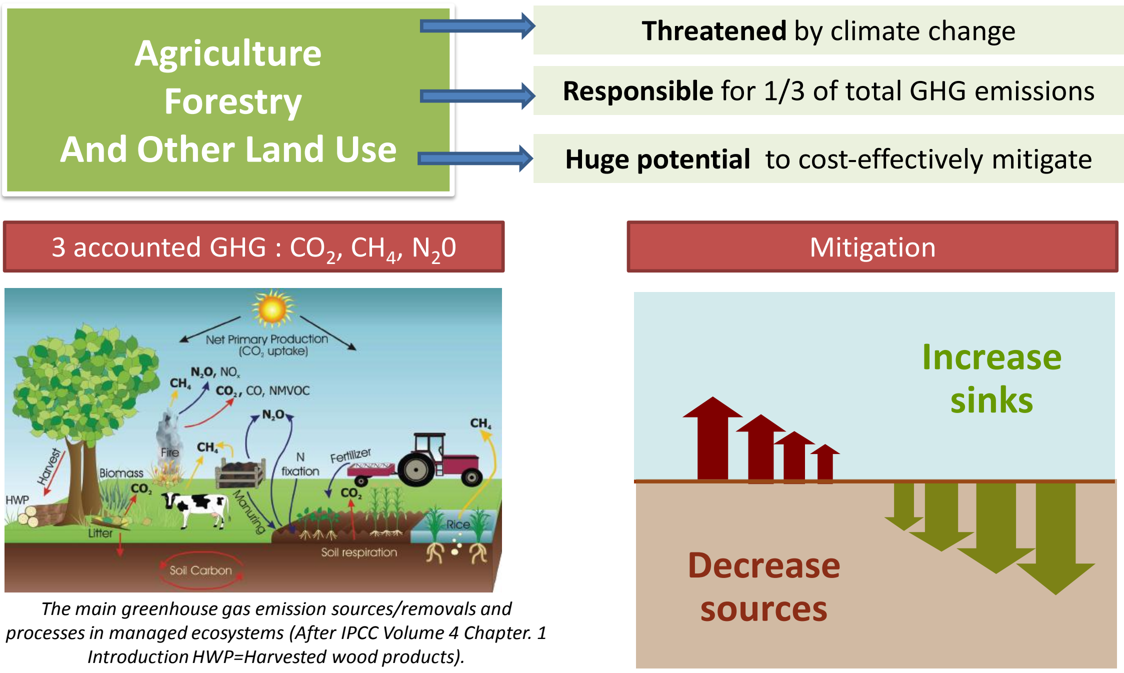
- ***The AFOLU sector: A Source of GHG Emissions***

Agriculture is a major source of greenhouse gases, contributing directly to 10-12 per cent or 5.1 to 6.1 $GtCO_2$-e/yr of total global anthropogenic emissions in 2005 (Smith, et al., 2007). When combined with related changes in land use, including deforestation (for which agriculture is a major driver), agriculture's contribution rises to more than one-third of total GHG emissions. Globally, agricultural production (crops and livestock) is responsible for about halve of methane emissions (cattle, rice plantations, and wetlands) and the majority of nitrous oxide emissions (application of fertilizer) (Smith, et al., 2007). The significant scale of global emissions from agriculture and land use change is expected to further increase in the future through mainly the projected increase in population, growing use of nitrogen fertilizers and the augmenting consumption of meat and dairy products.

- ***The Mitigation potential in AFOLU***

The potential for technical mitigation in agriculture is high and 74% of it can be found in developing countries. IPCC (Smith, et al., 2007) estimates the global technical mitigation potential by 2030 at 5500-6,000 $MtCO_2$-e/yr, which is comparable to the mitigation potential of the energy and industrial sector and bigger than in the transport sector (c.f. ibd.). How much of the technical potential will be realized depends thereby on the financial incentives per tonne of CO_2-e. IPCC (2007) thereby estimates the economic mitigation potential for various prices per tonne of CO_2-e at 1500-1600 $MtCO_2$-e/yr (20 US$), 2500-2700 $MtCO_2$-e/yr (50 US$), and 4000-4300 $MtCO_2$-e/yr (100 US$). This makes agricultural mitigation a cost effective mitigation strategy when compared with non-agriculture options as e.g. the energy sector, whereby specifically crop and livestock abatement options were identified as the most cost effective areas (c.f. ibd.).

Figure 1: Some facts about GHG emissions and agriculture



The main greenhouse gas emission sources/removals and processes in managed ecosystems (After IPCC Volume 4 Chapter. 1 Introduction HWP=Harvested wood products).

- ***Synergies between Mitigation, Adaptation and Food Security: The Paradigm of Climate Smart Agriculture***

There is much evidence that climate change is likely to lead to decreases in global efficiency and resilience of agriculture production,[1] while at the same time being confronted with increasing demand from a growing population as well as possibly other sources. Agriculture is thus not only a cause, but also strongly impacted by climate change. Complementing its overall economic importance, agricultural systems are thereby more than any other sector directly linked to the livelihood of vulnerable people and their food security situation. Thus e.g. Nelson, et al. (2009, p11) estimates that by 2050 negative impacts of climate change on agricultural production will lead to a decrease in the daily per capita calorie availability in developing countries by 16 per cent as compared to an alternative scenario without climate change. [2]

Measures that promote climate change mitigation thereby contain the potential to strongly co-benefit adaptation and food security, if targeted in an adequate way. The comprehensive consideration of all three elements constitutes the paradigm of Climate Smart Agriculture (CSA) (FAO, 2013). CSA practices are innovative and proven practical techniques that seek to increase productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change, and diminish agriculture's contribution to climate change by reducing greenhouse gas emissions and increasing carbon storage. Two practical examples are e.g. the benefits for soil fertility and soil moisture from soil carbon sequestration as well as decreased emissions and production costs from micro-dosing of fertilizer. The CSA approach is thereby explicitly aware of the possibility that also trade-offs between mitigation objectives and other CSA objectives may occur. Prioritization of selected development goals may thus in some cases be necessary. Thereby CSA conceptually intents to avoid mitigation benefits that compromise on productivity and food security goals and aims at the identification and active targeting of *sweet spots* that allow the simultaneous

[1] C.f. (Gornall, et al., 2010), (IPCC, 2007), (Beddington, et al., 2012), (HLPE, 2012), (Thornton & Cramer, 2012)

[2] Assuming average daily per capita calorie availability at 2,886 kcal/day in the scenario without climate change, while at 2,410 kcal/day (NCAR model) and 2,432 kcal/day (CISRO model) under climate change and without carbon fertilization.

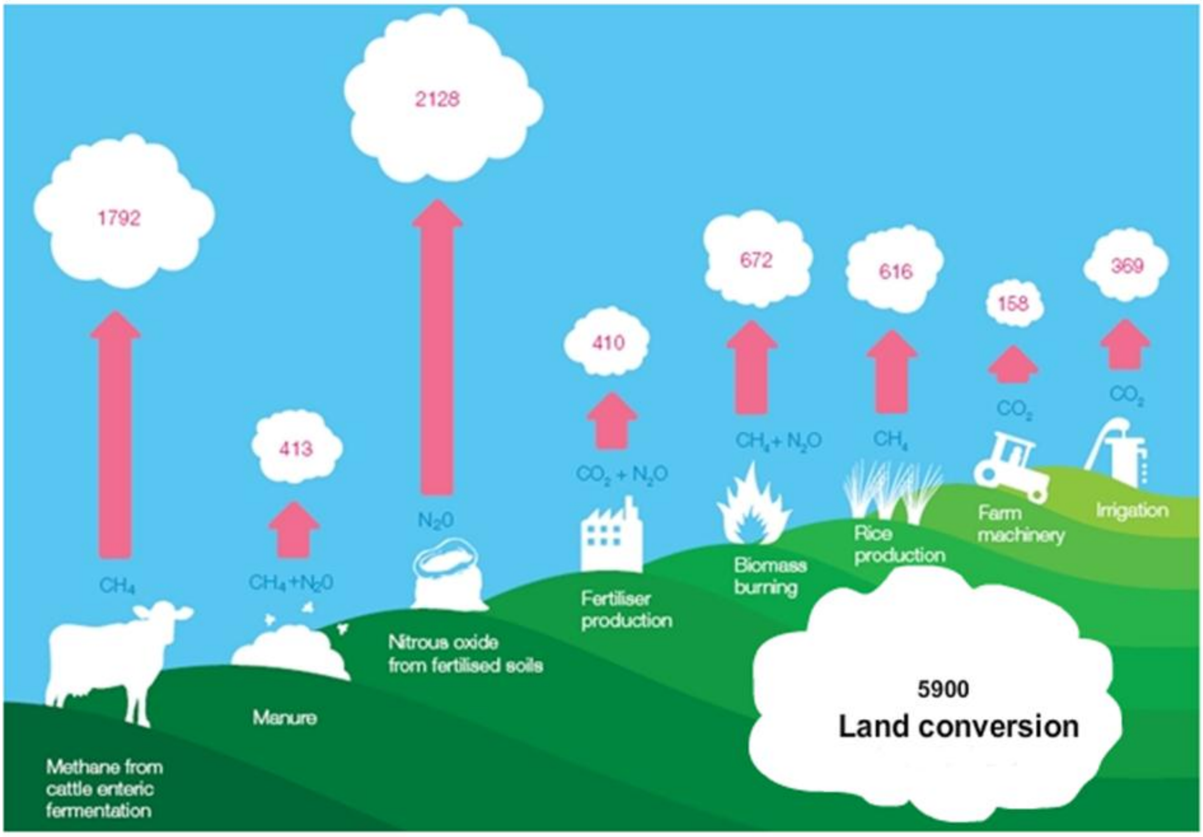
achievement of the multi-dimensional objectives of CSA. For more information on CSA and funding possibilities refer to Annex 5 and the Climate Smart Agriculture Sourcebook (FAO, 2013).

E. Main emission sources and mitigation potentials of AFOLU

Complementing the previous provided global overview of agriculture, forestry and land use change as an emission source, this section provides a brief sub-differentiated overview that specifies the main practices and activities that are sources of emissions as well as those with the strongest mitigation potential.

As the figure below illustrates, the biggest GHG emission sources in relation to agriculture are constituted by land conversion (5900 MtCO_2-e; largely driven by agriculture; (Andrasko, et al., 2007)), nitrous oxide emissions from fertilised soils (2128 MtCO_2-e) and methane emissions from enteric fermentation of cattle (1792 MtCO_2-e). Further relevant emissions stem from biomass burning, rice production and manure decomposition.

Figure 2: GHG emissions from agricultural sector by practices (in Mt CO_2-e)



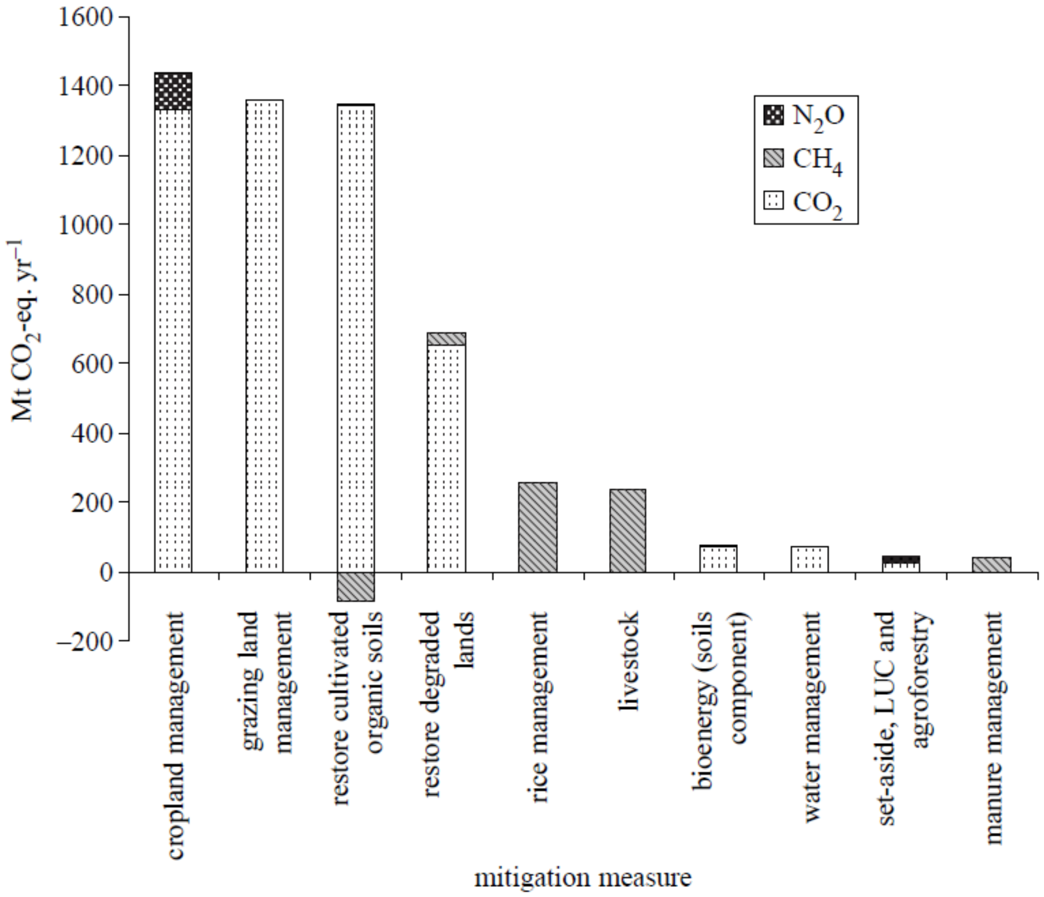
Graphic: Adapted from (Bellarby, et al., 2008).

Similarly to the depicted forms of land use change, also land conversions without any relation to agriculture are an additional substantial emission source.

Turning now from the question of the strongest emission sources to the most relevant options for GHG mitigation, they are on the one hand most evidently given by a reduction in the just depicted strongest emission sources (e.g. crop expansion). Besides, in agriculture there is further considerable mitigation potential from soil carbon sequestration as well as the avoidance of new emission sources and trends.

Considering only the technical mitigation potential directly related to agriculture until 2030, 89% of it is based on reducing emissions from cultivated soils and increases in soil carbon sequestration, while 9 % stem from reduced methane and 2% from reduced nitrous oxide emissions (Smith, et al., 2008). More precisely the main mitigation potentials are linked to the practices depicted in the figure below and are given firstly by improvements in cropland management, which are constituted by improved tillage practices and better adapted nutrient, water and manure management on croplands and secondly by improved grazing land management. Besides, the restoration of cultivated organic soils as well as the restoration of all degraded lands are major constituents of the technical mitigation potential by 2030. Subsequently rice management and livestock production are important mitigation options not related to soil organic carbon.

Figure 3: Global technical mitigation potential in agriculture by 2030 (in CO_2-e yr^{-1})



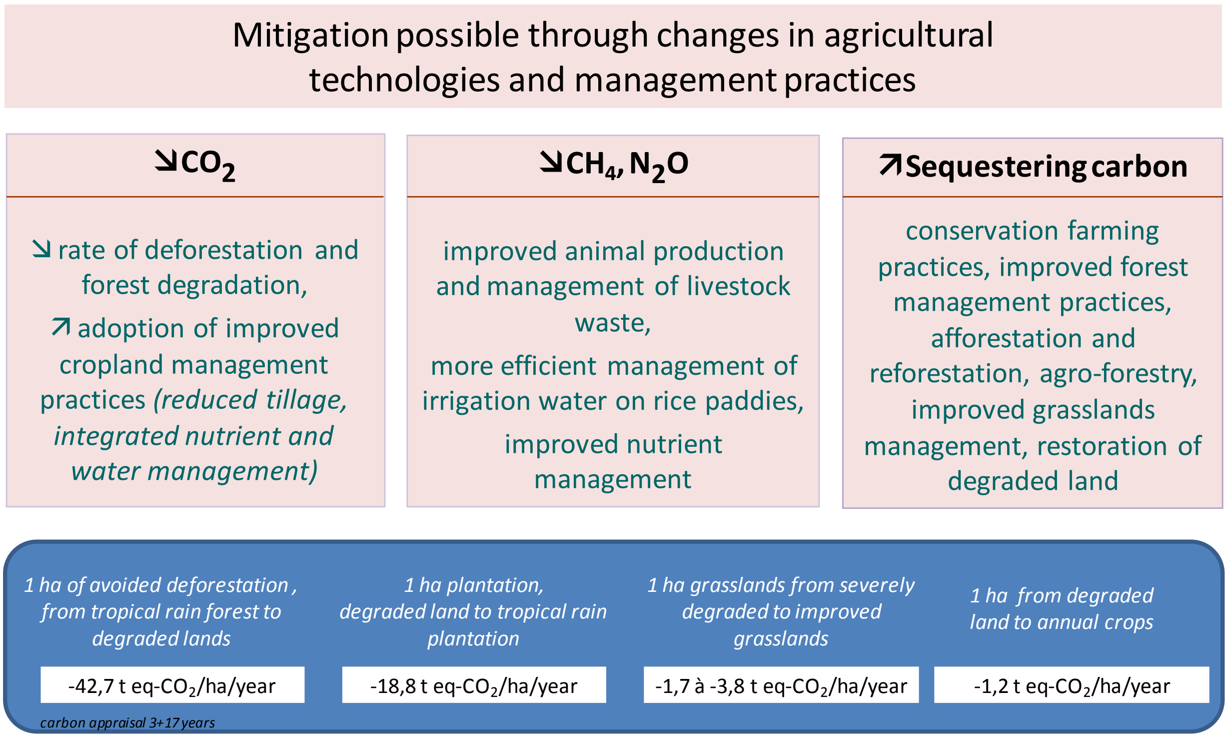
Source: (Smith, et al., 2008, p. 802)

The mitigation potential from the forestry sector is instead oriented towards the long term objective to establish sustainable forms of forest management that maintain or increase forest carbon stocks, while producing an annual sustained yield of timber, fibre and energy. The direct practices thereby centre on the reduction of deforestation, changed forest management as well as increases in afforestation and agroforestry (Andrasko, et al., 2007).

Summarizing the above presented evidence, the mitigation potential of the Agriculture, Forestry and Other Land Use (AFOLU) sector is high and many of the technical options are readily available and could be deployed immediately.

The figure below once more summarizes the most important mitigation practices in the AFOLU sector, differentiated by type of GHGs that are impacted and carbon sequestration. The four boxes below depict besides the estimated GHG-balance of four different forms of land use change as accounted for by EX-ACT and already provide a rough overview of the different impacts of various activities.

Figure 4: Main mitigation options of the agriculture, forestry and other land use (AFOLU) sector



Chapter 2: Overview of EX-ACT

A. The added-value of a carbon-balance appraisal

The introduction of this user guide stated largely why climate change mitigation in general as well as specifically in the AFOLU sector is an important target to be included in investment project design. Besides this need of a profoundly established overall rationale and justification, the engagement in a carbon-balance appraisal also should provide direct instrumental advantages that support the work of investment and policy planners in international financial institutions as well as of national stakeholders from ministries.

Such instrumental advantages of engaging in a carbon-balance appraisal can be mainly identified by:

1. Allowing to better target mitigation objectives by choosing in an informed manner between alternative project options.
2. Providing the functionality to proof to third parties that mitigation objectives are targeted (design stage) and achieved (monitoring stage).
3. Allowing to target supplementary finance for climate change mitigation.

In line with the development to stronger include climate change concerns within public decision making, aspects of climate change mitigation and adaptation are given more importance. Such increased concern also leads to new “green” funding facilities, whose mobilization can be facilitated by the utilization of carbon-balance appraisals. Ex-ante carbon-balance appraisals are also a first essential step towards better monitoring and evaluation of the agricultural sector potential for contributing to mitigation objectives.

From a process point of view, it is thereby essential to accelerate the integration of climate mitigation and adaptation aspects within the AFOLU sector and environmental policies. Thereby measures of capacity building within planning and policy units of agriculture and rural development ministries, as well as the strengthening of inter-ministerial coordination to coordinate and pilot agriculture and rural sector mitigation actions within a multi-objective framework is essential. This affects most directly policy and investment stakeholders involved in watershed management, forestry strategies, livelihood resilience, disaster management, sustainable intensification and food security policies.

B. Selecting the right carbon-balance accounting tool

In order to facilitate the further above depicted targeting of climate change mitigation in agriculture various GHG accounting tools have been developed that nevertheless follow different main objectives that are again reflected in different data needs, geographical scope, coverage along the value chain as well as regional and sub-sector specificity. The available tools can largely be subdivided into the following categories:

- Awareness raising: Simple tools using limited parameters and revealing main hotspots without reliable emission quantifications.
- National reporting: Tools that allow accounting for the sum of emissions and sinks in a given territory. They cover the full area of different agricultural sub-sectors and need to be populated with national data on changes in agricultural practices and land use, leading to an approximate identification of major emission sources and sinks.
- Project evaluation: Tools for project evaluation monitor specific project data throughout the implementation phase, using it as input data into project tools that allow the estimation of emissions throughout the project as compared to an alternative baseline scenario. They have to be able to accommodate the specific agricultural sub-sectors and variables of agricultural practices the project activities focus on. Some project tools can in a similar way analyse the impact of policies as well.
- Product oriented tools: Product oriented tools provide the carbon footprint per product unit. They cover different scopes of the life cycle e.g. from production to retail or over the full life span. They aim at identifying and remunerating efforts for emission reduction that have been carried out by actors from the private sector and thus serve purposes of product differentiation and environmental branding.

- Modelling tools: Modelling tools can be used for various of the above purposes and require thereby a much stronger set of input data concerning daily climate variations, a wide set of detailed soil parameters and selected management practices. Examples are e.g. Daycent/Century, DNDC or GEFSOC.

The study by Colomb, et al. (2012) – on which further information is provided in Annex 7 – identified eighteen GHG tools and characterized them as follows:

Table 1: GHG accounting tools classified according to their main objective and geographical zone

OBJECTIVE OF THE USER		TOOLS AND GEOGRAPHICAL ZONE OF APPLICATION
Raising awareness		Carbon Calculator for New Zealand Agriculture and Horticulture (NZ), Cplan v0 (UK); Farming Enterprise GHG Calculator(AUS); US cropland GHG calculator (USA).
Reporting	Landscape tools	ALU (World); Climagri (FR), FullCam (AUS)
	Farm tools	Diaterre(FR); CALM (UK); CFF Carbon Calculator (UK);IFSC (USA)
Project evaluation	Focus on carbon markets	Farmgas (AUS), Carbon Farming tool (NZ);Forest tools : TARAM (world), CO_2 fix (world)
	No focus on carbon markets	EX-ACT (World); US AID FCC (Developing countries), CBP (World), Holos(CAN), CAR livestock tools(USA)
Product oriented tools		Cool farm tool (World); Diaterre (FR), LCA tools and associated database (SimaPro, ecoinvent, LCA food etc: mainly data for developed countries.)

AUS: Australia; CAN: Canada; FR: France, NZ: New Zealand; UK: United Kingdom; USA: United States of America;
(Colomb, et al., 2012)

The tested calculators are accounting for different GHG sources and emissions and share with the NGGI-IPCC 2006 nearly all the identical methodological basis. The different tools are characterized by strong differences concerning the considered scope of emission sources as well as the considered geographical scale that can be represented in the tools, which impacts estimated emissions significantly.

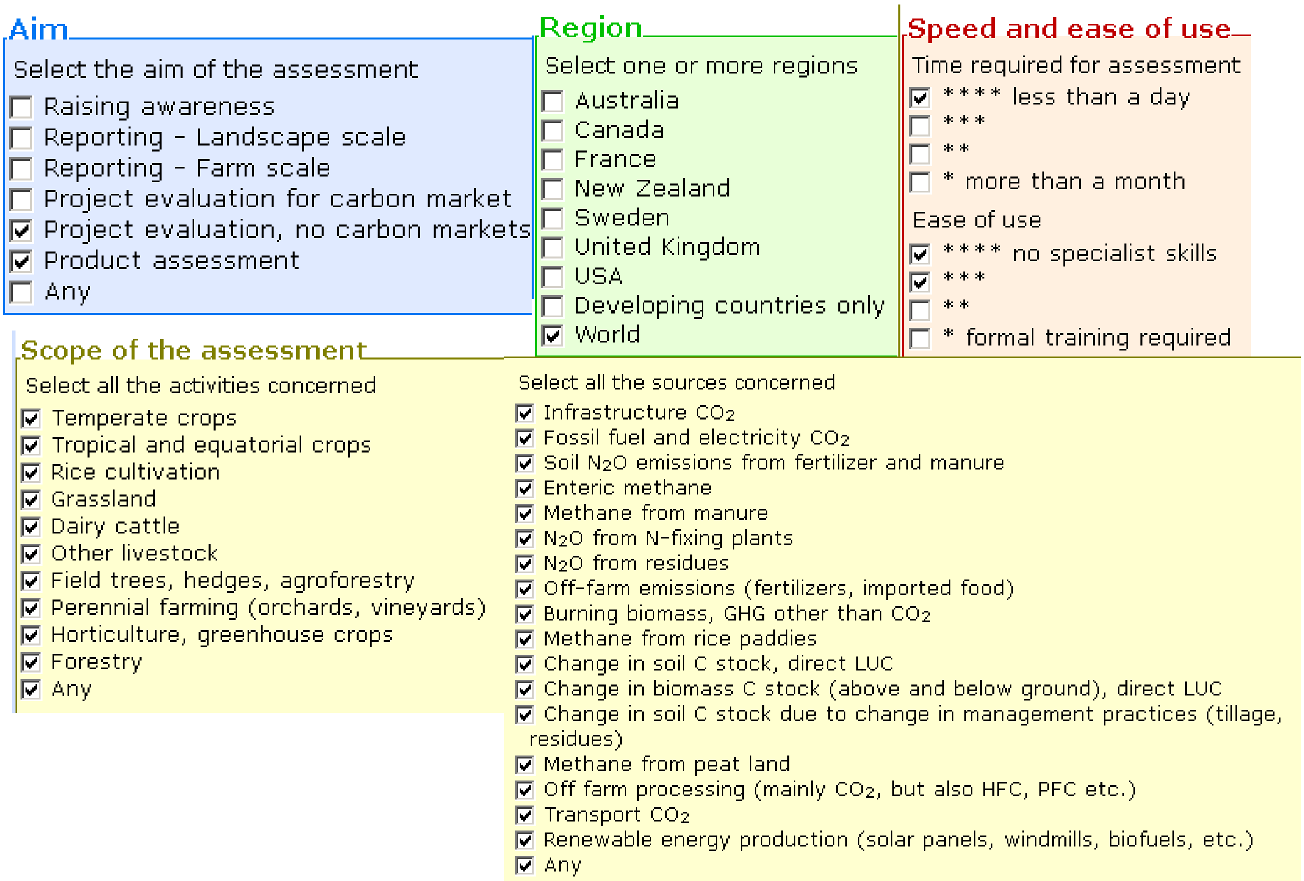
The various GHG calculators have specific, differing main objectives. Usually they possess the clear competitive advantage in their own field of specialization and should be the first choice for specific analyses. In order to guide users in an easy way to the most adapted tool for their purposes, IRD, ADEME and FAO have developed a multi-criteria GHG tool selector in form of an interactive website that guides tool selection (available at: **www.fao.org/tc/exact/review-of-available-ghg-tools-in-agriculture**). It is based on Colomb et al. (2013) and considers the above listed 18 GHG calculators. The website lets users specify the main preferences for their analysis using the five categories:

- Region of analysis
- Aim of analysis
- Speed and ease of use
- Scope of the assessment
    - By activity
    - By emission source

Based on these specifications the website then lists the set of best fitting tools on the bottom of the page. By clicking on each GHG tool, users are subsequently provided with detailed information and weblinks.

Figure 5: Exemplary screenshot of the online selection guide to GHG emission calculators

→ ***Available at: www.fao.org/tc/exact/review-of-available-ghg-tools-in-agriculture***



Calculator	Score	Region	Activities	Sources	Speed	Ease
Cool Farm Tool	94%	100%	90%	88%	50%	100%
EX-ACT	88%	100%	90%	68%	100%	100%
Carbon Benefits Project calculator	83%	100%	90%	59%	25%	50%
Holos	29%	0%	60%	53%	25%	100%
Dia'terre	28%	0%	60%	53%	50%	25%
USAID Forest Carbon Calculator	26%	0%	75%	29%	100%	100%
AFD Carbon footprint tool	25%	0%	50%	44%	50%	100%

This manual is interested in the functionality of project evaluation, characterized by relatively low data and cost requirements in order to fit with the requirements of a relatively cost-effective investment project design process, as common in agricultural planning. A tool should at the same time, be able to accommodate certain location specificity and thus exceed pure Tier 1 functionality. Furthermore it is required that all agricultural sub-sectors as well as all types of GHGs and emission processes in the AFOLU sector, be covered.
For these purposes EX-ACT is evaluated as the tool with the biggest competitive advantage.

C. What is EX-ACT: Main structure and outputs

The EX-Ante Carbon-balance Tool (EX-ACT) was jointly developed by three FAO divisions and is aimed at providing ex-ante estimations of the impact of development programmes, projects and policies in the agriculture, forestry and other land use sector on GHG emissions and carbon stock changes, constituting the carbon-balance.

EX-ACT is a land-based accounting system, measuring GHG and C impacts per unit of land, expressed in tCO_2-e per ha and year. A selected functionality accounting for the C balance per unit of produce is also available (c.f. Annex 5: *Use of EX-ACT in assessing product carbon footprints along the value chain*). The ex-ante C-balance guides the project design process and decision-making on funding aspects, complementing the usual ex-ante economic and environmental analysis of investment projects and development policies. EX-ACT has thus the potential to support project designers to select project activities with higher benefits both in economic and climate change mitigation terms and the output could be used in financial and economic analysis.

EX-ACT is an easy tool that can be used in the context of ex-ante project/program formulation. Further, it is cost effective, requires a compared small amount of data, and has resources (tables, maps) which can help finding the required information. While EX-ACT is mostly used at project level it may easily be up-scaled to the programme/sector level.

Basic contents of EX-ACT: Module structure

EX-ACT requires the user to specify information concerning few geographical, climatic and agro-ecological variables and a wider set of information regarding land-use change activities and agricultural management practices. More specifically the input data requirements in EX-ACT are composed of six linked Microsoft Excel sheets/Modules in which project designers can insert information concerning:

1. **General description of the project**
   (geographic area, climate and soil characteristics, duration of the project);

2. **Land use change**
   (deforestation, afforestation/reforestation, non-forest LUC)

3. **Crop production and management**
   (agronomic practices, tillage practices, water & nutrient management, manure application)

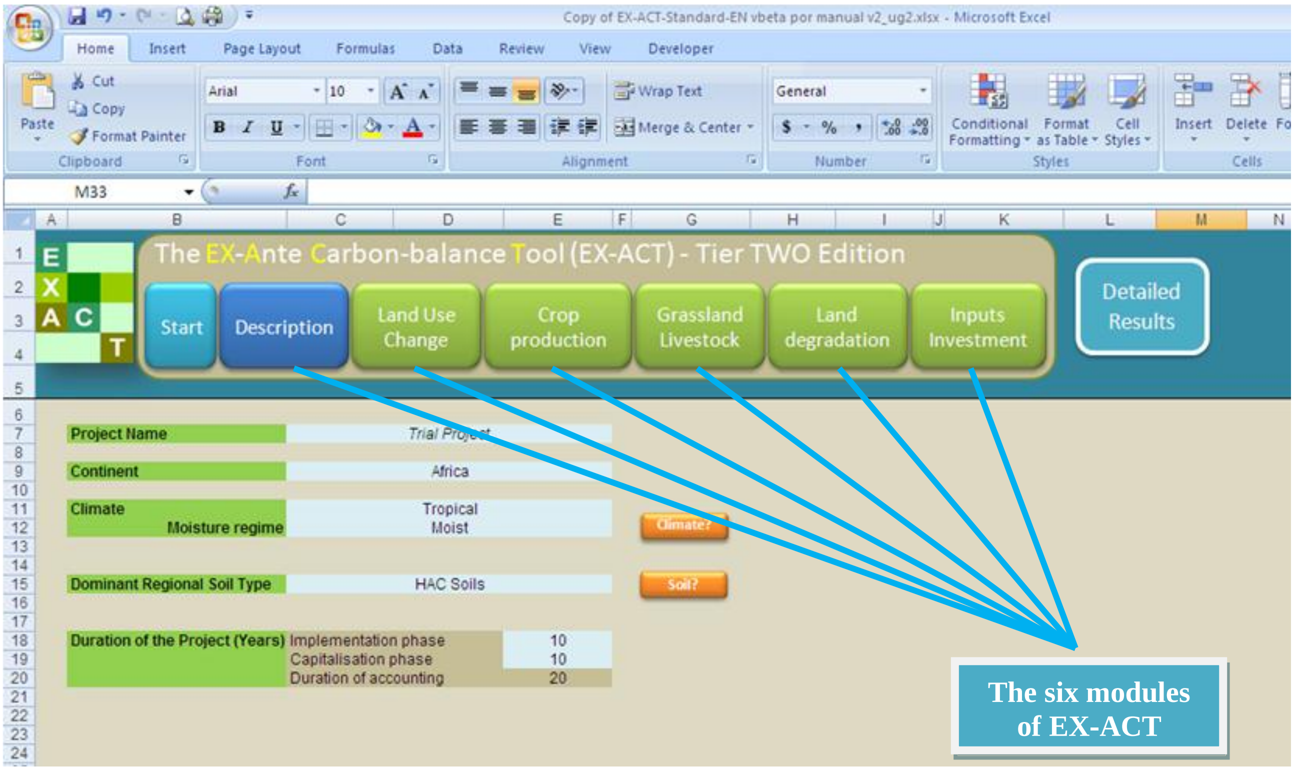
4. **Grassland and livestock**
   (grassland management practices, feeding practices)

5. **Land degradation**
   (forest degradation, drainage of organic soils, peat extraction)

6. **Inputs and further investments**
   (fertilizer and agro-chemical use, fuel consumption, electricity use)

Figure 6 below shows once more the six topic modules of EX-ACT. Here depicted as they appear in Excel as navigation bar on top of the window.

Figure 6: Screenshot of EX-ACT



The wide coverage of these six topic modules allows that EX-ACT is able to analyse a wide range of agricultural and forestry development projects, such as besides others projects with a main focus on:

- Livestock development
- Crop production intensification
- Rural development
- Food security
- Forest protection and management
- Watershed development
- Land rehabilitation
- Bio-energy
- Climate change mitigation (forestry, ...)

Depending on the specific project, data collection and model completion is nevertheless only necessary in the limited number of modules relevantly altered by the project. The main data needs occur thereby only in the focal areas of the project. Indeed, rather than using modules according to project type, they are thereby chosen in regards to project impacts i.e. what is affected by the project.

This flexibility also allows for the adequate consideration of multi-segment projects and leads the project designer to think of possible indirect impacts on not directly targeted areas, as e.g. increased pressure for deforestation or grassland degradation.

The table below offers a concise check-list for users to decide on which modules to use. The same question will be dealt with in more detail in the section on data collection:

Table 2: Checklist for choosing relevant modules in EX-ACT

Carbon-balance Impact Main Impact Area			**EX-ACT** **Module(s) to be filled**	**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		
	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		

Basic contents of EX-ACT: Scenario building

Ex-ante evaluations of an activity plan compare the impacts of a planned intervention to the business as usual scenario. It is thus in the basic logic of EX-ACT that the specified data is required for three points in time:

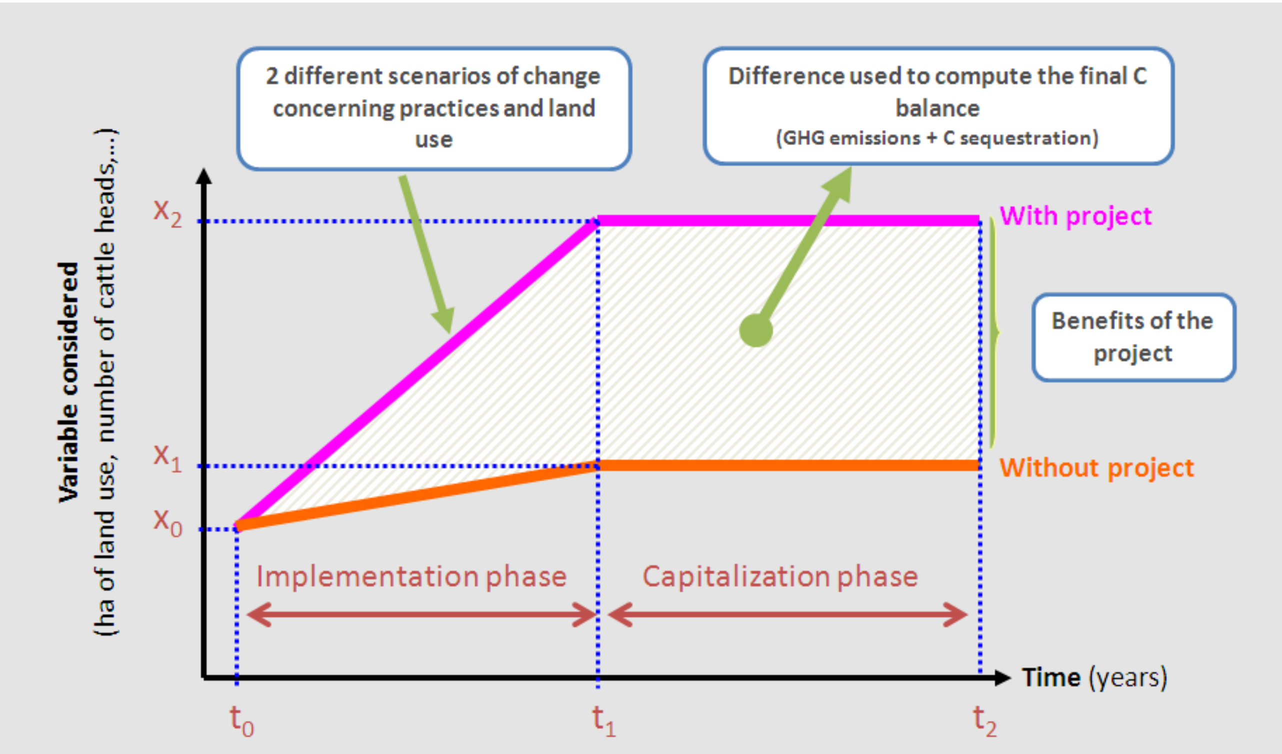
- The situation at project start
- The With-Project scenario
- The Without-Project scenario (business as usual/baseline scenario)

Figure 5 here below illustrates this essential differentiation which is crucial to the correct understanding and application of EX-ACT: Thus $\mathbf{x_0}$ gives the **initial situation** of land use and management practices of a given project. Due to the consecutively starting project intervention, specific changes on these input variables are expected e.g. the intensification of agricultural crop management systems. This defines the **With-Project scenario** that leads to $\mathbf{x_2}$.

By contrast the initial situation would have experienced different alterations if the project would not have taken place. An adequate method has thus to be used to derive all relevant of the specified data needs for the **Without-Project scenario** that leads to $\mathbf{x_1}$.

Thereby EX-ACT differentiates between two time periods: The **implementation phase** defines the time period in which active project activities are carried out and lasts from $\mathbf{t_0}$ until $\mathbf{t_1}$. 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 e.g. in soil carbon content or in biomass, that are caused by the prior intervention. This period defines the **capitalization phase** which lasts from $\mathbf{t_1}$ until $\mathbf{t_2}$.

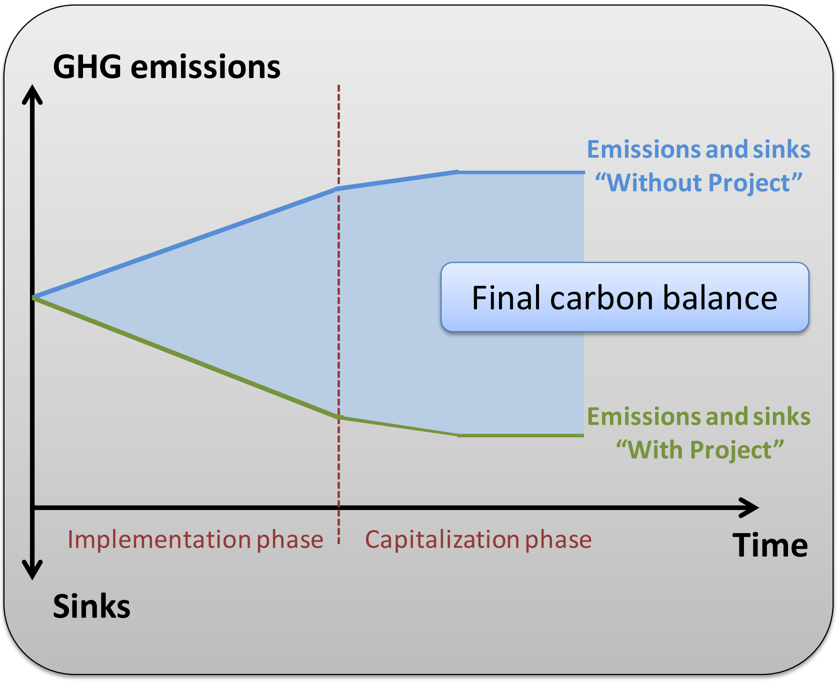
Figure 5: Building of development scenarios for the use in EX-ACT



The three different sets of input data from the situation at project start, the With- and Without-Project scenario then lead, to the calculation of GHG emissions and carbon stock changes. Figure 6 below illustrates the combined impact on GHG emissions and sinks of the With-Project and the Without-Project scenario. The graph shows that both scenarios are net emission sources, while the Without-Project scenario leads to much higher GHG emissions than the With-Project scenario.

The final carbon-balance that compares the expected emissions and sinks under the With- and Without project scenario may then be derived as the blue area between the two emission scenarios. It is the marginal difference that is brought about by project implementation.

Figure 6: Comparing the GHG impact of different scenarios



Basic contents of EX-ACT: Main output

Taking the example of the FAO / World Bank "Accelerated Food Security Project" (AFSP) in Tanzania an exemplary overview of such main results of an EX-ACT application is presented here below.

The *AFSP* introduced the combined package of increased farmers' access to critical agricultural inputs – as mainly fertilizers and improved seeds – while at the same time promoting sustainable land management practices that e.g. do not use burning practices for residue management or land preparation. The total project size accounted for roughly 1 million hectares.

Figure 7: Exemplary results of an EX-ACT appraisal

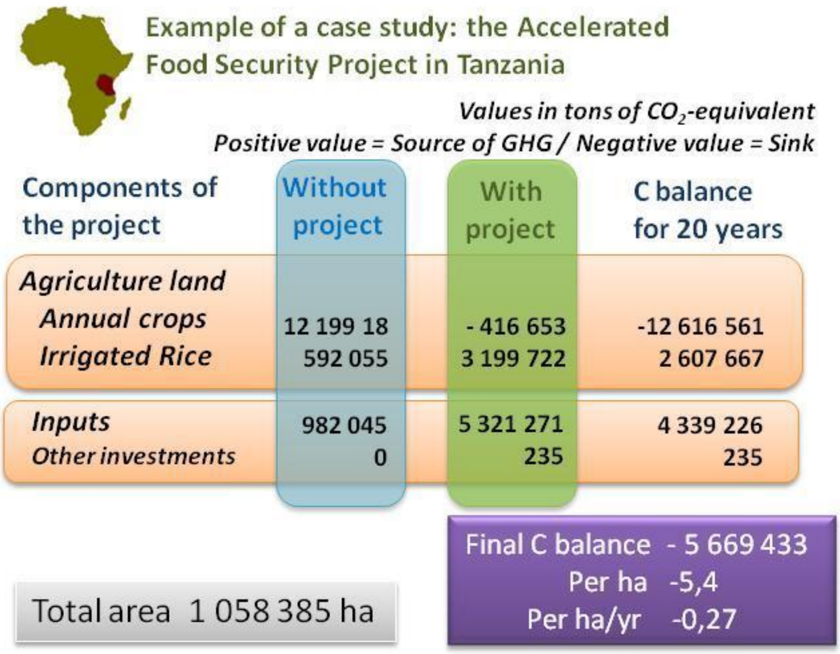


Figure 10 above shows that the increase in fertilizers ("Inputs") as well as the intensification of flooded rice systems ("Irrigated rice"), which are essential parts of the food security objectives of the programme, both lead to substantial increases in GHG emissions. The emissions and sinks of the With-Project scenario (above in the green frame) thus show that the project is an overall emission source, with the irrigated rice systems causing 3.2 Mt of CO_2-e and the agricultural inputs causing 5.3 Mt of CO_2-e. The enhanced land and crop management practices that are not expected to compromise on yields and are adequate technological choices within more intensified systems, are instead carbon sinks of -0.4 Mt of CO_2-e.

Although the through productivity gains legitimized project components lead to significant GHG emissions and make the project in the end an overall source of GHG emissions, the project is nevertheless also compared to the baseline scenario – here given by the continuation of prior prevailing agricultural practices (in the blue frame).

Comparing this With-and Without-Project scenario shows in this case that the project leads to a reduction in emissions as compared to the business-as-usual scenario. Over the full period of analysis of 20 years, the project thus leads to a carbon-balance of -5.6 Mt of CO_2-e that are less emitted due to project implementation. This is equal to a carbon-balance of -0.27 $MtCO_2$-e per hectare and year. This project analysis made use of the EX-ACT modules: *Description, Crop Production and Inputs*.

EX-ACT appraisals want to allow for a realistic first estimation of project impacts on the GHG-balance. Though a project that both is an overall sink of GHGs and has in addition a favourable GHG-balance is preferable and indicates positive outcomes for climate change mitigation, EX-ACT explicitly does not evaluate every sink & favourable GHG-balance as necessary positive and every emission source & unfavorable GHG-balance as negative. Also, it is not advocated for a process of re-designing a project until it possesses a favorable GHG-balance at all costs.

Instead it is clearly acknowledged that certain project types tend relatively automatically to be overall emission sources, while other project types or activities are very easily overall sinks. In this context it is firstly necessary to evaluate the GHG-balance in relation to the wider pursued development objectives that might e.g. justify a negative GHG-balance. Secondly, it is the strength of EX-ACT to lead to a reflection on marginal differences: Thus it is not solely important whether a project is an overall sink or source of GHGs, but to lead to a marginally improved GHG-balance through the consideration of various project options and without compromising on the wider pursued development goals.

Figure 8: Some practical principles for the easy use of EX-ACT

- Only modules that are directly impacted by project activities have to be filled
- Sophisticated main data needs occur only in the focal areas of the project
- It is normal that many data entry cells will not be used
- Information is entered on changes occurring *With Project vis a vis Without Project* situation.
- Most obvious changes are entered first, especially on effects generated by the project for which there is quantitative information (number of hectares with improved techniques, quantity of inputs...)
- Projects of small scale usually utilize a baseline scenario of “no change”, assuming that land use and agricultural practices from the project start situation would be continued in absence of any project intervention

D. Main reasons for using EX-ACT

Taking these requirements together, EX-ACT proposes a consistent combination of the following attributes. It does not pose complex software requirements and with Excel, offers a widely familiar user interface that does not require permanent internet access.

Complementing the question of the value-added from engaging in a carbon-balance appraisal, the following list provides a concise overview of the main reasons why EX-ACT is an instrumental and effective tool for preparing a carbon-balance appraisal. It is intended as a brief overview that summarizes central points, while other elements will be only clarified in detail in the results section of this *User Manual*.

Comprehensive appraisal: EX-ACT offers the advantage of an integrated analysis of greenhouse gases, through its inclusion of a wide spectrum of activities from the agriculture, forestry and other land use sector. It is able to account for the carbon-balance concerning the activities of deforestation, afforestation and reforestation, land use change and conservation, land degradation, annual crop production, agroforestry and production of perennial crops, irrigated rice as well as livestock production.

Besides being thus widely inclusive in terms of activity areas, it is also fully comprehensive in covering all five carbon pools of above-ground biomass, below-ground biomass, dead wood, litter, and soil carbon. The tool considers CO_2, CH_4 and N_2O as sources and associated greenhouse gases, from biomass growth and removal, site preparation (cutting, burning), project management (fuel, fertilization, liming and irrigation) and exported harvested wood products. It also considers CH_4 from rice and CH_4 and N_2O from livestock production and management.

Landscape and scaling up: EX-ACT is well-suited for the assessment of projects activities on various land-use areas and scales. While the tool works best at project level, given that only one dominant soil and climate type can be considered at a time, it can nonetheless be easily up-scaled to regional and national levels. In such cases sensitivity analyses concerning soil and climate conditions or separate EX-ACT analysis by region may complement the usual analysis process and ensure precise results. In such a way it has already been used to analyze national agricultural programs and policies in Nigeria and Morocco, product carbon footprint studies in Madagascar as well as various ARD projects.

Data Flexibility: EX-ACT offers a high data flexibility, allowing the user to choose between site-specific data and default values from the IPCC that are furnished by EX-ACT, based on the targeted level of precision and based on data availability. The tool also provides a wide range of resources (tables, maps) which can direct the user to the required information in order to effectuate the estimation. All such default values can be chosen from drop-down menus if no project-specific data is available.

Long-term projection: EX-ACT can handle projections for longer time horizons (in comparison to other tools) and takes into account the saturation effects concerning soil carbon content and vegetation growth in forests.

Cost-efficient planning tool: EX-ACT is a tool that can be applied with little cost and time intensity. For data collection purposes a link to project teams within the project country or to other country stakeholders can thereby strongly facilitate cost effective data collection. More precisely, a brief workshop of the project analyst that effectuates the EX-ACT appraisal with the national project team that allows to introduce the technical aspects of the tool and is followed by an in-depth, project-specific data assessment and scenario building process will equip the appraisal team with sufficient data to carry out the full carbon-balance appraisal.

Interactive and participatory: The EX-ACT appraisal process is interactive as well as participatory, and can strengthen the overall project design process, especially when a training and workshop element (for project teams, government counterparts, and other stakeholders) is integrated as part of the process. This happened exemplarily as part of EX-ACT appraisals in Russia, India, and Niger. It also enables the identification of the factors that hinder the adoption of more carbon-neutral activities (or adjustments to proposed activities) and may facilitate the discussion on ways to create incentives and institutional conditions that can promote their uptake (such as payments for environmental services).

Simulation and scenario building tool: EX-ACT stimulates stakeholders to actively engage in scenario building exercises that compare different project and development options over time, possibly involving simulation and modelling. This engagement may lead to a clearer identification and reflection on the long-term goals and helps to adjust initial assumptions for their reasonability.

Chapter 3: Methodological Background

This chapter lays out the methodological background of EX-ACT. It presents logic and scientific sources of the underlying methods, elaborates how they have been developed and describes their strength and limitations. Further explanations are provided on the difference between ex-ante, monitoring and evaluation approaches.

This chapter is thus of special importance for readers that intent to clarify methodological questions of the carbon-balance estimation in more detail, while it does not focus on users that mainly want to improve their handling of the tool.

E. The methodological basis

EX-ACT is a land-based accounting system that relates activities in the Agriculture, Forestry and Other Land Use (AFOLU) sector to:

- Estimated values of the five carbon pools above ground biomass, below ground biomass, dead wood, litter and soil organic carbon and
- Estimated coefficients of $CH_{4,}$ N_2O and selected other CO_2 emissions.

Based on activity data from the AFOLU sector, EX-ACT allows estimations of carbon stocks, stock changes and $CH_{4,}$ N_2O and CO_2 emissions, which are the basis of the overall carbon-balance.

As introduced in the section *key concepts and terminology* EX-ACT offers users the functionality to utilize default values for carbon pools and emission factors, making it relatively easy to derive a carbon-balance by specifying activity and land use change data. For the specified default values, but also in accounting structure and logic EX-ACT has been developed using mostly the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and from Chapter 8 of the Fourth Assessment Report from working group III of the IPCC (Smith, et al., 2007) for specific mitigation options not covered in NGGI-IPCC-2006. Other required coefficients are from published reviews or international databases. For instance embodied GHG emissions for farm operations, transportation of inputs, and irrigation systems implementation come from Lal (Lal, 2004) and electricity emission factors are based on data from the International Energy Agency (IEA).

Using still the thus given accounting structure, users have further the possibility to utilize more site specific values replacing default values for carbon pool and emission factors. Table 1 below specifies in a transparent manner all sources used by EX-ACT in order to assume default values for emission factors and carbon values.

A main conceptual differentiation in EX-ACT is the distinction between land categories that remain in the same land use and lands converted into another land-use category during the period of analysis. Thereby EX-ACT adopted the six broad land use categories (and their sub-categories) proposed by the IPCC, and makes the strongest differences between the three land uses: Forest land, cropland, and grassland.

Table 1: Specification of sources for carbon values and emission factors used in EX-ACT

Table 1 - Overview of Modules used for C-Balance calculation.

Name of the Module	Main category	IPCC-category	GHG concerned	Link with other Land-related Module	Main methodologies and references
Deforestation	LUC[1]	Land converted to another land-use: Forestland to land	Mostly CO_2, but also CH_4* and N_2O*	MC Modules and Matrix	Volume 4 (Chapter 4) of NGGI (IPCC, 2006)
Afforestation and Reforestation	LUC	Land converted to another land-use: land to Forestland	Mostly CO_2, but also CH_4* and N_2O*	MC Modules and Matrix	Volume 4 (Chapter 4) of NGGI (IPCC, 2006)
Other Land Use Change	LUC	Land converted to another land-use: non-Forestland to another non-Forestland	CO_2	MC Modules and Matrix	Volume 4 (Chapters 4-6) of NGGI (IPCC, 2006)
Annual Crops	MC[2]	Cropland remaining Cropland	Mostly CO_2, but also CH_4* and N_2O*	Matrix	Volume "Mitigation" (Chapter 8) of the fourth Assessment Report of the IPCC (Smith et al., 2007a)
Agroforestry / Perennial Crops	MC	Cropland remaining Cropland	Mostly CO_2, but also CH_4* and N_2O*	Matrix	Volume "Mitigation" (Chapter 8) of the fourth Assessment Report of the IPCC (Smith et al., 2007a)
Rice	MC	Cropland remaining Cropland	Mostly CH_4, but also N_2O*	Matrix	Volume 4 (Chapter 5) of NGGI (IPCC, 2006)
Grassland	MC	Grassland remaining Grassland	Mostly CO_2, but also CH_4* and N_2O*	Matrix	Volume 4 (Chapter 6) of NGGI (IPCC, 2006)
Livestock		Not a land use category	CH_4 and N_2O		Volume 4 (Chapter 10) of NGGI (IPCC, 2006) and Volume "Mitigation" (Chapter 8) of the fourth Assessment Report of the IPCC (Smith et al., 2007a)
Inputs		Not a land use category	CO_2 and N_2O		Volume 4 (Chapter 11) of NGGI (IPCC, 2006) and Lal (2004)
Project Investment		Not a land use category	CO_2		Volume 1 of NGGI (IPCC, 2006), Lal (2004) and U.S. Department of Energy (2007)

[1]LUC = Land_Use Change, [2]MC = Management Change, *from biomass burning (Chapter 2 of NGGI - IPCC, 2006), [3]NGGI = Guidelines for National Greenhouse Gas Inventories.

(Bernoux, et al., 2010)

Complementing the information given in the table above, the following list gives a better understanding for the process by type of carbon pool and type of GHG:

• Above ground biomass: Default values correspond to estimates provided by NGGI-IPCC-2006 and expressed in t ha^{-1} of dry matter. The corresponding C stock (in t of C) is calculated using the specific C content, e.g. 0.47 for above-ground forest biomass.

• Below ground biomass: In most cases the below-ground biomass is estimated using a ratio (R) of below-ground biomass to above-ground biomass. EX-ACT uses the default values provided by NGGI-IPCC-2006, e.g. R is 0.37 for all tropical rainforest and 0.27 for tropical mountain systems. In some cases the total above plus below ground biomass is used if it is not mandatory for calculation to have separate estimates.

• Litter and dead-wood: It is assumed that litter and dead wood pools are zero in all non-forest categories (excluding tree crops and perennial systems) and therefore transitions between non-forest categories involve no C stock changes in these two pools. For other transition default values are provided.

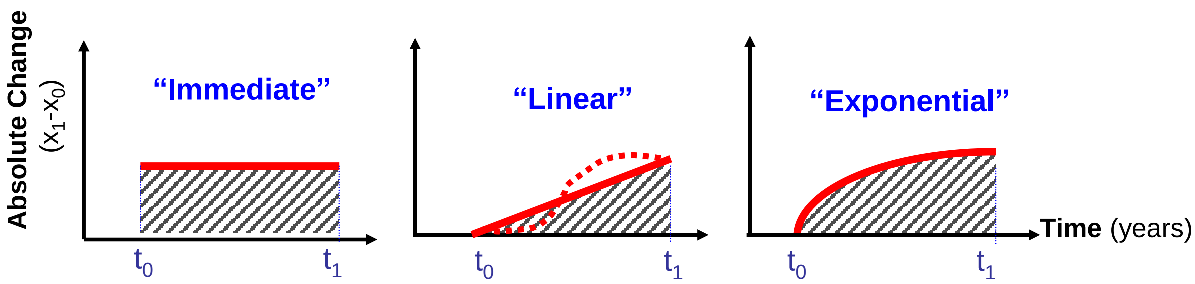
• Soil C: For the soil C estimates, the default values are based on default references for soil organic C stocks for mineral soils down to a depth of 30 cm. When soil organic C changes occur over time (land use change or management change), a default time period of 20 years is assumed for transitions between equilibria. These values are found in both IPCC 1997 and 2006 Guidelines, compiled from a wide range of observations and data from long-term monitoring. Some modules use C change rates instead of the soil C stock difference and therefore do not require information on absolute soil C stocks. In both approaches it is hypothesized that soil organic C stock changes during the transition to a new equilibrium occur with a linear pattern. Although soil C changes in response to management changes may often be best described by a non linear function, the linear assumption greatly simplifies the methodology and provides a good approximation over a multi-year period.

• CH_4, N_2O and some CO_2 emissions not covered in AFOLU chapter: For CH_4 and N_2O emissions, the generic approach consists of multiplying an emission factor for a specific gas or source category with activity data related to the emission source (e.g. area, animal numbers or mass unit…). Emissions of N_2O and CH_4 are either associated with a specific land use category or subcategory (e.g. CH_4 emissions from rice), or are estimated at project aggregated data (e.g. emissions from livestock and N_2O emission from fertilizers). Further emissions of CO_2 instead are associated with indirect emissions from production, transport and storage of artificial inputs or with direct burning of fossil fuels. CH_4 and N_2O emissions are converted into CO_2-e emissions based on the global warming potential of each gas. The user has the ability to use either the official values under the Kyoto Protocol of the UNFCCC, or the last update provided by the IPCC (2007).

F. Dynamics of change in EX-ACT

Periods of land use change as well as changes in further variables (livestock herd sizes or new agricultural practices and management options) specify the so called *implementation phase* in EX-ACT. For the impact on GHG emissions and carbon sequestration it is thereby relevant in which pace changes occur. EX-ACT offers thereby the three options of *default (linear or s-curve)*, *immediate* or *exponential* dynamics of change, as illustrated in Figure 9. Users have thus to specify whether e.g. deforestation on all the specified area takes place immediately during the start of the implementation phase, increases linearly throughout it or occurs exponentially until at the end of the implementation phase the complete land has been deforested.

Figure 9: Different dynamics of change available in EX-ACT



G. Defining project boundaries

As a first step users should clearly define the location and delimitation and size of the project intervention area. Thereby they should differentiate between the delimitation of activities and impacts, meaning:

1. The direct zone where activities of the project are implemented, targeting a certain number of farmers.
2. Non target zones in which clear spillovers or externalities from project implementation occur.

Exemplarily an agricultural development project that increases access to extension services and strengthens farmers' cooperatives that diffuse technology for sustainable intensification may not only lead to production changes on the targeted project area. Instead, it may lead at the same time to prevent or promote further expansion of agriculture on forested lands (externalities) or lead as well to changes in agricultural practices on existing agricultural cropland in proximity (spillover).

The EX-ACT analysis usually concentrates on the direct project implementation zone. Zones that are affected by project externalities should only be included into the EX-ACT analysis, when there is clear empirical evidence on the way they are impacted and their alteration is not purely hypothesized and assumption based.

This step of documenting the intervention area may very well entail the documentation of the specific project location coordinates. Besides, visual mapping tools may be very useful means for communicating central information during data collection and as part of later project analysis.

H. Ex-ante versus ex-post

Methodologically it is further important to differentiate between ex-ante appraisals – the primary mode of operation of EX-ACT – and ex-post evaluations.

Ex-ante appraisals aim at improving the quality of new or renewed programmes. They can be carried out as part of a planning process in parallel with or as a part of the programme design, feeding results into the preparation of the proposal (ARD, World Bank, 2011).

Examples where EX-ACT has been used as ex-ante methodology include e.g. World Bank projects in Russia (Forest Fire Response Project), China (China Integrated Modern Agriculture Development Project), India (India Rajasthan Agricultural Competitiveness Project) and Madagascar (Irrigation and Watershed Management Project) (FAO, 2013).

Ex-post evaluations or impact assessments are instead conducted after project completion, or after completion of certain segments of a project, e.g. as part of a monitoring and evaluation plan. The purpose of an ex-post assessment is to judge the effectiveness and/or efficiency of completed projects with sufficient scientific quality, to increase the accountability of project implementation and to lead to improvement of future interventions and institutional learning (Contreras & Gregersen, 1995).

Examples where EX-ACT has been used as ex-post evaluation include e.g Niger (Projet d'Action Communautaire pour la Résilience Climatique), Morocco (Plan Maroc Vert), Madagascar (all IFAD projects), India (Sodic Soil III project), Brazil (Santa Catarina Rural Competitiveness Project, Rio de Janeiro Sustainable Rural Development Project) and Nepal (IFAD, Leasehold Forestry livestock project).

I. The baseline scenario

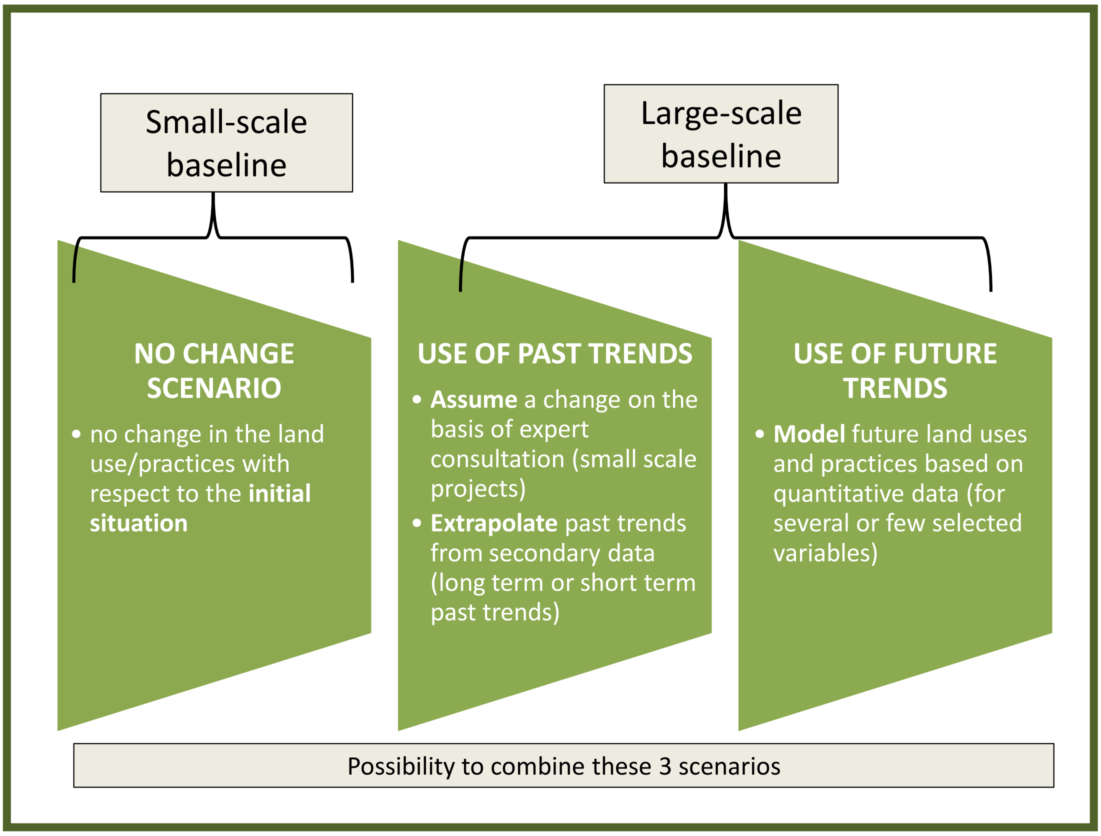
The creation of a baseline scenario is a central component of an EX-ACT appraisal. It depicts the counterfactual outcome in terms of input variables as well as resulting GHG emissions and sinks that would most likely have occurred in absence of the project intervention.

The baseline scenario is thus the instrumental step to estimate and prove the **additionality** of a project, meaning its capacity to lead to less GHG emissions than without project.

Since the EX-ACT GHG-balance of a project is given by the difference of the overall effects of project and baseline scenario, the final results of EX-ACT are determined as strongly by the project as the baseline scenario. This is why the baseline scenario is of central importance and one of the major steps of an EX-ACT analysis. It is important to recognize that setting a baseline can have political implications as well as technical, as the level of emissions that a country or project might claim as a right, is not necessarily the same as the most likely emissions growth scenario without the project. This is a highly contentious issue in the UNFCCC and as yet there is no agreed standard for setting agricultural mitigation baselines internationally.

EX-ACT thereby proposes three main methods to develop a baseline scenario: Assuming that no changes to the status-quo situation will occur throughout the baseline time span, assuming changes using past trends, modelling changes using future trends (c.f. Figure 10).

Figure 10: Three main approaches to develop baseline scenarios



a. No change scenario: The *no change* scenario assumes that in the absence of the project, no changes in land use or agricultural practices will occur. Instead the status-quo situation at project start is assumed to continue in absence of the project. This assumption represents the most simplistic scenario, requires no additional data and is largely used for projects of small scale. In countries and regions undergoing profound agricultural transformation processes e.g. characterized by strong pressure for land conversion and incentives towards intensification users should use instead another baseline methodology.

b. Use of past trends: This approach assumes that the changes in land use and agricultural practices will continue to evolve in the near future with the same dynamic as in the close past. The scenario therefore forecasts the future situation, extrapolating either long term (30 years) or short term (5-10years) past trends using secondary data. For most variables of land use change dynamics and agricultural practices, short term trends are preferred over long term trends, due to their strong dependency on dynamically fluctuating context variables (Bernoux, et al., 2011).

c. Use of future trends: This approach requires advanced methodological tools to engage in actual modelling of the future development of land use and agricultural practices using a wide range of quantitative input data.
Compared to the other approaches it requires the use of dedicated software, high data needs and is more time intensive, while also being associated to uncertainties due to the initial assumptions of parameters and equations. The use of future trends might especially be a useful approach whenever non-project related processes with strong impacts on land use and practices emerge, which are not reflected by past trends. This might e.g. be the case after introduction of input subsidy schemes or changes in ownership

rights of state and communal land. Modelling techniques are especially helpful when regarding very large project areas as e.g. on national level and when focussing on longer time periods.

The extent of complexity of the baseline scenario building depends thus largely on the chosen approach. Future projections are thereby always associated to high uncertainty levels. This also translates into the situation that the three different baseline methodologies can possibly lead to considerably different results. The graph below demonstrates such an example for the case of future deforestation:

Figure 11: Example of results for the three types of baseline scenario (source FAO Stat)

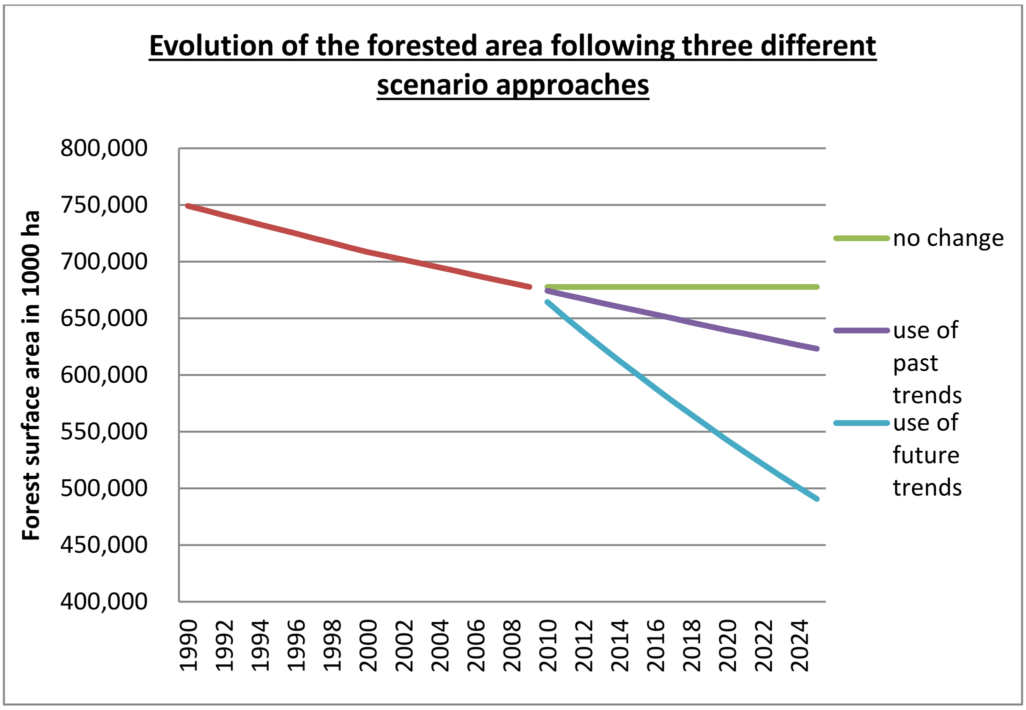


Figure 11 thus shows that the green *no change scenario* would suggest that any deforestation activity would have stopped from the moment of project start and the forest area remains unchanged from 2010 onwards. If no strong context conditions suggest such a scenario, it is thus highly unlikely and should not be considered as a baseline. In the violet *past trend scenario*, the annual deforestation rate of 0.5% of the past 20 years is extrapolated in the future. It is thus assumed that the drivers of deforestation continue to take effect with the same strength as in the close past. In the blue *future trends scenario* a modelling software has been applied in order to come up with the future deforestation rate as determined by a wide set of input variables. It assumes that the increasing demand for wood and agricultural land will increase the deforestation rate to 2% per year.

Beyond this short illustration it is thus imaginable that EX-ACT users may want to engage in a sensitivity analysis comparing two baselines with each other – specifically whenever two strongly opposing baselines are both plausibly imaginable.

Choosing the most adapted baseline approach

The choice between these three types of scenarios depends largely on the scale of the project intervention area, the data availability as well as the time frame of the analysis. It is also important to consider potential sources of financing and the requirements they may set for establishing the baseline.

The no change scenario is often applied in the case of small-scale projects, for simple appraisals or when the intervention area is characterized by a markedly static situation. It is the simplest way of building the baseline scenario, as the current situation is a well-known entry point and does not demand any additional data needs. Also, emission results based on current conditions are often easier to communicate to third actors as when comparisons to assumed future changes are done. However it gives a biased view in contexts subject to strong dynamics.

Another alternative is to combine different baseline methodologies in order to develop the entire project baseline. The table below indicates in such a way that the use of past trends is in EX-ACT the most common method for deriving baselines of the development of land use as well as adoption rates of fertilizer and irrigation technology use. Instead it is mostly common to assume a no change baseline for the adoption of sustainable land management practices and the use of improved varieties:

Table 2: Guidance on choosing an adapted baseline scenario

Type of data	No change	Past trends	Future trend
Land use & land use change	If no data	Most common choice	Preferred choice if data available
Technology adoption: Irrigation and fertilizers	No	Most common choice	No
Technology adoption: SLM & improved varieties	Most common choice	Preferred choice if data available	No

The following virtual case study provides a concrete example of combining different baseline methodologies to derive an overall project baseline.

Case Study 1: Exemplary development of a baseline scenario

Short Project Description:

"Support the development of cattle rearing in the Eastern region of country A"

Context:

- 20, 000 cattle heads (20 per breeder)
- Pastoral systems (50, 000 ha)
- Moderately degraded pasture
- 1,000 livestock breeders

Project:

- Improve 50% of pasture areas
- Increase drought resilience with adapted water management techniques (pastoral wells)
- Increase productivity per head of cattle by 30% (increase of weight per head) while no further expansion of herd sizes
- Introduce a common pasture management preventing overgrazing

Data Available:

- The pasture area went through an in pace increasing degradation dynamic in the recent 10 years but did not experience any land use change;
- The newly established mining industry and resulting population inflow in country A leads in the next years to higher demand and prices for livestock products.

Baseline scenario:

The below derived project baseline utilizes a purposeful combination of all three methodologies (duration: 10 years):

→ **No change:**

- No land use change / constant area of 50,000 ha of pasture

→ **Extrapolation of past trend:**

- Continuing, 1.5% of pasture becomes moderately degraded per annum

→ **Modelling of future trends:**

- A quantitative model derives a future annual increase in livestock herd size by 2%, based on input data considering e.g. increasing price incentives for livestock products and open access management of pasture

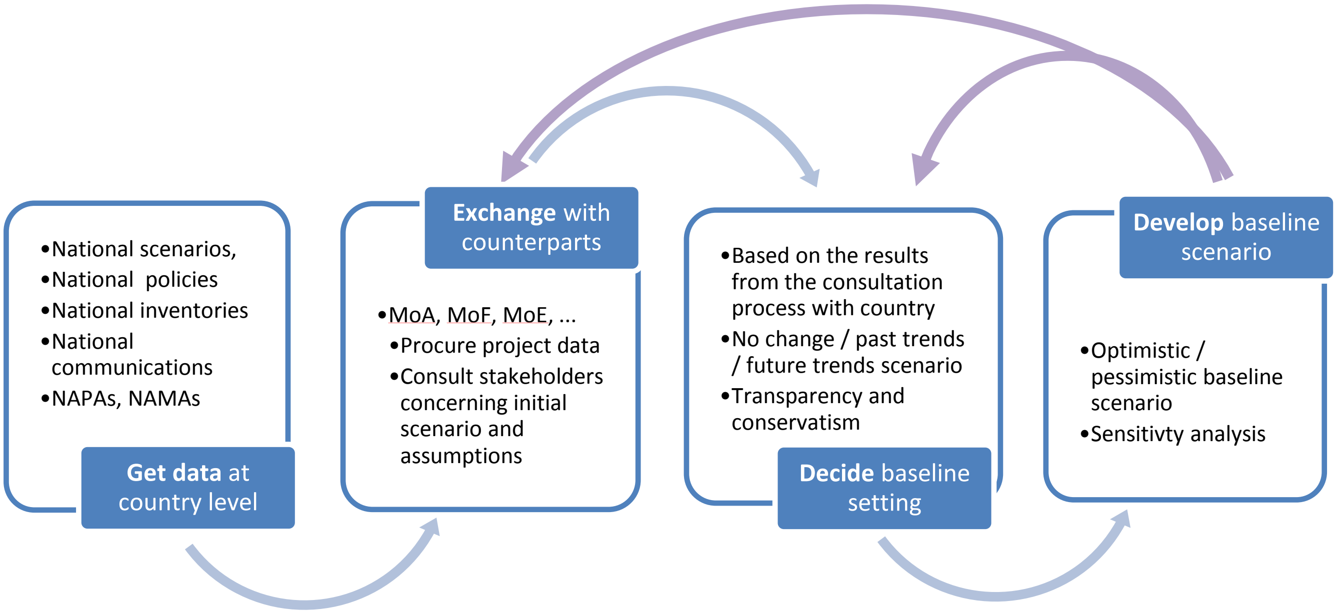
Source Photos: SDC (2010)

Process guidance for baseline development

Focussing on the practical process of developing a baseline scenario, the graphic below describes the typical iterative approach:

Available data as part of national statistics and main climate change policy documents may thus serve as the first entry point to central information. This is complemented by a consultation process with project implementing and other regional staff that leads to a first scenario building and clarification of major assumptions. After the detailed development of the actual baseline scenario, country stakeholders should be re-consulted and confronted with the results, leading eventually to an iterative correction of the initially taken assumptions. Throughout the entire process it is of central importance that all assumptions are clearly documented and presented as part of the EX-ACT analysis.

Figure 12: Overview of the process of building a baseline scenario for the use in EX-ACT



Part B: Step-by-Step Guide to Use EX-ACT

Chapter 4: Data Requirements and Data Collection

This chapter provides the reader with specific information on the data that needs to be collected in order to adequately use EX-ACT and offers guidance on methods of data collection.

Distinct data collection designs may be associated to differences in data quality and precision as well as cost and time intensity. The EX-ACT *User Manual* intends to provide users with a comprehensive overview of the main available options of data collection methods, while leaving it to individual users to take an informed decision on which method to use.

A. Choosing the valid EX-ACT modules

EX-ACT does not necessarily require a full inventory of all land-uses in the project area, but is centrally concerned with all land areas which are altered due to the analyzed project process. Thereby data is needed on all those areas, **where change is observed between project start and end of the capitalization phase** as well as on those areas **where such alterations would have been observed in case of the business-as-usual scenario**.

Thus e.g. existing native forest land or grasslands in a state of equilibrium which are not under conversion and without any considerable withdrawals (grazing, firewood collection) or depositions (fertilization), are no source of GHG emissions or changes in carbon stocks and do not have to be object of data collection. This may hold true e.g. for areas kept as nature reserves.

Given the fact that for each specific project it will be only necessary to fill a limited sub-set of the topic modules of EX-ACT, the table provided here below lists typical development projects by type and identifies which are the most relevant EX-ACT modules that need to be filled in order to calculate the GHG-balance. The here provided information thus revisits the checklist (Table 2) that was provided in Chapter 2.B and has a similar purpose.

It must be reminded that EX-ACT is a flexible tool based on project impacts rather than objectives, implying that one type of project can involve several modules, but that, in the same respect, not all modules will need to be filled depending on what the project entails.

In the table below the first question to answer to is: *What type of project is taking place*? According to the project's nature, it can be directly decided which modules will necessarily be used (such as the crop production module in the case of a classical projects of agricultural intensification). However, projects can affect other land uses/ domains, thus a second question must be answered: *Which other modules may be impacted by the project i.e. what other specific positive or negative effects are occurring with or without the project?*

Table 3: Modules to be used according to project profile

First question to answer: what is the type of project?		**Modules to be used**
IF... Sustainable intensification project	*Go to* →	Crop Production & Inputs
IF... Livestock project	→	Grassland & Livestock
IF... Watershed project	→	Afforestation/ Reforestation
IF... Forest Management / Forest conservation	→	Land Use Change
IF... Irrigation project	→	Inputs & Crop production
IF... Land use change project	→	Land Use Change
IF... other Multi-objective projects	→	See next
Second question: Which other modules are needed based on project actions?		**Modules to be used:**
All project types	**Specific positive or negative effects occurring with or without project?**	
	IF deforestation/afforestation with or without project ○ For expanding agriculture area or pastures ○ Additional land areas planted with forest *Go to* →	Land Use Change
	IF degraded land transformed in annual crops or pasture land **IF** annual crops switched to perennials, pastures **IF** agriculture land transformed in other land →	Land Use Change
	IF Inputs used and energy consumed →	Inputs & Investment
	IF Drainage of organic soils →	Land Degradation
	IF Investment in buildings, roads, storages →	Inputs & Investment
	IF Irrigated areas rehabilitated with improved systems →	Inputs & Investment
	IF Degradation or improvement of existing pastures →	Grassland & Livestock
	IF Increased annual crop areas with manure – compost use →	Crop Production & Inputs
	IF Degradation or improvement of forestry areas →	Land Degradation
	IF Improved techniques in annual crops ○ stop burning residue, compost, terracing… →	Crop Production
	IF Inputs consumed in value chain processing, transport →	Carbon Footprint functionality (see annex)

B. Overview of data needs

In the following the reader is provided with concrete specifications of the data needs for EX-ACT. It is thereby differentiated between such information that is largely compulsory when considering a specific EX-ACT module and such information that is optional and may lead to higher degrees of precision of the analysis. This reflects the difference between using the Tier 1 coefficients provided by the IPCC (2006), as opposed to providing regional specific values for e.g. biomass densities per hectare or carbon content in soil. The extent that a user attempts to procure location specific values may follow the extent of precision chosen in other parts of the respective project analysis and should also be aligned to the overall purpose of engaging in the carbon-balance appraisal.

As specified above, users thereby only need to procure information in modules relevant to their project context. In the following the main data needs are described. Thereby it is imperative to follow the basic logic of EX-ACT, being based on the comparison of a project scenario to the situation at project start and the situation in a baseline scenario. The depicted data needs just to be collected and/or estimated for all three situations. Readers can find a detailed table with all data needs (including Tier 2) in the annex.

Description module

As a first step, EX-ACT users need to fill information in the description module. This encompasses the specification of the name of the project, the duration of its implementation and capitalization phase and the most central agro-ecological variables of:

- The continent (or sub-continent) of the project location
- The type of climate
- The moisture regime of the zone
- The dominant regional soil type

Due to the fact that EX-ACT provides as part of the excel sheets various resources to correctly procure the needed information for the description module, we will not specify data issues in further detail here, but in the later section on data entry.

Land use change module

The land use change module focuses on deforestation, afforestation/reforestation and other land use change.

According to the IPCC Report on Land Use, Land Use Change, and Forestry (IPCC, 2000), Land Use Change (LUC) refers to a change in the use or management of land by humans, which may lead to a change in land cover. Thereby the IPCC considers the six land covers: Forest land, Cropland, Grassland, Wetland, Settlements and Other land.

As part of the module users need to procure information specifying which land use changes are taking place and how the conversion process is executed. Most explicitly the areas of land use that are transformed need to be clearly specified in size and whether the conversion involves burning, in which pace the conversion takes place and whether wood is exported before burning.

Based on the categorization of the IPCC, EX-ACT differentiates between the land covers:

- Annual Crop
- Perennial / Tree crop (< 5 years)
- Perennial / Tree crop (6-10 years)
- Perennial / Tree crop (> 10 years)
- Flooded Rice
- Degraded Land
- Set Aside
- Grassland

- Other Land

In order to refine the analysis, users can specify the concrete above and below ground biomass of the respective forest type, as well as the carbon content for soil, litter and deadwood. In the case of reforestation/afforestation users may also specify the biomass growth rates, while in the case of forest burning also specific values of the combustion process can be specified.

Crop production module

The module on crop production is subdivided in annual systems, perennial systems and irrigated rice. Most centrally users need to collect data on the area on which each crop is cultivated, the associated management practices and all eventually occurring changes in both variables throughout the different scenarios (project vs. baseline). More specifically data needs to be procured specifying yields, the time dynamic of crop shifts and the existence of crop residue burning.

This data basis can be further complemented by location specific rates of e.g. annual soil C sequestration, annual biomass growth for perennials or the specific amount of residues burnt throughout the year.

Irrigated rice instead asks still for a rough differentiation of the duration of flooding during cropping season and preseason as well as the forms of management of organic amendments.

Grassland and livestock module

For the grassland module users need to collect data on the size and state of degradation of grassland, the grass yield, practices of grassland burning and the time dynamic of changes in the degradation state of the respective grassland area.

The livestock part of the module instead requires information on the type and number of livestock and the percentage of herd size that receives improved feeding practices, dietary additives that reduce CH_4 emissions (Ionophores, vaccines, bST, etc.) or are subject to improved breeding practices.

Information on livestock emissions may be refined by specifying the mean annual temperature as well as regional specific values for the emissions of CH_4 and N_2O from manure management and the CH_4 emissions from enteric fermentation.

Land degradation module

The land degradation module covers issues of degradation as well as rehabilitation and comprises the issues of forest degradation as well as degradation of organic soils, while the change in the state of degradation of grasslands is already dealt with in the grassland module.

Most centrally forest degradation requires information about the type and size of forest area, the extent of change in its state of degradation, the time dynamic of occurring changes as well as the frequency and intensity of forest fires.

The analysis of forest degradation can again be refined by location specific values on above and below ground biomass, soil organic carbon content as well as the carbon stocks in litter and deadwood.

The issue of degradation of organic soils requires the specification of size and vegetation type of the area concerned by drainage of organic soils as well as peat extraction. This can be further complemented with specific values on how much carbon is lost due to drainage of organic soils and on-site CO_2 and N_2O emissions from peat extraction.

Inputs & Investments module

The inputs and investments module focuses on aspects of agricultural inputs, energy consumption and building of infrastructure.

Users need to collect data on the quantity of applied fertilizer, pesticides as well as liming and need to specify the quantity of nutrient content. This may be refined by context specific emission factors for direct emissions from application as well as indirect emissions from production, transport and storage.

Further information is needed on the quantity of electricity, liquid and gaseous fuel as well as wood consumed. Also here, specific emission factors may refine the analysis.

The type and size of irrigation infrastructure build and buildings constructed under the project is another data need.

The table below provides a concise overview of the main data that can be collected, focusing on the information needed for a Tier 1 analysis. Step 1 data is mandatory, as the description Module will always need to be filled for EX-ACT. However, all later information only needs to be collected in case that the respective EX-ACT module and activities are relevant for the analyzed project (c.f. section 4.A *Choosing the relevant EX-ACT module*). Complementing the table below, a list including also all Tier 2 data that can be accommodated in the tool is provided in the annex.

Table 4: Overview of Tier 1 activity data that can be accommodated in EX-ACT

	Description module	
Obligatory	- Sub-continent - Type of climate - Moisture regime	- Dominant regional soil type - Project duration
Only if project related	**Land use change module**	
	• **Deforestation**	
	- Forest type and size - Area deforested	- Final land use after conversion - Burning during conversion?
	• **Afforestation & reforestation**	
	- Type of current land use - Type of future forest	- Burning during conversion?
	• **Other land use change**	
	- Type of current land use - Type of future land use	- Burning during conversion?
	Crop production module	
	•	
	- Current and future planted crop area (by type of crop) - Crop management practices	- Practices of residue burning?
	• **Perennial systems**	
	- Current and future planted crop area (by type of crop)	- Practices of residue burning?
	• **Irrigated rice**	
	- Specifications of water management practices	
	Grassland and livestock module	
	• **Grassland**	
	- Current and future grassland area by state of degradation	- Practices of grassland burning?
	• **Livestock**	
	- Type and number of livestock	- Feeding and breeding practices
	Land degradation module	
	• **Forest degradation**	
	- Dynamic of forest degradation/ rehabilitation by forest type and size	- Occurrence of forest fires?
	• **Degradation of organic soils (peatland)**	
	- Vegetation type and size concerned by drainage of organic soils	- Area affected by peat extraction
	Input and investment module	
	• **Agricultural inputs**	
	- Weight of agricultural inputs by type	
	• **Energy consumption**	
	- Quantity of electricity, liquid and gaseous fuel, and wood consumed	
	• **Building of infrastructure**	
	- Size of area with newly established irrigation infrastructure or buildings (by type)	

C. Data collection methods and central data sources

While the previous section provided the overview of the type of data needed for an EX-ACT appraisal, this section specifies which different methods may be used for data procurement and which main data sources may be accessed.

Following from the basic structure of EX-ACT in situation at project start, project scenario and baseline scenario, EX-ACT is interested to specify one set of input data based on empiric information (project start information) and two sets of input data as a result of projections (project & baseline scenario). The project scenario thereby should follow the information given in the project document, while nevertheless the reasonability of its assumptions should strictly be evaluated by and be based on the available empiric information. The baseline scenario can be constructed either largely depending on static statistical information or a combination of expert judgments and modelling approaches, as depicted earlier in this user guide.

While most explicitly for the situation at project start, all three situations depend to some extent on input or benchmarking with empiric data. The following section thus presents central methods of data procurement and also presents important data sources.

Secondary data sources

National statistics and other statistical data may be an important data source for several of the previously stated data needs.

As part of the Excel sheets EX-ACT already provides global soil maps that offer the user with a first orientation on soil types that prevail in various locations and also provides a specific list how to convert soil classes from the international classification “World reference base for soil resources” (IUSS, ISRIC, FAO, 2006) to the IPCC soil taxonomy. For more location specific information on local soils, readers should instead use available national information or international datasets, such as the “Harmonized World Soil Database” (FAO, IIASA, ISS-CAS, JRC, 2009).

Secondary data may furthermore be very valuable whenever Tier 1 emission factors or assumed values of carbon content in soil and biomass can be replaced by representative, location specific values. This thus concerns besides others emission factors from manure management and from enteric fermentation, the biomass growth rate of trees as well as the carbon sequestration rate of soil under specific management practices and the concentration of nutrients in organic and inorganic fertilizers.

The table below offers a concise overview of central data sources that can be consulted for the procurement of secondary data.

Table 5: Central data sources for information on land use, land use change and agricultural practices

Type of data	Database – Data source
Numerous agricultural and forestry data at national level	• National Offices of Statistics • Ministries of Agriculture, Forestry, Rural Development, Environment
Land Use: I. Arable land II. Forest land III. Irrigated land IV. Permanent crops V. Rice	• FAOSTAT Land Use Database http://faostat.fao.org • FAO country profile http://www.fao.org/countries • World Bank country profiles http://data.worldbank.org/data-catalog/country-profiles • Global Land Cover Facility http://glcf.umiacs.umd.edu/data/ • Global Land Cover Network http://www.glcn.org/dat_0_en.jsp
Forests: VI. Deforestation rate VII. C content in different pools VIII. Forest land	• Forest Resources Assessment (FRA) http://www.fao.org/forestry/fra/fra2010/en • GlobAllomeTree http://www.globallometree.org • U.S. Geological Survey – Land Cover Institute http://landcover.usgs.gov/globallandcover.php • Global Land Cover Facility http://glcf.umiacs.umd.edu/data/ • Global Land Cover Network http://www.glcn.org/dat_0_en.jsp
Soil and climate characteristics	• Harmonized World Soil Database http://www.fao.org/nr/land/soils/harmonized-world-soil-database • CGIAR-CSI (CGIAR Consortium for Spatial Information) http://csi.cgiar.org/WhtIsCGIAR_CSI.asp
Climate change: IX. GHG assessment X. CC vulnerability XI. Policies/strategies of adaptation/mitigation	• UNFCCC submissions (GHG inventory, National communications, NAMA, NAPA) http://unfccc.int/national_reports/items/1408.php

Primary data collection

Other information might instead be difficult to procure by secondary data, as e.g. the case for specific agricultural management practices, livestock feeding practices or wood extraction rates from forests. In order to evaluate current practices as well as the likelihood of future changes in management practices, it might be of relevance to collect a limited number of primary data by conducting surveys on a sub-sample of the targeted farms. Besides questions of agricultural management practices, also the consumption of fossil fuels and construction of irrigation systems and infrastructure can in such a way be accessed by surveys. Besides farmer surveys also soil surveys may be conducted in a small sample size to estimate soil organic carbon content.

Apart from farm surveys remote sensing is an important supplementary data source that especially can furnish land cover and land use data. It is furthermore an especially relevant method when engaging in monitoring and evaluation of projects, which will be further discussed in the annex.

Expert judgments and stakeholder discussions

Complementing the previous information the discussion with regional agricultural experts as well as project implementing staff can be an essential complementary data source to assume missing data which could not be procured by other methods. It is also an important mean to identify problematic assumptions that were made earlier on. All assumptions made by the EX-ACT user should be clearly stated, acknowledging the consulted institutions and allowing a maximum of transparency to readers.

Chapter 5: Appraisal Getting Started – The Description Module

A. Introduction of the graphical interface

Users can download the EXCEL file containing EX-ACT for free at www.fao.org/tc/exact/carbon-balance-tool-ex-act. EX-ACT uses a graphical interface that provides easy orientation throughout the analysis, which will be shortly explained here.

EX-ACT navigation bar

On the top users can find the navigation bar, allowing users to easily navigate between the different topic modules. Duplicating largely the Excel worksheets it provides the main overview about the topic and activity areas of relevance to EX-ACT. By clicking on the EX-ACT logo on the top left, users navigate directly to the EX-ACT homepage where they can find additional information.

EX-ACT Screenshot 1: EX-ACT module bar

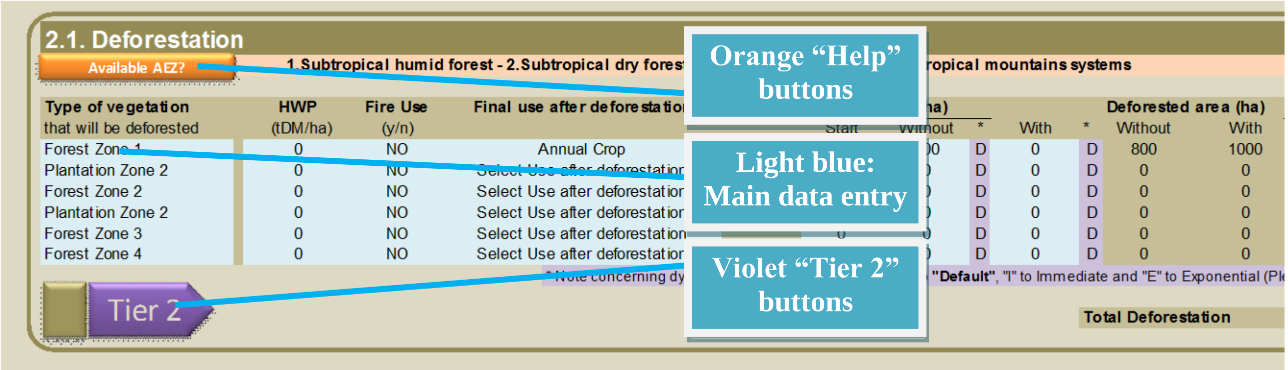
EX-ACT colour codes

Every EX-ACT module is subdivided into its different components using boxes. Exemplarily you see here below the box on Deforestation which is part of the Land Use Change Module. It is clearly delimited by an outside frame from other module components.

EX-ACT thereby uses a repeating colour code throughout all modules. Thus cells in "light blue" indicate where users have to specify information, while the background colour, as here e.g. brown, specifies the variables and units that have to be provided as well as resulting changes in GHG emissions and carbon stock changes.

By clicking on the orange boxes used throughout EX-ACT, users may find additional information and help that facilitates filling the relevant module components. The violet boxes indicating "Tier 2" instead allow users to specify location specific values for carbon pools (e.g. soil carbon content) and GHG emission factors.

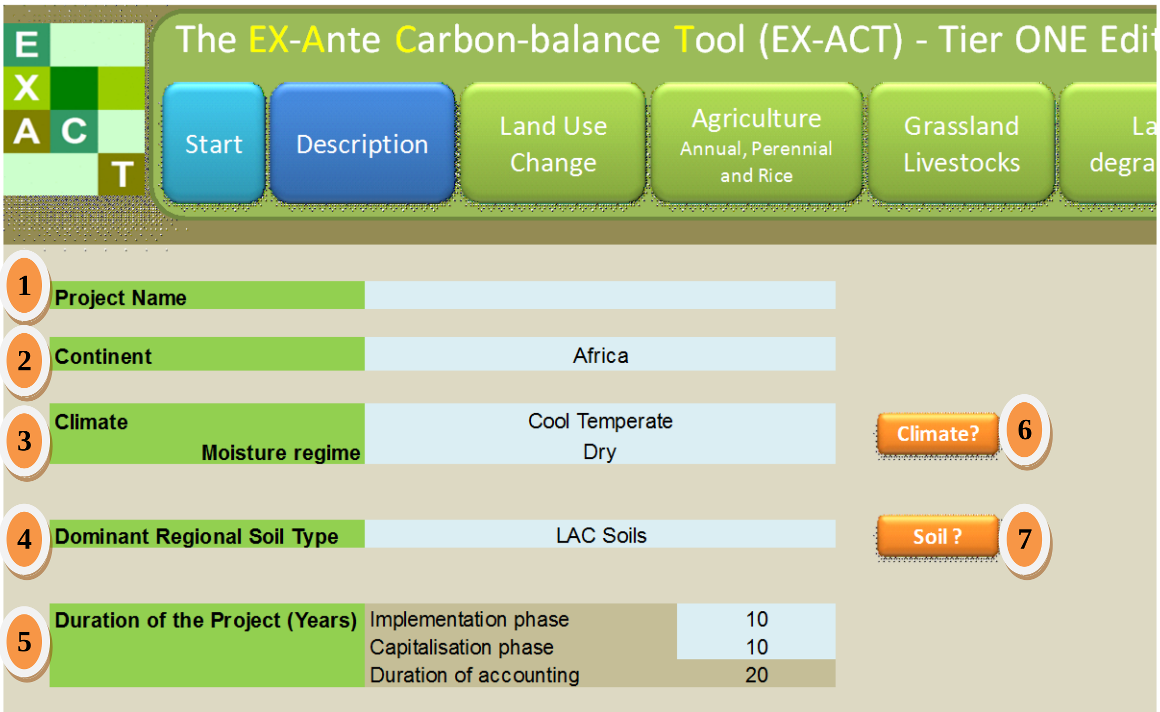
EX-ACT Screenshot 2: EX-ACT colour codes



B. The description module

After leaving the start screen, the first module users have to fill is the *description module*. It has to be filled with central descriptive information on the project and regional agro-ecological conditions. Every user should start always with filling the description module since the rest of EX-ACT otherwise does not contain the necessary input information to proceed. Precisely, users should fill in the following information:

EX-ACT Screenshot 3: The description module



1 ***Project name***: Provide the name of the project, programme or policy.

2 ***Location***: Select the continental region in which the project will take place from the provided drop down list, which will preselect a set of default values for the later emission calculations. In such a way e.g. emissions from dairy cattle vary according to the location and the IPCC coefficients allow for an averaged differentiation between them.

The eleven continental regions are: *Africa / Asia (Continental) / Asia (Indian subcontinent) / Asia (Insular) / Middle East / Western Europe / Eastern Europe / Oceania / North America / Central America/ South America.*

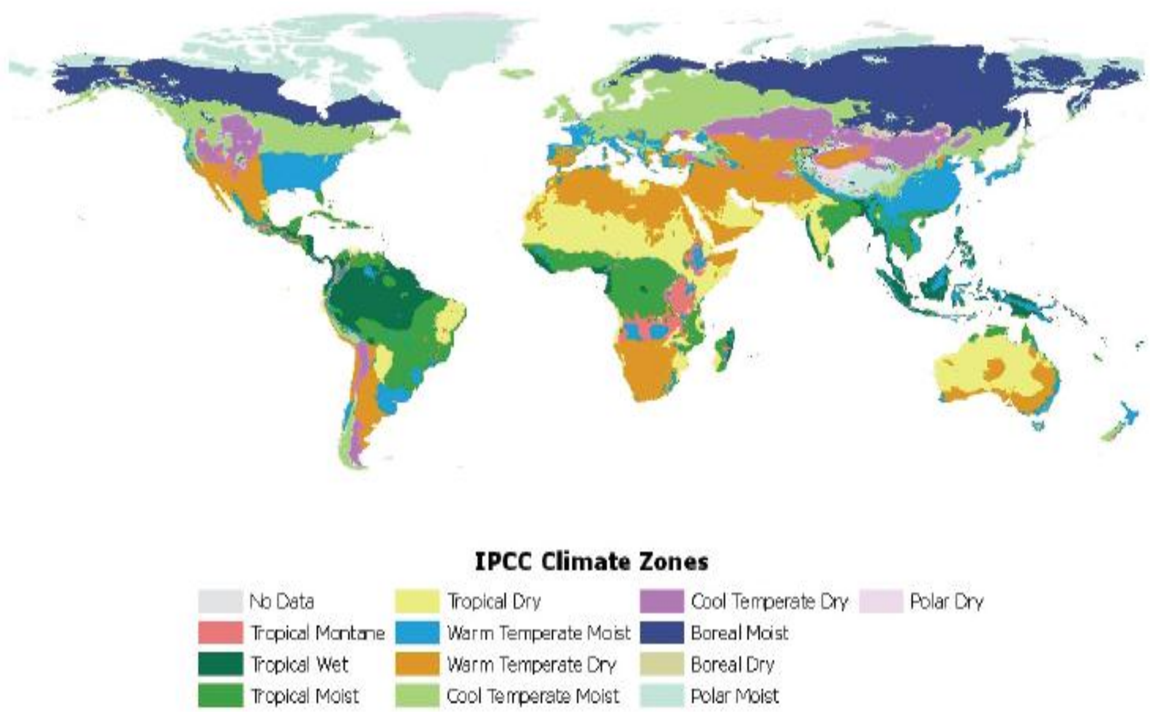
3 ***Climate***: The climate is strongly influencing GHG emissions and carbon sequestration in agriculture. A careful choice of the correct climate information is thus essential. The default options are thereby: *Boreal / Cool Temperate / Warm Temperate / Tropical / Tropical Montane* (see also help facility below). The default options for the dominant moisture regime are: *Dry / Wet / Moist*.

4 ***Dominant soil type***: The user should indicate the main dominant soil type using the simplified IPCC classification. IPCC retains only 6 soil categories: *High Activity Clay Soils (HAC) / Low Activity Clay Soils (LAC) / Sandy Soils / Spodic Soils / Volcanic Soils / Wetland Soils*.

5 ***Project duration***: Users specify the duration of the active project intervention, which defines the implementation phase in EX-ACT, as well as the duration that further impacts from project interventions on GHG occur before a new equilibrium is reached. The latter defines the implementation phase of EX-ACT and is e.g. important when land use change activities implemented in a short time frame impact changes in SOC over a longer time period. According to (Lal, 2004), the joint period of implementation and capitalization should not be shorter than 20 years when relevant land use change takes place. This is established as a minimum period by the scientific literature in which the most important impacts on carbon stocks are expected to take place.

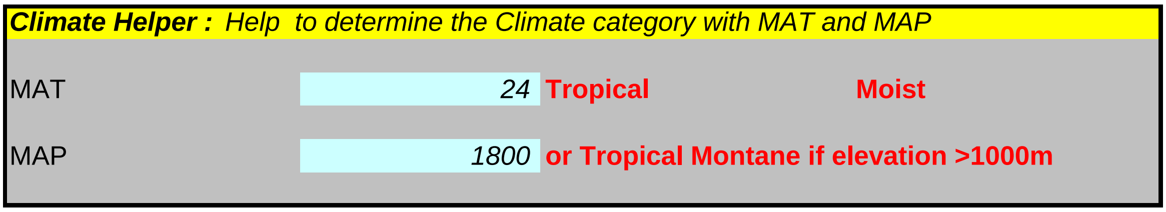
6 ***Help for climate selection***: By clicking on Climate? the user has access to further information assisting him to select the right climate and moisture regime. Thereby the below map of IPCC climate zones can often give already the necessary information.

Figure 13: Representation of IPCC climate zones (IPCC NGGI 2006)



Besides, users may insert the Mean Annual Temperature (MAT) in degree Celsius and the Mean Annual Precipitation (MAP) in millimetre, in order to receive a guiding climate and moisture indication by EX-ACT (c,f, Figure 14).[3]

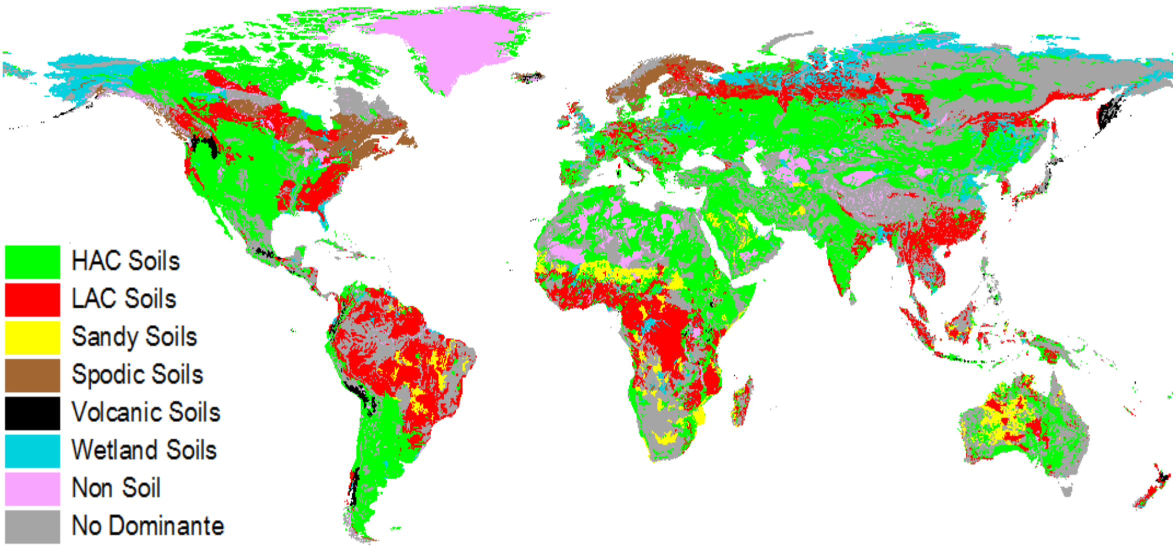
Figure 14: The climate help tool



7 ***Help for soil selection***: By clicking on Soils? this section provides guidance on which IPCC soil category to use as dominant soil type.

First of all it provides a global map that gives a first orientation of the distribution of IPCC soil categories.

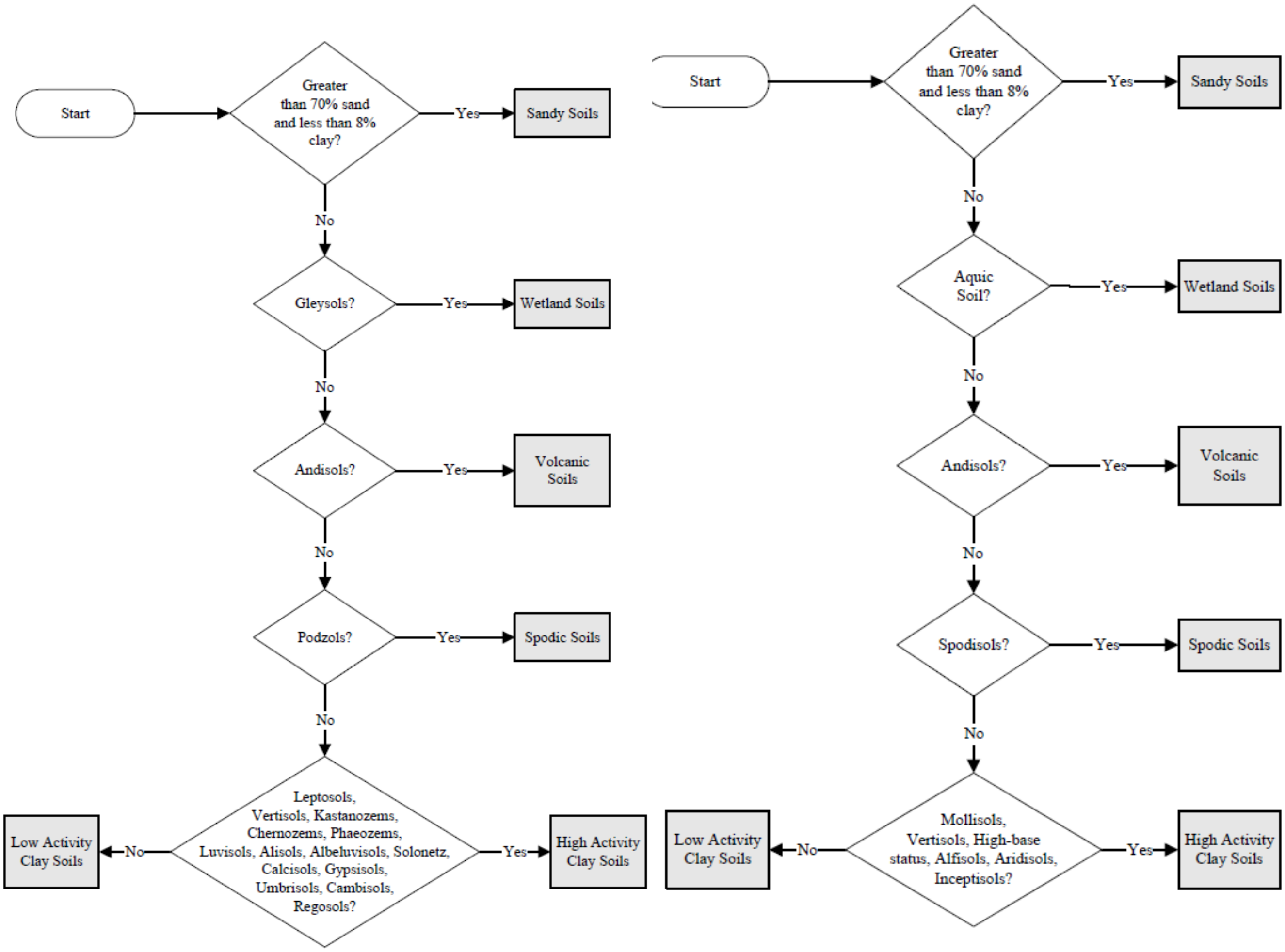
Figure 15: Tentative map of the distribution of the dominant soil type using IPCC classification



As a further reference than the World Reference Base for Soil Resources (WRB) and the USDA soil taxonomy are essential, since secondary data on available soil types often follow their categorization system. In the following it is firstly provided an easy to use decision-tree while the help-facility in EX-ACT offers in addition a more detailed list of how to translate soil categories from the WRB and the USDA taxonomy into IPCC soil categories.

[3] This tool is based on the classification scheme for default climate regions proposed in Figure 3A.5.2 (page 3.39 of NGGI-IPCC-2006).

Figure 16: Decision tree for translating soils according to USDA taxonomy (left) and WRB (right) into



IPCC soil classes (NGGI-IPCC, 2006)

If not considering the concise and intuitive overview given by the decision tree, more detailed information on IPCC soils is thereby consciously described by the following:

- **High Activity Clay Soils (HAC).** These mineral soils are light to moderately weathered soils, which are dominated by 2:1 silicate clay minerals. Following the World Reference Base for Soil Resources (WRB), they include Leptosols, Vertisols, Kastanozems, Chernozems, Phaeozems, Luvisols, Alisols, Albeluvisols, Solonetz, Calcisols, Gypsisols, Umbrisols, Cambisols, and Regosols. In accordance with the USDA soil taxonomy, HAC soils include Mollisols, Vertisols, high-base status Alfisols, Aridisols, Inceptisols. As exception Ferric and Plinthic Luvisol are categorized as LAC Soils.
- **Low Activity Clay Soils (LAC).** LAC soils are highly weathered soils, dominated by a composition of 1:1 clay minerals and amorphous iron and aluminium oxides. In accordance with WRB this includes Acrisols, Lixisols, Nitisols, Ferralsols, Durisols, while in the case of the USDA classification it comprises Ultisols, Oxisols, acidic Alfisols.
- **Sandy Soils** include (regardless of their taxonomic classification) all soils having > 70% sand and < 8% clay, based on standard textural analyses. Following WRB this includes Aerosols, in accordance with the USDA classification it includes Psamments.
- **Spodic Soils** are soils exhibiting strong podzolization. Following WRB this includes Podzols; in the USDA classification it comprises Spodosols.
- **Volcanic Soils** are derived from volcanic ash with allophanic mineralogy. In accordance with the WRB classification they comprise Andosols, following the USDA taxonomy they comprise Andisols.

- **Wetland Soils** are defined by restricted drainage leading to periodic flooding and anaerobic conditions. Wetland soils are Gleysols following WRS, and soils in aquic suborders in the USDA classification.

Chapter 6: Entering Land Use Changes

The land use change module comprises the elements deforesteation, afforestation and reforestation as well as other land use change.

A. Deforestation

When using the deforestation sub module, the following types of information will be needed:

Identifying the current forest type:

1 Based on the climatic information provided in the Description Module users are provided with up to four different types of agro-ecological forest categories.

2 EX-ACT differentiates in addition between naturally grown forest and plantation forest. In such a way, users chose from the drop down list between the in this example eight different potential forest types. EX-ACT offers six rows for the definition of different forest areas.

The distinction in natural grown and plantation forest is justified by the fact that main characteristics (e.g. the growth rate of trees and respective biomass quantities) strongly depend on the management regime. Therefore a distinction should be made between intensively (e.g., plantation forestry) and extensively (naturally re-growing stands with reduced or minimum human intervention) managed forests. For each of the default vegetations, the five carbon pools are quantified according to the earlier presented generic methodologies.

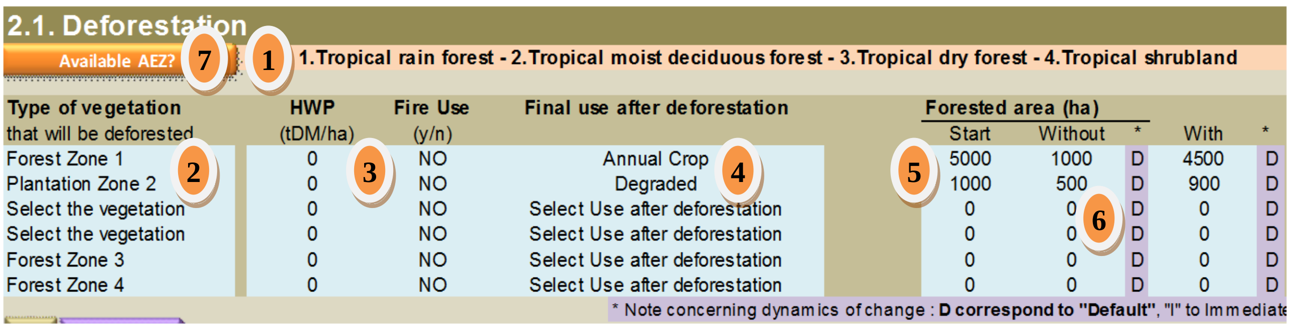
3 ***Harvest wood products (HWP) & fire use***: The carbon stored in above ground biomass as especially wood is in most cases release when deforestation takes place. EX-ACT nevertheless considers explicitly whether wood is lodged and exported in order to be used in manufacturing. Users can thus specify the amount of wood harvested per hectare. Furthermore they chose from a drop-down list whether fire is used for land conversion.

4 ***Identifying the final land use after deforestation***: As the next step users specify the final land use after conversion, which determines default C stocks in the year following the conversion. Available options are: *Annual Crop / Perennial or Tree Crop / Paddy Rice / Set Aside / Grassland / Degraded / Other*.

5 ***Surface deforested***: In this step users then specify the plot size of the forested area for each forest type. Thereby information is entered on the forest sizes at project start, at the end of the project and at the end of the baseline scenario. This explicitly concerns area covered by forest, while the area subject to deforestation is automatically displayed by EX-ACT (not visible on the excerpt of the below screenshot).

6 ***Dynamic of change***: In case of any changes in forest sizes (ha) between the start and either the outcome of the project or baseline scenario, the dynamic of this land use change can be specified by the user either as linear (default), immediate or exponentially taking place.

EX-ACT Screenshot 4: Deforestation (Land use change module)


2.1. Deforestation

Available AEZ? 7 | 1 1.Tropical rain forest - 2.Tropical moist deciduous forest - 3.Tropical dry forest - 4.Tropical shrubland

Type of vegetation that will be deforested	HWP (tDM/ha)	Fire Use (y/n)	Final use after deforestation	Forested area (ha) Start	Without	*	With	*
Forest Zone 1	0	NO	Annual Crop	5000	1000	D	4500	D
Plantation Zone 2	0	NO	Degraded	1000	500	D	900	D
Select the vegetation	0	NO	Select Use after deforestation	0	0	D	0	D
Select the vegetation	0	NO	Select Use after deforestation	0	0	D	0	D
Forest Zone 3	0	NO	Select Use after deforestation	0	0	D	0	D
Forest Zone 4	0	NO	Select Use after deforestation	0	0	D	0	D

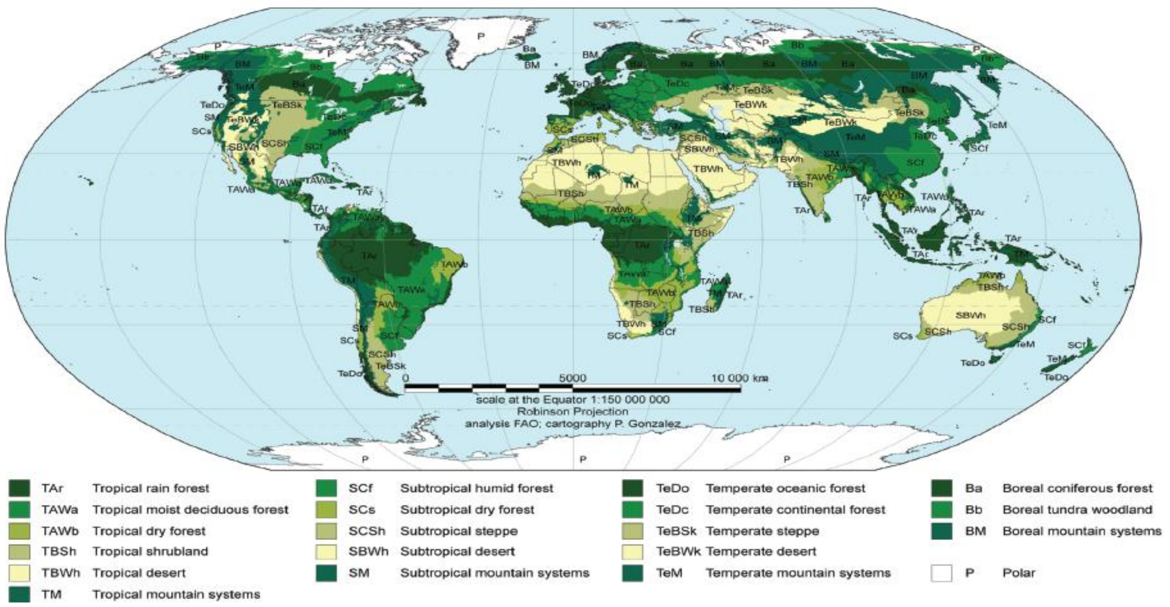
* Note concerning dynamics of change : D correspond to "Default", "I" to Immediate

7 ***Help for selecting the correct agro-ecological zone***: Also the deforestation module provides a small help facility for the selection of the most adequate agro-ecological zone, as based on observed climate and vegetation patterns. Though giving a first orientation and often indeed indicating already the actual agro-ecological conditions of the analysed area, users should validate this indication with the available information from project documents and national statistics if necessary.

Figure 17: Global ecological zones based on observed climate and vegetation patterns.

Global ecological zones, based on observed climate and vegetation patterns (FAO, 2001). Data for geographic information systems available at http://www.fao.org.

Back to "Deforestation" Module



B. Afforestation and reforestation (A/R)

In this part of the spreadsheet users will have to specify any ongoing activities of afforestation and reforestation, i.e. describe the type of initial vegetation concerned, the type of forest that is planted and if fire is used for land conversion.

1 ***Type of forest planted***:
Users specify here the type of forest that is planted by choosing from the drop-down list. To identify which type of forest is meant by *"plantation zone 1"* and the other specifications, users again consult the top row (here marked with 1a).
User can thereby either select in the case of afforestation one of the present forestry systems (forest 1-4) or choose between plantation forests in the case of reforestation (plantation 1-4).

2 ***Previous land use***: Here, users indicate the previous land use prior to the new establishment of trees. The available options from the drop-down list are: *Annual Crop / Perennial & Tree Crop (<5yrs; 6-10 yrs; >10 yrs) / Paddy Rice / Set Aside / Grassland / Degraded Land*. According to the selected land uses, EX-ACT proposes the default changes in carbon stocks per hectare.

3 ***Fire use***: Users then specify whether fire is used as a means of land conversions. If it is set to "yes" the corresponding emission factors associated with the vegetation are used to estimate the emissions from the amount of concerned biomass.

4 ***Surface afforested & reforested***: In this field user identify how many hectares are subject to afforestation and reforestation for the with- and without-project scenario.

5 ***Dynamic of change***: In the small violet boxes users can again specify whether the changes between the start situation and the without- and with-project situation materialize linearly (default) over time, occur immediately or exponentially.

EX-ACT Screenshot 5: Afforestation & reforestation

Available AEZ	1.Subtropical humid forest - 2.Subtropical dry forest - 3.Subtropical steppe - 4.Subtropical mountains systems 1a					
Type of vegetation	**Fire Use**	**Previous land use**	**Area that will be afforested/reforested**			
that will be planted	(y/n)		Without	*	With	*
Plantation Zone 1	NO	Annual Crop	100	D	0	D
Plantation Zone 2 1	NO 3	Grassland 2	4 0	D	200	D 5
Select the vegetatio	NO	Select previous u	0	D	0	D
Select the vegetation	NO	Select previous use	0	D	0	D
Select the vegetation	NO	Select previous use	0	D	0	D
Select the vegetation	NO	Select previous use	0	D	0	D

C. Non forest land use change

This component describes other land use changes that do not concern forest, but e.g. the change from grassland to annual cropping systems or from degraded land to agroforestry systems. Users have to specify the following information:

1 ***Naming the specific land use change***: As a first step users may fill in an own title that describes properly which land use change is taking place.

2 ***Specifying initial land use***: Then users specify from a drop-down list the initial land use.

3 ***Specifying final land use***: Equivalently, the final land use has to be specified. The user may choose between *Annual Crop / Perennial and Tree Crop (<5yrs; 6-10 yrs; >10 yrs) / Paddy Rice / Set Aside / Grassland / Degraded Land / and Other Land.*

4 ***Fire use***: Specification whether fire is used as means of land conversion.

5 ***Surface of area under land use change***: Here, users specify the area sizes of each land use change activity taking place.

6 ***Dynamic of change in land use***: In the small violet boxes users can again specify whether the changes between the start situation and the without- and with-project situation materialize linearly (default) over time, occur immediately or exponentially.

EX-ACT Screenshot 6: Other land use change

2.3. Other Land use changes								
Fill with you description	**Initial land use**	**Final land use**	**Message**	**Fire use (y/n)**	**Area transformed** Without	*	With	*
Cereal expansion	Grassland	Annual Crop		YES	4000	D	2000	D
Mango tree plantation	Degraded Land	Perennial/Tree Crop		NO	0	D	2000	D
	Select Initial Land Use	Select Final Land Use	Fill initial LU	NO	0	D	0	D
	Select Initial Land Use	Select Final Land Use	Fill initial LU	NO	0	D	0	D
	Select Initial Land Use	Select Final Land Use	Fill initial LU	NO	0	D	0	D
	Select Initial Land Use	Select Final Land Use	Fill initial LU	NO	0	D	0	D
	Select Initial Land Use	Select Final Land Use	Fill initial LU	NO	0	D	0	D
	Select Initial Land Use	Select Final Land Use	Fill initial LU	NO	0	D	0	D
	Select Initial Land Use	Select Final Land Use	Fill initial LU	NO	0	D	0	D
	Select Initial Land Use	Select Final Land Use	Fill initial LU	NO	0	D	0	D

All final land uses that are expected to emerge as in this case a new annual crop area of 2000 ha and a new perennial crop on as well 2000 ha, will automatically appear in the respective module on crop production and do not have to be entered separately there.

D. Results per component

Based on the areas indicated, the vegetation characteristics and the information on conversion practices, EX-ACT provides the GHG-balance in CO_2-e for each component of the Land Use Change Module. It is exemplarily depicted here below for the deforestation activities: In this simplified example the net emissions from deforestation happening under the project lead to net reductions in carbon stocks and CO_2 emissions accounting for 464,000 tonnes of CO_2-e. Since this scenario nevertheless contains strongly reduced deforestation as compared to the baseline scenario, the GHG-balance of the project scenario account for -3,122,000 tCO_2-e of preserved stocks and prevented emission sources.

EX-ACT Screenshot 7: Aggregated EX-ACT results for deforestation

2.1. Deforestation				
Deforested area (ha)		**Total Emissions (tCO2-eq)**		**Balance**
Without	With	Without	With	
4000	500	3,372,549	421,569	-2,950,980
500	100	213,845	42,769	-171,076
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
Total Deforestation		3,586,393	464,338	-3,122,056

E. Tier 2 specifications in the land use change module

The central functionality of EX-ACT is to provide the user with default coefficients for carbon stocks of various carbon pools and emission factors of specific practices. Refining the analysis, EX-ACT nevertheless allows specifying more location specific carbon values and emission coefficients. In the Land Use Change Module this mainly concerns the specification of:

1. Above ground biomass (t dm ha^{-1})
2. Below ground biomass (t dm ha^{-1})

3. Soil carbon content (t C ha^{-1})
4. Carbon stocks in litter and deadwood (t C ha^{-1})
5. Average growth rates for above and below ground biomass before and after the first 20 years after planting (t C ha^{-1})

More specifically the screenshots below present the variables that may be specified with location specific values.

EX-ACT Screenshot 8: Tier 2 values for deforestation

Back

You have indicated that your are using the following types of vegetatioı Forest Zone 1
Plantation Zone 2

Use this part only if you want to refine analysis with Tier 2 coefficients **All values are in t of carbon per ha (tC/ha)**
(default values are provided for your information, each time you fill a specific values, EX-ACT will use this value in calculation)

Type of vegetation (that will be deforested)	Above-ground		Below-ground		Litter		Dead wood		Soil C	
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	Tier 2
Forest - Zone 1	145.7	163.0	53.9	55.3	3.7	3.2	0.0		65.0	67.3
Forest - Zone 2	122.2		29.3		3.7		0.0		65.0	
Forest - Zone 3	56.4		15.8		3.7		0.0		65.0	
Forest - Zone 4	32.9		13.2		3.7		0.0		65.0	
Plantation - Zone 1	70.5		26.1		3.7		0.0		65.0	
Plantation - Zone 2	56.4	53.2	11.3	9.6	3.7	3.2	0.0		65.0	58.6
Plantation - Zone 3	28.2		7.9		3.7		0.0		65.0	
Plantation - Zone 4	14.1		5.6		3.7		0.0		65.0	

1 ***Reviewing relevant types of vegetation***: In the first row EX-ACT presents you with the vegetation types that were earlier specified as relevant under the analysed project. Since in this case only "forest 1" (Tropical rainforest) and "plantation zone 2" (tropical moist deciduous forest) are land uses that are altered under project or baseline scenario, we are only concerned with these two respective rows.

2 ***Above-ground biomass***: Users specify the location specific value for above-ground biomass in tonnes of Carbon per hectare.

3 ***Below-ground biomass***: Equivalently, users specify here the location specific value for below-ground biomass in tonnes of Carbon per hectare.

4 ***Litter***: Users may specify here the amount of carbon present in the respective forest from litter.

5 ***Deadwood***: Equivalently, users specify here the amount of carbon present in the respective forest from deadwood.

6 ***Soil carbon***: Lastly, users can define location specific values of carbon stored in soil. This is thereby one of the most important variables for Tier 2 specifications.

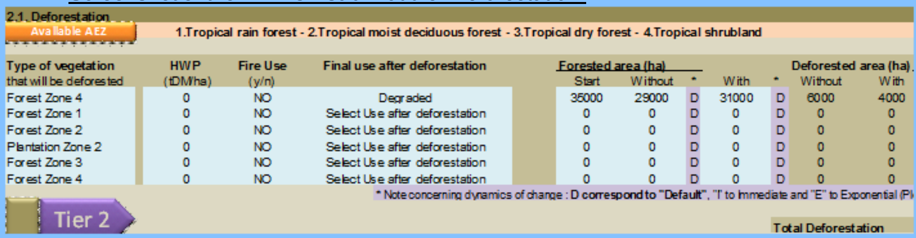
The Tier 2 specifications for the Afforesteation and Reforestation component follow the identical logic though asking instead of the existing biomass, for the growth rates in biomass of the newly established forest.

Case Study 2: Irrigation and Watershed Management in Madagascar

__Decreasing the rate of deforestation__: The analyzed project is implemented on 35,000 ha of tropical shrubland. The project area experienced in the past high rates of deforestation, leading to increasing areas of degraded land and destabilization of watersheds.

Without the project intervention it is expected that the forested area will decrease by **6000 ha**. With the project, it is expected that only **4000 ha** of the current forests will be deforested. EX-ACT accounts for these activities in the "***deforestation***" sub-module.

Screenshot of the EX-ACT sub-module "Deforestation"



2.1. Deforestation

Available AEZ: 1.Tropical rain forest - 2.Tropical moist deciduous forest - 3.Tropical dry forest - 4.Tropical shrubland

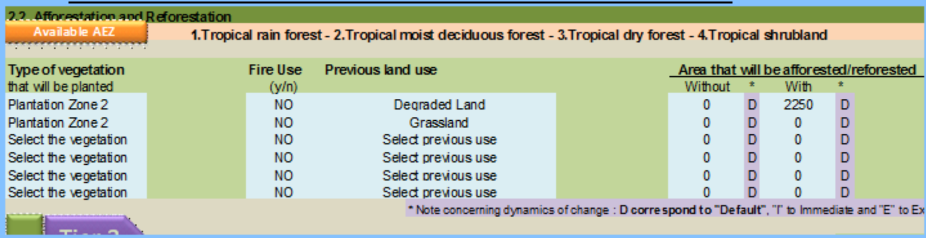
Type of vegetation that will be deforested	HWP (tDM/ha)	Fire Use (y/n)	Final use after deforestation	Forested area (ha) Start	Without	*	With	*	Deforested area (ha) Without	With
Forest Zone 4	0	NO	Degraded	35000	29000	D	31000	D	6000	4000
Forest Zone 1	0	NO	Select Use after deforestation	0	0	D	0	D	0	0
Forest Zone 2	0	NO	Select Use after deforestation	0	0	D	0	D	0	0
Plantation Zone 2	0	NO	Select Use after deforestation	0	0	D	0	D	0	0
Forest Zone 3	0	NO	Select Use after deforestation	0	0	D	0	D	0	0
Forest Zone 4	0	NO	Select Use after deforestation	0	0	D	0	D	0	0

* Note concerning dynamics of change : D correspond to "Default", "I" to Immediate and "E" to Exponential (P

Total Deforestation

__Increase in forested areas:__ Besides, the project is expected to convert **2250 ha** of degraded land into tropical moist deciduous forest that otherwise would have remained degraded. These information is entered in as activity of "afforestation & reforestation".

Screenshot of the EX-ACT sub-module "Afforestation & Reforestation"



2.2. Afforestation and Reforestation

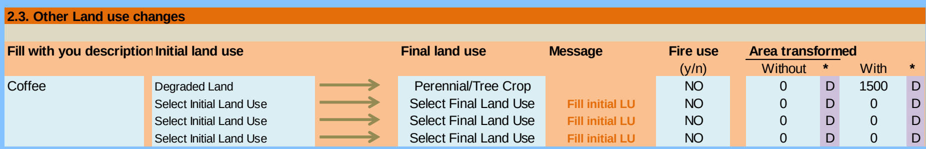
Available AEZ: 1.Tropical rain forest - 2.Tropical moist deciduous forest - 3.Tropical dry forest - 4.Tropical shrubland

Type of vegetation that will be planted	Fire Use (y/n)	Previous land use	Area that will be afforested/reforested Without	*	With	*
Plantation Zone 2	NO	Degraded Land	0	D	2250	D
Plantation Zone 2	NO	Grassland	0	D	0	D
Select the vegetation	NO	Select previous use	0	D	0	D
Select the vegetation	NO	Select previous use	0	D	0	D
Select the vegetation	NO	Select previous use	0	D	0	D
Select the vegetation	NO	Select previous use	0	D	0	D

* Note concerning dynamics of change : D correspond to "Default", "I" to Immediate and "E" to Ex

__Developing agroforestry:__ **1500 ha** of degraded land will furthermore be developed into coffee plantation. This will be accounted for under the "***land use change***" section of EX-ACT.

Screenshot of the EX-ACT sub-module "Other Land Use Change"



2.3. Other Land use changes

Fill with you description	Initial land use	Final land use	Message	Fire use (y/n)	Area transformed Without	*	With	*
Coffee	Degraded Land	Perennial/Tree Crop		NO	0	D	1500	D
	Select Initial Land Use	Select Final Land Use	Fill initial LU	NO	0	D	0	D
	Select Initial Land Use	Select Final Land Use	Fill initial LU	NO	0	D	0	D
	Select Initial Land Use	Select Final Land Use	Fill initial LU	NO	0	D	0	D

The establishment of coffee bushes will lead under such conditions lead in the long run to increase soil carbon stocks, build up fertility and also provide additional biomass through coffee itself as well as other vegetation that is more likely to grow after the soil rehabilitation measures.

Chapter 7: Entering Crop Production

A. Entering annual crops

One important determinant of release and sequestration of carbon in soil are the specific management practices applied on the respective land area. Especially annual crops thereby are usually characterized by more intensive forms of land preparation. EX-ACT allows users to differentiate between agricultural management practices of major importance for soil carbon dynamics.

For the directly below following EX-ACT sub-module on annual crops it is thus essential to differentiate between the following improved practices:

- Improved agronomic practices: They comprise all practices that may increase yields and thus generate higher quantities of crop residues. Examples of such practices reported by Smith et al. (2007) are the use of improved crop varieties, extending of crop rotations, and rotations with legume crops.
- Improved nutrient management: This includes the application of fertilizer, manure or biosolids in a way that improves either the efficiency (adjusting application rate, improving timing and location) or diminishes the potential losses (forms of fertilizer with slow release rate or nitrification inhibitors).
- Improved tillage and residue management: This category comprises the adoption of tillage practices of less intensity ranging from minimum tillage to no-tillage. It may include or not include mulching of crop residues and thus also comprises a key element of conservation agriculture.
- Enhanced water management: This stands for the use of enhanced irrigation measures that can lead to an increase in productivity and hence augment the quantity of residues.
- Manure application: This comprises the application of manure and biosolids as improved source of nutrients and organic matter.

The here listed practices may as well have direct and indirect impacts on N_20 and CH_4 emissions, e.g. by increases in artificial inputs as well as organic fertilizer. These impacts are nevertheless already accounted for in the separate topic modules on inputs and livestock and EX-ACT is here only concerned with the changes in soil carbon.

The combination of various improved practices thereby is not expected to lead to the addition of the single sequestration potential of each measure. Since there is only limited scientific evidence on the sequestration potential of combined improvements in management practices, EX-ACT always only considers the sequestration potential of the strongest single improved practice. This is a matter of caution that intents to strictly avoid the overestimation of soil carbon sequestration. As part of the Tier 2 specifications users may also instead specify their own management practices and associated mitigation potential (in t C ha^{-1} yr^{-1}).

EX-ACT Screenshot 9: Overview annual crops

3.1. Annual systems (to be used also for pluri-annual systems such as cotton or sugarcane)

3.1.1. Annual systems from other LUC or converted to other LUC ***(Please fill step 2.LUC previously)***

Description	Improved agro-nomic practices	Nutrient management	NoTill./residues management	Water management	Manure application	Residue/Biomas Burning	Yield (t/ha/yr)	Area (ha) Start	Without	With
Annual after Deforestation	?	?	?	?	?	YES		0	4000	500
Converted to A/R	?	?	?	?	?	NO		100	0	100
Annual after non-forest LU	?	?	?	?	?	NO		0	4000	2000
Converted to OLUC	?	?	?	?	?	NO		0	0	0

3.1.2. Annual systems remaining annual systems ***(total area must remains contant)***

Fill with you description	Improved agro-nomic practices	Nutrient management	NoTill./residues management	Water management	Manure application	Residue/Biomas Burning	Yield (t/ha/yr)	Area (ha) Start	Without	*	With	*
Conventional Maize	?	?	?	?	?	YES		1500	1400	D	0	D
Improved Maize	Yes	?	?	Yes	?	NO		0	0	D	1200	D
Conventional Sugar Cane	?	?	?	?	?	NO		100	200	D	0	D
Improved Sugar Cane	Yes	?	?	?	Yes	NO		0	0	D	400	D
description 5	?	?	?	?	?	NO		0	0	D	0	D
description 6	?	?	?	?	?	NO		0	0	D	0	D
description 7	?	?	?	?	?	NO		0	0	D	0	D
description 8	?	?	?	?	?	NO		0	0	D	0	D
description 9	?	?	?	?	?	NO		0	0	D	0	D
description 10	?	?	?	?	?	NO		0	0	D	0	D
							Total	1600	1600		1600	

The screenshot above shows the entire sub-module on annual crops. It is divided into two big parts: In the section on the top EX-ACT automatically inserted the three annual crop areas that are concerned by land use change as specified in the Land Use Change Module in EX-ACT. In the lower part instead users enter additional areas continuously managed as annual crop areas. For the sake of simplicity we present in the following only the lower part of the table. The upper part is filled equivalently.

Detail of screenshot 9:

3.1.2. Annual systems remaining annual systems ***(total area must remains contant)***

Fill with you description	Improved agro-nomic practices	Nutrient management	NoTill./residues management	Water management	Manure application	Residue/Biomas Burning
Conventional Maize	?	?	?	?	?	YES
Improved Maize	Yes	?	?	Yes	?	NO
Conventional Sugar Cane	?	?	?	?	?	NO
Improved Sugar Cane	Yes	?	?	?	Yes	NO
description 5	?	?	?	?	?	NO
description 6	?	?	?	?	?	NO
description 7	?	?	?	?	?	NO
description 8	?	?	?	?	?	NO
description 9	?	?	?	?	?	NO
description 10	?	?	?	?	?	NO

To fill the annual crop sub-module users need to specify:

1 ***Naming the specific cropping system***: At first users should clearly denominate the cropping system in order to avoid any misunderstandings in data entry and allow for easy orientation also when refining the analysis at a later time or sharing the EX-ACT file with colleagues.
In this case we analyse four different cropping systems: At project start conventional cropping practices of maize and sugar cane dominate, while under the project improved management practices for both crops are introduced.

2 ***Specifying management practices***: Under this point users should specify which of the further above depicted improved management practices are applied in the respective annual systems. Users chose from a drop-down list between Yes/No. A question mark, which is the default value, counts as if the improved practice would not be applied. The five concerned sets of improved practices are:

- Improved agronomic practices
- Improved nutrient management
- No-tillage and residues management
- Improved water management
- Manure application

3 ***Fire use***: In addition users specify whether crop residues are burned after harvest. A default amount of 10 t of dry matter per ha is thereby assumed as default value but may be replaced by a user specific value.

Detail of screenshot 9:

Fill with you description	Yield	Area (ha)				
	(t/ha/yr)	Start	Without	*	With	*
Conventional Maize	1.5	1500	1400	D	0	D
Improved Maize	2.5	0	0	D	1200	D
Conventional Sugar Cane	48	100	200	D	0	D
Improved Sugar Cane	57	0	0	D	400	D
description 5		0	0	D	0	D
description 6		0	0	D	0	D
description 7		0	0	D	0	D
description 8		0	0	D	0	D
description 9		0	0	D	0	D
description 10		0	0	D	0	D
	Total	1600	1600		1600	

4 ***Specifying yield (optional)***: Users may then specify also the yield level of their crop. Yields do not need to be specified necessarily, but only if users intent to derive results also inform of the carbon-balance per unit of produce later on.
In our example both improved management systems lead to strong yield increases as visible above.

5 ***Surface of annual crops***: Essentially, users need to specify the different surface sizes of the various annual cropping systems for the three situations of project start, end of project and outcome of the baseline scenario.

In the here displayed case, the implemented project leads to a relative decrease in conventional cropping practices and introduces instead those cropping systems under improved management practices.

6 ***Dynamic of change***: In the small violet boxes users can again specify whether the changes between the start situation and the without- and with-project situation materialize linearly (default) over time, occur immediately or exponentially.

B. Entering agroforestry and perennial systems

The sub-module on perennial crops follows again the structure of being subdivided into an upper section in which perennial crop areas subject to land use change are depicted. Surface sizes subject to land use change are again automatically filled by EX-ACT, based on the specifications made in the Land Use Change Module. Equivalent to the earlier description, only the lower part will be described in more detail here below. The upper elements are filled using the same logic.

EX-ACT Screenshot 10: Perennial crops

3.2. Perrenial systems (Agroforestry, Orchards, Tree crops…)

3.2.1. Perrenial systems from other LUC or converted to other LUC *(Please fill step 2.LUC previously)*

Description	Residue/Biomass Burning	Yield (t/ha/yr)	**Area (ha)** Start	Without	With
Perennial after Deforestation	NO		0	0	0
Converted to A/R	NO		0	0	0
Perennial after non-forest LU	NO	7	0	0	2,000
Converted to OLUC	NO		0	0	0

3.2.2. Perennial systems remaining perrenial systems *(total area must remains contant)*

Fill with you description	Residue/Biomass Burning	Yield (t/ya/yr)	**Area (ha)** Start	Without	*	With	*
Mango	NO	7	100	100	D	300	D
Oilpalm	NO	3.5	400	400	D	200	D
Enter description of your system 3	NO		0	0	D	0	D
Enter description of your system 4	NO		0	0	D	0	D
Enter description of your system 5	NO		0	0	D	0	D
		Total	500	500		500	

To fill the perennial crop sub-module users need to specify:

1. ***Naming the specific cropping system***: At first users should again clearly denominate the cropping system in order to avoid any misunderstandings in data entry or later data modification. In this case we analyse the two different cropping systems of oil palm plantation and mango orchards.

2. ***Fire use***: In a next step users specify whether crop residues are burned after harvest.

3. ***Specifying yield (optional)***: Users may then again specify the relevant yield. Once more we point out that yields levels do not necessarily need to be specified, but are only of use if later a more complex analysis of the carbon-balance per unit of produce is carried out.

4. ***Surface of perennial crops***: Here again surface sizes of the crops need to be specified.

   In the here displayed example at project start oil palm trees are dominating as perennial crop, while under the project half of them are converted to mango orchards. Thereby the project does not introduce any improved management practices on the plots that continue to be managed as oil palm plantation.

6 ***Dynamic of change***: In the small violet boxes users can again specify whether the changes between the start situation and the without- and with-project situation materialize linearly (default) over time, occur immediately or exponentially.

C. Entering flooded rice systems

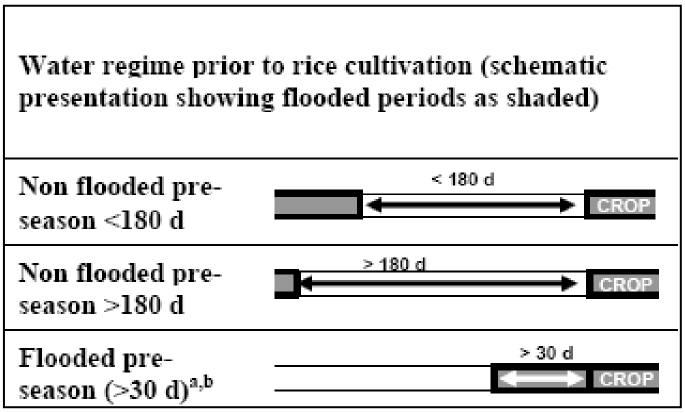
While all other annual crops are dealt with in the above described sub-module, the production of flooded rice systems, be it under irrigation or rainfed but deepwater conditions, has special implications for CH_4 emissions and is thus dealt with separately in this sub-module. Rice that is grown without any extended flooding period, as e.g. upland rice, is thus still entered as annual crop in the respective sub-module above.

The GHGs concerned by this sub-module are (i) methane emissions produced from anaerobic decomposition of organic matter and (ii) non-CO_2 GHG emissions (CH_4 and N_2O) from biomass burning. CO_2 emissions from biomass burning do not have to be considered since the carbon release during the combustion is assumed to be reabsorbed by the vegetation during the next growing season. The N_2O emissions from N-fertilizer are thereby again accounted for in the “Inputs Module”.

For emissions from flooded rice systems it is of central importance to differentiate between the various water management regimes during the pre-season as well as throughout the growing season. EX-ACT follows the central differentiation by the NGGI-IPCC (2006).

Firstly it is roughly differentiated between those cultivation systems with a non-flooded preseason of either less or more than 180 days and those cultivation systems with a flooded preseason of at least 30 days or longer.

Figure 18: Different water management regimes for flooded rice (c.f. NGGI-IPCC, 2006)



Secondly, it is differentiated between three water regimes during the growing period:

- **Irrigated – Continuously flooded**: Fields have standing water throughout the entire growing season and only dry out for harvest (end-season drainage).
- **Irrigated – Intermittently flooded:** Fields have at least one aeration period of more than 3 days during the cropping period; no difference is made here for single or multiple aeration.
- **Rainfed, deep water**: Fields are flooded for a significant period of time, while the water availability depends solely on precipitation. It includes the following subcases: (i) regular rainfed (the water level may rise up to 50 cm during the cropping season), (ii) drought prone (drought periods occur during every cropping season), and (iii) deep water rice (floodwater rises to more than 50 cm for a significant period of time during the cropping season).

Also the sub-module on flooded rice follows again the same structure to denote firstly on top those rice areas that are impacted by land use change, while it specifies in the lower part of the sub-module those areas that are constantly cultivated as flooded rice. Since both parts are filled in the equivalent way, only the areas constantly cultivated with flooded rice are exemplarily depicted here.

EX-ACT Screenshot 11: Flooded rice (Detail 1)

Fill with you description	Cultivation period (days)	Water Regime: During the cultivation Period	Water Regime: Before the cultivation period	Organic Amendment type (Straw or other
Conventional flooded	150	Irrigated - Continuously flooded	Flooded preseason (>30 days)	Compost
Improved flooded	150	Irrigated - Intermittently flooded	Non flooded preseason >180 days	Compost
Rice 1	2	Please s 3 water regime	Please select p 4 ason water regime	Please select typ 5 rganic Amendment
Rice 4		Please s water regime	Please select p ason water regime	Please select type rganic Amendment
Rice 5	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment
Rice 6	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment
Rice 7	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment
Rice 8	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment
Rice 9	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment
Rice 10	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment

To fill the flooded rice sub-module users need to specify:

1. ***Naming the specific cropping system***: At first users should again clearly denominate the cropping system in order to avoid any misunderstandings in data entry or later data modification. In this case we analyse one longer and one shorter flooded rice system.

2. ***Cultivation period***: In a next step users specify the length of the cultivation period.

3. ***Water regime during the cultivation period***: Users then chose whether the rice field is continuously or intermittently flooded. As another option it may also be managed as a deepwater, rainfed system.

4. ***Water regime during the pre-season***: Then, users specify from a drop-down list, whether the preseason is flooded, or not flooded and whether the non-flooded preseason is shorter or longer than 180 days.

5. ***Organic amendment***: The next step specifies how crop residues are managed and utilized. The different options are: *Straw burnt / straw exported / straw incorporated short or long before cultivation / compost / farmyard manure / green manure*.

EX-ACT Screenshot 12: Flooded rice (Detail 2)

Fill with you description	Yield (t/ya/yr)	Area (ha) Start	Without	*	With	*
Conventional flooded	6 2.5	250	7 250	D	8 0	D
Improved flooded	2.3	0	0	D	250	D
Rice 3		0	0	D	0	D
Rice 4		0	0	D	0	D
Rice 5		0	0	D	0	D
Rice 6		0	0	D	0	D
Rice 7		0	0	D	0	D
Rice 8		0	0	D	0	D
Rice 9		0	0	D	0	D
Rice 10		0	0	D	0	D
	Total	250	250		250	

6 ***Specifying yield (optional)***: Also in the flooded rice sub-module users can specify the yield, if later analysis per produced unit is intended.

7 ***Surface of flooded rice***: The next step is to specify the surface sizes of the different rice management systems at project start as well as under project and baseline scenario.

In the here displayed example the analyzed area shifts from a more intense flooding system to a less flood dominated system under the project scenario.

8 ***Dynamic of change***: In the small violet boxes users can again specify whether the changes between the start situation and the without- and with-project situation materialize linearly (default) over time, occur immediately or exponentially.

D. Tier 2 specifications in the annual crop module

Also in the annual crop module users may replace a wide range of default coefficients with location specific values for carbon pools and growth rates as well as emission coefficients. This concerns the variables:

- Rates of soil carbon sequestration (t C/ha/yr)
- Quantity of residues and biomass available for burning as well as periodicity of burning practice (t of dry matter per ha
- Above and below ground biomass growth rate (t C/ha/yr)

In all three sub-modules user can specify Tier 2 values when clicking on the violet Tier 2 button:

Chapter 8: Entering Livestock and Grassland Management

A. Grassland management

Grasslands are an important stock of soil carbon and may be a relevant source for emissions as e.g. through degradation or periodic burning. As the entire crop production module also the grassland sub-module is divided into an upper section in which grassland that is subject to land use change is entered. In the lower section instead, areas that permanently stay grassland are considered. For the sake of briefness, we only show screenshots from the latter section, since it provides the full information on how to effectuate data entry.

EX-ACT Screenshot 13: Grassland

4.1.2. Grassland systems remaining grassland systems *(total area must remains contant)*								
Description	Initial state	Final state of the grassland		Fire use to manage				**Area**
		Without project	With project	Without		With		
				(y/n)	(year)	(y/n)	(year)	(ha)
Cattle grazing area	Moderately Degraded	Severely Degraded	Improved with inputs improvement	YES	5	NO	5	2,500
Less frequented area	Non degraded	Non degraded	Non degraded	NO	5	NO	5	1,000
1	Select state 2	Select state	3 Select state	NO	5	4 NO	5	5
	Select state	Select state	Select state	NO	5	NO	5	
	Select state	Select state	Select state	NO	5	NO	5	0
	Select state	Select state	Select state	NO	5	NO	5	0
	Select state	Select state	Select state	NO	5	NO	5	0
	Select state	Select state	Select state	NO	5	NO	5	0
	Select state	Select state	Select state	NO	5	NO	5	0
	Select state	Select state	Select state	NO	5	NO	5	0

To fill the grassland sub-module users need to specify:

1 ***Naming the specific cropping system***: At first users should again clearly denominate the grassland area in order to avoid any misunderstandings in data entry or later data modification. In this case we analyse two different types of grassland, one is frequently grazed, while another area is remotely located and only in limited ways frequented for grazing or any other activities.

2 ***Initial state of degradation***: In this step users specify the initial state of degradation of the grassland area by choosing from a drop-down list between the options: *Non-degraded / moderately degraded / severely degraded / improved without inputs / improved with inputs*.

3 ***Final state of degradation***: Users then go over to specify the final state of degradation for the without- and with-project scenarios, selecting again from the same options as previously.

4 ***Fire use***: In the following step users specify whether and how frequent grassland is burned. In the presented example fire is used every five years on the area used for cattle grazing under the baseline scenario, while there are no burning practices anymore under the project scenario.

5 ***Surface size of grassland***: In the last step users specify the size of the considered grassland areas.

B. Livestock management

The livestock sub-module was developed based on NGGI-IPCC (2006). For specific technical mitigation options not covered in NGGI-IPCC-2006, information was taken from the Fourth Assessment Report from working group III of the IPCC (Smith, et al., 2007).

GHGs covered by the livestock sub-module are (i) methane emissions from enteric fermentation, (ii) methane emissions from manure management, (iii) nitrous oxide emissions from manure management as well as, (iv) some additional technical mitigation options for methane emissions from livestock.

EX-ACT Screenshot 14: Livestock management

4.2. Livestocks

Livestock categories	**Head number** (mean per year)					**Technical mitigation option (%)**								
						Feeding practices*			Specific Agents*			Breeding*		
	Start	Without project	*	With project	*	Start	Without	With	Start	Without	With	Start	Without	With
Dairy cattle	0	0	D	0	D	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other cattle	300	400	D	300	D	0%	0%	70%	0%	0%	0%	0%	0%	100%
Buffalo	80	120	D	80	D	0%	0%	70%	0%	0%	0%	0%	0%	100%
Sheep	0	0	D	0	D	0%	0%	0%	0%	0%	0%	0%	0%	0%
Swine (Market)	0	0	D	0	D									
Swine (Breeding)	0	0	D	0	D									
Please select	0	0	D	0	D									
Please select	0	0	D	0	D									
Please select	0	0	D	0	D									

Feeding practices: e;g. more concentrates, adding certain oils or oilseeds to the diet, improving pasture quality,…

Specific agents: specific agents and dietary additives to reduces CH4 emisisons (Ionophores, vaccines, bST…)

Breeding: Increasing productivity through breeding and better management practices (reduction in the number of replacement heifers)

To fill the livestock sub-module users need to specify:

1. ***Choosing the adequate animal categories:*** First users choose in which row they can find the relevant animal categories concerned by the project. Therefore they either use the already inserted animal types or choose from further types from a drop-down list.

2. ***Livestock numbers***: In the second step users then specify livestock numbers at project start as well as at the end of the baseline and project scenario.

3. ***Dynamic of change***: In the small violet boxes users can again specify whether the changes between the start situation and the without- and with-project situation materialize linearly (default) over time, occur immediately or exponentially.

4. ***Technical mitigation options***: In this part of the analysis users specify which percentage of the livestock herds is subject to (i) improved feeding practices, (ii) application of specific agents, or (iii) improved breeding practices.

C. Tier 2 specifications in the livestock sub-module

Also the livestock sub-module allows for the specification of regional specific variables. The variables that can be defined are:

- Mean annual temperature (MAT) of the region (in °C)
- Emission of N_2O from manure management (kg N-N_2O/kg N)
- Emissions of CH_4 from manure management (kg CH_4 per head/yr)
- Enteric fermentation (kg CH_4 per head/yr)

Chapter 9: Entering Land Degradation

A. Entering forest degradation

Currently there are no international recognized methodologies to assess forest degradation. The different available states of degradation within EX-ACT correspond to an average level of degradation, also expressed in terms of percentage of degraded area (see explanation here below).

EX-ACT Screenshot 15: Forest degradation

5.1. Forest degradation

Available AEZ — 1.Tropical rain forest - 2.Tropical moist deciduous forest - 3.Tropical dry forest - 4.Tropical shrubland

Type of vegetation that will be degraded	Degradation level of the vegetation: Initial state	At the end: without project	At the end: with project	Fire occurrence and severity: Without (y/n)	Without: Periodicity	Without: (% burnt)	With (y/n)	With: Periodicity	With: (% burnt)	Area (ha) Start (t/ha)
Forest Zone 1	Very low	Moderate	None	YES	1	25%	NO			500
Forest Zone 1	Low	Large	Very low	NO			NO			1000
Select the vegetation	Select level	Select level	Select level	NO			NO			0
Select the vegetation	Select level	Select level	Select level	NO			NO			0
Select the vegetation	Select level	Select level	Select level	NO			NO			0
Select the vegetation	Select level	Select level	Select level	NO			NO			0

To fill the forest degradation sub-module users need to specify:

1 ***Choosing the adequate forest type***: First users choose the respective forest type. Equivalent to the deforestation sub-module they choose from a drop-down list the relevant forest type either being a naturally grown forest or a plantation forest and consulting the different agro-ecological zones presented on top of the screenshot.

2 ***Initial state of degradation***: In the second step users then specify the initial state of degradation and can choose from the following options in the drop-down list: *None (0%) / very low (10%) / low (20%) / moderate (40%) / large(60%) / extreme (80%)*. In such a way 100 ha of low degraded forest is characterized by the same carbon stock as 80 ha of non degraded forest when considering all five carbon pools.

3 ***Final state of degradation***: In the preceding step users then specify the final degree of degradation for the baseline and project scenario. In the above example the project leads to a slight rehabilitation on both forest areas.

4 ***Fire occurrence and severity***: Afterwards it is identified with which annual periodicity fire occurs (1 = annual occurrence, 5 = fire occurrence every five years) and how much of the forest is burnt in one of the incidences.

5 ***Forest size***: In the last step users specify the size of the forest that is subject to such changes in their state of degradation.

B. Entering organic soil drainage and peat extraction

Two additional changes in land use that are of high specificity and only occur in limited contexts, though at the same time being of strong relevance for GHG emissions, are drainage of organic soils (as wetlands) and peat extraction. Peatlands are drained to gain fertile organic soils for agricultural production, while peat may be extracted for various purposes including as energy source, for horticulture production, for waste water treatment and further purposes.

When peatlands are transformed into aerobic conditions the initiating decomposition of soil organic matter leads to CO_2 and N_2O emissions, while CH_4 emissions decrease, leading to an overall effect of net emission growth. EX-ACT thereby allows for calculating the impact of the drainage of organic soils on four types of land uses: Managed forest, annual crops, perennial crops and grassland.

EX-ACT Screenshot 16: Drainage of organic soils and peatland extraction

5.2 degradation of organic soils (peatlands)

5.2.1. Drainage of organic soils (peatlands)

Vegetation type where drainage is occuring	**Superficies of drained organic soils** (ha)				
	Start	Without	*	With	*
Managed Forest	0	150	D	0	D
Annual	0	0	D	200	D
Perennial	0	0	D	0	D
Grassland	0	0	D	0	D

5.2.2 Active peat extraction

Type of peat	**Superficies of drained organic soils** (ha)				
	Start	Without	*	With	*
Nutrient-poor peat	100	0	D	0	D
Nutrient-rich peat	0	0	D	0	D

To fill the peatland drainage and extraction sub-module users need to specify:

1 ***Surfaces concerned by organic soil drainage***: Users first specify the area sizes concerned by organic soil drainage. In the example above the baseline scenario would lead to drainage of 150ha of managed forest, while the project scenario would establish effective drainage on 200 ha of existing annual crop area.

2 ***Surfaces concerned by peat extraction***: Secondly users specify on which surface size peat extraction is taking place. They can thereby choose between the categories of more nutrient rich or more nutrient poor peat. Nutrient-poor peat bogs predominate in boreal regions, while in temperate regions, nutrient-rich fens and mires are more common.

In the above example active peatlant extraction takes place at project start on 100 ha, while both the baseline as well as the project scenario would lead to the discontinuation of any peatland extraction.

3 ***Dynamic of change***: In the small violet boxes users can again specify whether the changes between the start situation and the without- and with-project situation materialize linearly (default) over time, occur immediately or exponentially.

C. Tier 2 specifications in the land degradation module

The variables that can be specified by location specific coefficients in the land degradation module are the following:

- Degradation level (in % of biomass lost)
- Specification of forest:
    - Above ground biomass (t dm ha-1)
    - Below ground biomass (t dm ha-1)
    - Soil carbon content (t C ha-1)
    - Carbon stocks in litter and deadwood (t C ha-1)
- Emissions factor for loss of C associated with drainage of organic soils (t C/ha/yr)
- On-site CO_2 and N_2O emissions from active peat extraction (t C/ha/yr, kg N_2O-N/ha/yr)

Case Study 3: Russia Forestry Fire Response Project

Fire is a major natural disturbance in Russian natural ecosystems. Particular the high number of forests situated in regions with limited amounts of precipitation and/or frequent occurrences of long drought periods are prone to severe fire events. The objective of the Forestry Emergency Response Project (FERP) is to improve forest fire prevention and management and enhance sustainable forest management. Using the forest degradation sub-module, assumptions for the evolution of forest degradation and the link to the evolution of fire occurrence have been entered as shown here below:

5.1. Forest degradation

Available AEZ: 1.Tropical rain forest - 2.Tropical moist deciduous forest - 3.Tropical dry forest - 4.Tropical shrubland

Type of vegetation that will be degraded	Degradation level of the vegetation: Initial state	At the end without project	with project	Fire occurrence and severity (y/n)	Periodicity (year)	Impact (% burnt)	(y/n)	Periodicity (year)	Impact (% burnt)	Area (ha) Start (t/ha)	Without (t/ha)	*
Forest Zone 1	Very low	Low	Very low	YES	1	20%	YES	5	20%	24,430,000	24,430,000	D
Select the vegetation	Select level	Select level	Select level	NO			NO			0	0	D
Select the vegetation	Select level	Select level	Select level	NO			NO			0	0	D
Select the vegetation	Select level	Select level	Select level	NO			NO			0	0	D
Select the vegetation	Select level	Select level	Select level	NO			NO			0	0	D
Select the vegetation	Select level	Select level	Select level	NO			NO			0	0	D

* Note concerning dynamics of change : D correspond to "Default", "I" to Immediate and "E" to Exponential (Please refer t

Tier 2

Total forest degradation

Initially forest fires reduced on average 20% of forest carbon stocks each year, with a mean annual burnt forest area of 4,886,000Ha during the last 13 years. Thus the fire impact was set to 20% in EX-ACT. It was hypothesized that with the project, fire will occur every 5 years rather than each year for the same area. This is equivalent to a decrease in 80% concerning the area concerned by fire annually. The total forest area accounts thereby for 24,430,000 ha.

Use of tier 2 data: Average above ground biomass were set to 36.2 t C per hectare as derived from Sohngen (2005) to allow for a stronger regional specific approach. Soil carbon content instead was derived from Moiseev (2003) and was set to 64.8 tC.ha-1.

Type of vegetation (that will be degraded))	Above-ground Default	Tier 2	Below-ground Default	Tier 2	Litter Default	Tier 2	Dead wood Default	Tier 2	Soil C Default	Tier 2
Average russian forest	23.5	36.2	9.2	14.0	47.00	5.0	0.0	15.0	68.0	64.8
Forest - Zone 2	7.1		2.7		47.00		0.0		68.0	
Forest - Zone 3	23.5		9.2		47.00		0.0		68.0	
	0.0		0.0		0.00		0.0		0.0	
Plantation - Zone 1	18.8		7.3		47.00		0.0		68.0	
Plantation - Zone 2	7.1		2.7		47.00		0.0		68.0	
Plantation - Zone 3	14.1		5.5		47.00		0.0		68.0	
	0.0		0.0		0.00		0.0		0.0	

Chapter 10: Entering Inputs and Investments

A. Entering inputs

The methodological background used to develop this sub module can be found in NGGI-IPCC (2006) and was complemented with Lal (2004) for embodied GHG emissions associated with the use of agricultural chemicals in farm operations.

GHGs generated by the inputs are (i) carbon dioxide emissions from lime application, (ii) carbon dioxide emissions from urea application, (iii) nitrous oxide emissions from N application on managed soils (except for manure management aspects that were treated in the livestock sub-module) and also (iv) emissions (in CO_2 equivalent) from production, transportation storage and transfer of agricultural chemicals.

EX-ACT Screenshot 17: Agricultural inputs

6.1 Inputs (liming, fertilizers, pesticides, herbicides,…)					
Description and unit to report	Amount applied per year				
Lime application	Start	Without		With	*
Limestone (tonnes per year)	1,000	1,000	D	1,000	D
Dolomite tonnes per year)	0	0	D	0	D
not-specified (tonnes per year)	0	0	D	0	D
Fertilizers					
Urea (tonnes of N per year - Urea has 46.7% of N)	0	10,000	D	50,000	D
Other N-fertilizers (tonnes of N per year)	0	0	D	30,000	D
N-fertilizer in irrigated rice (tonnes of N per year)	0	0	D	0	D
Sewage (tonnes of N per year)	0	0	D	0	D
Compost (tonnes of N per year)	0	0	D	0	D
Phosphorus (tonnes of P2O5 per year)	0	0	D	0	D
Potassium (tonnes of K2O per year)	0	0	D	0	D
Pesticides					
Herbicides (tonnes of active ingredient per year)	100	100	D	0	D
Insecticides (tonnes of active ingredient per year)	100	0	D	0	D
Fungicides (tonnes of active ingredient per year)	0	0	D	0	D

To fill the sub-module on agricultural inputs users need to specify:

1. ***Quantities of agricultural inputs***: Annual quantities for the various agro-chemical products used as well as organic fertilizers have to be specified for project start, the baseline scenario as well as the project scenario. Specifications have thereby to be made in quantities of active components, as e.g. in tonnes of nitrogen.
   In the here used example, the application of limestone stays unchanged throughout all three project scenarios, while the implementation of the project leads to strong increases in the use of urea as well as organic N-fertilizer.

2. ***Dynamic of change***: In the small violet boxes users can again specify whether the changes between the start situation and the without- and with-project situation materialize linearly (default) over time, occur immediately or exponentially.

B. Entering energy consumption

Material used to develop this module came from diverse sources according to the specificity of the sector covered: Energy related emissions can be found in NGGI-IPCC (2006), in the "Bilan Carbone" used by AFD and from the International Energy Agency. Default values associated with the installations of irrigation systems are from Lal (2004).

GHGs covered here are (i) GHG emissions associated with electricity consumption, (ii) GHG emissions associated with fuel consumption, (iii) GHG emissions associated with installation of irrigation systems and (iv) GHG emissions associated with building infrastructure.

EX-ACT Screenshot 18: Fossil energy consumption

6.2 Energy consumption (electricity, fuel,…)					
Description and unit to report	Quantity consumed per year				
	Start	Without		With	
Electricity (MWh per year)			*		*
Angola 1	2 1000	1000	D	5000	D 3
Liquide or gaseous (in m^3 per year)					
Gasoil/Diesel	100	100	D	500	D
Gasoline	50	50	D	100	D
Gas (LPG/ natural)	0	0	D	0	D
Butane	0	0	D	0	D
Propane	0	0	D	0	D
Ethanol	100	250	D	400	D
Solid (in tonnes of dry matter per year)					
Wood	1000	1000	D	5000	D
Peat	0	0	D	0	D

To fill the sub-module on fossil energy consumption users need to specify:

1 ***Country of electricity production***: First users have to specify in which country the consumed electricity was produced, since this determines to which extend it is related to GHG emissions. Thereby it has not necessarily to be the country of project implementation.

2 ***Consumed quantities of fossil energy***: Then, users have to specify the quantity of annual consumed fossil energy for each energy source.
In the presented example, the project scenario leads to strong increases in energy consumption, as especially of gasoil and ethanol.

3 ***Dynamic of change***: In the small violet boxes users can again specify whether the changes between the start situation and the without- and with-project situation materialize linearly (default) over time, occur immediately or exponentially.

C. Entering infrastructure construction

Agricultural development projects may also lead to additional construction of irrigation systems, roads and buildings that cause GHG emissions during their construction. The sub-module on infrastructure allows accounting also for these emissions.

EX-ACT Screenshot 19: Infrastructure construction

6.3 Construction of new infrastructure for the project (irrigation systems, buildings, roads)				
Description and unit to report	Surface concerned			
	Without		With	
Irrigation systems (total in ha)		*		*
Permanent sprinkle 1	0	D	2000	D
Please select	0	D	0	D
Buildings and roads (total in m²)			3	4
Agricultural Buildings (concrete) 2	0	D	500	D
Road for medium trafic (concrete)	0	D	2500	D
Please select	0	D	0	D
Please select	0	D	0	D
Please select	0	D	0	D
Please select	0	D	0	D
Please select	0	D	0	D

To fill the sub-module on fossil energy consumption users need to specify:

1 ***Type of irrigation system installed***: Users can choose from a drop-down list the type of irrigation system that is installed under the project. Available options are: *Surface without or with IRSS / solid set sprinkler / permanent sprinkler / hand moved sprinkler / solid roll sprinkler / centre-pivot sprinkler*.
In the given example the project is responsible for the installation of an irrigation system using permanent sprinklers.

2 ***Type of buildings and roads constructed***: Afterwards users specify the type of buildings and roads that were constructed under the project. As an example, it is assumed here that the project constructs agricultural buildings from concrete and medium sized roads from concrete.

3 ***Infrastructure size***: In the next step users specify how many surfaces are newly broad under irrigation or is covered by roads and buildings. In the example at hand, the project leads to increases concerning all three elements.

4 ***Dynamic of change***: In the small violet boxes users can again specify whether the changes between the start situation and the without- and with-project situation materialize linearly (default) over time, occur immediately or exponentially.

D. How to account for energy produced by the project (biogas, biofuel, etc.)

In case that a project leads to the production of renewable energy as e.g. in the case of biogas plants, there are three possible options of how this energy is consumed and how to account for it:

- The produced energy is consumed by the project and is replacing alternative sources of energy (fuel consumption or electricity consumption)
- The energy is added in the form of electricity into the national electricity grid, where it substitutes the equivalent of electricity (produced with specific emissions based on the national energy mix)
- The produced energy is used outside the project, substituting a specific type of energy (e.g. fuelwood in a remote area)

In the first case, the contribution of the project activity to reducing GHGs can be accounted by reducing the actual and/or assumed consumption of the relevant fossil fuels by the project in the EX-ACT sub-module on energy consumption.

In the second case the project leads – vice versa – to an effective substitution of electricity by the renewable energy produced as part of the project. In case that the project scenario has no own electricity demand that could be minimized in the EX-ACT module on energy consumption, the substituted quantity of electricity may be inserted as energy consumed in the *Without Project* scenario.

In the third case, we also can assume a hypothetical consumption of equivalent energy in the without-project scenario, while the specific energy type should be taken into account (e.g. fuelwood).

E. Tier 2 in the energy and investments sub-module

Also in the energy and investments sub-module users may replace selected variables with location specific values by clicking on the violet "Tier 2" button. The variables that may be specified as part of the energy and investment module are:

- CO_2 and N_20 emission factors from direct applications and indirect emissions (various units)
- Emission factors by type of energy source
- Emission factors by type of construction works (t CO_2/m^2)

Part C: Making Effective Use of EX-ACT Results

Chapter 11: Analysis of Results

While the part B showed users how to procure data and enter it into the tool, the chapter at hand shows how to first interpret and then utilize the results provided as the carbon-balance in tonnes of CO_2 equivalents.

A. Checking the land use table

One first important output from EX-ACT is the evolution of land use, comparing the initial situation, the baseline scenario and the project scenario. It allows a concise overview of the information entered in EX-ACT in all topic modules at a central place. It is thus a central functionality that allows users to verify the correctness of all entered data, be it concerning the size of specific land uses as well as the consideration of equal total surface sizes under all three points in time. The latter element is evidently a basic precondition of the correct application of EX-ACT since the tool otherwise compares the emission potential from different sized territories. The screenshot below displays this first concise overview.

Thus it is visible that at all three points in time EX-ACT calculates with a total area of 20200 ha and thus does not engage in any major accounting mistake. Besides it is visible that under all scenarios the total forest area and total grassland area diminishes, but that the project scenario reduces the pace of this land use change pattern.

EX-ACT Screenshot 20: Land use evolution in EX-ACT

Surfaces evolutions by land use / category (hectares - ha)		State at the beginning	Without Project	With Project
Forest/Plantation		7500	3100	7100
Cropland	Annual	1700	9600	4200
	Perennial	500	500	2500
	Rice	250	250	250
Grassland		7700	3700	5500
Other Land	Degraded	2000	2500	100
	Other	0	0	0
Organic soils		550	550	550
Total area =		20200	20200	20200

Detailled matrices of changes

By clicking on the button for the detailed matrices of land use change, the same information is once more displayed in more detail: Instead of only showing the total land use at different points in time, it specifies precisely which type of land use remains the same and which type of land use is transformed into a specific other one.

EX-ACT Screenshot 21: Detailed land use matrices

Matrix of changes without project

Mineral soils (ha)			FINAL						
			Forest/ Plantation	**Cropland** Annual	**Cropland** Perennial	**Cropland** Rice	**Grassland**	**Other Land** Degraded	**Other Land** Other	Total Initial
INITIAL	**Forest/Plantation**		3000	4000	0	0	0	500	0	7500
	Cropland	Annual	100	1600	0	0	0	0	0	1700
		Perennial	0	0	500	0	0	0	0	500
		Rice	0	0	0	250	0	0	0	250
	Grassland		0	4000	0	0	3700	0	0	7700
	Other Land	Degraded	0	0	0	0	0	2000	0	2000
		Other	0	0	0	0	0	0	0	0
		Total Final	3100	9600	500	250	3700	2500	0	19650

Matrix of changes with project

Mineral soils (ha)			FINAL							
			Forest/ Plantation	Cropland			Grassland	Other Land		
				Annual	Perennial	Rice		Degraded	Other	Total Initial
INITIAL	Forest/Plantation		6900	500	0	0	0	100	0	7500
	Cropland	Annual	0	1700	0	0	0	0	0	1700
		Perennial	0	0	500	0	0	0	0	500
		Rice	0	0	0	250	0	0	0	250
	Grassland		200	2000	0	0	5500	0	0	7700
	Other Land	Degraded	0	0	2000	0	0	0	0	2000
		Other	0	0	0	0	0	0	0	0
		Total Final	7100	4200	2500	250	5500	100	0	19650

The screenshot above provides one matrix each for the without- and with-project scenario. They specify on the middle diagonal all those land uses that do not experience any land use change from project start until the end of the project or baseline scenario. Reading the table in rows, provides the reader with the entire initial land use: In the upper "Without Project" table there have been thus initially 7,500 ha of forest, from which 4,000 ha have been converted into annual cropland and 500 ha into degraded land by the end of the baseline scenario. Reading the table along columns provides the reader instead with the sum of the final land uses: E.g. in the lower table showing the situation "With Project" there are 2,500 ha of perennial cropland at the end of the project scenario, whereby 2,000 ha of these stem from rehabilitated degraded land.

In such a way EX-ACT users may once more control the inserted information on land utilization and land use change at a central place and control total surface sizes for each land use.

B. Analyzing non-aggregated module results

Before presenting the main carbon-balance, users will have already recognized that in each EX-ACT module non-aggregated results are directly displayed on the right.

EX-ACT Screenshot 22: Sub-aggregated results annual crop sub-module

3.1.2. Annual systems remaining annual systems *(total area must remains contant)*								
Fill with you description	Area (ha)					1 Total Emissions (tCO2-eq) 2		Balance
	Start	Without	*	With	*	Without	With	
Conventional Maize	1500	1400	D	0	D	22,266	4,704	-17,562
Improved Maize	0	0	D	1200	D	0	-25,650	-25,650

In such a way the screenshot above presents an excerpt of the sub-aggregated results for the annual crop module, for which data entry was described earlier. Summarizing the project scenario induced a shift from conventional cropping practices in maize to improved practices with benefits for productivity as well as GHG emissions.

1 ***Total net emissions***: The first results indicate the net emissions from project start until the end of the baseline and project scenario. In this way the cultivation of conventional maize over the full time period in the baseline scenario and its linear phasing out in the project scenario lead to accumulated net emissions of 22,266 tCO_2-e or 4,704 tCO_2-e respectively. The improved maize cultivation instead that is linearly increased under the project scenario to reach 1,200 ha at the end of the implementation phase is itself a sink of carbon and leads to accumulated carbon sequestration of -25,650 tCO_2-e.

2 ***Carbon-balance***: The second type of results provided by EX-ACT is the carbon-balance that is given by the difference between the net emissions of project and baseline scenario. In such a way the phasing out

of conventional maize production as opposed to its continuation under the baseline scenario leads to a net carbon-balance over the whole period of -17,552 tCO_2-e.

Both, net emissions and carbon-balance may be summed up within and across the single modules and thus lead to overall results for the project and baseline scenario.

C. Analysing total results: Gross result and carbon-balance

In the following the overall results of applying the EX-ACT tool and thus the most central output of the analysis will be presented. While provides you the complete overview of the entire results, the following two screenshots show the table for convenience reasons once more separated in bigger size.

EX-ACT Screenshot 23: EX-ACT Gross Results and Carbon-balance

Component of the project	Gross fluxes			Share per GHG of the Balance					Results per year		
	Without	With	Balance	Result per GHG					without	with	Balance
	All GHG in tCO2eq			CO2			N2O	CH4			
	Positive = source / negative = sink			Biomass	Soil	Other					
Land Use Changes											
Deforestation	3,740,693	481,117	-3,259,576	-2,873,750	-385,826		0	0	187,035	24,056	-162,979
Afforestation	-61,922	-59,994	1,928	-7,367	9,295		0	0	-3,096	-3,000	96
Other	398,762	-51,877	-450,640	-22,293	-425,425		-1,677	-1,244	19,938	-2,594	-22,532
Agriculture											
Annual	55,507	-27,852	-83,359	0	-37,260		-12,760	-33,340	2,775	-1,393	-4,168
Perennial	-7,000	-304,467	-297,467	-276,467	-21,000		0	0	-350	-15,223	-14,873
Rice	44,898	17,973	-26,925	0	0		0	-26,925	2,245	899	-1,346
Grassland & Livestocks											
Grassland	121,601	-113,685	-235,286	0	-229,873		-3,108	-2,306	6,080	-5,684	-11,764
Livestock	12,563	9,699	-2,864				-1,034	-1,830	628	485	-143
Degradation	499,722	103,011	-396,711	-521,698	146,218		-6,427	-14,803	24,986	5,151	-19,836
Inputs & Investments	162,352	664,934	502,581			287,139	248,443		8,118	33,247	25,129
Total	4,967,178	718,860	**-4,248,318**	-3,701,575	-943,871	287,139	223,437	-80,447	248,359	35,943	-212,416
Per hectare	246	36	-210	-169.0	-46.7	11.1	-4.0	0.0			
Per hectare per year	12.3	1.8	-10.5	-8.5	-2.3	0.6	-0.2	0.0	12.3	1.8	-10.5

Detail of Screenshot 23:

Component of the project	Gross fluxes Without	With	Balance
	All GHG in tCO2eq		
	Positive = source / negative = sink		
Land Use Changes			
Deforestation	3,740,693	481,117	-3,259,576
Afforestation	-61,922	-59,994	1,928
Other	398,762	-51,877	-450,640
Agriculture			
Annual	55,507	-27,852	-83,359
Perennial	-7,000	-304,467	-297,467
Rice	44,898	17,973	-26,925
Grassland & Livestocks			
Grassland	121,601	-113,685	-235,286
Livestock	12,563	9,699	-2,864
Degradation	499,722	103,011	-396,711
Inputs & Investments	162,352	664,934	502,581
Total	4,967,178	718,860	**-4,248,318**
Per hectare	246	36	-210
Per hectare per year	12.3	1.8	-10.5

The EX-ACT results may be interpreted in the following way:

1 ***Overall gross results***: Users may first of all see the overall gross emissions and sequestration results of the without- (left) and with-project scenario (right). The indications are made in tonnes of CO_2 equivalents as total over the entire period of analysis, but also per hectare and per hectare and year.
In the here chosen example the without-project scenario leads to combined effects from GHG emissions and carbon sequestration that add up to 4,967,178 tCO_2-e. This translates into 246 tCO_2-e per hectare over the full analysis duration or into 12.3 tCO_2-e per hectare and year. The hypothetical project scenario has a considerably lower impact on GHG emissions and carbon sequestration leading only to a total impact of 718,860 tCO_2-e.

2 ***Overall carbon-balance***: Comparing the gross results between the without- and with-project scenario gives the difference achieved through project implementation, which is also called the project's carbon-balance. It accounts for a total of -4,248,318 tCO_2-e of avoided emissions or increased carbon sequestration over the full analysis duration of 20 years. This is equivalent to a combination of -210 tCO_2-e per hectare over the full duration or -10.5 tCO_2-e per hectare annually.

3 ***Gross results and carbon-balance by module***: The three columns in the middle allow the sub-differentiating of gross results and carbon-balance by module. This is an essential functionality to identify those practices and activities that are the strongest sources of emissions or most important sinks leading to carbon sequestration.
Regarding the gross results of the with-project scenario, the central components leading to reduced emissions or carbon sequestrations are the establishment of perennial crop land (-304,467 tCO_2-e) and the rehabilitation of degraded grassland (-113,685 tCO_2-e). The leading causes of carbon losses and GHG emissions are instead the use of fertilizers and other inputs (664,934 tCO_2-e) as well as the ongoing deforestation (481,117 tCO_2-e).

Considering gross losses from the with-project scenario is thereby strongly different than considering the carbon-balance, as the difference between both scenarios. The strongest element contributing to the positive carbon-balance of the with-project scenario is thereby the reduction in pace of deforestation (-3,259,576 tCO_2-e), which is alone responsible for more than 75% of the projects carbon-balance. The following most important activities contributing to a positive carbon-balance of the project are the non-forest land use change activities (-450,640 tCO_2-e), and the rehabilitation of degraded land (-396,711 tCO_2-e).

Going in further detail the EX-ACT results section also offers other information.

Detail of Screenshot 23:

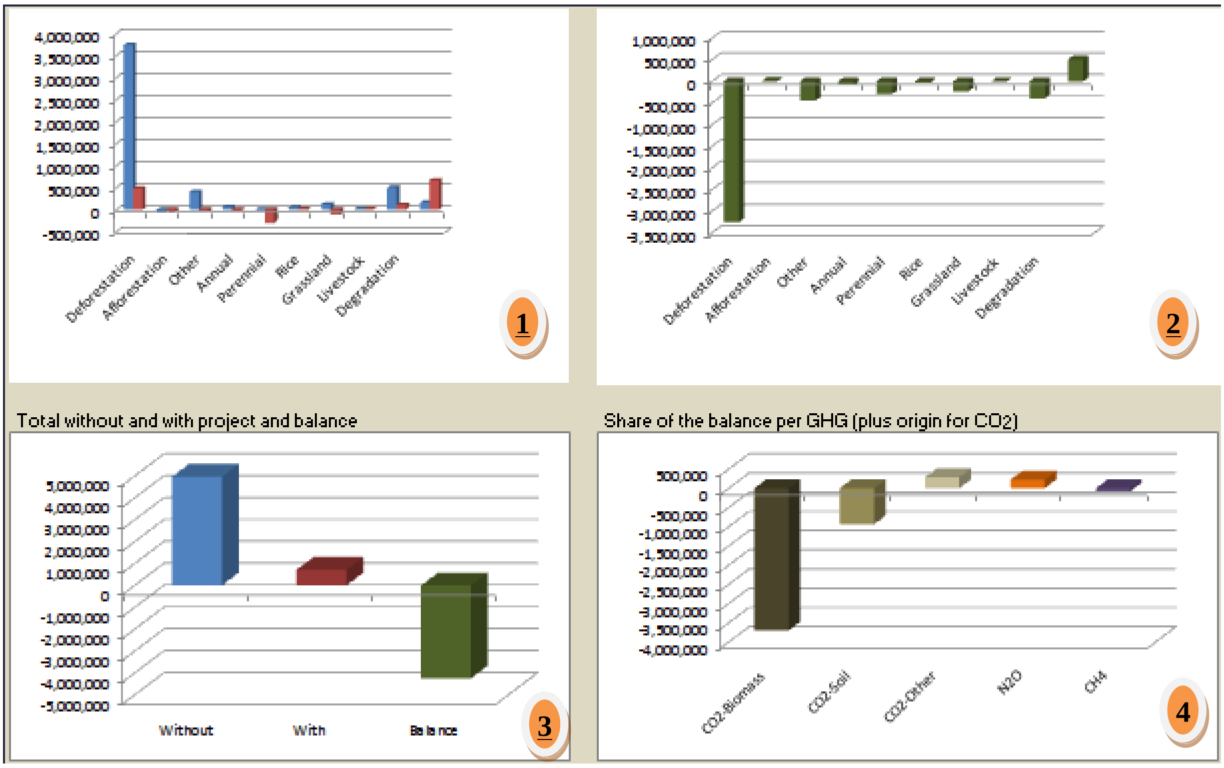
Component of the project	4 Share per GHG of the Balance Result per GHG CO2					5 Results per year		
	Biomass	Soil	Other	N2O	CH4	without	with	Balance
Land Use Changes								
Deforestation	-2,873,750	-385,826		0	0	187,035	24,056	-162,979
Afforestation	-7,367	9,295		0	0	-3,096	-3,000	96
Other	-22,293	-425,425		-1,677	-1,244	19,938	-2,594	-22,532
Agriculture								
Annual	0	-37,260		-12,760	-33,340	2,775	-1,393	-4,168
Perennial	-276,467	-21,000		0	0	-350	-15,223	-14,873
Rice	0	0		0	-26,925	2,245	899	-1,346
Grassland & Livestocks								
Grassland	0	-229,873		-3,108	-2,306	6,080	-5,684	-11,764
Livestock				-1,034	-1,830	628	485	-143
Degradation	-521,698	146,218		-6,427	-14,803	24,986	5,151	-19,836
Inputs & Investments			287,139	248,443		8,118	33,247	25,129
Total	-3,701,575	-943,871	287,139	223,437	-80,447	248,359	35,943	-212,416
Per hectare	-169.0	-46.7	11.1	-4.0	0.0			
Per hectare per year	-8.5	-2.3	0.6	-0.2	0.0	12.3	1.8	-10.5

4 ***Carbon-balance per GHG***: The carbon-balance may nevertheless not only be sub-differentiated by activity, but also by type of GHG and carbon pool. Block 4 provides the non-aggregated emissions from methane, nitrous oxide and shows as well the impact of carbon sequestration in soil and biomass. Exemplarily it is thus visible, that the strongest factor constituting that avoided deforestation effectively leads to a positive carbon-balance stems form the conservation of carbon stocks in biomass that account in our example for -2,873,750 tCO_2-e.

5 ***Annual results per module***: The sub-differentiated results that were already presented under point 3 are here once more expressed in form of their annual impact.

The thus in numerical forms provided results are also presented in graphical form by EX-ACT.

EX-ACT Screenshot 24: Results graphs



The graphical results are once more presenting:

1. <u>*Gross results of without- and with project scenario*</u>
2. <u>*Carbon-balance by module*</u>
3. <u>*Gross results per scenario and overall carbon-balance*</u>
4. <u>*Carbon-balance per GHG*</u>

D. Emission intensity per product unit and further indicators

Development interventions most often follow multiple objectives and thus possibly lead besides changes in emissions per hectare also to changes in productivity levels. It is thus imaginable that an intervention increases emissions per hectare though decreasing emissions per product unit.

In order to detect the project's impact on the carbon footprint per produce from agricultural production, EX-ACT needs to be filled for one target product only. This procedure is described in detail in the annex on product carbon footprints, which also may includes a complete life cycle assessment of GHG emissions.

Besides this accurate methodology, EX-ACT also provides a first rough indication as part of the full project analysis that may be assessed by clicking on the *value chain* button in the results section:

After having inserted all relevant information as indicated earlier in this user guide, EX-ACT automatically provides the aggregated carbon footprint per product type (annual crop, perennial crop, rice, grassland, livestock). Thereby they exclude emissions from artificial inputs, such as fertilizer, which only can be taken into account in the more detailed methodology specified in the annex. Because of the two characteristics of excluding emissions from inputs and aggregating along different crops within the same product category, this facility can only be used as a first orientation and a detailed analysis has to follow the requirements specified in the annex.

The screenshot below provides an overview of the product carbon footprint of three crop and livestock products covered by an exemplary project.

EX-ACT Screenshot 25: Product carbon footprint from agricultural production (except inputs)

Name of the project	trial project		Climate	Tropical (Moist)			D
Continent	Africa		Soil	HAC Soils			Tot

Component of the project	Gross fluxes Without	With	Balance	Production t of product Without	With	Gross emission Intensity tCO_2eq per t of product Without	With
	All GHG in tCO_2eq						
All Land Use Changes	1 0	0	0	2		3	
Annual	62,720	-70,000	-132,720	200,000	350,000	0.314	-0.200
Perennial	-28,000	-28,000	0	240,000	440,000	-0.117	-0.064
Rice	0	0	0	0	0	0.000	0.000
Grassland	0	0	0	0	0	0.000	0.000
Livestock	68,425	49,514	-18,911	36,000	36,000	1.901	1.375
Degradation	0	0	0				
Inputs & Investments	0	0	0				

The screenshot above is based upon a project that has each one annual crop, one perennial culture and one livestock product. Within the project rational it is proposed:

- Annual crop: To shift from conventional to improved *maize cultivation* that leads to soil carbon sequestration and higher productivity.
- Perennial crop: To shift from conventional to improved *mango production* that is characterized by the same amount of emissions, but higher productivity.
- Livestock product: To shift to improved breeding and feeding practices leading to less emissions, while maintaining the same productivity level of *cattle meat*.

Focusing in more detail e.g. on the results for conventional and improved maize production, the carbon footprint table provides:

1 *Gross results and carbon-balance*
First the results from the annual crop module are once more provided. In our case we see that the conventional maize practices, that included residue burning, were a net source of GHG emissions. Instead the improved maize, that is making use of no tillage and mulching, leads to carbon sequestration.

2 *Total production level*
Following the yield specifications in the annual crop module, yield levels can be increased strongly as part of the intervention. The additional effects from increases in fertilizer use are thereby not accounted here. For this analysis please follow the specifications in the value chain section in the annex.

3 *Emission intensity per product unit*
The third column then provides the product carbon footprint from the agricultural production stage. Instead of emitting 314 kg of CO_2-e per tonne of maize under the conventional production system, the improved maize leads to sequestration of 200 kg for each tonne of maize. Since also the productivity had increased, the sequestration per product unit is thereby relatively low.

These results give an important evidence of the direction of changes concerning the carbon footprints of products under the different scenarios. In case the estimation of product carbon footprints is at the centre of the user's interest, other methods should nevertheless be consulted and a refined analysis should be carried out as specified in the annex.

Case Study 4: Banana Carbon Footprint from Production to Retail

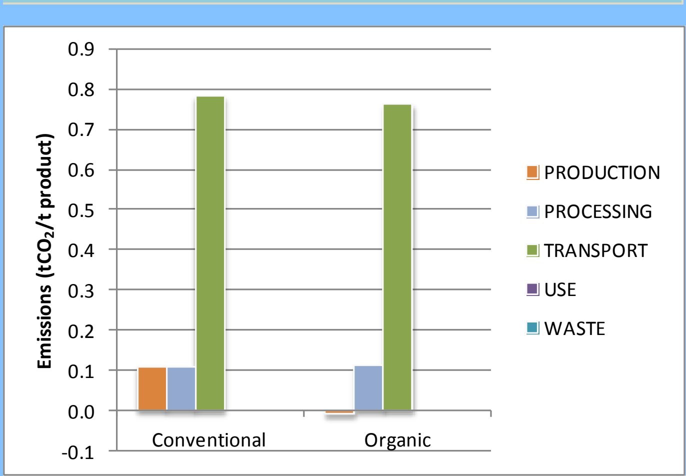
This example illustrates the use of EX-ACT for the estimation of a product carbon footprint along a variable part of the value chain as explained in detail in the annex. The example uses production data from a banana farm which is in the process of converting from conventional to organic production and analyzes emissions from the production stage until the shelf of the supermarket.

The introduction of the organic production system lead to a slightly decreased productivity, while at the same time demanding less fertilizer and pesticides as well as avoiding their aerial application.

Using EX-ACT for the emissions from production and company data as well as emission coefficients identified from the literature lead to the table on the right, specifying emissions per product unit from each stage of the production. Using unverified secondary data, it was firstly identified that the production stage contributed relatively little to the overall carbon footprint of 0.99 t (conventional) and 0.86 t (organic) CO_2 per t of banana.

Whereby packaging and transport still used largely the same procedures, emissions from the production level strongly decreased: While the conventional system had a carbon footprint from production of 110 kg CO_2 per t of banana, the organic system is largely carbon neutral (-10 kg CO_2 / t of banana).
The analysis could thus show that the combined effect from slightly less productivity and considerably reduced input use leads to an overall effect of a reduced carbon footprint.

Total Emissions in t CO_2-eq		Emissions (tCO_2/t product)	
		Conventional	Organic
PRODUCTION		0.11	-0.01
PROCESSING		0.11	0.11
TRANSPORT		0.78	0.76
USE		0.00	0.00
WASTE		0.00	0.00
	TOTAL	0.99	0.86



E. Further indicators

Besides the on GHG emissions focused results, EX-ACT also summarizes how much of the total area is irrigated and how much of the total area is managed with burning of vegetation or crop residues.

EX-ACT Screenshot 26: Further indicators – irrigation and fire use

Other Indicators			
Area Irrigated - ha	State at the beginning	Without Project	With Project
Irrigated Rice	250	250	250
Annual crop	0	0	1200
Total	250	250	1450
Cumulated areas burnt - ha	State at the beginning	Without Project	With Project
From deforestation		0	0
From degradation		10000	0
Plantation		0	0
Other LUC		4000	2000
Annual		1770000	300000
Perennial		0	0
Irrigated Rice		0	0
Grassland		10000	0
Total		1794000	302000

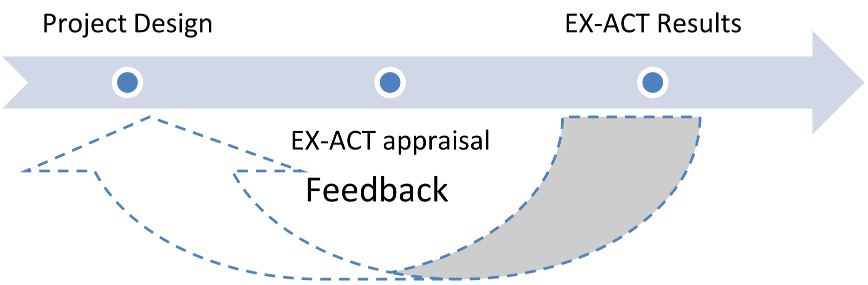
Integrating all previously presented results of the EX-Ante Carbon-balance Tool thus provides the essential means to compare different project scenarios with each other for their impact on climate change mitigation.

Questions on how to utilize the presented EX-ACT results for further analysis will be analyzed in the following.

F. Comparing project options or impact scenarios: Simulation work

Within project identification and formulation processes, there are steps where project designers may need to compare project options in terms of their differential impact. EX-ACT allows quantifying the differential impact of alternative project components on the carbon-balance.

Figure 19: Using EX-ACT to compare different scenarios and refine project documents



Once the initial EX-ACT appraisal is effectuated, the tool provides a very cost and time effective possibility to estimate ex-ante estimates for technical planning as well as for discussions with donors and decision makers. Some of the many typical emerging issues as part of project design are e.g. given by the questions:

- What is the differential impact of targeting province A, versus province B?
- What is the impact of specific land use changes: E.g. has it a negative carbon-balance to establish perennial crops on non-degraded grassland, or leads the expansion in annual cropland always to a negative carbon-balance?

- What is the impact of specific management changes: What is the per product carbon-balance of considerable increases in fertilization when it leads to strongly higher yields?
- What happens if we upscale a specific project component: Consider e.g. the project presented in the box below. While watershed conservation measures are only a small part of the project's initial design an alternative scenario with stronger watershed conservation measures is analyzed for its impact on the carbon-balance.
- What is the impact of an added agroforestry component as part of a project aiming at the rehabilitation of degraded mountainous territory?

The example below describes a comprehensive simulation scenario with direct effects both on budget costs and the carbon-balance.

Case Study 5: Irrigation and Watershed Project (Madagascar) - Watershed Scenarios

The analyzed watershed project was reduced in size to US$ 4.58 million prior to implementation due to funding limitations. Two scenarios in EX-ACT were used to identify the differential impacts under both project sizes, in order to potentially attract incremental funding, as e.g. integrated in a second phase of the project.

Table: Watershed activities in project and in new scenario

	Current project	New scenario
Afforested areas (ha)	2,250	**15,000**
Avoided deforestation (ha)	2,000	**6,000**
Improved pasture (ha)	2,500	**34,000**
Agro forestry (ha)	1,500	**10,000**
Total of surface improved (ha)	8,250	**65,000**
Total Surface of watershed component	**100,000**	**100,000**

In the up-scaled project option, watershed conservation activities would be implemented on 65,000 ha, while the reduced project focused on 8,250 ha only. It will include: (i) 15,000 ha of areas for afforestation, (ii) 6,000 ha of avoided deforestation, (iii) 34,000 ha of improved pasture and the establishment of (iv) 10,000 ha of agro forestry.

The incremental improved areas will require additional funding, whereby the differential costs of the measures are estimated as: US$ 1500 per ha reforested area, US$ 300 per ha of avoided deforestation, US$ 400 per ha of improved pasture, US$ 1000 per ha of agro forestry). The additional watershed components are thus estimated to require funding of US$ 47.9 million.

Table: Budget and carbon balance of project and new scenario

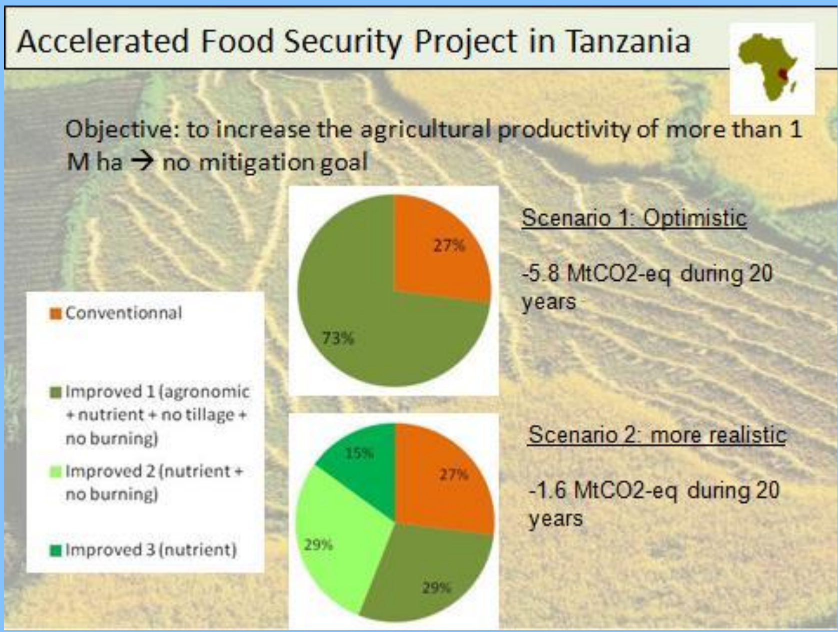
	Current Project	New Scenario
Area covered (Ha)	112 950	**134 200**
Budget (Million USD)	40.5	**83**
Carbon Balance (million T CO2)	2.4	**12.4**
Carbon balance/Ha on 20 years TCO2	21	**93**
CB/ ha / year in T CO2	1.05	**4.6**

The total project budget increases thereby to around **US$ 83 million (+103%).** By doubling the budget of the project in this scenario, and by allocating the incremental funds to watershed management activities, the benefits in terms of GHG mitigation are not doubling but multiplied by six from 2.4 million tonnes of CO2-eq to 12.4 million tonnes over the full 20 years.

While the previous example focused on the simulation of alternative project components that can actively be chosen by project designers, simulation is also an important element when high degrees of uncertainty are associated to central project assumptions: In such a way the case study below assumes differential adoption rates of improved agronomic practices by smallholder farmers in the context of a food security project. The intervention relies on changes in agronomic practices as an important project component. Thereby it is a good practice to be cautious about assuming too high adoption rates, given the numerous empiric evidence for barriers to adoption of e.g. sustainable land management practices. In addition it should be tested whether a project still has a positive impact when assuming a pessimistic scenario, which is one way of testing the validity of the project in mitigation terms.

Case Study 6: Accelerated Food Security Project in Tanzania (AFSP) – Adoption Scenarios

This project aims at contributing to higher food productivity as well as total production levels by most importantly improving farmers' access to critical agricultural inputs. It is thus part of a strategy to prevent potential food crises in the light of fluctuating food and input prices. It targets 2.5 million farmers and focuses on the production areas for 1 million ha of maize and 86,000 ha of rice.



The first activity targeted by the project is the provision of input packages to maize and rice farmers by a voucher scheme. It consists of urea, phosphorous and nitrogen synthetic fertilizers, and quality seeds. The project will also promote the adoption of improved agricultural practices, consisting of extension of crop rotations, precision application of fertilizers and discouraging burning of crop residues. The later is achieved through the mixture of extension and the indirect effects from increased nutrient availability through fertilizers.

The higher nitrogen efficiency and reduced burning are estimated to have direct positive effects on the carbon balance.

Adoption rates nevertheless cannot be estimated without uncertainty. As rough distinction the EX-ACT analysis thus considered two different adoption scenarios: The more optimistic project assumption assumed 73% of farmers to apply the whole set of improved techniques. In an additional less optimistic scenario it was assumed that 73% of farmers apply some form of improved techniques, but never the complete package of practices. This leads to a three times smaller, but still beneficial carbon-balance leading to active mitigation.

G. Using EX-ACT to support monitoring schemes

EX-ACT as described in this manual may most directly be used for ex-ante appraisals or ex-post evaluations of projects, programmes and policies. Giving its data needs and conception it may also inform the design of monitoring schemes.

Climate Smart Agriculture projects implicitly integrate longer-term and larger-scale processes. They also involve a greater number of potential tradeoffs. Unlike many projects where monitoring and evaluation address areas, beneficiaries and stakeholders within the projects' boundaries for a shorter subsequent period, CSA projects are more likely to require longer-term post-project monitoring of trends and additional comparison areas (FAO, 2013).

Some expected outcomes and impacts may not be evaluated at the time of project monitoring and evaluation. This is particularly true for monitoring and evaluation of mitigation benefits. Increases in soil carbon content in response to improved practices cannot continue indefinitely. Eventually, soil carbon storage will approach a new equilibrium where carbon gains equal carbon losses. A default time period, usually 20 years, is assumed for this transition. On the other hand achieved soil carbon levels may also again be subject to reductions at a later point in time (see below).

Projects and other interventions that engage in regular data collection of their key variables thereby for cost reasons often make use of proxy indicators, such as:

- *Soil carbon content measurement*: the chosen proxy is the effective application of improved Climate Smart Agriculture techniques in hectares by type.
- *Methane emission measurement*: the chosen proxy is the evolution of the number of heads of livestock and there feeding and breeding practices.
- *Fuel consumption*: the chosen proxy is a rough estimate of the type of vehicles with their annual distance achieved (kilometres).
- *Agroforestry development*: instead of assessing total number and characteristics of all trees planted, tree density and tree types are assessed and extrapolated from a limited set of areas.

The issue of leakages and permanency is important for the monitoring and evaluation of climate change mitigation.

Permanency refers to the principle that emission reductions, represented by an offset, should be maintained over time. In some cases, abandoning a CSA practice after only a few years will counterbalance the emissions previously avoided. A post-project monitoring and evaluation is useful to ensure that the improved practices are maintained. Such a post-project phase is also needed in case of payments for carbon services.

Leakage refers to a situation where emissions abatement achieved in one location is offset by increased emissions in unobserved locations. In this regard, the difficulty lies in the choice of appropriate boundaries to conduct the appraisal and might imply that selected monitoring in neighboring non-target areas is necessary.

Since the main set of data used in EX-ACT relates to the distribution of land uses and practices at project start the collection of adequate data concerning the starting situation is crucial for any monitoring scheme that wants to engage in comparisons to the situation throughout project implementation.

A focus on incentives and effective adoption rates

Since most Climate Smart Agriculture projects face the issue of barriers to adoption, projects need to be scrutinized in regards to the way they manage incentives and are able to monitor adoption rates.

Adoption rates of improved techniques (% of areas with a specific improved technique) are monitored through household surveys and/or field visits. They should focus equally on monitoring positive practices (e.g. sustainable management practices) as well as from a mitigation perspective negative activities (e.g. residue burning). Essential practices thereby also include agroforestry techniques, improved pasture management and the rehabilitation of degraded forestlands.

A meso-analysis of energy and inputs consumed

In term of input and energy use, consumption per household or per farm is monitored using representative samples (tonnes of fertilizer, gasoline, pesticides, MW of electricity per year). Such data can be cross-checked e.g. with surveys from local merchants of agricultural inputs.

Summarizing, in such a way EX-ACT may be used to identify which data needs to be collected as part of a monitoring scheme. In case an ex-ante appraisal of EX-ACT has been carried out the main emission sources and sinks may especially be targeted by such data collection.

The monitoring of changes in natural capital – as discussed in the annex – is thereby an important complementary activity that can be carried out with strong synergies.

Chapter 12: Using the Carbon-Balance as Part of Economic Analyses and Fund Mobilisation

The previous chapters focused on the question of the estimation of probable technical mitigation potentials of a given project, policy or programme to inform intervention choices and design.

In many contexts the pure technical mitigation potential in tonnes of CO_2 equivalents is nevertheless not sufficient as decision criteria, but needs to be translated into a monetary value as part of an economic analysis. This serves especially the purposes of:

- Estimating the economic value of a specific amount of GHGs mitigated, defined by the prevented economic costs to society through climate change impacts
- Comparing the benefits from mitigated GHGs and the costs spend in form of public project funds, as e.g. in public policy planning or cost-benefit analyses of projects
- Comparing the benefits from mitigated GHGs and the financial incentives needed for farmers to engage in the related practices, as e.g. in the voluntary carbon market and in schemes of Payments for Environmental Services (PES)

In the following, firstly the main relevant contexts for the economic analysis are shortly introduced and a typology of projects is provided that clarifies their differing main objectives. The project type thereby largely determines in which type of economic analysis project designers are interested and whether additional efforts in a specific economic analysis are indicated and useful. Subsequently, different elements of economic analyses are presented conceptually and illustrated with case studies and also the options of using a carbon-balance appraisal and its economic analysis in fund mobilization are illustrated.

A. Main concepts for the economic analysis of mitigation benefits

This paragraph will shortly introduce central concepts used as part of the economic analysis of mitigation benefits. It focuses on the definition and differences of public goods, positive externalities, co-benefits and public values.

Public Goods: Many environmental services have in fact the characteristic of public goods as given by their characteristic that people cannot be excluded from the provided benefits, while in addition the use of the service by one person does not diminish the availability of that service to other users. Many environmental services, ranging from flood control to climate change mitigation, are characterized by this non-rivalry in consumption and non-excludability from benefits.

Carbon sequestration and reduced GHG emissions have thereby the specificity that the boundary of these characteristics are global, making them a pure international public good. One tonne of carbon emissions mitigated e.g. in Scotland have thus the same benefits for any global citizen as the same amount of GHGs mitigated in any other location (if we for the moment only focus on the climate change benefits from carbon sequestration and not on its other benefits as e.g. soil fertility).

Value of carbon sequestration: There is no agreed single social monetary value of carbon sequestration and GHG emission reductions. This is much due to the fact that climate change impact studies are associated to great uncertainties. Mitigation of climate change can thereby be considered a transfer of wealth from the present to future generations.

Furthermore the carbon value is neither static over time and GHGs mitigated today or in the near future are worth more than those in the distant future (Bateman, et al., 2003). Two distinct options of deriving prices are thereby (i) carbon markets and (ii) social costs of carbon:

- Carbon markets are not per se related in their pricing mechanism to the future costs induced by further emissions, but instead introduce and increase prices of emissions through regulatory approaches that set maximum emission levels and allow for trade of emission rights between users. Other segments of the carbon market also simply provide monetary

compensations for reduced emissions without necessarily involving a third party that increases its emission rights.
Thereby public and voluntary carbon markets did not experience in the close past strong any intervention measures that would have been sufficient to overcome the current crises of oversupplied emission rights and low costs of emission permits.
Nevertheless past, current and intended price levels on carbon markets may be used for simulation work and scenario building within EX-ACT and constitute a central point of departure.

- The "social cost of carbon" (SCC) is instead an approach directly derived from studies trying to estimate the future costs of climate change impacts generated through today's GHG emissions. In other words it is the estimated monetary damages associated with an incremental increase in carbon emissions in a given year. This includes besides others changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of decreased ecosystem services. While there are various studies that established strongly different values, whereby the problem of high uncertainty levels is greatly accepted, one widely used study has been carried out by the U.S. Interagency Working Group on Social Cost of Carbon that established a value of 21 USD per tonne of CO_2-e (Interagency Working Group on Social Cost of Carbon, 2010). It increases over time to $24 in 2015 and $26 in 2020.

An externality is a cost or benefit resulting from an economic transaction that is borne or received by parties not directly involved in the transaction. An externality occurs when the consumption or production of a good impacts on people other than the producers or consumers that are participating in the market for that good (Hebling, 2012). Externalities can be either negative (e.g. water pollution caused by industrial production) or positive (e.g. the role of agriculture in maintaining the countryside and rural communities). In this perspective an agricultural development project which is not targeted to reduce greenhouse gas emissions and which however allows such GHG reduction is generation such impacts as a positive externality with no additional cost.

Co-benefits refer to the occurrence of multiple benefits that concern distinct dimensions resulting from one project, programme or policy. Co-benefits occur in interventions that are implemented for various reasons. Thus they are mainly differing from positive externalities by the fact that they are actively targeted at the same time. The most policies designed to address greenhouse gas mitigation also have other, often at least equally important, rationales (e.g. related to objectives of economic development, sustainability, or social outcomes). The term co-impact is thereby used in a more generic sense to cover both the positive and negative side of the benefits.

Farmers can become important suppliers of climate change mitigation services, which may be to a different degree associated to such co-benefits or trade-offs with agricultural production (FAO, 2007). Since the agricultural sectors of developing countries have undergone years of declining investment and neglect, mitigation finance can be an important potential source for the needed investments in efficient, productive and sustainable production systems that are often out of reach due to high initial costs and only later occurring benefits (Bernoux, et al., 2010).

B. Typology of projects to be appraised

Making use of the earlier introduced terminology it is necessary to distinguish between different types of investment projects. As a main difference, benefits arising from a positive carbon-balance may be regarded just as project externality, while on the other side of the extreme it is a central and explicit project target from the start. In this perspective, we distinguish three types of projects:

- Type 1: Development projects
- Type 2: Multi-objective projects
- Type 3: Mitigation projects

Main goal of Type 1 projects (*Development projects*) is the enhancement of food security through agricultural productivity increases and improvement of the net returns to agricultural production. These projects are formulated without specific mitigation targets as their main objective is to support a broader notion of agricultural development. In this project framework any positive impact on climate change mitigation is only considered as a positive externality.

Table 3: Project typology from a climate change mitigation perspective

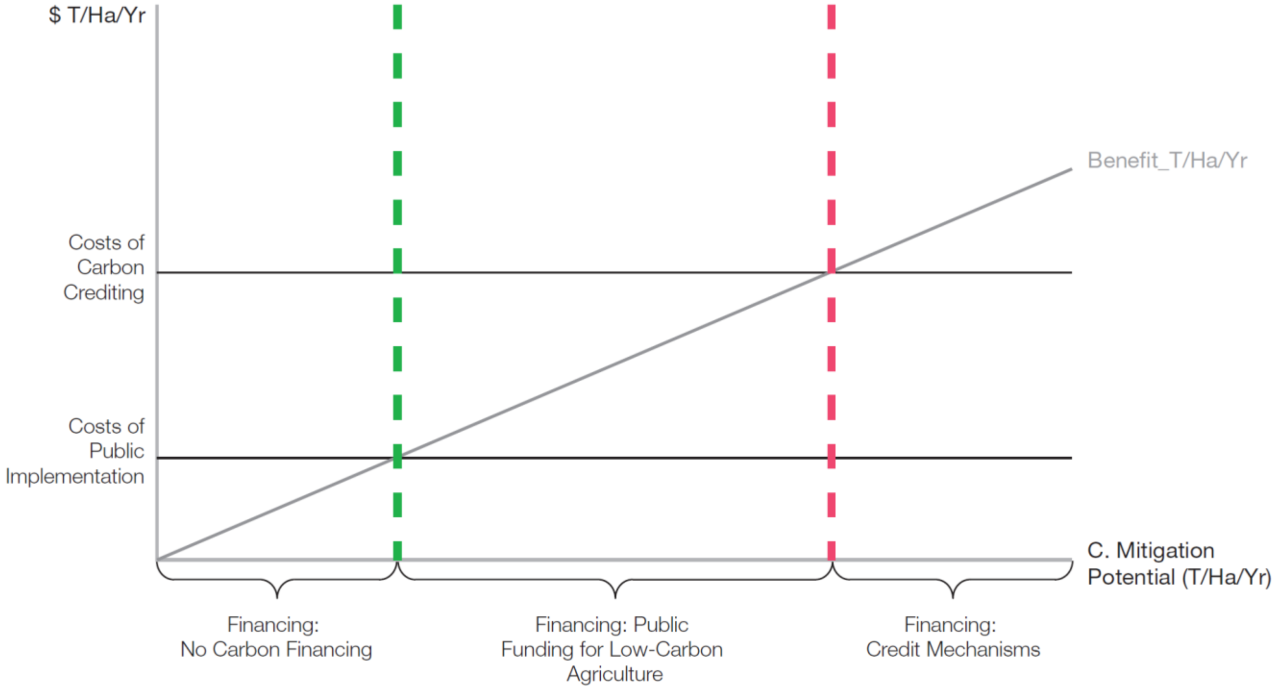
Case studies	Country	Project type	Geographic area	Test
Accelerated Food Security Project	Tanzania	Type 1	Africa	Desk
National Agricultural Program	Eritrea	Type 2	Africa	Field
Irrigation and Watershed Management	Madagascar	Type 1	Africa	Desk
The Santa Catarina Rural project	Brazil	Type 1	Latin America	Field
The Rio Rural project	Brazil	Type 1	Latin America	Field
Grassland Restoration and Conservation	China	Type 3	Asia	Field

Type 2 projects (*Multi-objective projects*) are designed with explicit multiple objectives, as in the case of many integrated rural development projects. Typical examples are projects that are aiming at socio-economic and environmental objectives, as projects promoting productivity increases and enhanced soil organic carbon levels at the same time. This might be the case of projects that target the rehabilitation of degraded land. In this case, mitigation should be considered as a co-benefit. If policy decisions in the future lead to a stronger integration of mitigation objectives into sector development plans, the importance of such multipurpose frameworks will strongly increase.

Type 3 projects (*Mitigation projects*) are those where mitigation is the primary objective. They are most closely linked to carbon markets or specific mitigation project funds.

The following graph illustrates the difference between the three project types, relating them to their cost structure and total mitigation potential.

Figure 20: Financing options for agriculture development and mitigation projects



Source: adapted from (FAO, 2009).

C. Basic elements of economic analyses: NPV and IRR

Independently from the conceptualization of the carbon-balance as positive externality, co-benefit or main objective, the calculation of the Net Present Value (NPV) and Internal Rate of Return (IRR) may serve as main points of orientation for valuing the benefits from mitigation. Based on the projects closeness to carbon markets, one should thereby decide whether to adopt a unit price of emissions stemming from carbon markets (simulating different prices beyond the current low levels may thereby be essential) or from estimations of the social costs of emissions (as introduced earlier in this document).

The calculation of NPV and IRR is not included in the standard worksheets of EX-ACT and should be managed separately making use of EX-ACT results. Thereby project appraisals usually assume a constant price per tonne of CO_2-e as well as a constant discount rate to compute the NPV of mitigated emissions. Although certain project appraisal methodologies propose lower discount rates for environmental project components (3-5%), in the case of carbon markets it is recommended to use the same discount rate as in the rest of the economic project analysis.

The carbon-balance results may then be multiplied by the NPV per tonne of CO_2-e to derive the total NPV of the mitigation benefits. The case study below provides an example of such calculations, assuming a progressive evolution of emission prices on the voluntary market.

Case Study 7: Economic Analysis of the Carbon-balance - Irrigation and Watershed Management Programme in Madagascar

The considered irrigation and watershed management programme supports improved practices of water management, residue management and leads to sustainable intensification measures on annual crop lands. Besides it contributes to a stronger diversification between irrigated and rainfed systems, focussing on their competitive advantages, reduces deforestation and leads to afforestation. EX-ACT estimated that an overall net carbon balance of almost 2.4 million tons of CO2 –eq is generated through the project.

The calculation of NPV and IRR in the table below shows simulations for different carbon price scenarios, while also considering non-carbon related economic benefits from project implementation. The different carbon prices are: (i) no value of carbon, (ii) US$ 2, (iii) 5 US$, and (iv) a progressive increase of the carbon price over the next 10 years from either US$ 2 to US$ 10, or from US$ 2 to US$ 20. NPV and Internal rates of return are computed for every price scenario.

The analysis shows that although NPV and IRR fluctuate considerably with the carbon price, the actual changes are relatively small. This is due to the fact that the biggest economic project value stems from other project activities. Nevertheless this example shows clearly how environmental benefits can be integrated into economic project analysis.

Economic Analysis at Different Carbon Prices

	Carbon price constant US$/ton	Total public value million US$	Project Net Present Value million US$	Internal Rate of Return
without price incentive	*0*	*0*	*9.1*	*14.7%*
with carbon price at	2	4.7	10.5	15.3%
with carbon price at	5	11.9	12.7	16.2%
with carbon price at	**3.5**	**8.3**	**11.6**	**15.8%**
carbon price increasing between 2010 and 2020	from 2 to 20	38.7	17.8	17.7%
carbon price increasing from 2010 to 2020	from 2 to 10	20.4	13.9	16.5%

D. From the carbon-balance to climate finance and public funding

Available finance is a key element for available mitigation options to materialize. While the sections above introduced the main differentiation of project and policy funded versus market funded initiatives, the section at hand provides some practical examples of how the carbon-balance may be used as part of both efforts to attract and justify funding negotiations.

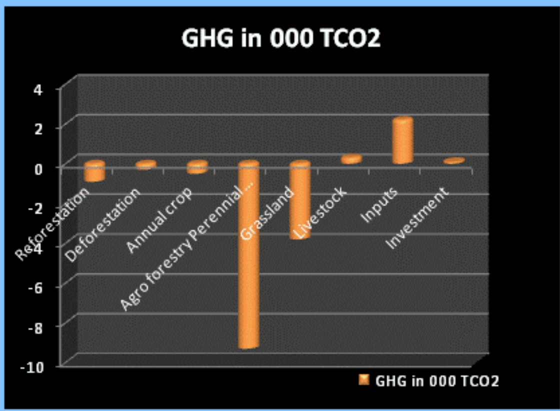
Monitoring, Reporting and Verification (MRV) systems vary structurally with the associated different funding sources and take thereby also an important part of the policy planning process. In other words the cost per hectare for MRV of carbon mitigation projects may vary strongly by MRV requirements, which should be considered actively as an overall cost element when carbon prices are estimated that shall sufficiently incentivize changes in agricultural practices. MRV costs are currently particularly high for carbon market schemes in agriculture and access to carbon markets remains thus complex for agriculture projects. Designing and developing a carbon project takes a long time, requires a lot of technical expertise and considerable financial resources for the initial set-up.

Currently well performing projects funded over the carbon market can thereby be characterized by four main similarities: (i) a clearly defined geographic delimitation, (ii) an aggregator that groups the various beneficiaries within an organizational structure and provides a functioning channel for providing incentives and carrying out MRV in a cost effective manner, (iii) a clearly quantified carbon reduction target based on a GHG calculator and (iv) access to clearly defined carbon funds.

The case study below presents the Santa Catarina project, who's carbon-balance appraisal has been used in funding and financing negotiations.

Case Study 8: BRAZIL - The Carbon-balance of the Rural Competitiveness Project (Santa Catarina)

Project objectives and components: The project seeks to increase the competitiveness of small-scale, rural family agriculture and their producer organizations in Santa Catarina, on approximately 3.6 million hectares (equivalent to 37% of the state area). It provides financial capital, technical assistance and incentives for technological innovation, diversification and productivity increases. The project will also reinforce the provision of public services including decentralized management of water and environmental resources, sanitation as well as legal and environmental services. By promoting and scaling-up the adoption of SLWM practices, the project will also contribute to climate change mitigation.



The main practices with positive impacts on the carbon balance can be listed as: Expansion of perennial crops and agroforestry, promotion of improved grassland and annual crop management, rehabilitation of Areas of Permanent Preservation (APP - *Areas de Preservaçao Permanente*) as well as the conservation of Legal Reserves (RL - *Reserva* Legal), protection of existing forests and stimulating forest regeneration or rehabilitation.

Overall, the project is estimated to sequester 15 MtCO_2e while emitting "only" 2 MtCO_2e over the full project duration. The average mitigation impact per hectare accounts for 1.0 tCO_2e annually. As shown on the right, major parts of the mitigation potential stem from the expansion of agro-forestry systems (60%) and the adoption of improved grassland management (25%).

These mitigation outcomes may be considered as co-benefits that occur besides the main intensification and income objectives of the project. The ecosystem services (C sequestration) supplied by the project and estimated through the C-balance, could then be priced, valued and incorporated in the project economic analysis, examining how the discounted measures of project worth (e.g. NPV, IRR) will change when taking into account carbon sequestration benefits. Also, a set of indicators can complement the economic analysis providing useful information about the efficiency of the project in providing ecosystem services or the potential contribution of such services to farm incomes.

The project could therefore potentially obtain funds from carbon finance related to these mitigation co-benefits quantified using EX-ACT.

Existing funding mechanisms have started to move towards a more integrated view of adaptation and mitigation. Accordingly, funding eligibility criteria are changing to more readily accommodate combinations of adaptation and mitigation financing. The increasingly cross-cutting perspective also extends to the combination of climate change with other related areas such as forest management, biodiversity or land degradation.

This shift better reflects the reality of integrated policy planning as e.g. represented by the approach of Climate Smart Agriculture. Regarding the overall availability of resources, the Green Climate Fund (GCF) can be identified as a relevant upcoming initiative, which was created with the expectation to disburse US$ 100 billion annually by the year 2020. The GEF approach towards combining adaptation and mitigation activities also actively promotes the CSA approach. This significant shift has implications well beyond the GEF itself, as it serves arguably as the most important source of examples and experiences for the design of upcoming initiatives (FAO, 2013).

Also national policy planning nevertheless is expected to stay an essential element to provide incentives for environmental and climate smart practices. As an example the *Plan Maroc Vert* follows an integrated approach, also providing public incentives for CSA. In its river basin management activities, the strategy takes account of the increasing challenges posed by water scarcity in the agricultural sector of Morocco. With its dual approach it provides in irrigated areas incentives for improving water management and conservation measures that allow for the further integrating and expansion of national value chains within international markets. In rain-fed areas, the *Plan Maroc Vert* increases access to social services and supports participatory natural resource management initiatives. It thereby focuses stronger on replacing arable crops with more drought tolerant olive trees and other tree crops. A more specific description is given in the box below (c.f (Sutter, 2012)).

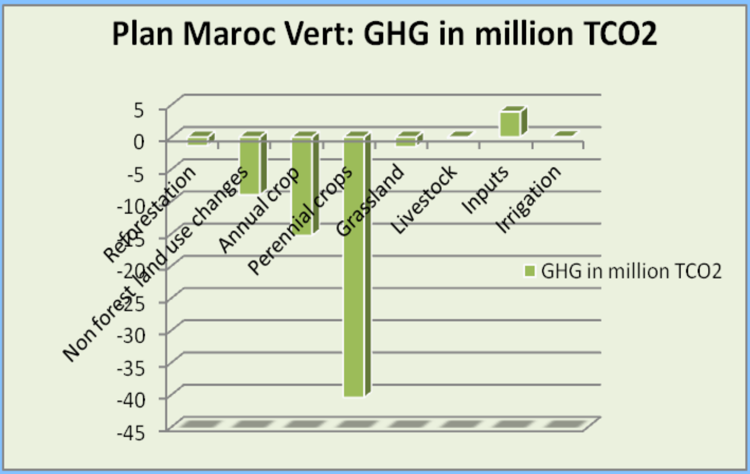
Case Study 9: Use of EX-ACT in National Policy Analysis: The *Plan Maroc Vert*

EX-ACT was used to assess the scope for climate-smart agriculture in the context of the Plan Maroc Vert (PMV), which is the main national agricultural strategy in Morocco. Launched in 2008, the Plan Maroc Vert seeks to double the value-added of the agricultural sector within a decade through an overall transformation concerning the sector structure (cropping patterns, land tenure, and agricultural taxation).

Climate change is foreseen to challenge these sector goals by decreasing yields of key crops and increasing the volatility of agricultural production. With 85 percent of the agricultural land without irrigation, farmers are exposed to erratic rainfall and drought. A series of pilot activities were used for the appraisal exercise to compare options (i) Plantation of rainfed and irrigated olive orchards by converting cereals systems on two different project sites (8,000 ha, 1,600 ha) , (ii) Improvements to cereals systems, through improved varieties and conservation agriculture (1,000 ha).

The results of the carbon appraisal show that the adoption of the on climate change adaptation focused activities could mitigate a total of **63 MtCO2eq during 20 years**. This mitigation potential is mainly linked with the plantation of perennial crops and the adoption of Sustainable Land Management practices for annual crop systems.

The pilot analysis thus provides an example no how EX-ACT may be used as a „litmus test" for whether to actively target climate finance. In the concrete case the exercise opened up a dialogue on carbon finance in agriculture and as a follow-up, the Moroccan Ministry of Agriculture is planning an analysis of knowledge and capacity building needs to access carbon funds.



Besides, the Ministry is also discussing with the WB the need of establishing a national monitoring system for GHG emissions. The demonstration of additionality and the complex procedures to access climate funds for agricultural projects are thereby main constraints that limits the realization of agriculture's potential for mitigation.

E. Using the carbon-balance to assess potential Payments for Environmental Services (PES)

Payments for Environmental Services (PES) are regularized payments for clearly defined environmental services that are not provided under pure market conditions due to limited incentives. They most often focus on services that provide direct benefits to the general public. PES are thereby an environmental policy tool that is becoming increasingly important in developing and developed countries that addresses environmental problems through positive incentives to land managers. As poverty is a major cause of environmental degradation, rewarding poor producers to adopt more environmentally friendly systems of production, would result in both environmental benefits and poverty reduction. Such existing PES initiatives with strong co-benefits for GHG mitigation and located in developing countries thereby focus often on:

- Restoring natural habitat or afforestation
- Maintaining existing natural habitats and protecting them from alteration (forest, grassland conservation)
- Improving existing land use (soil conservation, efficient inputs use, etc.)

Landscapes and watersheds as well as value chains appear thereby as relevant levels for aggregating producers in order to effectively include them in payment schemes, as opposed to systems that work directly with individual landowners. This seeks to overcome some of the existing challenges to the implementation of PES schemes, as mainly the high transaction costs, difficulties in ensuring conditionality and limited inclusiveness leading to inequitable distribution of benefits.

In this perspective, some simulations of PES scenarios have been added in selected cases to the usual EX-ACT appraisal, mainly focusing on watershed support programmes (e.g. Madagascar, Uganda Agriculture Technology and Agribusiness Advisory Services Project) and rural development projects with strong environmental components (e.g. Brazil Santa Catarina Project, Rio De Janeiro Sustainable Development Project) or even in national policy simulations (e.g. Nigeria Vision 2020 – Assessing Low-Carbon Development in Nigeria).

Case Study 10: From the Carbon-balance per farmer and hectare to a pre-assessment of the potentials of Payments for Environmental Services (PES)

Assuming net payments of US$3.5 per tonne of CO2-e the actual annual payments to smallholder farmers under the Madagascar Irrigation and Watershed Project are with US$ 14 very low. However, cumulated at village level they account for US$ 1400 annually, which for pure illustration purposes is equivalent to the wage income of 3 full time permanent village workers (US$ 40 per month) or a team of 12 workers during 3 months at the given low rural wage rate. At watershed level it can provide regular funds for all kinds of environmental services (control and reduce deforestation, afforestation activities).

For every considered watershed, the carbon rent could fund the equivalent of **40-45,000 man-days of public work** (200 workers at 20 days per month during 7-8 months per year in every watershed).

Table 22: Appraising the carbon potential rent at different levels of possible use within project implementation

at low carbon price of US$ 3.5	Annual Equivalent	Agregated amount
Carbon value per ha	US$ 3.7	US$ 72
Carbon value per farmer	US$ 14	US$ 276
Equiv Carbon financial rent per village	US$ 1 400	US$ 27 600
Equivalent carbon financial rent per watershed	US$ 104 000	US$ 2.1 million

These figures are provided to illustrate **the potential employment generation through Payment Schemes for Environmental Services (PES) in the area of climate change mitigation**.

Targeting employment opportunities to vulnerable people and the full respect of the principles of decent rural employment should thereby be strict parts of PES schemes. This also means decent rural wage rates and objectives of productive and thus qualified work activities.

Table 23: Options of Payment of Environment Services (PES) within a simulation of increasing carbon price to all farmer/ Social Safety Nets (SSN)

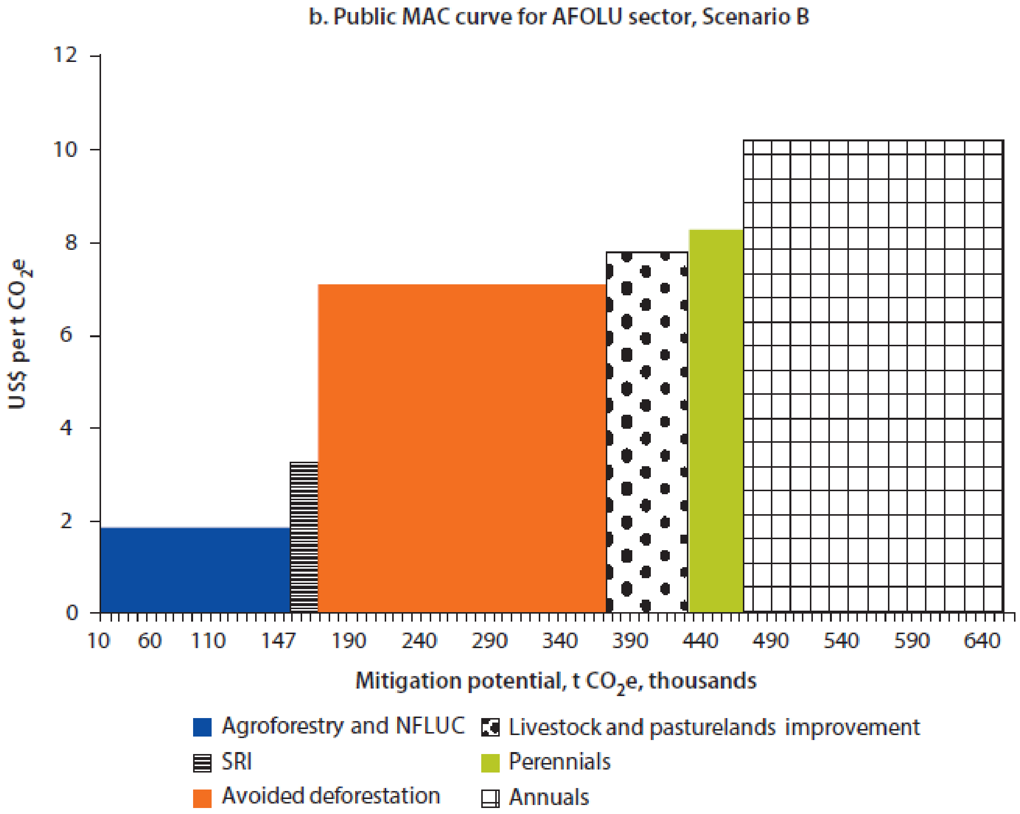
at increasing carbon price of US$	equivalent by 2015 at US$ 9/ ton	equivalent by 2020 at US$ 12/ton	equivalent by 2025 at US$ 15/ton
Annual Carbon value (US$ million)	1.1	1.4	1.7
Carbon value per ha per year	US$ 9.5	US$ 12.6	US$ 16
Carbon value per farmer per year	US$ 35	US$ 55	US$ 77
Equivalent carbon fund per village per year	US$ 3500	US$ 5500	US$ 7700
Equivalent carbon fund per watershed per year	US$ 275 000	US$ 350 000	US$ 425 000

F. Using a Marginal Abatement cost Curve (MACC) to compare low carbon options

A marginal abatement cost curve provides a relation between the cost-effectiveness of different abatement options and their total GHG abatement potential.

In such a way the figure below shows on the horizontal axis the total mitigation potential of various agricultural practices and on the vertical axis the associated costs per tonnes of CO_2-e.

Figure 21: Exemplary Marginal Abatement Cost curve of different policy options in the agricultural sector in Nigeria (Cervigni, et al., 2013, p. 46)



Using this method various institutions analyzed the global GHG abatement cost curves for different sectors, including agriculture, as e.g. (McKinsey&Company, 2009). MACC was also used as part of various EX-ACT analyses.

The basics of the Marginal Abatement Cost Curve (MACC) methodology is presented in annex 4. Further information may besides be found in the guidelines “Using Marginal Abatement Cost Curves to Realize the Economic Appraisal of Climate Smart Agriculture Policy Options” (Bockel, et al., 2012).

ANNEX TO EX-ACT USERS MANUAL

Contents

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ANNEX 2: Glossary and Acronyms

Glossary

Additionality: Additionality in the context of the UN Framework Convention on Climate Change (UNFCCC) refers to an effort that is supplemental to the business-as-usual (BAU) scenario.

The additionality of a project for GHG emissions is given by its characteristic to achieve additional emission reductions that would otherwise not have occurred in the absence of the project under a business-as-usual scenario. Besides this for us most relevant meaning, additionality may also be used in the context of mitigation finance, where it refers to the additionality of financial contributions to mitigate climate change, as e.g. in the context of the Clean Development Mechanism.

Afforestation: Afforestation refers to the process of establishing and growing forests on bare or cultivated land, which has not been forested in recent history (c.f. (World Bank, 2012)). Article 3.3 of the Kyoto Protocol limits afforestation to activities since 1990. The canopy cover should reach at least above a 19 percent threshold (FAO, 2013).

Anaerobic digestion: Anaerobic Digestion is a natural process in which micro-organisms break down organic matter, in the absence of oxygen, into biogas (a mixture of carbon dioxide and methane) and digestate (a nitrogen-rich fertiliser) (FAO, 2013)**.**

Baseline scenario: A hypothetical scenario that reasonably represents the anthropogenic emissions removals or storage by sources of greenhouse gases (GHG) that would occur in the absence of the proposed project activity (CAALTD, 2013).

Carbon-balance or GHG-balance: The carbon-balance for a specific project (or scenario of action) in comparison with a reference, is defined as the net balance from all GHGs expressed in CO_2 equivalent that were emitted or sequestered due to project implementation as compared to a business-as-usual scenario. It thus accounts for the emissions from all GHGs as well as all kind of carbon pools concerned by the AFOLU sector. The expressions carbon-balance and GHG-balance are used synonymously. The Carbon-balance can be realized at different scales, for an investment project, the resource impact of an organization, or for a region, a value chain, a country, the planet (Bockel, et al., 2011).

Carbon footprint: A carbon footprint measures the total greenhouse gas emissions caused directly and indirectly as a result of a clearly defined process or activity. Often it is thereby differentiated between the carbon footprint of a product, value chain or organization (c.f. (Carbon Trust, 2013):

- Organizational carbon footprint
  Emissions from all the activities across an organization, including buildings, energy use, industrial processes and company vehicles.
- Value chain carbon footprint
  Includes emissions which are outside an organization's own operations (also known as Scope 3 emissions). This represents emissions from both suppliers and consumers, including all use and end of life emissions.
- Product carbon footprint
  Emissions over the whole life of a product or service, from the extraction of raw materials and manufacturing right through to its use and final reuse, recycling or disposal

Carbon sequestration: Carbon sequestration (storage) is the natural or artificial isolation of carbon dioxide from the earth's atmosphere by increasing its storage in another form of reservoir. It may refer to the natural process of removing carbon dioxide from the atmosphere through the activity of plants leading to carbon sequestration in soil and biomass or to artificial processes that capture CO_2 either intentionally (e.g. carbon capture and storage) or as a by-product of industrial processes (e.g. petroleum refining).

Carbon sink: Processes that remove more carbon dioxide from the atmosphere than they release, as part of the carbon cycle. For example, forests and oceans act as carbon sinks (Live Smart BC, 2013).

Climate Smart Agriculture (CSA) (FAO, 2013)**:** Climate-smart agriculture, forestry and fisheries (CSA), as defined and presented by FAO at the Hague Conference on Agriculture, Food Security and Climate

Change in 2010, contributes to the achievement of sustainable development goals. It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is composed of three main pillars:

- sustainably increasing agricultural productivity and incomes;
- adapting and building resilience to climate change;
- reducing and/or removing greenhouse gases emissions, where possible.

CO_2 equivalent (CO_2-e): CO_2-e is the universal unit of measurement used to indicate the global warming potential of each of the six greenhouse gases. Carbon dioxide— a naturally occurring gas that is a byproduct of burning fossil fuels and biomass, land-use changes, and other industrial processes— is the reference gas against which the other greenhouse gases are measured. One unit of a gas with a CO_2-e rating of 21, for example, would have the warming effect of 21 units of carbon dioxide emissions (over a time frame of 100 years) (World Bank, 2012).

Emission factor: A factor allowing emissions to be estimated from a unit of available activity data (e.g. tonnes of fuel consumed, tonnes of product produced).

Enteric fermentation: Enteric fermentation is a natural part of the digestive process for many ruminant animals where anaerobic microbes, called methanogens, decompose and ferment food present in the digestive tract producing compounds that are then absorbed by the host animal. A resulting byproduct of this process is methane (FAO, 2013).

Ex-ante GHG assessment: Estimating expected future GHG effects of policies and actions before implementation.

Global warming potential (GWP): The Global Warming Potential is the factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GHG relative to one unit of CO_2 over a specific time period. It thus allows expressing all sources and sinks of GHGs in CO_2 equivalents, which leads to the evaluation of the combined climate impact of a project.

For instance the official values for Clean Development Mechanism of methane (CH_4) are set to 21 (meaning that 1 kg of CH_4 is as effective, in terms of radiative forcing, as 21 kg of CO_2) and to 310 for nitrous oxide (N_2O). EX-ACT allows users to choose either the GWP standards of the CDM or of the last IPCC update.

Greenhouse gases (GHGs): GHGs refer to the six gases considered as main responsible for climate change as specified under the Kyoto protocol. They are carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); sulfur hexafluoride (SF6). They also may include the indirect GHGs such as SO_2, NOx, CO and NMVOC (UNFCCC, 2013).

Intergovernmental Panel on Climate Change (IPCC): The leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. In the same year, the UN General Assembly endorsed the action by WMO and UNEP in jointly establishing the IPCC. The IPCC is a scientific body under the auspices of the United Nations (UN). It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters (IPCC, 2013).

Kyoto protocol: The Kyoto Protocol to the Framework Convention on Climate Change () was adopted at the Third Session of the Conference of the Parties (COP) in 1997 in Kyoto. It contains legally binding commitments, in addition to those included in the UNFCCC. Annex B countries agreed to reduce their anthropogenic GHG emissions (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) by at least 5 percent below 1990 levels in the commitment period 2008-2012. The Kyoto Protocol came into force on 16 February 2005 (FAO, 2013).

Leakage: Leakage is defined as the net change of anthropogenic emissions by sources of greenhouse gases (GHGs) which occurs outside the project boundary, and which is measurable and attributable to the project activity (CAALTD, 2013).

Marginal Abatement Cost Curve (MACC): A Marginal Abatement Cost Curve represents the relationship between the cost-effectiveness of different abatement options and the total amount of GHGs abated. It reflects the additional costs of reducing the last unit of carbon and is usually upward-sloping: i.e. marginal costs rise with the increase of the abatement effort.

National Adaptation Programmes of Action (NAPAs): Documents prepared by least developed countries (LDCs) that identify the activities to address urgent and immediate needs for adapting to climate change (FAO, 2013).

Nationally Appropriate Mitigation Actions (NAMAs): A set of government prioritized actions aimed at reducing or limiting greenhouse gas emissions (FAO, 2013).

Net GHG emissions: Net GHG emissions refer to the aggregation of GHG emissions (positive emissions) and removals (negative emissions) from a specified activity or process.

Payment for Environmental services (PES): An economic instrument designed to provide positive incentives to users of agricultural land and those involved in coastal or marine management. These incentives are expected to result in continued or improved provision of ecosystem services, which, in turn, will benefit society as a whole (FAO, 2013).

Soil carbon sequestration: Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids, and in a form that is not immediately reemitted. This transfer or "sequestering" of carbon helps off-set emissions from fossil fuel combustion and other carbon-emitting activities, while enhancing soil quality and long-term agronomic productivity (Ohio State University, 2004).

Soil organic matter (SOM): Soil organic matter is any material produced originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process. At any given time, it consists of a range of materials from the intact original tissues of plants and animals to the substantially decomposed mixture of materials known as humus (FAO, 2013).

Technical and economic mitigation potential: The technical mitigation potential refers to the maximum amount of GHGs that can be mitigated under current technological conditions. The economic mitigation potential instead refers to the amount of GHGs that are expected to be mitigated given a specified incentive structure and socio-economic context (e.g. a specific carbon price).

Tier level (Tier 1, Tier 2 and Tier 3): A Tier represents a level of methodological complexity to estimate greenhouse gas emissions following the definition in NGGI-IPCC-2006. EX-ACT can accommodate two of these precision levels: Tier 1 and Tier 2.

> **Tier 1** methods are designed to be the simplest to use, for which equations and default parameter values (e.g., emission and stock change factors) are provided in NGGI-IPCC-2006. While users need to furnish project specific activity data, the IPCC based emission coefficients are mostly applicable globally or at regional level.
>
> **Tier 2** can use the same methodological approach as Tier 1 but applies emission and stock change factors that are based on country- or region-specific data. Country-defined emission factors are used characterized by more specificity for the climatic regions, land-use systems and livestock categories in that country. Higher temporal and spatial resolution and more disaggregated activity data are typically used in Tier 2 to correspond with country-defined coefficients for specific regions and specialized land-use or livestock categories.
>
> **Tier 3** refers instead to the use of more complex methodologies, including GHG modelling techniques. They are tailored to address national circumstances and are driven by high-resolution

activity data and disaggregated at sub-national level. Their strong data requirements makes an application time and resource intensive.

United Nations Framework Convention on Climate Change (UNFCCC): An international treaty, developed at the 1992 UN Conference on Environment and Development, which aims to combat climate change by reducing global greenhouse gas emissions. The original treaty was considered legally non-binding, but made provisions for future protocols, such as the Kyoto Protocol, to set mandatory emissions limits (CAALTD, 2013).

Watershed: A topographically delineated area that is drained by a stream system, i.e. the total land area that drains to some point on a stream or river. The watershed is a hydrologic unit that has been described and used as a physical-biological unit and a socio-economic-political unit for planning and managing of natural resources (FAO, 2013).

Acronyms

A/R:	Afforestation and Reforestation
AFOLU:	Agriculture, Forestry and Other Land Use
ARD:	Agriculture and Rural Development
BEF:	Biomass Expansion Factor
C:	Carbon
CO_2:	Carbon Dioxide
CH_4:	Methane
CC:	Climate Change
CSA:	Climate Smart Agriculture
EC:	European Commission
EU:	European Union
EX-ACT:	Ex-Ante Carbon-balance Tool
FAO:	Food and Agriculture Organization of the United Nations
FFRP:	Forest Fire Response Project
GCCA:	Global Climate Change Alliance
GCF:	Green Climate Fund
GEF:	Global Environment Facility
GHGs:	Greenhouse Gases
GIS:	Geographic Information Systems
Gt:	Giga tonne
GWP:	Global Warming Potential
Ha:	Hectare
HAC:	High Activity Clay Soils
IEA:	International Energy Agency
IFAD:	International Fund for Agricultural Development
IFI:	International Financial Institutions
IIASA:	International Institute for Applied Systems Analysis
IMAD:	China Integrated Modern Agriculture Development Project
IPCC:	Intergovernmental Panel on Climate Change
IRR:	Internal Rate of Return
IRD:	Institut de Recherche pour le Développement
ISRIC:	World Data Center for Soils
ISSCAS:	Institute of Soil Science, Chinese Academy of Sciences
IUSS:	International Union of Soil Sciences
JICA:	Japan International Cooperation Agency
JRC:	Joint Research Centre of the European Commission
LAC:	Low Activity Clay Soils
LCA:	Life Cycle Assessment
LDCF:	Least Developed Countries Fund
LFLP:	Leasehold Forestry and Livestock Programme
LUC:	Land Use Change
MACC:	Marginal Abatement Cost Curve
MAT:	Mean Annual Temperature
MDB:	Multilateral Development Bank
MICCA:	Mitigation of Climate Change in Agriculture
MRV:	Monitoring, Reporting and Verification
Mt:	Mega tonne
N_2O:	Nitrous Oxide
NGGI-IPCC-2006:	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
NPV:	Net Present Value
NTFP:	Non-Timber Forest Products
OECD:	Organization for Economic Co-operation and Development
PES:	Payments for Environmental Services

REDD:	Reducing Emissions from Deforestation and Forest Degradation
REED:	Rural Energy Enterprise Development
SCC:	Social Costs of Carbon
SCCF:	Special Climate Change Fund
SEEA:	System of Environmental Economic Accounting
SLWM:	Sustainable Land and Water Management
SOC:	Soil Organic Carbon
SOM:	Soil Organic Matter
UN:	United Nations
UNEP:	United Nations Environment Programme
UNFCCC:	United Nations Framework Convention on Climate Change
USD:	United States Dollar
USDA:	U.S. Department of Agriculture
WGS84:	World Geodetic System 1984
WMO:	World Meteorological Organization
WRB:	World Reference Base for Soil Resources
WRI:	World Resource Institute
WWF:	World Wildlife Fund

ANNEX 3: List of Tables, Figures and Case Studies

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ANNEX 4: Use of Marginal Abatement Cost Curves (MACC) in appraising low carbon options

Background of Marginal Abatement Cost Curves

As explained by Mc Leod (Barnes, et al., 2010), Marginal Abatement Cost Curves (MACC) were first developed after the two oil price shocks, in the 1970's. They were aimed at reducing crude oil consumption, and later electricity consumption ((Farugui, et al., 1990), (Jackson, 1991)). The MACC was then used for different purposes: assessment of abatement potential and costs of air pollution ((Silverman, 1985), (Amann, et al., 1994)) or water availability (McKinsey & Company, 2009). MACC began to be used in the agricultural sector in the years 2000, using qualitative judgments by the European Union ((European Climate Change Programme, 2001), (Weiske, 2005)) and other stronger empirically oriented methods ((MacCarl, 2003), (US-EPA, 2006), (Weiske & Michel, 2007), (Holm-Müller & Pérez Domínguez, 2005)).

In recent years, MACC has become very popular with policy makers, but also through the McKinsey report (McKinsey&Company, 2009), analysing the global GHG abatement cost curves for different sectors, including agriculture. In this light, policy-makers use MAC-curves in order to demonstrate how much abatement an economy can afford in the area of focus, with respect to policies, to achieve the emission reductions.

Recently, the study "*Climate Change in Agriculture – Impacts, adaptation and mitigation*" (Wreford, et al., 2010) has identified the development of marginal abatement cost modelling as one of the five areas of research and policy advocacy relevant for the OECD in relation to advancing the stand of knowledge on the economics of climate change in agriculture.

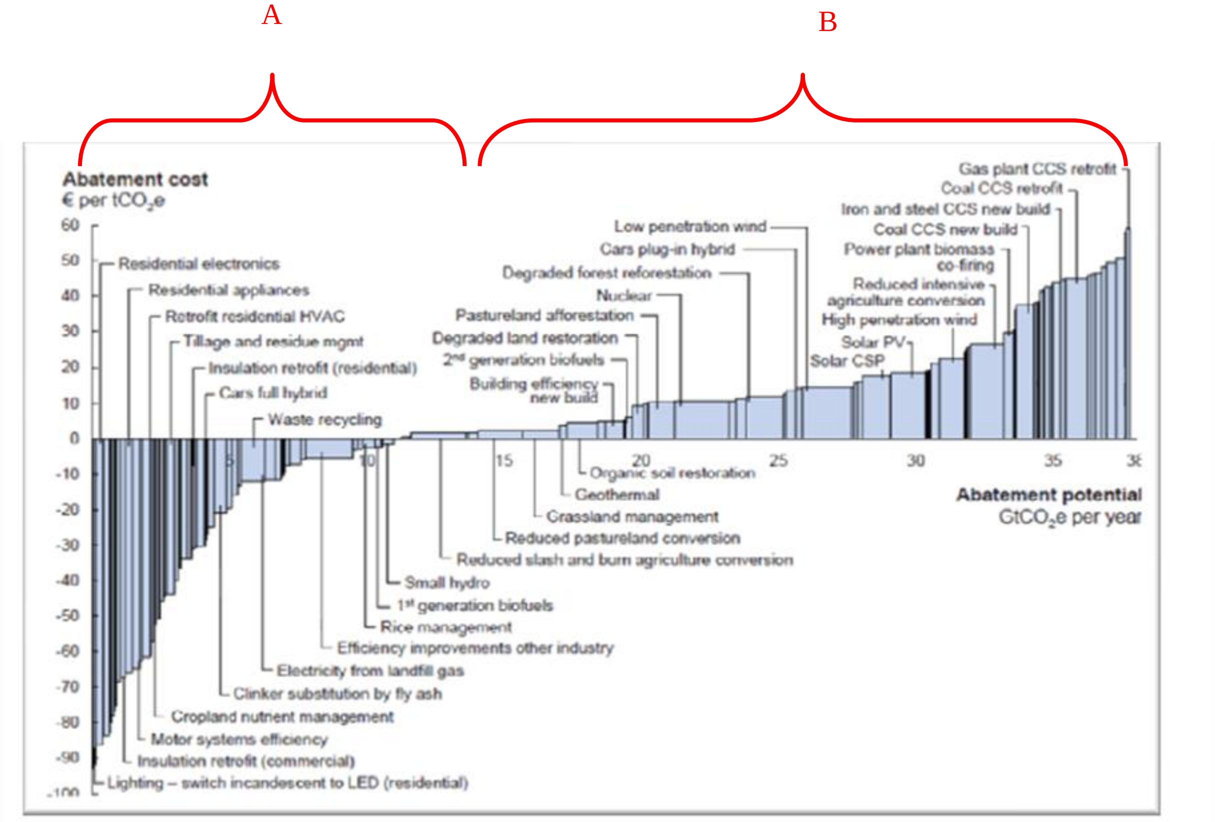
Methodology and limits of MACCs

A Marginal Abatement Cost Curve represents the relationship between the cost-effectiveness of different abatement options and the total amount of GHGs abated *(cf. table 10)*. It reflects the additional costs of reducing the last unit of carbon and is usually upward-sloping: i.e. marginal costs rise with the increase of the abatement effort.

MACCs can be derived in different ways, either as a histogram or as a curve, as presented in the table below.

Table 6: The two presentations of MACC

A) Histogram: Global MAC curve



Source: (van Tilburg, et al., 2010)

The histogram assesses the costs and reduction potential of each single abatement measure.

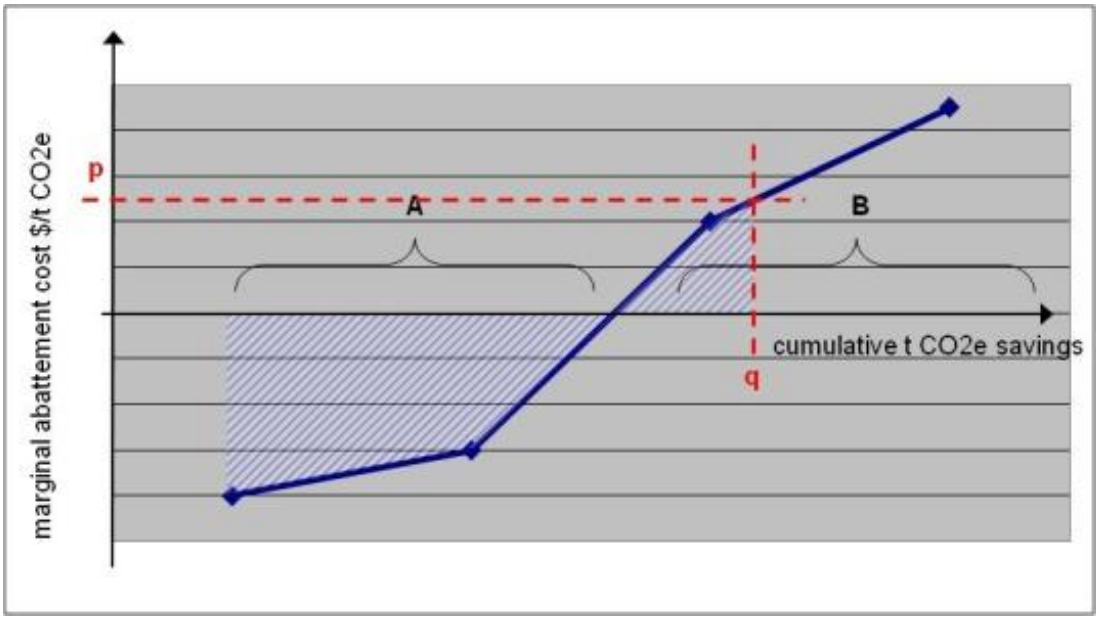
Each bar represents a single mitigation option.

- The width of the bar represents the amount of abatement potential available from the action (in $MtCO_2$-e).
- The height of the bar represents the average unit costs of the action (cost per tonne of CO_2-e saved).
- The area (height * width) of the bar represents the total costs of the action, i.e. how much it would cost altogether in order to deliver all the CO_2 savings from the action.

The total width of the MACC shows the total CO_2 savings available from all actions, and the sum of the areas of the total amount of bars represents the total costs of abatement for all actions.

This type of MACC representation is easy to understand; the marginal cost and the mitigation potential can be unambiguously assigned to one option.

B) Curve



Source: FAO 2011

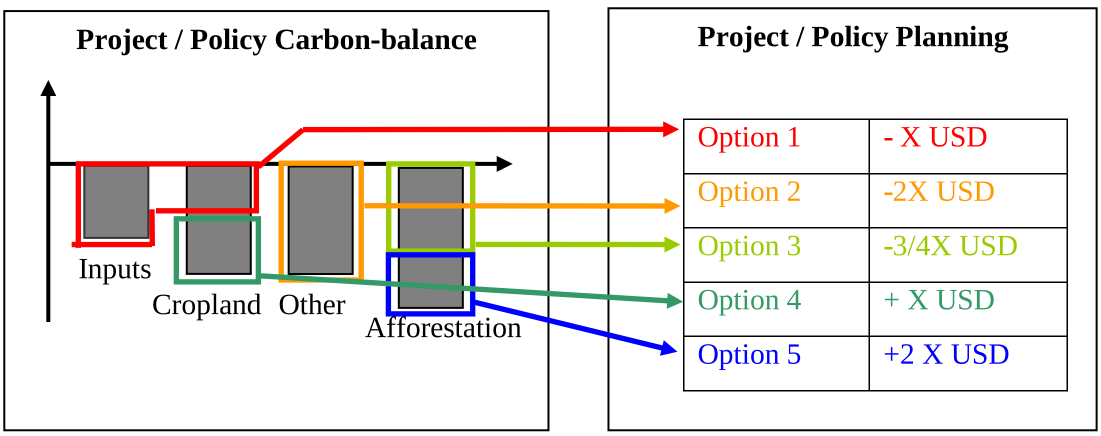
The curve indicates the costs (usually in \$/t CO_2-e) associated with the last unit of emission abatement (usually in million tonnes of CO_2). The curve enables to analyze the cost of the last abated unit of CO_2 for a defined abatement level (marginal costs), while the integral of the abatement cost curve (the area under the curve) gives us the total abatement costs. For example here, the point (q,p) represents the marginal cost, p, of abating an additional unit of carbon emissions at quantity q. The integral of the area under the curve (shaded area) represents the total abatement costs.

In both cases, moving along the curve from left to right worsen the cost-effectiveness of low carbon options since usually each additional tonne of CO_2-e mitigated is associated to increasing marginal costs. Different mitigation options will occupy different positions on the curve, some options being more cost efficient (A) than others (B).

Linking EX-ACT results with MACC

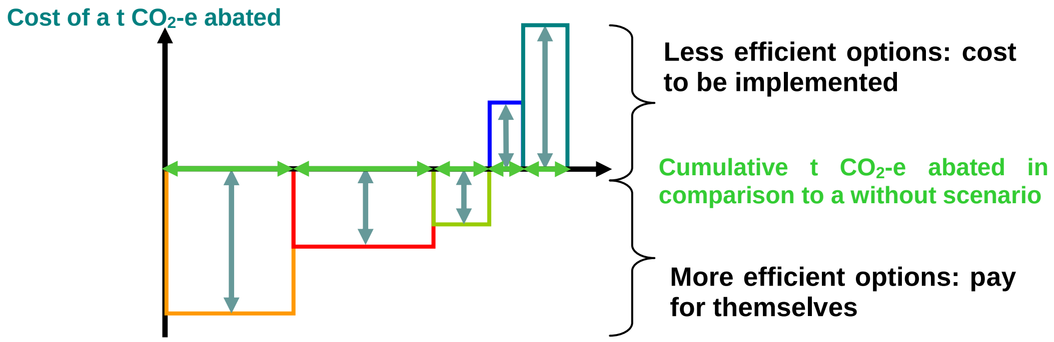
The low carbon options planned by project designers are occasionally crosscutting the EX-ACT modules. The modular approach prevents us from clearly seeing the carbon-balance of each adopted activity.

Figure 22: How to manage the complexity...



A MACC facilitates the management of these two dimensions of complexity. The curves, presented to businesses or public policy makers, can lead to result in the comparison of different investments in terms of carbon storage and benefits.

Figure 23: ... with MACC to synthesize information



For visibility purposes it is recommended to limit the number of activities included in one MACC graph. A specific agricultural practice may be split into several EX-ACT modules, e.g. annual crop and inputs. In such slightly more complex cases it is thus necessary not to simply represent the results from one EX-ACT module within the MAC curve, but e.g. first sum the mitigation potential from the annual crop and input modules that together constitute a specific agricultural management practice.

Evaluation of the cost effectiveness and analysis of the MACC results

The next step is to calculate the costs of each option as well as its benefits. Costs reflect the implementation of the land use change or agricultural practice, which might occur only once (tree plantation, certification of organic farms...) or recurrently (nutrient management, no-tillage, use of pesticides, better feeding practices...).

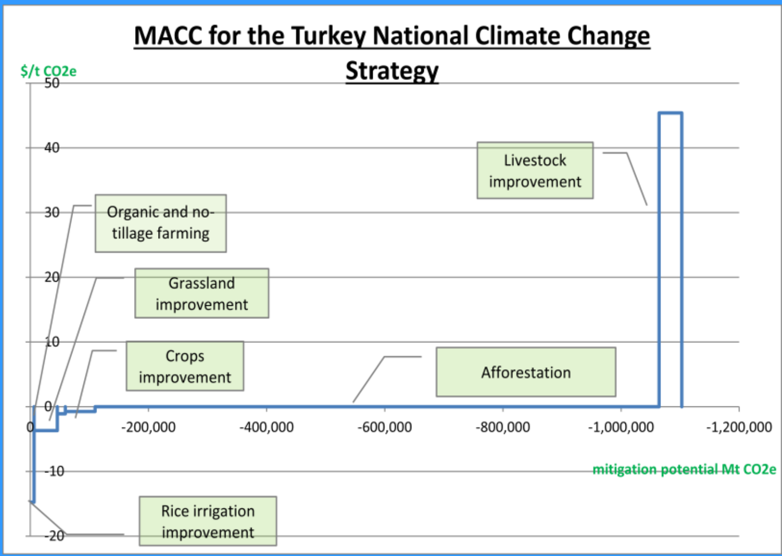
Thereby it is an especially useful exercise to differentiate between public and private costs, establishing the notion of private and public MACC, that help to identify the different outcomes for private actors as well as the general public. In regards to these costs, different analyses could be done, such as e.g. using the cost for the government to help and encourage the adoption of the option (e.g. vouchers to buy concentrates for the animals, bearing the costs of certification for farmers who want to turn to organic agriculture, free distribution of improved seeds). In the case presented below, the available data allows us to study the private costs occurring to farmers, except for the afforestation option, which is occurring to the government.

The benefits have to be known as well, in order to calculate the free cash flow and the NPV. An Internal Rate on Return (IRR) and a payback period can equally be calculated, to enrich the economic analysis. Most of the benefits directly concern the farmer, e.g. increase in yield, savings concerning fertilizer purchase, water use and fuel (no-till). Other benefits occur both to society and farmers like the benefits from prevented erosion.

Different situations have been analyzed to take into account the limits of a MACC assessment, varying discount rates and the extent to which there are interaction between the considered options. Thus it is in some cases reasonable to assume that the per unit costs of one option – e.g. improved livestock feeding practices – change based on the adoption of another proposed activity – lets say the establishment of forage crops on strongly degraded grassland. In the case below we compare a scenario using two different discount rates of 3.5% and 10%.

Figure 24: Comparison of the MACC results depending on the discount rate

Public discount rate of 3.5%



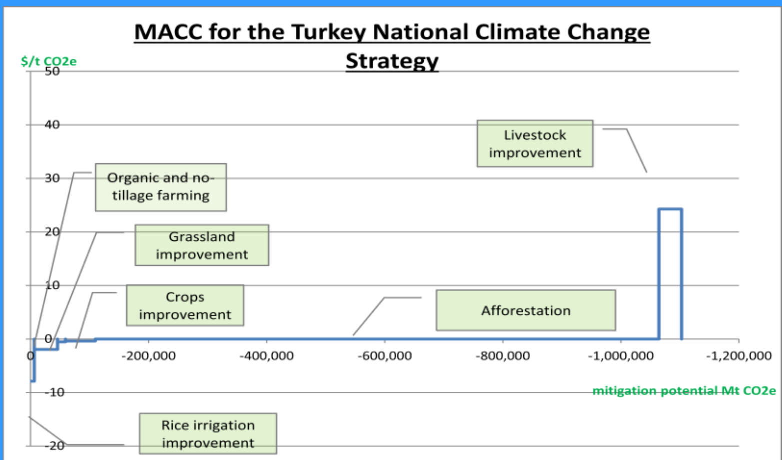
Scenario 1: The improved rice irrigation is the most cost-effective action with an average price of -15 \$/t CO_2-e (leading to actual private benefits). Each tonne of GHGs avoided due to crop improvement, afforestation and grassland improvement represents an almost zero cost option (prices between -1 and -0.1 \$/t). The activities planned within the livestock management option are the most expensive, with an average price of 45 \$/t CO_2-e.

The afforestation provides most of the mitigation potential.

Regarding the total cost of mitigation (mitigation potential * average cost per t CO_2-e), the promotion of organic and no-tillage farming is the cheapest action, followed by rice irrigation. Even if rice irrigation has a more profitable cost per t of CO_2-e, its limited mitigation potential explains why it is not the more profitable option globally. Also concerning total costs the livestock management activities are the most expensive.

The public discount rate gives an optimistic view of the abatement potential that can be achieved at profits for society through improved rice irrigation and the development of organic farming.

Private discount rate of 10%



Scenario 2: Also with a changed discount rate the ranks of the different considered mitigation options stay the same. Thus improved rice irrigation still has the most favourable marginal costs -8\$/t CO_2-e while livestock management is still the most expensive (24\$/t).

The higher private discount rate thus leads to less optimistic values for the most cost efficient options (rice) and to the estimation of less cost pessimistic values for the most cost intensive options (livestock).

The choice of the discount rate will depend on the adopted point of view for the MACC analysis. If it is to evaluate the mitigation potential and the cost of a farm or an agricultural cooperative, the private discount rate is the most appropriate. If the MACC is done from the point of view of a government, it would be more accurate to use a discount rate that includes both public and private criteria. Indeed, the interaction between both actors, the government and the private sector, is an important element for the design of mitigation policies.

ANNEX 5: Using EX-ACT to Assess the Product Carbon Footprint along the Value Chain

The business mantra "you cannot manage it if you cannot measure it" applies as much to carbon emissions as to resources and costs. Industries in Annex 1 countries of the UNFCCC have to calculate and report their emissions. In parallel to this obligation, a new type of carbon measurement has been developed during the last 10 years: the carbon footprint of a product, which takes into account the emitted CO_2-emissions across the supply chain, from cradle to grave. The lifecycle assessment of GHG emissions of a good presents several benefits that can be classified into three main advantages: i) reduction of GHG emissions, ii) support to decision making and supply chain management, iii) differentiation on the market and trade advantages.

Definition of the product carbon footprint

The carbon footprint of a product is the quantity of greenhouse gases (GHGs), expressed in carbon dioxide equivalent (CO_2-e), emitted across the value chain for a single unit of that product. Though boundaries of the analysis may vary, reasonable approaches may be e.g. from production to retail *(cradle to shelf)* or over the full life cycle *(cradle to grave)*.

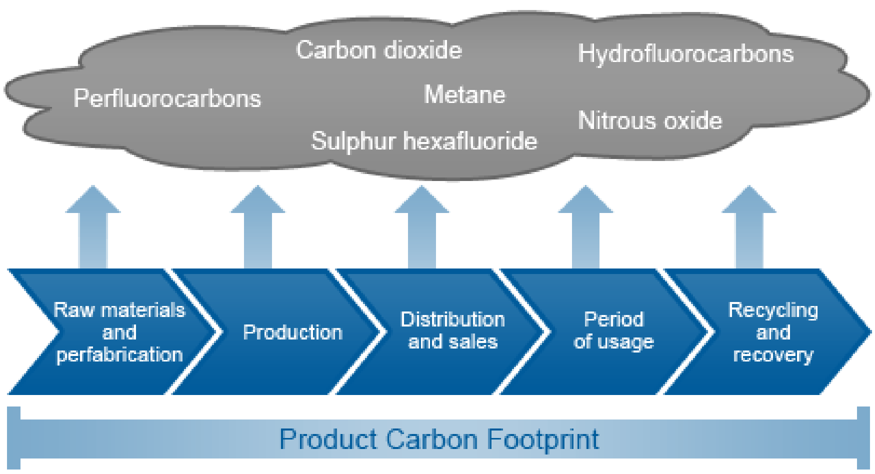
Within the declared analysis each step of the value chain should be taken into account. As shown in figure 23 this includes emissions from the production of raw materials, transportation and transformation, product use as well as waste disposal and recycling.

A further main differentiation is whether all indirect emissions are accounted for e.g. on the respective emissions generated by the production of products that serve as inputs for the analyzed production system.

Depending on the methodology used to calculate the carbon footprint (CFP), the GHGs taken into account could comprise either the six main gases highlighted in the Kyoto protocol (carbon dioxide CO_2, methane CH_4, nitrous oxide N_2O, hydrofluorocarbons HFCs, perfluorocarbons PFCs, sulphur hexafluoride SF6) or only a limited number of them.

These numerous options show that a clear specification of boundaries and scope of a carbon footprint analysis is an important precondition for a transparent and adequate approach.

Figure 25: The scope of a product carbon footprint



Source: *http://reclay-group.com/?id=267&L=1*

In such a way the carbon footprint along the value chain allows for a comparison of emission intensity within different value chain stages. This should nevertheless be approached with caution as all those stages along the value chain, with little emission intensity, can also contribute significantly to mitigation potentials.

The product carbon footprint is, as explained previously, usually expressed in t CO_2-e per product unit. Though reasonable in order to compare different production processes with each other, measures per product unit do not allow comparisons between products. In this light, selected authors have tried to establish emission intensity per nutrient content, energy content, fat or protein content. An alternative is to consider the emission intensity per economic value of the product (Schau & Fet, 2008). While the existence of these approaches is acknowledged here, we focus in the following on a classical carbon footprint analysis by product unit.

How to enter Value chain data in EX-ACT

In the results section of this *User Manual* it was explained how to use EX-ACT as part of a regular project, programme or policy analysis in order to obtain a first estimation of the interventions impact on product carbon footprints in the agricultural production stage. In order to properly include the effects from artificial inputs, such as fertilizers, and have a refined analysis it is nevertheless advised to fill an empty EX-ACT sheet separately with only one crop of interest.

In such a way, EX-ACT can be used to estimate the product carbon footprint of production for a single agricultural product, but also to compare different production practices. In the example below, EX-ACT is used to analyze the changes in product carbon footprint from converting conventional banana cultivation into organic production. Using exemplary data from a model farm in Central America (c.f. (Grewer & Bockel, 2012)) that documented its conversion process, and complementing missing data based on assumptions from regional data, the main changes are given by a decrease in productivity, changes in agricultural practices, changes in the fertilization regime and phasing out of synthetic pesticides.

For the purpose of the analysis EX-ACT is filled exactly in the same way as described earlier in this *User Manual*, but information is only specified on the relevant area cropped with banana. Thereby the conventional production system is inserted as without-project scenario and the organic cultivation practices as a with-project scenario. The screenshot below shows how the annual module and the input module have been filled:

EX-ACT Screenshot 27: Annual and Input Module for Carbon Footprint Assessment

3.1.2. Annual systems remaining annual systems *(total area must remains contant)*

Fill with you description	Improved agro--nomic practice	Nutrient management	NoTill./residues management	Water management	Manure application	Residue Burning	Yield (t/ha/yr)	Area (ha) Start	Without	*	With	*
Conventional banana	?	?	?	?	?	NO	45	200	200	I	0	I
Organic banana	Yes	?	?	?	Yes	NO	35	0	0	I	200	I

6.1 Inputs (liming, fertilizers, pesticides, herbicides,...)					
Description and unit to report	Amount applied per year				
Lime application	Start	Without	*	With	*
Limestone (tonnes per year)	2,100	2,100	D	2,100	D
Dolomite tonnes per year)	0	0	D	0	D
not-specified (tonnes per year)	0	0	D	0	D
Fertilizers					
Urea (tonnes of N per year - Urea has 46.7% of N)	0	0	D	0	D
Other N-fertilizers (tonnes of N per year)	5,089	5,089	I	3,375	I
N-fertilizer in irrigated rice (tonnes of N per year)	0	0	D	0	D
Sewage (tonnes of N per year)	0	0	D	0	D
Compost (tonnes of N per year)	0	0	D	0	D
Phosphorus (tonnes of P2O5 per year)	0	0	D	0	D
Potassium (tonnes of K2O per year)	0	0	D	0	D
Pesticides					
Herbicides (tonnes of active ingredient per year)	0	0	D	0	D
Insecticides (tonnes of active ingredient per year)	0	0	D	0	D
Fungicides (tonnes of active ingredient per year)	986	986	I	0	I

After inputting the information on the stages of agricultural production, users switch to the *Life Cycle Carbon Footprint* section of the results section. Here the emissions per tonne of banana from production are already automatically are provided, including emissions from all agricultural inputs. Thus the conventional production system leads to annual emissions of 107kg of CO_2-e per tonne of banana, while the organic system is estimated to sequester 6kg of CO_2-e, it may thus be evaluated as carbon neutral.

EX-ACT Screenshot 28: Detailed carbon footprint from production (including emissions from input)

Life cycle carbon footprint		
Detailled Emissions in t CO_2-eq for the different phases of the Value Chain	**Emissions (tCO_2/t product)**	
	Without	**With**
PRODUCTION Level (corresponding emissions calculated as a percentage of total quantity used)		
Direct and indirect (induced LUC, degradation, Inputs & Investments) emissions	**0.107**	**-0.006**

Nevertheless, product carbon footprints are usually not only estimated at the production stage, but also for a longer sequence of the value chain. For this purpose it is specified here how to analyze the product carbon footprint of bananas from cradle to supermarket shelf. Thereby we further assume a production in Central America, with shipment to Europe and road transportation to Germany. The used data is exemplary secondary data that was not verified by FAO. It is very likely that the listed resource needs are incomplete and the realistic carbon footprint is expected considerably higher. We assume for this example that organic and conventional bananas do not differentiate in terms of their resource needs for packaging and transportation. The following screenshot shows the information inserted along the value chain.

EX-ACT Screenshot 29: Carbon footprint from cradle to shelf

Life cycle carbon footprint						
Detailled Emissions in t CO_2-eq for the different phases of the Value Chain					**Emissions (tCO_2/t product)**	
					Without	**With**
PRODUCTION Level (corresponding emissions calculated as a percentage of total quantity used)						
Direct and indirect (induced LUC, degradation, Inputs & Investments) emissions					**0.107**	**-0.006**
PROCESSING Level (list inputs or processes necessary)						
Name of input	**Emission per input**		**Input per t product**			
	Without	With	Without	With		
Electricity	*0.6*	*0.6*	*0.014*	*0.014*	0.01	0.01
Diesel	*2.9*	*2.9*	*0.005*	*0.005*	0.01	0.01
Corrugated board	*1.2*	*1.2*	*0.072*	*0.071*	0.08	0.08
Plastic (LLDPE)	*1.7*	*1.7*	*0.001*	*0.001*	0.00	0.00
				Total Processing level	**0.11**	**0.11**
TRANSPORT level (list the differents inputs or steps necessary)						
Name of input	**Emission per input**		**Input per t product**			
	Without	With	Without	With		
Electricity	*0.6*	*0.6*	*0.159*	*0.156*	0.10	0.09
Diesel	*2.9*	*2.9*	*0.015*	*0.014*		
*Refrigerants**	*1.0*	*1.0*	*0.022*	*0.021*		
Heavy fuel	*3.4*	*3.4*	*0.202*	*0.198*	0.68	0.67
Ethylene	*1.7*	*1.7*	*0.000*	*0.000*	0.00	0.00
				Total of transport Level	**0.78**	**0.76**
* For refrigerants Luske (2010) only reports t CO2/ton of transported banana. Thus we cannot calculate with an emission factor here.						
Total Emissions in t CO_2-eq for the different phases of the Value Chain					**Emissions (tCO2/t product)**	
					Without	**With**
PRODUCTION					**0.11**	**-0.01**
PROCESSING					**0.11**	**0.11**
TRANSPORT					**0.78**	**0.76**
USE					**0.00**	**0.00**
WASTE					**0.00**	**0.00**
				TOTAL	**0.99**	**0.86**

The above displayed EX-ACT section on the *Life cycle carbon footprint* is structured along the value chain and focuses sequentially on production, processing, transport, use phase and waste disposal. The latter two stages are omitted here since we only focus on a cradle to shelf analysis.

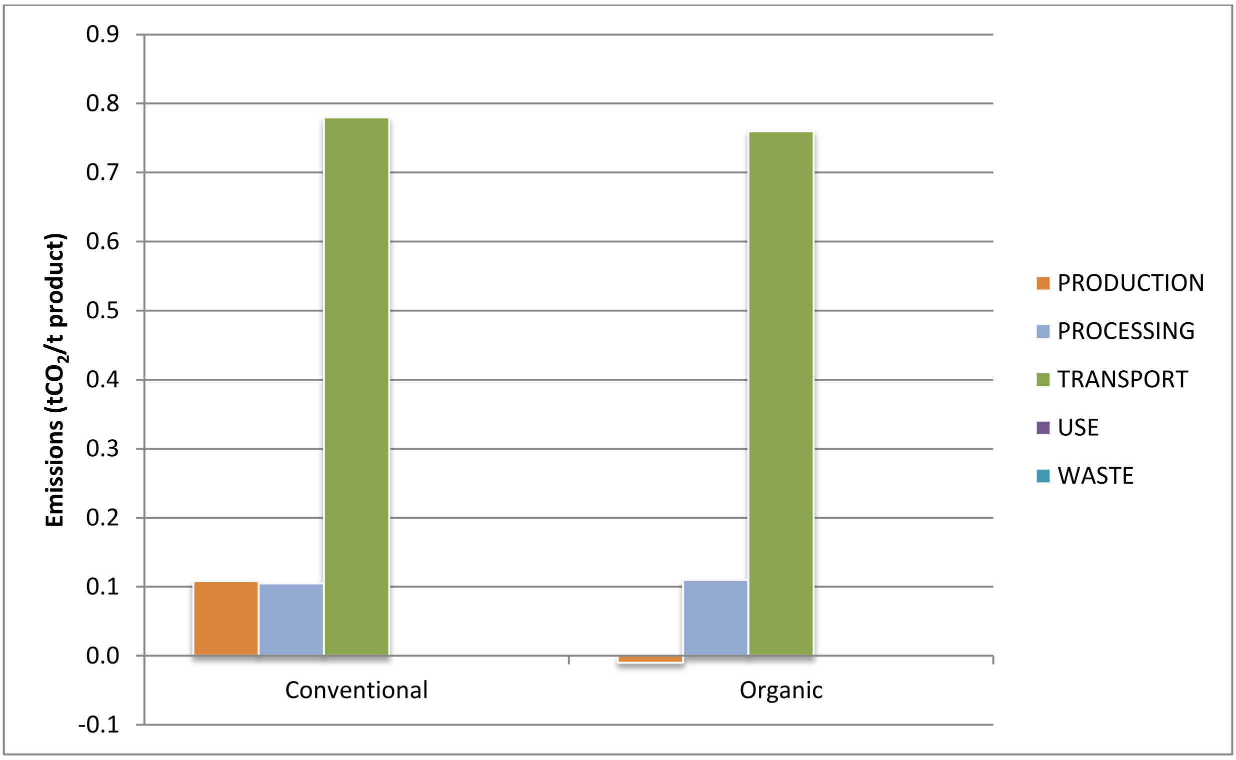
The needed specifications are as follows:

1. *Listing of all resource needs for processing, packaging and transportation.*
2. *Specification of the emission factor for the respective resource in tCO2-e per resource unit for both scenarios.*
3. *Quantification of the amount of inputs per tonne of final product (banana) for both scenarios.*
4. *Then users are provided with the respective disaggregated emissions per tonne of final product, stemming from the specified input.*
5. *Lastly, users are provided with the aggregated carbon footprint per value chain stage and as overall total.*

In our example, the conventional bananas have a product carbon footprint from cradle to shelf of 994 kg CO_2-e per tonne of banana, while the performance of organic bananas is slightly more positive at 865 kg CO_2-e per tonne of banana.

Thus organic production systems reduce overall emissions on a per hectare basis in a strong enough manner to outplay the reduction in productivity. The overall analysis along the value chain shows that both overseas and road transportation are responsible for the biggest share in emissions. This is further visualized by the below graph.

EX-ACT Screenshot 30: Banana carbon footprint along the value chain



ANNEX 6: EX-ACT Appraisal and Funding for Climate Smart Agriculture

(Excerpts from (FAO, 2013))

EX-ACT is currently mostly used (i) to appraise climate smart AFOLU projects, (ii) to assess the climate smartness of projects, or (iii) to appraise low carbon CSA policy options. Common questions are thereby “how to finance such projects?” or "how far do EX-ACT appraisals allow to mobilize funds?”. While this has been selectively answered as part of this manual, the here included annex provides some additional background information on climate change finance taken from the Climate Smart Agriculture Sourcebook (FAO, 2013).

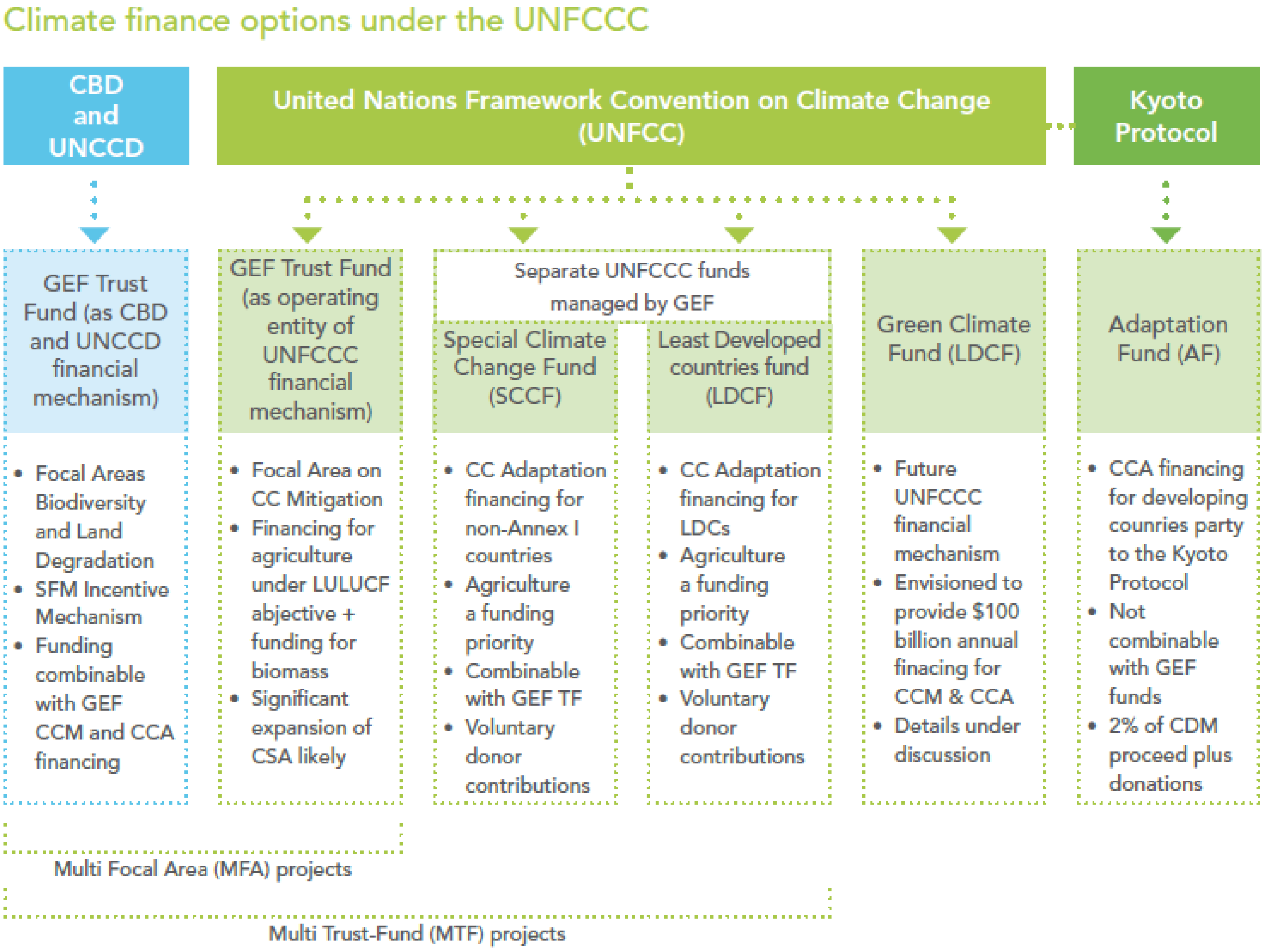
The reform of agricultural sectors to incorporate climate change considerations ultimately relies on the restructuring of agricultural investments, public as well as private, at the national level. Nevertheless, international financing plays a crucial role in this transition. International climate finance can act as a catalyst for the broader adoption of CSA practices by demonstrating the feasibility of CSA approaches, facilitating climate change mainstreaming into national policy and legal frameworks, and promoting the creation and transfer of skills, knowledge and technologies. If used correctly, the leverage of relatively small amounts of international climate finance can help to transform public agriculture budgets and private investments into sources of CSA financing. For many countries, learning how to access and effectively use international financing options represents the first step in the long-term transition towards CSA.

The landscape of CSA financing options is complex, featuring a multitude of funding channels with different objectives and eligibility criteria. Financing options, specifically targeting CSA, are still limited, necessitating a strategic use and combination of existing funding sources. The basis for any CSA activity should be the identification of a country’s opportunities and vulnerabilities, corresponding needs and preferred options for CSA activities. After national priorities have been defined, a strategic approach to sources of international finance, based on an understanding of available channels, will not only increase the chances for approval, but also enhance the fit between the finance option and the country’s overall approach to climate change in agriculture. Without making the futile attempt to cover all available sources of international climate finance, it is possible to identify six categories of important climate finance options provided by:

1. Financing mechanisms directly under the UNFCCC;
2. United Nations (UN) organizations or programmes;
3. Multilateral Development Banks (MDBs);
4. Bilateral public financing channels;
5. Compliance and voluntary carbon markets; and
6. Private sector actors and philanthropy

The first category entails climate finance options for CSA directly connected to the UNFCCC (see Figure 24). The Global Environment Facility (GEF) serves as one of the “entities operating the financial mechanism” of the UNFCCC. Through the GEF Trust Fund, donor countries provide financing to cover the incremental cost developing countries incur when undertaking activities that create global environmental benefits. Climate change mitigation, as a particularly clear-cut case of global environmental benefits, represents one of the GEF’s largest focal areas. Climate change adaptation activities are not funded under the GEF Trust Fund, but receive financing through separate funds, the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF) described below.

Figure 26: Climate finance options under UNFCCC



UN Agencies and Programmes: UN Agencies and Programmes play a central role as implementing agencies for the activities financed through the funding channels under the UNFCCC described in the previous section. In addition, UN Agencies also provide climate financing directly, primarily through multi-donor trust funds financed by member states. The UN REDD programme and the Rural Energy Enterprise Development (REED) Programme are two prominent examples for this category of international climate finance.

Multilateral Development Banks (MDBs) : The primary function of MDBs is to provide loans under conditions and objectives based on their overall principles as well as the specific agreements between a specific country and the respective development bank. The agricultural sector remains one of the primary target sectors of MDB loans, representing a share of the agricultural official development assistance. As main MDBs are increasingly incorporating environmental sustainability criteria into their agricultural lending practices and recently signed a consensus towards a systematic use of carbon-balance and GHG performance in project appraisal, they should progressively increase their role as a financing option for CSA projects.

Bilateral Public Financing Channels: Bilateral instruments remain one of the primary sources of climate finance. Analysis provided by the Climate Policy Initiative estimates that total annual climate finance to developing countries through bilateral sources (ca. US$ 23 billion) is in fact higher than the amount channeled through multilateral instruments (ca. US$ 17 billion). This gap becomes even wider when looking at climate change adaptation activities separately with bilateral sources amounting to US $3.6 billion and multilateral channels disbursing less than US $0.5 billion. Bilateral Financial Institutions play a central role as intermediaries disbursing climate funding to developing countries. Spending on climate change by the French Development Agency, the German Development Bank and the Japan International Cooperation Agency amounted to US$ 11.4 billion in 2009, including both official development assistance and non-official development assistance finance (UNEP, 2010). In addition, levels of South-South bilateral climate finance are increasing. The Brazilian Development Bank, China Development Bank, the Indian Renewable Energy Development Agency and the Overseas Private Investment Corporation have provided approximately US$ 4 billion of climate finance in 2010 (Buchner, et al., 2011). As with other funding channels, most of the bilateral climate financing is concentrated in the industrial and energy sectors and therefore not available for CSA activities.

The member states of the European Union have traditionally been the main source of climate change financing assisting developing countries, both through national level initiatives as well as climate finance activities coordinated at the European Union level. Recently, the Global Financial Crisis and the European Debt Crisis have had devastating effects on the European Union's funding levels for climate change. The official development assistance numbers released by the Organisation for Economic Co-operation and Development (OECD) show that European Union contributions for climate change adaptation in developing countries has dropped by 55 percent from € 1.4 billion in 2010 to € 619 million in 2011[10]. Nevertheless, the European Union continues to finance a number of major initiatives providing international climate finance. One important programme from a CSA perspective is the Global Climate Change Alliance (GCCA), launched in 2007 as a European Union initiative coordinated by the European Commission (EC).

Carbon Markets: Despite all the difficulties with its implementation, the concept of putting a price on GHG emissions and installing a market-based price-setting mechanism through certificate trading provides a powerful instrument of climate finance. Carbon markets could possibly be a large source of international funding for CSA activities. However, the inclusion of carbon credits from agricultural GHG reductions in compliance with carbon markets has been a matter of continuous controversy for at least two decades. The scope of this annex does not allow for a full presentation of the complex debate on agricultural carbon credits. However, this is a list of some of the central concerns: a) challenge of MRV and related difficulties to ensure environmental integrity with respect to possible leakage, uncertain permanence and additionality of GHG reductions; b) high transaction costs, especially through the coordination of large numbers of smallholder farmers that would be required to make soil carbon Certified Emission Reductions profitable; c) high opportunity costs through the diversion from conventional climate change efforts towards the complex process of achieving carbon market readiness... These issues are usually embedded in a more general rejection of carbon markets as a tool for agricultural mitigation, highlighting the unstable situation of carbon markets overall and concerns about shifting the burden of emission reductions to developing countries

Private Sector and Philanthropy : In the context of this section, private sector CSA investments do not mean the "transformed" agricultural investments by agribusiness or smallholders that follow CSA principles, but international private sector funding that contributes to catalysing this transition. Looking at the entire landscape of climate finance, the private sector is in fact the single largest source of financing (Buchner, et al., 2011). However, private sector funding in the form of market-rate loans or capital investments is almost exclusively targeted at climate change mitigation activities in the renewable energy sector and in industrial energy efficiency. In agriculture, there are a number of innovative private sector initiatives worth highlighting in this context. Usually, these are driven by a combination of three factors: a) protection of a company's value chain from climate change impacts; b) opportunities for increased profits through environmental certification schemes; and c) corporate social responsibility linked to a company's image and self-understanding. These motives particularly apply to large, multinational food-product corporations with strong interests in increasing climate resilience of agricultural production within their value chain.

Private sector: promoting the advancement of sustainable sugarcane in Brazil

In 2007, The Coca-Cola Company and World Wildlife Fund (WWF) confirmed a joint commitment to improve water efficiency, reduce carbon emissions, and help conserve seven of the world's most important freshwater river basins. As a critical piece of this initiative, Coca-Cola affirmed the goal of advancing sustainable agriculture practices through promoting environmental stewardship and ensuring workplace rights. Among agricultural products, sustainability in the sugarcane supply chain (farm, mill, and refining processes) is a key priority for The Coca-Cola Company and a focal point of the WWF/Coca-Cola partnership. As such, they also worked with Brazilian Sugar Mill suppliers.

Coca-Cola and WWF have identified Bonsucro certification as a means of ensuring increased sustainability, and believe the newly formed standard will provide a globally recognized, third-party certification for sustainably produced sugarcane. Developed through an independent, multi-stakeholder initiative, the Bonsucro certification provides a mechanism for achieving sustainable production from sugarcane in respect of economic, social and environmental dimensions. Coca-Cola, in partnership with WWF, has collaborated with key suppliers to initiate activities that assist sugar mills to understand and work towards certification. As Coca-Cola and WWF support mills to meet certification standards, sugarcane producers will continue to benefit, with global implications of aligning the industry towards responsible and sustainable environmental stewardship.
Source: Sustainable Agriculture Initiative, 2010

Fragmentation of climate finance sources has been a particular challenge for concepts such as CSA that draw their comparative advantage from the utilization of cross-cutting synergies. With the ongoing shift in focus towards integrative approaches, exploring ways to sensibly and effectively combine thematically separated channels of funding, this barrier to accessing international funding for CSA projects is gradually diminishing. This conceptual change is reinforced by an overall increasing attention on agriculture in a climate change context, representing not only the arguably most important sector for climate change adaptation, but at the same time one of the world’s largest sources of GHG emissions. Especially in combination with forest degradation and competing land use, agriculture is increasingly recognized as one of the crucial parts of the global climate challenge.

While underdeveloped financing channels, like private sector investments or carbon markets, are likely to provide only limited financing for specific niches (e.g. manure management or product certification) in the midterm, bilateral as well as multilateral public financing is starting to put more explicit emphasis on CSA activities. For example, the ongoing process of the GEF-6 replenishment is pointing in this direction. Perhaps most importantly in the mid-term future, the current design process of the Green Climate Fund might be influenced by this overall dynamic, which bodes well for the development of CSA financing. Assuming that the GCF will have a significant impact on the entire climate finance landscape, not only in structure but also in prioritization and principles, a clear focus on CSA embedded in the GCF design would make a difference for the way CSA approaches can be realized and scaled-up in the coming decades.

For developing countries, this implies an opportunity as much as a challenge. In order to successfully access, but more importantly to effectively use increasing volumes of international CSA financing, developing countries will have to ensure that the necessary prerequisites are in place. While significant readiness activities have been ongoing in REDD+ for a long period of time, there are still more gaps to be filled in the agricultural sector to improve the basis for larger-scale CSA investments. Challenges include the usual suspects, such as the quality and quantity of available data, the effectiveness of monitoring systems to institutional and technical implementation capacity as well as the suitability of policy and legal frameworks. Existing knowledge and experiences on CSA as well as the wealth of climate change needs assessments and priority setting at the national level (e.g. through NAPAs, Nationally Appropriate Mitigation Actions, etc.) providing a solid basis for concrete and country-specific preparatory measures. In order to get a head-start on CSA, developing countries could consider putting the fundamentals in place now as to be ready to use new CSA opportunities as they emerge.

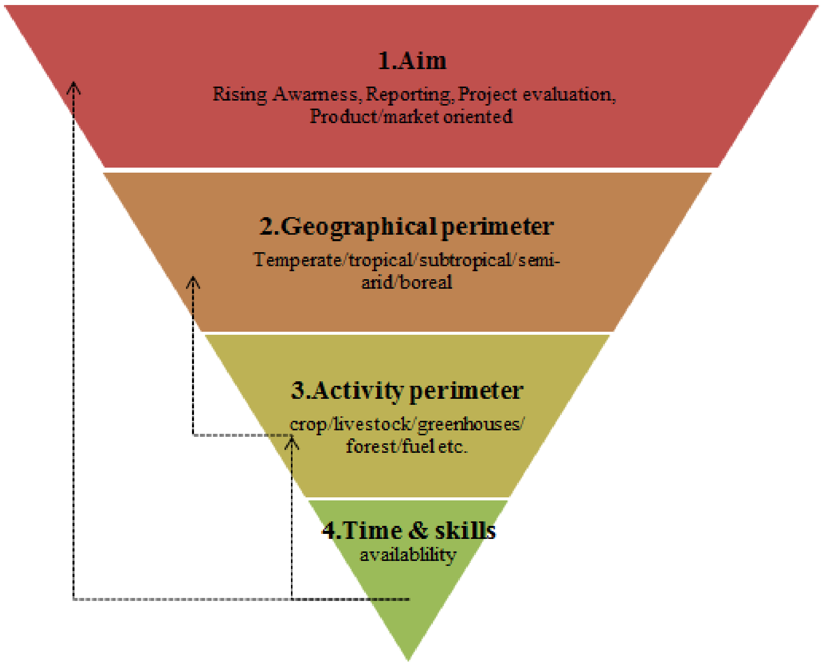
ANNEX 7: Review of GHG Tools for Mitigation in Agriculture

(c.f. Colomb, et al. (2012) and Colomb, et al. (2013))

As presented in Chapter 2.B a variety of GHG appraisal tools is available. This annex synthesizes central information from Colomb, et al. (2012) and Colomb, et al. (2013).

The study from Colomb, et al. (2013) is intended to help users select the most appropriate calculator for a landscape-scale greenhouse gas assessment of activities for agriculture and forestry. Eighteen calculators were assessed, which were designed for different objectives. Colomb et al. (2013) propose to differentiate between the tools using the criteria: Aim, geographical parameter, activity parameter as well as time & skill requirements, as depicted in the following figure:

Figure 27: Main criteria for differentiating between GHG tools



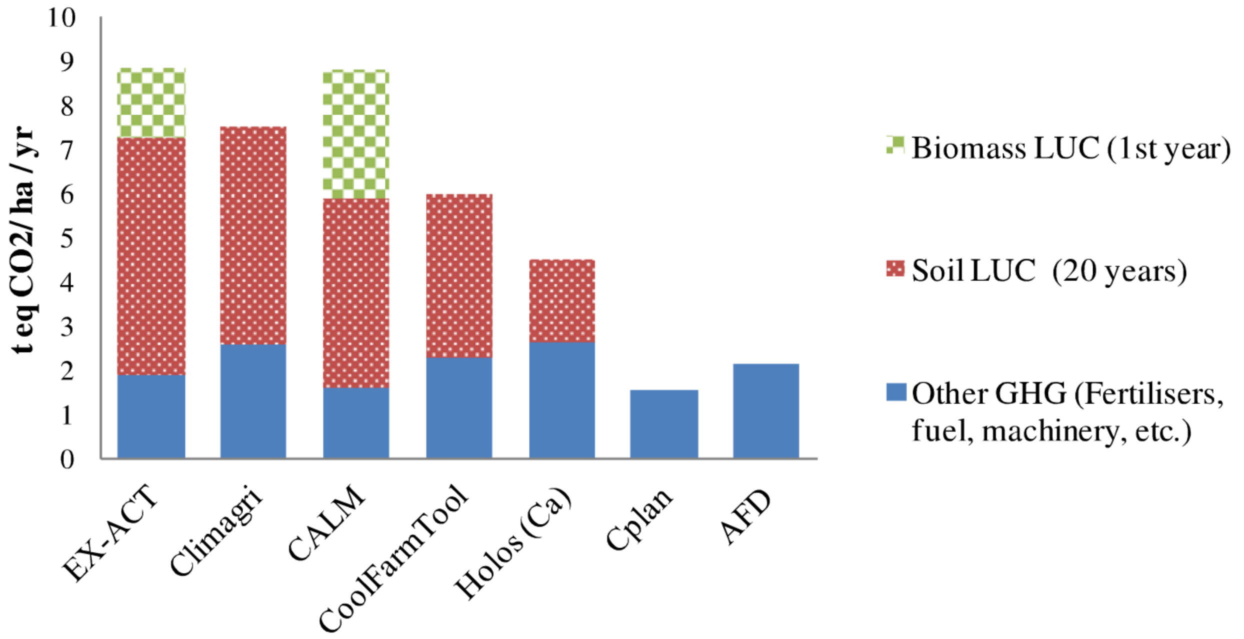
Following this structure the two papers assessed the main focus of the eighteen calculators across the given criteria. Focussing first only on criteria number 4, the speed of the assessment and the ease of use, the table below gives a rough orientation of the different tools:

Figure 28: Time and skill requirements for GHG tools
(+ time and skill intense; ++++ fast and easy)

Calculator	Speed of assessment	Ease of use
AFD calculator	+++	++++
ALU	+	+
CALM	+++	+++
Carbon benefit project CPB	++	++
Carbon Calculator for NZ Agriculture and Horticulture	++++	++++
Carbon Farming Group Calculator	++++	++++
CFF Carbon Calculator	+++	++
Climagri®	+	+
Cool Farm Tool	+++	+++
CPLAN v2	+++	+++
Dia'terre®	+++	+
EX-ACT	++++	+++
FarmGAS	++	++
Farming Enterprise Calculator	++++	++++
FullCAM	+	+
Holos	++	+++
IFSC	++++	++
USAID FCC	++++	+++

Another essential criterion is the scope of the activity parameters: Thus it is of central interest whether a tool e.g. includes or excludes emissions from CH_4 and is able to take count of a high variety of agricultural management practices. The figure below illustrates exactly this difference in tools in not accounting for exactly the same activities and emission/sequestration sources.

Figure 29: Mean annual net GHG emissions for wheat sown on grassland in temperate conditions



This illustration highlights that differences in emission estimates are often problems of scope and not of disagreement concerning the scale of emissions of a clearly defined practice. Thus the figure above illustrates that the different tools roughly estimate similar scales of emissions when considering the same emission and sequestration sources.

The broad typology of GHG calculators illustrates thereby main challenges in landscape assessment. Up-scaling from farm scale to landscape assessment implies a change in data availability. At plot scale and farm scale, technical data are easily available and can be provided directly by farmers. At regional scale, data inventory often needs to be obtained from statistical data bases or expert knowledge, increasing uncertainties.

Accounting for wider time periods is especially important to consider soil and biomass carbon pools, with large quantities of CO_2 at stake. These pools are impacted by management and land use changes. In the future, assisting technologies such as e.g. Near Infra-Red Spectroscopy or remote sensing might enable for cheap direct measurement of the carbon stock changes. Further development of process based models and cheap direct measurement methods for GHG fluxes, linked with GHG calculators are required to improve assessments accuracy.

When assessing different GHG tools also the link between emissions by area and production quantities needs to be kept in mind in order to avoid leakage, i.e. an increase of emissions outside of studied perimeters induced by changes of production in the studied area. Permanency issues also need to be kept in mind: some reductions/increases of emissions are temporary, while others are continuous due to change in production systems. A very important point is that environmental/sustainability assessments cannot be restricted to GHG assessment and improvements of the GHG-balance must not be done ignoring possible drawbacks on other criteria (e.g. increase of pesticide use, water scarcity, reduced biodiversity etc.).

In highly productive systems, GHG assessments should focus on improving input efficiency per production. In low productive systems the focus should be stressed on agriculture resilience and food security, through improvement of agronomic practices. There are clear synergies between agronomic efficiency and a strengthened agro-ecology approach as related to Climate Smart Agriculture.

An important finding of this review is that adapted tools for each situation are already available, whereby links with socio-economic parameters are still missing and should be strengthened for integrated assessments. Further methodological standardisation, similar to the case of Life Cycle Assessment (LCA) methodologies which follows international standards (e.g. ISO 14040) could also contribute to more clarity and transparent references.

Summarizing, depending on the final aim of the user, each calculator tries to find the best compromise between user-friendliness, time consumption and result accuracy. As long as GHG assessments is mostly voluntary and limited economic return is expected (no CO_2 tax, no labelling etc.), cost and skill requirements for using GHG calculators should be limited. If more restrictive policies should be implemented, then method standardization and improved accuracy are essential.

ANNEX 8: Use of EX-ACT in Assessing Natural Resources Stock Changes

Projects that rehabilitate soil on degraded land within a watershed, engage in reforestation of degraded mountainous areas, reconstitute the watershed capacity and regulate water stream flow or that simply reduce deforestation and land degradation, produce a wide set of benefits distinct from their climate change mitigation achievements. Environmental resources and non-degraded natural capital may provide an important source for food security and income.

Within the growing emphasis of sustainable development towards a green economy, an applicable appraisal method to analyse project impacts on the state of natural capital becomes thus crucial, e.g. in the context of rural development, watershed and land use investment projects.

This annex proposes such a method that makes use of the natural resource indicators that are automatically accounted for in the standard version of EX-ACT. It allows establishing project impacts on quantity and quality of a series of natural resources (Cubic meters of biomass, tons of Soil Organic Carbon, hectares of restored land...). This method is currently used at a pilot level and is still under development. Its special focus lies on watershed projects and sustainable land management projects. It will be further upgraded in the forthcoming period.

Accounting and valuation framework of natural resources

Accounting and valuing environmental resources is promoted by the World Bank as part of a its work on operationalizing the System for Environmental and Economic Accounting (SEEA). The SEEA is an extension of the System of National Accounts (SNA) to account for 1) increasing scarcities of natural resources and 2) the degradation of environmental quality (Bartelmus et al. 1991). In 2003 the first edition of the SEEA was issued; while a revision was published in 2012 (European Commission et al. 2012).

Valuation frameworks of natural resources need to adequately fulfil three objectives: first they have to provide a clear categorization framework for natural resources, then resource stocks and stock changes have to be estimated by adequate methodologies, and finally these stocks have to be valued at adequate prices for a given context.

These three steps of *categorization*, *resource stock estimation* and *environmental valuation* thus form the basis of the here below outlined approach and will each be discussed subsequently. The time reference of the analysis will thereby, equally to other EX-ACT analyses, be 20 years, which is seen as the minimal timeframe that needs to be covered in order to capture major impacts of an intervention on natural resources, as well as the approximation of a new state of equilibrium.

It must be mentioned that such an environmental valuation of total natural resource stock changes is associated to the following problem: it is unclear whether the total amount of natural resources created will ever be valorised in their full amount and at current prices even though it is relevant to measure it e.g. how much additional timber has been created in total throughout the project, the valuation of the full amount of resources at current timber prices only allows for an indicative interpretation of its potential worth, while this amount will not translate into an equal income stream to project beneficiaries and resource users.

Increased natural resource stocks are understood as a natural form of capital that provide at a given point in time a specific set of functional environmental services as well as opportunities for remuneration on markets. Directly occurring income benefits, due to sustainable agricultural intensification measures, are adequately captured as part of the classical financial project analysis.

Environmental resources that are for a considerable timeframe neither processed nor transacted, but are intermediately conserved in their natural state; provide distinct, additional private and public values that need to be accounted for separately.

Natural resources thereby provide benefits either a) by continuously being in their natural form (e.g. yield increases due to higher SOM content on rehabilitated land), b) by creating a single revenue stream in a considerable distant future (e.g. timber harvest from newly planted forest) or c) by providing public values that do not generate income streams (e.g. climate change mitigation or stream regulation function of watersheds).

The multiple benefits of natural resources for the rural population can thus be structured into:

- **Direct private values**
  This concerns the benefits from self-consumption or sale (in a considerable distant future) of additional timber, fuel wood and NTFP. It thus concerns a direct private benefit to the household, in the form of monetary revenue, increased household consumption or supply of inputs regarding yield benefits of higher SOM contents through soil conservation practices, soil rehabilitation measures, composting, or the greater availability of fodder for livestock.

- **Indirect private values**
  This category subsumes functions of natural resources that are over a longer period or that benefit mainly annual and perennial cultures but also, any other entities that provide indirect private values. It thus concerns the indirect contribution to increases in monetary household revenue or in household consumption.

  It also regards the indirect benefits due to prevention of future erosion or drought stresses, through practices that limit the impact of erratic rainfall and dry periods on yields or measures that increase water availability and protect productive areas from flooding.

- **Public values**
  The mitigation of GHG emissions and increases in carbon sequestration provide an important public value by minimizing further climate change and limiting resulting damages and abatement costs to society. Other public values that are provided by natural resources include biodiversity conservation and habitat provision, through protected and conserved natural areas as well as watershed functions (such as stream regulation and flood protection for settlements and infrastructure).

In such a way evaluated project benefits that occur through investment in natural resources, will be put into relations with the direct financial project benefits as calculated by standard project documents.

Categorization of natural resources stocks

The here below given classification provides a structured framework to account for the changes in natural resource stocks. It was oriented in elements at the *System of Environmental-Economic Accounting* (EC, OECD, UN and WB, 2012) and, was later further adapted in order to capture the main natural resources of the pilot study conditions in Nepal. Currently only used as part of a first test study, the framework will still be revised in future applications and should not be regarded as a final product.

Table 7: Categorization of natural capital stock changes

	Natural Capital	Unit
	Direct private value	
A01	Incremental accumulated SOC on cultivated land (soil fertility)	t C
A02	Incremental stocks of non-timber biomass	t dm
	Fuelwood and -material	t dm
	Fodder	t dm
	Compost	t dm
A03	Incremental stocks of NTFP in forestry and agroforestry	
	Indirect private value	
A04	Incremental area with erosion protection	ha
A05	Incremental area with increased drought resilience	ha
A06	Incremental water volume stored (dams, ponds, water harvesting)	m3
A07	Incremental water volume saved by improved irrigation practices	m3
A08	Incremental flood protected area	ha
	Public value	
A09	Incremental timber stocks in forestry and agroforestry	t dm
A10	GHG-balance (reduced emissions and C sequestration)	t CO_2-e
A11	Incremental protected natural areas (forestry, peatland, wetland) (existence value)	ha
A12	Incremental new forest plantation (existence value)	ha

Estimation and valuation of natural resource stocks and stock changes

Estimations and accounting of natural resource stocks can be done by different means, either by linking to survey based national statistical datasets or, for certain variables, to GIS data.

In the case of the given study, we make use of the documentation produced by IFAD project implementation staff as part of their regular project activities in Nepal, as well as on estimations and assumptions of project coordinators, implementing staff and other interviewed stakeholders. In some cases, the thus procured data was used directly in the section below, while for selected variables it served as input data into EX-ACT, where changes in biomass or SOC were estimated using the established EX-ACT methodology. It should be clearly recognized that no statistically representative dataset could be procured as the basis of this study. Options to improve the data quality, as well as propositions to include data collection on relevant aspects of project monitoring in future projects are discussed in the last chapter of this document.

Besides accounting for the natural resource stock changes in physical units, the objective was also to value the occurring benefits. While the categorization of natural resources provided above can also be used in similar country contexts, the monetary valuation is necessarily context specific. All specifications on resource valuation and selected precisions on estimations of resource stock quantities follow here below by resource category[4].

A01 Incremental accumulated SOC on cultivated land (soil fertility)

The effect on soil fertility from increased Soil Organic Matter is one of the most central and direct co-benefits between climate change mitigation and agricultural productivity. The capacity of increased levels of soil organic matter to bind carbon (mitigation), to increase the capacity to store water (adaptation) and to

[4] Thereby in the following only those resource categories are listed and valued for which stock changes actually occured in at least one of the cases of the four projects. Other resource categories are left out.

increase soil fertility (food security) makes it a central founding element of the concept of Climate Smart Agriculture. Further benefits of increases in SOM content include “increased soil warming rates in temperate latitudes, reductions in energy required for tillage, enhanced soil tilth, ph buffering and, [possibly] disease suppression” (Wander & Nissen, 2003). Increased SOC levels are achieved by beneficial forms of land use change (e.g. involving land rehabilitation), the shift to adapted crop rotations as well as the use of reduced tillage and manure application.

In contrast to the A2 indicator, here we do not account for increased SOC due to incorporation of biomass. Also we do not consider the benefits of avoiding future losses of SOC due to erosion, which is accounted for separately in A4.

The considered projects mainly achieve higher levels of SOC by reversing land degradation processes and bringing already strongly eroded land with low SOC content again under cultivation. The valuation of these benefits of SOM is nevertheless difficult. Wander & Nissen (2003) propose to link the value generated by marginal increases in SOC either to reduced production costs or improved yields. For this purpose they propose to estimate the increase in nitrogen availability through mineralization per additional SOC. Thereby the strength of this relation depends on many context variables, such as the initial SOM content or the soil type and structure. Nevertheless, to allow for a rough estimation, Wander & Nissen calculate for a given set of context parameters that, per tonne of SOC, 0.8 kg of nitrogen is made annually available through mineralization (Wander & Nissen, 2003). In this light, household data from Nepal States, e.g. DAP fertilizer prices at 20.3 RS/kg (Agrifood, 2003, p. 141), translate into 113 RS (USD 1.48[5]) /kg N. Thus we arrive to a value of $1.18 USD/t of SOC, where if we discount the 1.18 over 20 years, generates a total value of USD 11.37.

A02 Incremental stocks of non-timber biomass

(Fuelwood and –material, Fodder & Compost)

An increased amount of biomass provides a set of various benefits for the territory in which it occurs. These benefits are composed of a) the additional amount of animal fodder from fodder trees, grasses and crop residues, b) the increased amount of organic biomass for compost production and incorporation into agricultural soil and c) the increased quantity of available fuelwood, crop residues and animal dung for heating purposes.

In the below calculation it was thereby assumed that of the additional biomass created through the project, 10% could be valued for energy production, 10% used for compost generation and 20% as animal fodder.

The price of fodder was estimated at 12.96 USD/t, it was done by executing barter games with rural peasants, surveying how many hours they would be willing to work in exchange for a fixed amount of tree fodder in different locations of Nepal (Kanel, et al., 2012). The price per t of biomass used for compost was estimated at 10.06 USD, converting the biomass into resulting SOC and valuing it with the method displayed under A01.

For fuel wood, Bajgain & Shakya (2005) reported prices at $27 USD/t in the Hills and 20 USD/t in Terai. On another note, WECs (2006) shows that in Kathmandu the price lies considerably higher at around $115 USD/t. With data from Baland et al. (2007), it is instead possible to roughly estimate the benefits of fuel wood based on an average collection time of 5 hours per head load of firewood, which we assume at 25kg. With the reported average opportunity costs of labour of 11.55 NR/h (ibd.) this would result in a worth of $27.18 USD/t of fuel wood. Seeing this relation of benefits and opportunity costs of fuel wood collection, we will assume a conservative average price of $10 USD/t of fuel wood in order to avoid overestimations.

For the other variables, we executed estimations of the associated costs for labour in order to arrive to a net worth of fuel wood, tree fodder and compost using the prices from Richards, et al. (1999).

[5] Prices and exchange rate from 2002.

A03 Incremental stocks of NTFP in forestry and agroforestry

Medicinal and aromatic plants; lokta paper; pine resin; katha, and sabai grass are important Non-Timber Forest Products in Nepal (Asia-Pacific Forestry Sector Outlook Study, 1997). Since the current study has been undertaken without intensive data from field surveys, the marginal difference in availability and use of NTFP due to project activities cannot be evaluated and is thus not accounted for in this study. Nevertheless NTFP can account for a considerable share of additional benefits and constitutes an important part of rural livelihoods in Nepal.

A04 Incremental area with erosion protection

Complementing A01, it also has to be accounted for the benefits from prevented future erosion. Due to the dominantly mountainous project areas with predominance of slopes, soil erosion is a major issue.

As we have lower uncertainty that a further decrease in SOC content is indeed prevented and that it has not yet taken place to a huge extend, here is accounted for benefits from active anti-erosive measures on productive land. In this regard, it is only the area that in light of the project, switches to soil conservation practises, which is studied.

For managed agricultural land, based on recent work (Upadhyay, et al., 2005), it would be correct to use an average soil erosion rate of 7.5 t/ha/y, though there can be strong variation observed due to slope, soil texture, rainfall intensity and timing of crop plantation. We will evaluate the benefits of preventing this average rate of soil erosion using a cost of USD1.32 per tonne of lost soil, as established by Acharya et al. (2010) in the context of community forests in Nepal. This leads to annual benefits of USD9.87 per hectare, which are equal to discounted benefits of USD 94.8 per ha over the full 20 years.

A09 Incremental timber stocks in forestry and agroforestry

Estimating average timber quantity per hectare is associated with certain imprecision, given the considerable variation of dominant tree types and densities in Nepal’s 35 major forest types and 118 ecosystems (MoF; FAO, 2009).

EX-ACT estimates the total increased biomass on forestry and agro forestry area, whereby the IPCC guidelines (IPCC, 2003) provide an estimate of the average Biomass Expansion Factor (BEF) for tropical broadleaf forest at 3.4, which allows to calculate for the average amount of timber per amount of biomass.

Timber prices vary strongly by species and quality of the wood. While Kanel et al. (2012) provides the detailed government fixed prices by species, length, girth and state of processing of the wood (round timber, sawn timber), Bhushal (2011) states that prices lie at RS 800 (USD 11.5) per cubic feet for Sal, Rs 1,000 (USD 14) for Shisham and ranged between Rs 300 (USD 4) to 500 (USD 7) for other type of wood. Since marketable quantities at the above mentioned relatively high prices are nevertheless strongly limited, we used a lower timber price derived from international markets lying at USD87.72[6] per t of timber.

Again, for timber extraction we subtracted estimated production costs in order to better approximate the net worth of timber.

A10 GHG-balance (reduced emissions and C sequestration)

The analysed four IFAD projects have at this project stage no possibilities to receive funding from carbon markets. Also for similar projects that would be initiated nowadays, current market circumstances offer only

[6] Comparing the European price (78 US$/m3) and US price (US$ 33/ m3) in the end of 2012, a conservative price of US$ 50/ m3 was chosen. Transformed in equivalents per tonne using a timber density of 0.57, it is 87.72 US$/t.”

very limited options of payments for carbon benefits. Mitigation of climate change can be considered a transfer of wealth from the present generation to future generations.

Thus, not representing an actual realized value flowing to a private actor, we try to value in this section the public benefits of the GHG-balance or more precisely, the avoided public costs from additional emissions and reduced sequestration. Such social costs of carbon can be estimated by integrated assessment models such as DICE or FUND, and are associated to high uncertainty on “(1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages” (Interagency Working Group on Social Cost of Carbon, 2010).

Results of integrated assessment models vary strongly. For the purpose of this study we will use the value established by the U.S. Interagency Working Group on Social Cost of Carbon lying at 21 USD per avoided tonne of carbon (ibd.).

A11, A12 Incremental protected natural areas and new forest plantation

Additional conserved natural forest, the conservation of peatlands and wetlands as well as additional plantation forest are by many societal actors also perceived as having a pure existence value, beyond the instrumental benefits they provide. One example of such cultural values of natural resources is the importance of forests for religious beliefs and practices in Nepal. While this study did not value such existence values in any way, their general importance is here shortly acknowledged.

Case study: Nepal Leasehold Forestry Livestock Programme

In fragile mountain ecosystems specific to the Himalayan region, land-use changes, forest and soil degradation add to strengthen greenhouse gas emissions. The research community converges to consider Nepal as an interesting choice for analysing the dynamics of land-use changes, forest and soil degradation and C sequestration processes due to its highly fragile ecosystem, coupled with one of the most serious problems of forest and soil degradation in the world (Upadhyay, et al., 2005).

The Leasehold Forestry and Livestock Programme (LFLP) covers the middle hills area, where a large percentage of the population is poor. It targets low income households in the 22 districts not covered by the ongoing IFAD Western Uplands Poverty Alleviation Project, with particular attention to those living in areas adjacent to degraded forest and to those facing strong difficulties to secure enough food for their families all year round. With a budget of 16 million US$ (2005-2013), it targeted 43, 000 households, and combined with the precedent leasehold project, the Hills Leasehold Forestry and Forage Development Project (HLFFDP, 1991-2003), it represents an aggregate of 50,678 household beneficiaries (aggregated budget of 31 million).

The LFLP strongly targets to increase the benefits of households by improving the natural resource base on which their agricultural livelihoods are based upon. This section tries to estimate physical quantities of natural resource stock changes and provides as well a careful attempt of valuing them monetarily in order to provide a rough estimation of their importance.

Table below applies the earlier presented natural resource estimation and valuation framework on the LFLP.

Table 8: Impact of the LFLP on natural resource stock changes

		Units	Quantity (units)	Economic price (US$)	Estimated total Value (US$)
Project:	LFLP	1 United States Dollar = 85.85 (02/05/2013)			
Nb farmers	50678				
Area	45145				
Duration:	21				
	Natural Capital				
Direct private value					
A01	Incremental accumulated SOC on cultivated land (soil fertility)	t C	106859	$11.37	$1,214,991
A02	Incremental stocks of non-timber biomass	t dm	653634	/	$8,636,386
	Fuelwood and -material	t dm	163409	$7.00	$1,143,860
	Fodder	t dm	326817	$18.74	$6,124,796
	Compost	t dm	163409	$8.37	$1,367,730
A03	Incremental stocks of NTFP in forestry and agro-forestry				$0
			Sum direct private value		**$9,851,377**
Indirect private value					
A04	Incremental area with erosion protection	ha	33360	$94.80	$3,162,515
A05	Incremental area with increased drought resilience	ha	7095	11.7	$83,011
A06	Incremental water volume stored (dams, ponds, water harvesting)	m3	/	/	
A07	Incremental water volume saved by improved irrigation practices	m3	/	/	
A08	Incremental flood protected area	ha	/	/	
			Sum indirect private value		**$3,245,525**
Public value					
A09	Incremental timber stocks in forestry and agro-forestry	t dm	230608	$87.72	$20,228,776
A10	GHG balance (reduced emissions and C sequestration)	t CO2-e	4333801	$21.00	$91,009,814
A11	Incremental protected natural areas (forestry, peatland, wetland) (existance value)	ha	/	/	
A12	Incremental new forest plantation (existance value)	ha	/	/	
			Sum public value		**$111,238,590**
	Total Natural capital				**$124,335,492.70**

Valuing natural resources is associated to various difficulties and uncertainties, such as type, quantity and time frame of their use, but also on the differing benefits from their existence, consumption or sale. Environmental valuation in contexts of limited markets and limited information is thus necessarily an approximate endeavour.

Since the above listed resources will neither be valorised at the indicated prices, nor in full quantities, one has to strictly specify that the indicated values may not be interpreted as income streams flowing to any agent. The value of the natural capital stock instead is an indication and illustration of the value of natural resources created by the project beyond purely physical accounting.

In such a way, the LFLP caused over the full period of the analysis an estimated increase in *SOC* by 106,859 t. Measured with the value of annually provided Nitrogen by mineralization on cultivated area, this is equivalent to a fertilizer value of appr. USD 1,2 million. The incremental *fuelwood* stock is assumed at 163,409 t of dry matter, equivalent to a value of appr. USD 1.1 million. The additional *animal fodder* accounts for 326,817 t of dry matter with a value of $6.1 million. The project induced amount of *compost* and crop residues incorporated in topsoil (mulching) accounts for a total amount of 163,409 t of dry matter that increases SOC and thus N availability to an extend equal to a fertilizer value of USD 1,4 mio.

The area brought under active *anti-erosive measures* accounts for 33,360 ha, equal to an additional value provision of USD 3,2 million. Similarly only a small area of 7,095 ha under the LFLP is concerned by a higher *drought resilience* (and concerns former annual cultures that were brought under agroforestry), equal to a value of USD 83,011.

Besides this, the LFLP creates 230,608 t of dry matter of *timber* with a value of USD 20.2 million. As provided by the EX-ACT accounting further above, the LFLP's benefits of 4.3 million tCO_2-e can be valued at 21 USD as the estimated global Social Cost of Carbon. In such a way the LFLP provided additional public benefits of USD 91 million. Besides the physical number in CO_2-e, this monetary evaluation further underlines the strong co-benefits of the project for *GHG mitigation*.

Focusing on the *overall impact* of the LFLP on natural capital, it accounts for a created value of USD 124 million. This is equal to an increased value of USD 2,754 per hectare over all the analyzed period of 21 years, or an annual value of USD 131 per hectare.

Considering the high values of both, the additional natural resources as well as the GHG benefits, and acknowledging the crucial need for further increases in private household incomes, a moderate payment for such environmental services is imaginable. It would comprehensively target the different objectives of increasing incentives to invest in the natural resource base, mitigating GHG emissions and establishing a cash transfer to rural households.

ANNEX 9: Detailed List of Data Possibilities in EX-ACT

Complementing the most central information in section Chapter 4, the table below provides a full list of data and parameters that can be accommodated by EX-ACT.

Following the cited main chapter on data needs, also the table at hand differentiates between those variables that make use of the Tier 1 approach that relates activity data to corresponding default coefficients. This is opposed to Tier 2 specifications that provide themselves regional specific values for carbon pools and emission factors.

Thereby EX-ACT allows for a combination of the Tier 1 and Tier 2 approch and most oftenly a dominant Tier 1 approach is complemented with as much Tier 2 data as available. Data is only required when the analyzed project impacts the topic area.

Table 9: Detailed list of data that can be accommodated in EX-ACT

Tier level	Project start	Project scenario & Baseline scenario
1) Land use change module		
Deforestation		
Tier 1	**Current forest type (ha)**	**Area subject to deforestation & type of land use after conversion (ha)**
		Amount of wood exported before conversion (t DM ha^{-1})
		Burning as form of conversion (yes/no)
		Time dynamic of conversion (linear, immediate, exponential)
Tier 2 (optional)	Specification of forest: • Above ground biomass (t dm ha^{-1}) • Below ground biomass (t dm ha^{-1}) • Soil carbon content (t C ha^{-1}) • Carbon stocks in litter and deadwood (t C ha^{-1}) • Specifications on forest combustion (Percentage of dm burnt; emission factors for CH_4 and N_20)	

Tier level	Project start	Project scenario & Baseline scenario
Afforestation and Reforestation		
Tier 1	**Current land use (ha)**	**Future forest type (ha)**
		Burning as form of conversion (yes/no)
		Time dynamic of conversion (linear, immediate, exponential)

Tier 2 (optional)		Specification of newly established forest: • Average growth rates during first 20 years for above and below ground biomass (t C ha^{-1}) • Growth rates after first 20 years (t C ha^{-1}) • Soil carbon content (t C ha^{-1}) Carbon stocks in litter and deadwood (t C ha^{-1})

Other land use change		
Tier1	Current land use (ha)	Future land use (ha)
		Burning as form of conversion (yes/no)
		Time dynamic of conversion (linear, immediate, exponential)

2) Crop production module

Annual systems		
Tier 1	**Current crop production (ha)**	**Future crop production (ha)**
	Existence of the specific crop management practices: Improved agronomic practices, nutrient management, no till/residue management, water management, manure application (yes/no)	=
	Crop yield (t ha^{-1} yr^{-1})	=
	Practicing of residue / biomass burning	=
		Time dynamic of crop shift (if applicable; linear, immediate, exponential)
Tier 2 (optional)	Rates of soil C sequestration (t C ha^{-1} yr^{-1})	=
	Residues/Biomass available for burning (t dm ha^{-1})	=

Perennial systems		
Tier 1	**Current crop production (ha)**	**Future crop production (ha)**
	Crop yield (t ha^{-1} yr^{-1})	=
	Practicing of residue / biomass burning	=
		Time dynamic of crop shift (if applicable; linear, immediate, exponential)
Tier 2 (optional)	Above and below ground biomass growth rate (t C ha^{-1} yr^{-1})	=

	Rates of soil C sequestration (t C ha^{-1} yr^{-1})	=
	Burning (Quantity of residues and periodicity)	=

Irrigated rice		
Tier1	**Current crop production (ha)**	**Future crop production (ha)**
	Specification of management practices: • **Intermittently flooded, continuously flooded, deepwater/rainfed** • **Flooded preseason, non-flooded preseason length shorter or longer than 180 days** • **Specify how organic amendments are managed (burning, incorporation, export)**	=
	Crop yield (t ha^{-1} yr^{-1})	=
		Time dynamic of crop shift (if applicable; linear, immediate, exponential)
Tier 2 (optional)	Rates of soil C sequestration (t C ha^{-1} yr^{-1})	=
	Quantity of straw burnt (t dm ha^{-1})	=

3) Grassland and livestock module

Grassland systems		
Tier 1	**Current grassland area (ha)**	**Future grassland area (ha)**
	State of grassland degradation (non-degraded, moderately degraded, severely degraded, improved with or without inputs)	=
	Grass yield (t ha^{-1} yr^{-1})	=
	Practicing and periodicity of grassland burning	=
		Time dynamic of grassland alteration (if applicable; linear, immediate, exponential)

Livestock systems		
Tier 1	**Current type and number of livestock**	**Future type and number of livestock**
	Production quantity of most central product (meat, milk etc.)	=
	Feeding practices: Percentage of herd size subject to improved feeding practices, use of dietary additives/specific agents,	=

	improved breeding practices	
		Time dynamic of shift in livestock numbers (if applicable; linear, immediate, exponential)
Tier 2 (optional)	Mean annual temperature (MAT) of the region (in °C)	
	Emission of N_2O from manure management (kg $N\text{-}N_2O$/kg N)	
	Emissions of CH_4 from manure management (kg CH_4 per head & yr)	
	Enteric fermentation (kg CH_4 per head & yr)	
	% feed corresponding to pasture range and paddock systems	

1) Land degradation module

Forest degradation

Tier 1	**Forest type (ha)**	
	Type of forest by state of degradation (non, very low, low, moderate, large, extreme)	=
		Occurrence, periodicity and impact of fire
		Time dynamic of shift in state of degradation
Tier 2 (optional)	Degradation level (in % of biomass lost)	
	Specification of forest: • Above ground biomass (t dm ha^{-1}) • Below ground biomass (t dm ha^{-1}) • Soil carbon content (t C ha^{-1}) • Carbon stocks in litter and deadwood (t C ha^{-1})	

Degradation of organic soils (peatlands)

Tier 1		Vegetation type and area concerned by drainage of organic soils
		Area effected by peat extraction (nutrient rich / poor)
		Time dynamic of drainage or peat extraction
Tier 2 (optional)		Emissions factor for loss of C associated with drainage of organic soils (t C ha^{-1} yr^{-1})

		On-site CO_2 and N_2O emissions from active peat extraction (t C ha^{-1} yr^{-1}, kg N_2O-N ha^{-1} yr^{-1})

2) Inputs & investments module

Inputs		
Tier 1	**Quantity of fertilizer, pesticides, liming applied by type (in total tonnenes of nutrients per year)**	=
		Time dynamic of change in quantities of agricultural inputs
Tier 2 (optional)	CO_2 and N_20 emission factors from direct applications and indirect emissions	

Energy consumption		
Tier 1	**Quantity of electricity, liquid or gaseous fuel, and wood consumed by type**	=
Tier 2 (optional)	Emission factors by type of energy source	

Building of infrastructure		
Tier1		**Type and amount of irrigation infrastructure installed (ha)**
		Type and size of building constructed (m^2)
		Time dynamic of construction of irrigation infrastructure and buildings
Tier 2 (optional)		Emission factor (t CO_2/m^2)