Food and Agriculture Organization
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Ex-Ante Carbon-balance Tool for coastal wetlands, fisheries and aquaculture management

GUIDELINES

EX-ANTE CARBON-BALANCE TOOL EX-ACT

Ex-Ante Carbon-balance Tool for coastal wetlands, fisheries and aquaculture management

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© FAO/R. Grisolia: mangrove forest in a nature reserve
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©FAO/F. Botts: China, casting nets into man-made fish ponds
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Acronyms

AFOLU	Agriculture, Forestry and Other Land Uses
C	Carbon
CH_4	Methane
CO_2	Carbon dioxide
CO_2-e	CO_2 equivalent
EX-ACT	EX-Ante Carbon-balance Tool
FAO	Food and Agriculture Organization of the United Nations
FUI	Fuel Use Intensity
GHG	Greenhouse gas
ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
N_2O	Nitrous oxide
tCO_2-e	Tonne of CO_2 equivalent

Executive summary

The Ex-Ante Carbon-balance Tool (EX-ACT) is an appraisal system developed by FAO that provides ex-ante estimates of the impact of agriculture and forestry development projects, programs and policies on the carbon (C) balance. The carbon-balance is defined as the net balance from all greenhouse gases (GHGs), expressed in CO_2 equivalent (CO_2-e), that were emitted or sequestered due to project implementation, as compared to a business-as-usual scenario. EX-ACT was originally 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 tonne of CO_2 per hectare and year. The tool helps project designers to estimate and prioritize project activities that offer high benefits for economic and climate change mitigation. The amount of GHG mitigation may also be used as part of economic analyses and in the application of funding to additional project components. EX-ACT can be applied to a wide range of development projects from all agriculture, forestry and other land use (AFOLU) sub-sectors, including projects on climate change mitigation, watershed development, production intensification, food security, livestock, forest management or land use change, as well as to management activities in coastal wetlands, and in the fisheries and aquaculture sector. Furthermore, it is cost effective, requires a relatively small amount of data, and includes resources (tables, maps) which help in finding the required information. While EXACT is mostly used at the project level it can easily be scaled-up for use at the program/sector level and for policy analysis. This manual provides all essential information on the methodology, application and utilization of EX-ACT and prepares the reader for independent use of the tool. 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.

Users not familiar with the EX-ACT tool are advised to consult the quick guidance for an overview and description of methodology (Section B Quick Guidance for Tool Users). For more comprehensive details they can also refer to the EX-ACT User manual and to the EX-Ante Carbon-balance Tool, technical guidelines (Bernoux et al., 2017) for details on calculations.

1. Introduction

This manual explains how to use the EX-Ante Carbon-balance Tool, known as "EX-ACT", to estimate the impacts of management activities in **coastal wetlands**, **aquaculture** and **fisheries** on the GHG balance of projects. EX-ACT enables investment planners to design program activities that target high return outcomes, in terms of climate change mitigation, and is intended to complement conventional ex-ante economic analyses.

1.1. Background

Marine and coastal ecosystems are increasingly being degraded or destroyed by human activities. Pollution of coastal and marine waters, eutrophication, harmful algal bloom and over-fishing are just some of the numerous threats to marine ecosystems. Climate change is also expected to add cumulative or synergistic impacts on marine ecosystems, aquaculture and fisheries, and therefore on food security and livelihoods as well (Cochrane *et al.*, 2009; Shelton, 2014; Gattuso *et al.*, 2015). Rising sea levels are affecting low lying areas and islands most severely, increasing the risk of groundwater contamination and salt water intrusion in deltaic fish-farming (De Silva and Soto, 2009; Wong *et al.*, 2014). Ocean and atmospheric temperature changes are affecting the distribution of marine and freshwater species, fish and mollusc physiological processes, and altering the food webs. These demand changes in fishing operations, aquaculture practices and livelihoods strategies (Cochrane *et al.*, 2009; Gazeau *et al.*, 2014). CO_2 uptake in the oceans is increasing ocean acidity (lowering pH) and reducing the saturation state of carbonate minerals essential for the shell and skeletal formation of many coastal species (shellfish, molluscs, corals, etc.) which impacts species dependent on them at higher trophic levels (Gazeau *et al.*, 2013; Gattuso *et al.*, 2014). Indeed, eutrophication might locally increase the susceptibility of coastal waters to ocean acidification as, for instance, the excess organic matter produced in algal blooms subsequently undergoes microbial respiration, adding CO_2 and decreasing the pH of local waters (Cai *et al.*, 2011).

Coastal waters, on the boundary between the land, the open ocean and the atmosphere, are some of the most biogeochemically active areas in the world, receiving carbon and nutrient inputs from the land and exchanging flow and materials with the open ocean via the continental shelf. Tidal marshes, mangroves and seagrass meadows are major coastal ecosystems that provide a wide variety of regulating, provisioning, supporting and cultural services. These services include carbon cycling, fishery resources, nursery grounds for coastal fish and crustaceans, improvement of water quality, protection from storms, stabilization of the shoreline and provision of revenues for local communities from tourism activities (FAO, 2007, de Groot *et al.*, 2012). Despite this, vegetated coastal ecosystems are also highly vulnerable and have already been altered by anthropogenic activities. Current conversion rates range from 0.7 percent to 3 percent per year (Pendelton *et al.*, 2012). Globally, mangroves have lost 35 percent of their coverage, and seagrasses 29 percent (Valiela *et al.*, 2001; Waycott *et al.*, 2009). Drivers of their loss include aquaculture, conversion to shrimp ponds and fishery activities, e.g. in Southeast Asia (Béland et *al.*, 2006; Binh et *al.*, 1997; Primavera 1995). In West Africa, 40 percent of mangrove degradation originates from fishery post-production processes and fish smoking. Industrial pollution, urban, coastal and tourism development, over-harvesting for fuelwood and timber extraction, land clearing for agriculture and conversion to rice fields, and climate change are also strongly implicated in the loss of coastal ecosystems (Gilman *et al.*, 2008; Giri *et al.*, 2008; Waycott *et al.*, 2009; Ajonina *et al.*, 2014).

1.2. What is the blue carbon?

Coastal ecosystems have a natural capacity to sequester organic carbon, termed "blue carbon", within the soil, the above and below-ground living biomass, litter and dead wood (Herr *et al.*, 2011). Tidal marshes, mangroves and seagrass meadows have been named as blue forest ecosystems (Nellemann *et al.*, 2009). Unlike their terrestrial counterpart, blue forest ecosystems are highly efficient at storing and sequestering carbon in their soil. Their high rates of primary production and trapping of organic matter lead to the accumulation of carbon in the soil. The occurrence of tidal inundation or presence of a permanent water table subsequently limits the aerobic microbial degradation of the organic matter. Thus carbon can accumulate over millennia in the soil compartment of these ecosystems, and they continue to accrete vertically with sea level rise as long as they are not disturbed (McKee *et al.*, 2007). These coastal wetlands are often extremely rich in organic carbon and contain up to five times more carbon in their soil than tropical forests (Chmura *et al.*, 2003; Alongi, 2014).

Along with the wide range of ecosystems services they provide, their capacity to store and sequester carbon make coastal ecosystems exceedingly important for both climate mitigation and conservation. When coastal ecosystems are disturbed, degraded or converted, the carbon (C) stock in the biomass and soil is exposed to oxygen and the microbiological activity releases GHGs to the atmosphere or the water column. If the current degradation rate continues all unprotected mangroves could be lost within 100 years, with the release of carbon dioxide (CO_2) adding another 10 percent to carbon emissions from tropical deforestation (Pendelton *et al.*, 2012; Alongi and Mukhopadhyay, 2014). Conservation and restoration of these coastal ecosystems is then important for the maintenance of coastal biodiversity, coastal protection, community livelihoods and climate change mitigation.

1.3.Fisheries and aquaculture

Fisheries and aquaculture contribute to global GHG emissions during the fish capture/fish-farming, processing, transportation and storage stages. Energy consumption in the fishery sector depends on many factors, such as the structure and size of the vessel, the fishing gears used, the target species and their migration routes, the processing, cooling, packaging and transport (Muir, 2012; Basurko *et al.*, 2013; Ghosh *et al.*, 2014). During fish capture direct fuel energy input accounts for a share of 75-90 percent of total energy inputs to the sector, regardless of the fishing gear used or the targeted species (Guldbrandsen, 1986; Tyedmers, 2004). This direct energy is primarily used for vessel propulsion, but in some particular cases can include on-board processes like refrigeration and freezing. The remaining 10-25 percent derive from electricity for ice production ashore and embodied energy for the vessel construction and maintenance, fishing gears and baits (Tyedmers, 2004). The global fishing fleet uses about 40 million tonnes of fuel per annum, which generates 100 million tonnes of CO_2. Thus for global fisheries the median fuel use intensity (FUI), i.e. the fuel consumed per tonne of fish landed, is 639 litres per tonne (Parker and Tyedmers, 2014).

While the carbon footprint in fisheries is generally dominated by the fuel use, in aquaculture (fish-farming) the system is more complex. In aquaculture, fish feed is typically the most dominant factor in GHGs emissions, though low to high fuel/energy inputs (e.g. from extensive to intensive ponds, respectively) also contribute (Winther *et al.*, 2009). N_2O emissions derive from protein catabolism in the fish, with excretion of ammonia (NH_3) and its subsequent conversion to N_2O via nitrification and denitrification by microorganisms in the environment (Hu *et al.*, 2012). CO_2 is mainly released during generator use for aeration systems, temperature regulation, water circulation, manufacturing of feeds (in which fishmeal and fish oil are still important parts), or from energy used in post-production processes (Avadi *et al.*, 2014; Fréon *et al.*, 2016). In freshwater farming systems, a substantial amount of methane (CH_4) can be released from aquaculture ponds during waterlogging stages and the flooding period. In aquaculture, particularly in inland aquaculture wetlands, CH_4 emissions depend on numerous parameters such as temperature, oxygen, chemical oxygen demand, sediment carbon availability and aquatic vegetation (Liu *et al.*, 2015).

Environmental degradation, habitat destruction, loss of biodiversity, overexploitation of fish stocks, fleet overcapacity and loss of post-production processes all contribute to the unsustainable exploitation of the marine and freshwater ecosystems. Fisheries and aquaculture do not emit as many GHGs as agriculture, forestry or other land use (AFOLU) sector activities, but some mitigation strategies such as improving fuel efficiency by switching to more efficient gear types or vessels, switching to sails, changing fishing practices and lowering feed conversion ratios in aquaculture would reduce emissions from fishing and farming activities and could decrease damage to aquatic environments (Gulbrandsen, 1986; Suuronen *et al.*, 2012; Shelton, 2014). Moreover it has been highlighted recently that marine vertebrates (fish, mammals and turtles) might be active actors in the marine carbon cycle, either in carbon sequestration and/or protection against ocean acidification, as well as in safeguarding blue carbon stocks in coastal ecosystems, if fish stocks are kept intact (Lutz and Martin, 2014; Atwood *et al.*, 2015).

Therefore restoration/rehabilitation and conservation of coastal wetlands and adoption of less energy consuming management practices in the fisheries and aquaculture sector should have significant benefits for ecosystem services, social and economic aspects and climate change mitigation.

1.4.Why developing a blue carbon, fisheries and aquaculture modules in EX-ACT?

EX-ACT was first designed for terrestrial ecosystems to provide ex-ante estimations of the impact of agriculture and forestry development projects on GHG emissions and carbon sequestration, indicating its effects on the carbon balance. It was developed using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and other methodologies (for further details refer to Bernoux *et al.*, 2017). In 2013 the IPCC drafted a methodological guidance, the 2013 Wetlands supplement to the 2006 Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC, 2014) for estimating anthropogenic emissions/removals of GHGs from wetlands and drained soils. Chapter 4 of the IPCC 2014 focuses on mangroves, tidal marshes and seagrasses. This gives adapted default values and provides guidance on estimating emissions/removals of GHGs (CO_2, N_2O and CH_4) associated with specific activities on managed coastal wetlands, which may or may not result from land use change. These activities concern extraction and drainage of soil, and the processes of restoration and revegetation within these three coastal ecosystems.

These default data provide new or improved values for estimating the effect of land-use change on coastal ecosystems. For example, the new default values are important for estimating C stock changes in mangroves

(Kauffman and Donato, 2012) because the IPCC 2006 default values (Tier 1) may have an error range of 50 percent for the aboveground pool and up to 90 percent for the soil carbon pool of mangrove forests. The guidance and default data for emission factors and carbon content in the different pools, provided by the coastal wetlands chapter, are integrated into EX-ACT as a new module. Another new EX-ACT module specific to the fishery and aquaculture sectors includes emission factors for carbon emissions/removals from the fishery sector. These are based on *ad hoc* scientific literature and emission factors for coastal wetlands-based aquaculture. Methodology, the structure of EX-ACT and results from the blue carbon, fisheries and aquaculture modules are detailed in the "EX-ACT technical Guidelines"

2. Overview of data requirements

In this section the reader is provided with concrete specifications of the data requirements for coastal wetlands, fisheries and aquaculture in EX-ACT (Table 2). It is split between information that is largely compulsory for an EX-ACT module and information that is optional and may lead to higher degrees of precision in the analysis. This reflects the difference between using the Tier 1 coefficients provided by the IPCC 2006 and IPCC 2014 as opposed to providing regional specific values for biomass densities per hectare or carbon content in soil, for example. The extent to which a user attempts to procure location specific data may follow the level of precision chosen for other parts of the project analysis and should be aligned with the initial reasons for engaging in the carbon-balance appraisal.

Tier 2 data concern location specific variables that offer specifications on the carbon content and stock changes in all five carbon pools, as well as the emission factors for selected practices. All Tier 2 data requirements that can be accommodated in EX-ACT are fully listed in the annex of the *User Manual*. The present manual lists Tier 2 data requirements for blue carbon, fisheries and aquaculture in their respective chapters.

Collection of Tier 2 data is especially advised for core project components that are expected to be stronger sources or sinks of GHGs. This will result in a balanced mix of Tier 1 and Tier 2 data. However, data collection for Tier 2 variables is often difficult and time-consuming, so it will never be possible to collect Tier 2 information for all variables in conventional project planning.

The Blue carbon and Fisheries and Aquaculture modules are detailed in the next few chapters. The following sections describe some unique features which can be of use when analysing a blue carbon and/or fisheries and aquaculture project. Users should consult the *User Manual* and the *EX-ACT Technical guidelines* for a better understanding of the tool and its methods and calculations.

Table 1: Modules to be used according to the project profile

What module is appropriate for the type of project proposed?		Modules (*and associated sub-modules*) to be used:
All project types	Specific positive or negative effects that occur with or without the project *Go to* →	
	IF **mangrove biomass removal** without any change on the soil ○ Harvest, wood removal, fuelwood removal, charcoal production, etc.	Land Use Change (*Deforestation*)
	IF **Management practices in Mangrove degradation**, i.e. The degradation level of the mangroves will be positively or negatively affected by the project. In both cases the soil is not drained.	Management & degradation (*Forest degradation and management*)
	IF Burning or improved techniques for burning fewer **harvest wood products**	Inputs and Investments
	IF **Extraction** of coastal wetlands soil ○ For excavation to urban and marine development constructions (harbours, marinas, etcs) ○ For dredging to raise the elevation of land ○ For construction of aquaculture ponds and salt production	Coastal Wetlands (*extraction and excavation*)
	IF **Drainage** of tidal marshes or mangrove soil ○ For agriculture, forestry, mosquito control	Coastal Wetlands (*drainage*)
	IF **Rewetting** of coastal ecosystems, i.e. restoration of the hydrology on drained site and additional reseeding or replanting	Coastal Wetlands (*rewetting*)
	IF **Fish farming systems** in coastal wetland ponds	Fisheries and Aquaculture (*Aquaculture*)
	IF Aquaculture management with inputs ○ Pesticides, herbicides, lime, fertilizers	Inputs and Investments
	IF **Fisheries management** with ○ Fuel use during harvest ○ Ice production for preservation of catch ○ On-board refrigerant for preservation of catch	Fisheries and Aquaculture (*Fisheries*)
	IF Energy consumption for ice production ashore, for motors for pumps and aeration systems in aquaculture, for fuel for transport	Inputs and Investments
	IF Investment in buildings, roads, storages	Inputs and Investments

Table 2 : Overview of Tier 1 activity data that can be accommodated in EX-ACT

Obligatory	**Description module**	
	- Sub-continent - Type of climate - Moisture regime	- Dominant regional soil type[1] - Project duration
	Land use change module	
Only if project related	Deforestation : - area of mangrove deforested - quantity of harvested wood product	- Final land use after converion - Burning during conversion.
	Coastal wetlands mdule	
	- Wetland type and area concerned by extraction and/or drainage - Wetland type and area concerned by rewetting (restoration) and % of nominal biomass restored	
	Management and degradation module	
	Forest degradation and management Dynamics of mangrove degradation (positive or negative), magnitude and surface area	
	Fishery and aquaculture module	
	Fishery	
	Fishery category, gear-type, and catch data	Proportion of catch preserved on board with refrigerant systems Proportion of catch preserved on ice produced ashore and brought on board
	Aquaculture	
	Fish production	Feed carbon footprint and annual quantity
	Inputs and investments module	
	Agricultural inputs : Annual quantity by type	
	Energy consumption : annual quantity of electricity, liqui and gaseous fuel, and wood consumed	
	Building and infrastructures: size of area for irrigation infrastructure, buildings, roads… (by type)	

2.1.Description module

EX-ACT users must first fill in the description module. This encompasses information such as the name of the project, the duration of implementation and the capitalization phase and the most important agro-ecological variables (of those listed in Table 2). These pieces of information are mandatory, even for fisheries and aquaculture projects, as they set the Tier 1 data specifications used for the calculations in the different EX-ACT modules. All Tier 1 data can be refined at a Tier 2 level.

Soil information provided in the description module sets the default values for soil organic carbon stocks in mineral soils down to a depth of 30 cm. In the case of coastal ecosystems these values are only of use in the *deforestation* module and the *forest degradation and management* module. The coastal wetlands module uses specific soil carbon stocks down to a depth of 1 m (refer to the *EX-ACT technical guidelines* for methods). The dominant soil type should be the one representative of the adjacent land mass, as shown in the map from the help module in EX-ACT, as the coastal wetland is not a soil category recognised by the IPCC.

The climate domain "subtropical" for mangroves, as specified in the IPCC 2014, is included under the "temperate" domain in the EX-ACT terminology.

2.2.Land use change – Deforestation module

This module concerns **only deforestation of mangroves** with no further activities such as extraction or drainage that are accounted for directly in the coastal wetland module (cf. below). In the *deforestation* module, the areas required are:

[1] Users should choose the soil type of the adjacent land mass for coastal wetlands projects.

the area at the start, the areas during the with and without-project scenarios and the subsequent use of the area following deforestation (i.e. set aside or degraded).

Data can be refined (at Tier 2) for above and below-ground biomass, dead organic matter and litter carbon stock, and soil carbon content (down to a depth of 30 cm).

2.3. Management and degradation module – mangrove management practices

This module concerns management activities that will result in a change, either positive or negative, in the degradation level of mangroves. It is assumed that the soil is undrained and already covered in vegetation. This module is used to determine carbon stock changes following different levels of degradation or restoration between the situation at the start of the project, and the without and with-project scenarios. In this module, only the surface area covered by mangroves, the degradation level at the initial state and the without and with-project scenarios are required. Data can be refined (at Tier 2) for above and below-ground biomass, dead organic matter and litter carbon stock, and soil carbon content (down to a depth of 30 cm).

3. Coastal wetlands module

The Coastal wetlands module covers issues relating to management of coastal wetlands, including extraction/excavation of soil with removal of the above-ground biomass, drainage, rewetting (restoration of the hydrology or water quality of a drained soil and additional replanting).

3.1. Extraction – excavation and/or drainage activities

For both of these activities, users must specify the area of concern at the start of the project (the baseline scenario) and the percentage area undergoing extraction/excavation in the without and with-project scenarios (inputted in the "Extraction and Excavation" sub-module). This information will set the remaining area available for drainage activities

1 (as a percentage of the surface area at the start of the project as entered in the extraction/excavation sub-module).

When using the extraction/excavation and/or drainage sub-modules, the following information will be needed:

2 **The area of concern for Extraction <u>and</u> Drainage** at the start of the project (the baseline scenario) and the percentage of surface area in the without and with-project scenarios undergoing extraction/excavation and/or drainage.

3 **The percentage of the project's surface area undergoing extraction/excavation** for the with and without-project scenarios. This will set the surface area remaining for drainage activities (indicated in the red circle in Screenshot 1).

4 **The percentage of the project's surface area concerned with drainage activities** at the start of the project, and the percentage area undergoing drainage in the with and without-project scenarios.

Dynamics of change: in case of any changes in the surface area between the with and without-project scenarios. The dynamics of these parameters can be specified as occurring either linearly (default), immediately or exponentially.

Figure 1 : EX-ACT screenshot for extracti[2]nd drainage activities – management of coastal wetlands module

6.1. Management of coastal wetlands (Mangroves, [2]dal marshes and Seagrass meadow)

6.1.1. Extraction and Excavation [1] constuction, construction of aquaculture or salt production ponds,...) (this corresponds to deforestation of mangroves and

Type of vegetation	Area (ha) Start	% excavated Without	% excavated With	Area excavated (ha) Without	Area excavated (ha) With	Maximum area available for drainage Start	Maximum area available for drainage Without	Maximum area available for drainage With
Mangrove	100	0%	30%	0	30	100	100	70
Tidal marsh	0	0%	0%	0	0	0	0	0
Seagrass meadow	0	0%	0%	0	0	0	0	0

Total for extraction and excavation

6.1.2. Drainage [3] [4]

Type of vegetation	% drained Start	% drained Without		% drained With		Area drained (ha) Start	Area drained (ha) Without	Area drained (ha) With
Mangrove	0%	100%	D	50%	D	0	100	35
Tidal marsh	0%	0%	D	0%	D	0	0	0
Seagrass meadow	0%	0%	D	0%	D	0	0	0

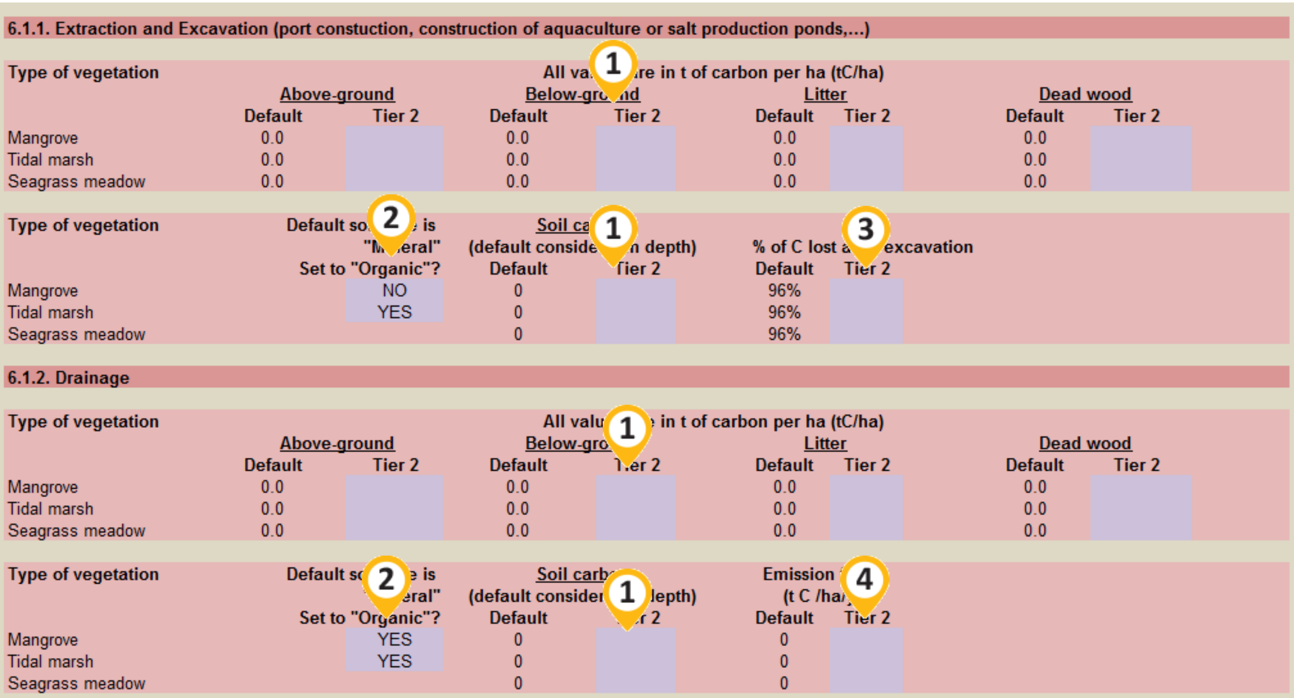
* Note concerning dynamics of change : "D" corresponds to default/linear, "I" to immediate and "E" to exponential (Please

Tier 2 options for extraction and drainage

Estimations can be refined (Tier 2) by entering specific coefficients of the following (also shown in Screenshot 2 below):

- The specification of the coastal ecosystems with :
  - Above-ground carbon content (tC ha^{-1})
  - Below-ground carbon content (tC ha^{-1})
  - Carbon stocks in the litter and deadwood (tC ha^{-1})
  - The soil carbon content (tC ha^{-1})
- The default soil type – mineral or organic. If it is not known whether the soil is organic or mineral the aggregated value can be used, which is the mean of the carbon stock between the mineral soil and the organic soil (e.g. 378.5 tC ha^{-1} for mangroves).
- The percentage of carbon lost after excavation:
  In mangrove carbon stocks 4 percent is considered refractory. This is also the default value for tidal marsh and seagrass meadow ecosystems.
- The emission factor for loss of C due to drainage of the soil (t C ha^{-1} yr^{-1})

Figure 2 : EX-ACT screenshot extraction and drainage – tier 2.



6.1.1. Extraction and Excavation (port constuction, construction of aquaculture or salt production ponds,...)

Type of vegetation	Above-ground Default	Above-ground Tier 2	Below-ground Default	Below-ground Tier 2	Litter Default	Litter Tier 2	Dead wood Default	Dead wood Tier 2
Mangrove	0.0		0.0		0.0		0.0	
Tidal marsh	0.0		0.0		0.0		0.0	
Seagrass meadow	0.0		0.0		0.0		0.0	

Type of vegetation	Default soil type is "Mineral" Set to "Organic"?	Soil carbon (default considered depth) Default	Tier 2	% of C lost after excavation Default	Tier 2
Mangrove	NO	0		96%	
Tidal marsh	YES	0		96%	
Seagrass meadow		0		96%	

6.1.2. Drainage

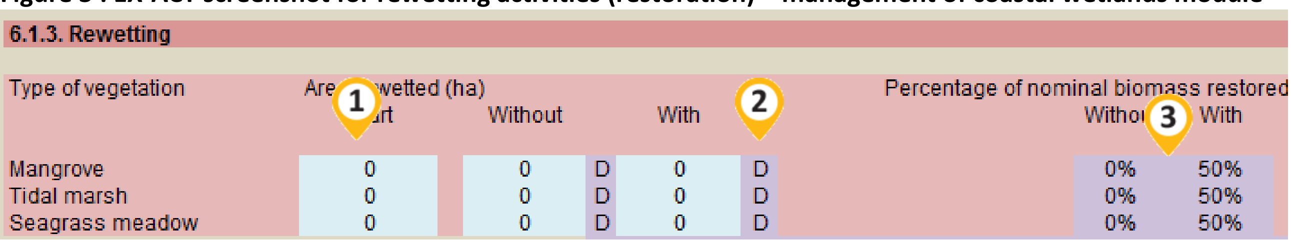
Type of vegetation	Above-ground Default	Above-ground Tier 2	Below-ground Default	Below-ground Tier 2	Litter Default	Litter Tier 2	Dead wood Default	Dead wood Tier 2
Mangrove	0.0		0.0		0.0		0.0	
Tidal marsh	0.0		0.0		0.0		0.0	
Seagrass meadow	0.0		0.0		0.0		0.0	

Type of vegetation	Default soil type is "Mineral" Set to "Organic"?	Soil carbon (default considered depth) Default	Tier 2	Emission (t C /ha/yr) Default	Tier 2
Mangrove	YES	0		0	
Tidal marsh	YES	0		0	
Seagrass meadow		0		0	

3.2.Restoration and revegetation (rewetting)

When using the rewetting component (the restoration of the hydrology or water quality of a drained soil and additional replanting), the following information will be needed:

Figure 3 : EX-ACT screenshot for rewetting activities (restoration) – management of coastal wetlands module



6.1.3. Rewetting

Type of vegetation	Area rewetted (ha) Start	Without		With		Percentage of nominal biomass restored Without	With
Mangrove	0	0	D	0	D	0%	50%
Tidal marsh	0	0	D	0	D	0%	50%
Seagrass meadow	0	0	D	0	D	0%	50%

1 **The area of concern**: at the start of the project (the baseline scenario), and the area concerned for with and without the project.

2 **Dynamics of change**: in case of changes to the surface area between the with and without-project scenarios. The dynamics of these parameters can be specified as occurring either linearly (default), immediately or exponentially.

3 **The percentage of biomass gained due to rewetting**: for the start of the project and for the with and without project scenarios.

Tier 2 options for restoration and revegetation

Users can refine their results using Tier 2 data. The variables that can be specified by location specific coefficients in the *Rewetting* section are the following (see also Screenshot 4 below):

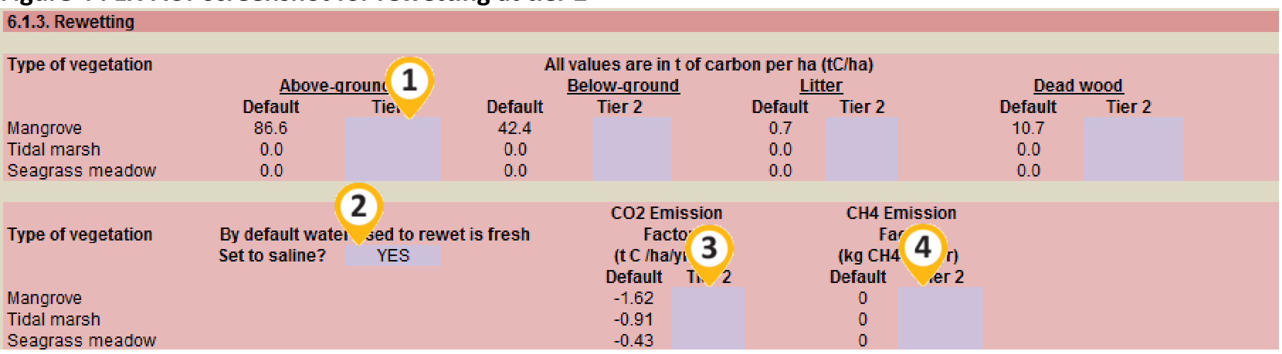
1 • The specification of the coastal ecosystems in terms of:
  - Above-ground carbon content (t C ha^{-1})
  - Below-ground carbon content (t C ha^{-1})
  - Carbon stocks in the litter and deadwood (t C ha^{-1})

2 • The salinity of the water used for hydrology restoration, set by default to saline. Users can choose to set it up to brackish water (i.e. waters with a salinity lower than 18).

3 • The emission factor of CO_2 associated with rewetting in the soil (t C ha^{-1} yr^{-1}).

4 • The emission factor of CH_4 associated with rewetting in the soil (kg CH_4 ha^{-1} yr^{-1}), independent of the salinity.

Figure 4 : EX-ACT screenshot for rewetting at tier 2



6.1.3. Rewetting

All values are in t of carbon per ha (tC/ha)

Type of vegetation	Above-ground Default	Above-ground Tier 2	Below-ground Default	Below-ground Tier 2	Litter Default	Litter Tier 2	Dead wood Default	Dead wood Tier 2
Mangrove	86.6		42.4		0.7		10.7	
Tidal marsh	0.0		0.0		0.0		0.0	
Seagrass meadow	0.0		0.0		0.0		0.0	

By default water used to rewet is fresh
Set to saline? YES

Type of vegetation	CO2 Emission Factor (t C /ha/yr) Default	Tier 2	CH4 Emission Factor (kg CH4/ha/yr) Default	Tier 2
Mangrove	-1.62		0	
Tidal marsh	-0.91		0	
Seagrass meadow	-0.43		0	

Case Study (a real project): Mangrove rehabilitation with restoration of the hydrology in the Gulf of Gujarat, India

This project aimed to conserve and protect coastal resources (i.e. mangroves, seagrasses and coral reefs) in the Gulf of Gujarat in India. Its activities included restoration of mangroves (16,100 ha), shelterbelt plantation with casuarina trees (1 500 ha), transplantation and regeneration of coral reefs, construction and/or up-grading of waste and sewage treatment plants.

As mangroves and shelterbelt plantations are proposed in areas that have not been forested for a long period of time, we use the afforestation module for the shelterbelt plantation and the rewetting module for mangrove plantation. Without intervention of the project, areas would have remained degraded and devoid of vegetation. With the various activities within the project we assume that of the 16 100 ha of replanted mangrove, 80 percent will be covered in biomass by the end of the project. This is shown in the screenshot below.

6.1.3. Rewetting

Type of vegetation	Area rewetted (ha) Start	Without		With		Percentage of nominal biomass restored Without	With
Mangrove	0	0	D	16100	D	0%	80%
Tidal marsh	0	0	D	0	D	0%	50%
Seagrass meadow	0	0	D	0	D	0%	50%

The following tables summarize the GHG sequestration and the share of the balance per GHG from the above project. Results are given in tonnes CO_2 equivalent (tCO_2-e). Positive numbers represent sources of CO_2-e emissions while negative numbers represent sinks. In the table below, the Gross fluxes section on the left-hand side summarizes estimated CO_2-e emissions and sinks from the scenario without the project (left column), from the scenario with the project (middle column) and the total balance (right column). The middle table details the Carbon Balance under project implementation, showing the CO_2 fluxes from biomass and soil carbon fluxes. The right table details annual CO_2-e fluxes for the different activities with and without project implementation.

In terms of climate mitigation, restoration of mangroves and shelterbelt plantations on about 18 000 ha of land represent a potential net carbon sequestration of -5 million tCO_2-e over 20 years (six years for implementation and 14 years for capitalization). This equates to -14 tCO_2-e yr^{-1} ha^{-1} (left-hand table below). The biomass and soil pools account for -3.6 million tCO_2-e and -1.3 million tCO_2-e of sequestered carbon, respectively.

Components of the project	Gross fluxes (All GHG in tCO2eq; Positive = source / negative = sink) Without	With	Balance	Share per GHG of the Balance (All GHG in tCO2eq) CO_2 Biomass	Soil	Other	N_2O	CH_4	Result per year Without	With	Balance
Land use changes											
Deforestation	0	0	0	0	0		0	0	0	0	0
Afforestation	0	-553,444	-553,444	-541,009	-12,436		0	0	0	-27,672	-27,672
Other LUC	0	0	0	0	0		0	0	0	0	0
Agriculture											
Annual	0	0	0	0	0		0	0	0	0	0
Perennial	0	0	0	0	0		0	0	0	0	0
Rice	0	0	0	0	0		0	0	0	0	0
Grassland & Livestocks											
Grassland	0	0	0	0	0		0	0	0	0	0
Livestocks	0	0	0				0	0	0	0	0
Degradation & Management	0	0	0	0	0		0	0	0	0	0
Coastal wetlands	0	-4,366,799	-4,366,799	-3,066,176	-1,300,622		0	0	0	-218,340	-218,340
Inputs & Investments	0	0	0			0	0	0	0	0	0
Fishery & Aquaculture	0	0	0			0	0	0	0	0	0
Total	0	-4,920,243	**-4,920,243**	-3,607,185	-1,313,058	0	0	0	0	-246,012	-246,012
Per hectare	0	-280	-280	-205.0	-74.6	0.0	0.0	0.0			
Per hectare per year	0.0	-14.0	-14.0	-10.2	-3.7	0.0	0.0	0.0	0.0	-14.0	-14.0

4. Fisheries and aquaculture module

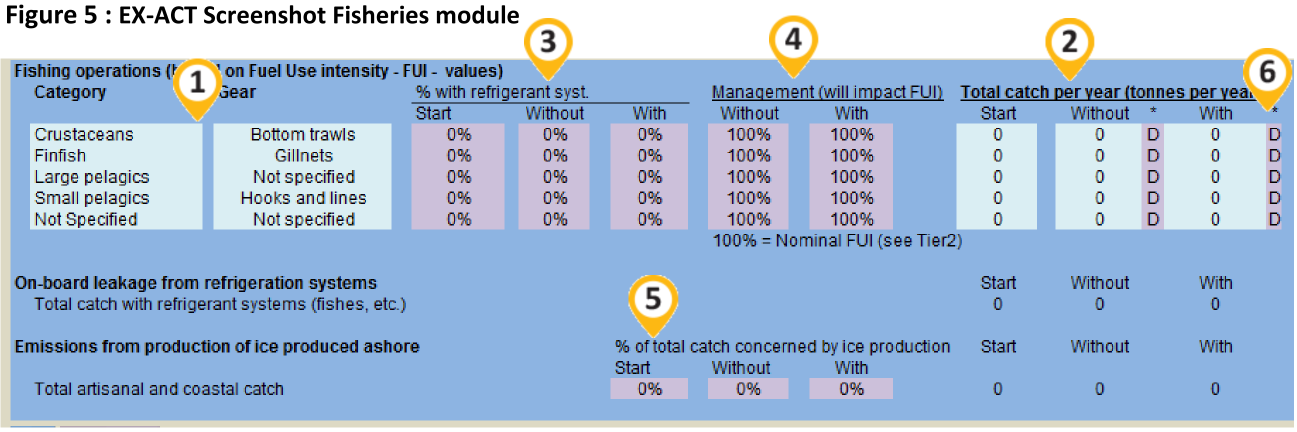
4.1. Management activities within the fisheries sector

GHG emissions accounted for in the fisheries module of EX-ACT are derived from: (1) fuel use for wild-capture fisheries during the harvest phase (2) on-board leakage from refrigerants, excluded in the artisanal fishery, and (3) Energy consumption for ice produced ashore and brought on board during the harvest phase. Energy consumption for the production of ice during <u>post production</u> phases can also be accounted for in Section 7.2 Energy inputs.

A case study for the fishery sector is analyzed in the appendix.

When using the fisheries sub-module, the following information will be needed:

Figure 5 : EX-ACT Screenshot Fisheries module



1 **Users select the fish category and associated gear type** from drop-down menus. The options are:

<u>Fish category</u>: *Crustaceans / Finfish / Flatfish / Large Pelagics / Molluscs / Salmonids / Small Pelagics / Not Specified*

<u>Gear-type</u>: *bottom trawls / gillnets /hooks and lines / pelagic trawls / pots and traps / surrounding nets / dredges / not specified*.

2 **Total catch per year** (in tonnes per year): In the second step users must specify the initial catch to set a baseline scenario, as well as expected total catch with and without the project.

3 **On-board leakage from refrigeration systems**: Users specify the percentage of the total catch preserved in on-board refrigeration systems at the initial stage of the project, as well as the total catch that will be preserved in on-board refrigeration systems with and without the project. Values are automatically reported on the line "Total catch with refrigerant systems (fishes, etc.)"

4 **Management activities**: Here, users are allowed to specify any changes (in percentage) that will affect Fuel Use Intensity with and without the project.

5 **Emissions from production of ice produced ashore and brought on-board**: Users specify the percentage of the total catch preserved on ice at the initial stage of the project, and the total catch that will be preserved in on-board refrigeration systems with and without the project. Values are automatically reported on the line "Total artisanal and coastal catch".

6 **Dynamics of change**: in case of any changes to the total catch between the start and either the outcome of the project or of the baseline scenario. The dynamics of these parameters can be specified as occurring either linearly (default), immediately or exponentially.

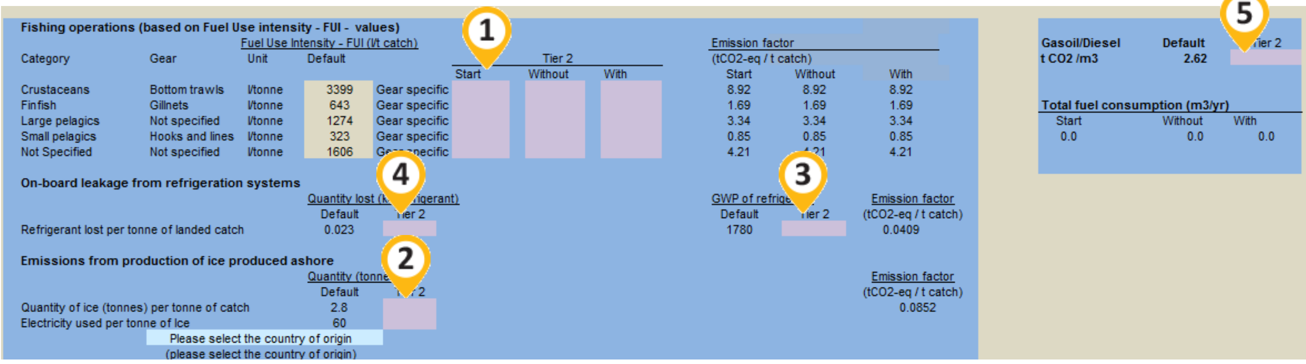
Tier 2 specifications in the Fisheries sub-module

In this module, users may also replace selected variables with location specific values by clicking on the violet "Tier 2" button. Variables that may be specified are:

1
- the FUI per tonne, with values according to the species catch and gear-type used

- 2 the quantity of ice (in tonnes) per tonne of catch for the preservation of the catch on board (the default value is 2.8 kg of ice per kg of fish), the electricity consumption for the production of ice (default value is 60 kWh per kg of ice) and the country of origin for the electricity production
- 3 the refrigerant's Global Warming Potential (GWP)
- 4 The quantity of refrigerant lost, in kg per tonne of fish landed
- 5 the emission factor for gas and oil/diesel used on board

Figure 6: EX-ACT Screenshot - Tier 2 in the Fisheries sub-module - Fisheries and Aquaculture module

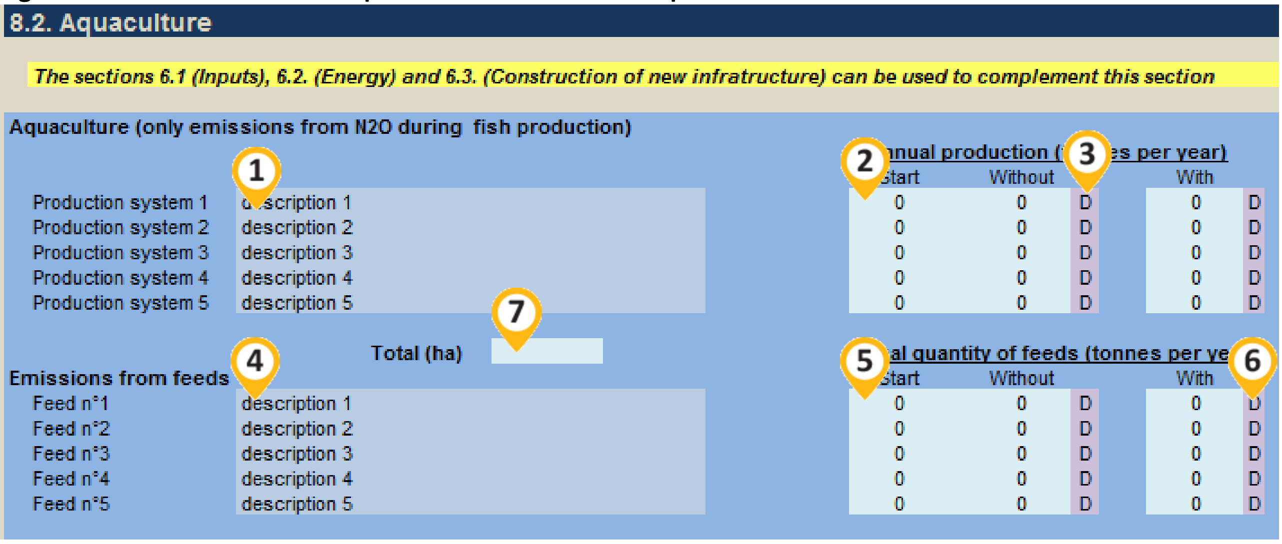


4.2.Aquaculture

Table 1 and Table 2 from the previous chapter provide information on the different modules, and their data requirements, that can be used when analyzing an aquaculture project. The present section describes how to use the Aquaculture module in EX-ACT.

In this module, only on-farm emissions are estimated: (i) the N_2O emissions from feed-fed fish farming and (ii) the feed carbon footprint. When inputting the total production it is important to take into account the percentage of dead fish before the harvest phase, as they will contribute to the buildup of $N\text{-}N_2O$ content in the water.

Figure 7 : EX-ACT Screenshot - Aquaculture – fisheries and aquaculture module



To fill the aquaculture sub-module, users must specify:

For fish production:

1 Users fill in a description of the production

2 Annual fish production (in tonnes per year): In this step users specify the initial fish production as a baseline scenario, as well as the fish production with and without the project.

3 Dynamics of change: in case of any changes to fish production between the start and either the outcome of the project or of the baseline scenario. The dynamics of this production can be specified as occurring either linearly (default), immediately or exponentially.

For the emissions from feed (carbon footprint):

4 Users fill in a description of the feed

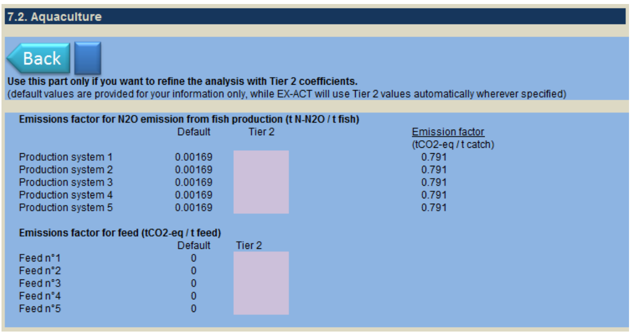
5 Annual feed quantity used (in tonnes per year): In the second step users may specify the initial quantity of feed (used as a baseline scenario) and the quantity of feed used with and without the project. Users must enter the carbon footprint of the feed in use as a Tier 2 entry, as EX-ACT does not yet provide a default value.

6 Dynamics of change: in case of any changes in feed quantity used between the start and either the outcome of the project or the baseline scenario. The dynamics of this quantity can be specified as occurring either linearly (default), immediately or exponentially.

7 The total surface area (in hectare, ha) of the project occupied by feed-fed fish farming systems, if the area of the pond is not already accounted for in other EX-ACT modules. For instance the area of a pond created due to excavation on coastal wetlands and conversion from rice paddies to shrimp ponds are already taken into account in EX-ACT calculations, so inputting them to the aquaculture module would double the total surface area of the project in the final carbon balance.

Tier 2 specifications in the Aquaculture sub-module

Figure 8 : EX-ACT Screenshot - Tier 2 for the Aquaculture – fisheries and aquaculture module



The variables that can be specified by location specific coefficients in the aquaculture module are as follows:

- The emissions factor for N_2O emissions from fish production (t $N\text{-}N_2O$ / t fish)
- The emissions factor for feed (t CO_2-e / t feed)

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Annex

Annex 1. Case study: an aquaculture and coastal wetlands management project in Mozambique

The project development objectives are to pilot an inclusive out-grower scheme in Mozambique and increase shrimp production. The project takes place near the bank of a river, on a site previously used for salt production. The project area currently comprises mostly dry saline mudflat and short saline grassland, closely located to mangroves and inter-tidal mudflats along the banks. The saline mudflats infrequently wetted are to be converted into aquaculture ponds. The project also includes mangrove plantation in the vicinity of the shrimp farm.

The three main components of the project are: (1) excavation activities in the mudflats; (2) the improvement of shrimp production, and (3) mangrove plantation in the vicinity of the shrimp farm on an area equivalent to 40 percent of the excavated area.

EX-ACT inputs

Table 3 : on farm parameters with potential associated GHGs emissions

Parameters	Inputs
Mudflats surface area for excavation (ha)	440
Length of cultivation (months)	6-7
Survival rate (%)	60
Annual production (tonne ha^{-1})	0.99
Lime (kg ha^{-1})	500
Feed conversion ratio (kg feed / kg shrimp)	1.3
Energy consumption from pumping stations ($ for 7 months)[2]	350
Mangrove plantation (ha)	176

An EX-ACT analysis was performed using the input data from Table 1. We use the Coastal wetlands module (excavation and rewetting), the inputs module for electricity consumption from on-farm activities and Fishery modules of EX-ACT. We considered the following as the without and with project scenarios: (1) In the absence of the project, no management activity on mudflats and shrimp farming would be performed and the environment remains intact; (2) for the with-project situation excavation of 440 ha of mudflats would be conducted for the construction of shrimp pond farming (with the associated parameters from Table 1) and mangrove plantation on 176 ha.

The project will be implemented over a period of five years (accounting for the progressive extraction of 440 ha of mudflat). However EX-ACT also assesses an additional 15 year period of capitalization over the occupation time of shrimp pond-farming.

We also use the Tier 2 approach to set carbon stocks of the litter, deadwood and the above and belowground pools to zero to account for the absence of woody vegetation. The soil carbon content is corrected according to several assumptions not detailed here (EX-ACT Screenshot 1).

Figure 9: EX-ACT Screenshot : A Tier 2 approach to the excavation of mudflats (total area 440 ha).

6.1.1. Extraction and Excavation (port constuction, construction of aquaculture or salt production ponds,...)

All values are in t of carbon per ha (tC/ha)

Type of vegetation	Above-ground Default	Above-ground Tier 2	Below-ground Default	Below-ground Tier 2	Litter Default	Litter Tier 2	Dead wood Default	Dead wood Tier 2
Mangrove	86.6	0.0	42.4	0.0	0.7	0.0	10.7	0.0
Tidal marsh	0.0		0.0		0.0		0.0	
Seagrass meadow	0.0		0.0		0.0		0.0	

Type of vegetation	Default soil type is "Mineral" Set to "Organic"?	Soil carbon (default consider 1 m depth) Default	Soil carbon Tier 2	% of C lost after excavation Default	% of C lost after excavation Tier 2
Mangrove	NO	286	56.5	96%	
Tidal marsh	YES	340		96%	
Seagrass meadow		108		96%	

[2] i.e. 7 months corresponds to the for the annual shrimp production over 1 ha. The kWh cost 0,07$ (year 2015) in Mozambique (data retrieved from http://www.doingbusiness.org/data/exploreeconomies/mozambique/getting-electricity/)

Screenshot 2 summarizes the GHG sequestration and share of the balance per GHG. Results are given in tonnes of CO_2 equivalent (tCO_2-e). Positive numbers represent sources of CO_2-e emission while negative numbers represent sinks. The left-hand section of the table summarizes estimated CO_2-e emissions and sinks from the without-project scenario (left column), from the with-project scenario (middle column) and the total balance (right column). The middle table details the Carbon Balance under project implementation, showing the CO_2 fluxes from biomass and soil carbon fluxes, GHGs associated with agricultural and energy inputs and GHGs from pond-farming activities and mangrove plantations. The right-hand table details annual CO_2-e fluxes for the different activities without and with project implementation.

Figure 10 : EX-ACT Screenshot 2: EX-ACT results including mangrove reforestation, gross fluxes and balance of greenhouse gases (GHG) of the without- and with-project scenarios, the share of the balance per GHG and annual CO_2-e emissions.

Project Name	*Mozambique aquaculture m*		Climate	*Tropical (Moist)*			Duration of the Project (Years)		*20*		
Continent	*Africa*		Dominant Regional Soil Type	*LAC Soils*			Total area (ha)		*616*		

Components of the project	Gross fluxes Without	With	Balance	Share per GHG of the Balance (All GHG in tCO2eq) CO_2 Biomass	Soil	Other	N_2O	CH_4	Result per year Without	With	Balance
	All GHG in tCO2eq; Positive = source / negative = sink										
Land use changes											
Deforestation	0	0	0	0	0		0	0	0	0	0
Afforestation	0	0	0	0	0		0	0	0	0	0
Other LUC	0	0	0	0	0		0	0	0	0	0
Agriculture											
Annual	0	0	0	0	0		0	0	0	0	0
Perennial	0	0	0	0	0		0	0	0	0	0
Rice	0	0	0	0	0		0	0	0	0	0
Grassland & Livestocks											
Grassland	0	0	0	0	0		0	0	0	0	0
Livestocks	0	0	0				0	0	0	0	0
Degradation & Management	0	0	0	0	0		0	0	0	0	0
Coastal wetlands	0	-21,407	-21,407	-90,619	69,212		0	0	0	-1,070	-1,070
Inputs & Investments	0	4,094	4,094			4,094	0	0	0	205	205
Fishery & Aquaculture	0	8,446	8,446			0	8,446	0	0	422	422
Total	0	-8,867	**-8,867**	-90,619	69,212	4,094	8,446	0	0	-443	-443
Per hectare	0	-14	-14	-140.5	112.4	6.6	13.7	0.0			
Per hectare per year	0.0	-0.7	-0.7	-7.0	5.6	0.3	0.7	0.0	0.0	-0.7	-0.7

The mangrove restoration (rewetting of mudflats and revegetation) after 20 years largely counterbalances emissions associated with mudflat excavation, via carbon sequestration in the biomass and soil. While the excavation leads to the oxidation of organic matter in soil amounting to 87 500 tCO_2-e (it is assumed that all the carbon is oxidized during the 1st year), mangrove plantations sequester about -109 000 tCO_2-e. The final carbon balance also significantly changes over the 20 years, amounting to -0.7 tCO_2-e ha^{-1} yr^{-1}.

Annex 2. Case study of a fisheries management and seagrass restoration in Vietnam

Viet Nam's fishery sector has experienced extremely rapid growth over the past two decades, in both marine fisheries and aquaculture. Yet despite this they remain highly vulnerable. It is clear that capture fisheries are unsustainable as a result of over-capacity of the fleet and overfishing. These lead to a decline in production and increased proportion of "trash fish" and smaller sized fish in the catch. The aquaculture sector also faces high mortality rates from viral disease and environmental pollution from overconsumption of agricultural inputs. The objective of the project, therefore, is to improve the sustainable management of coastal fisheries and aquaculture in Viet Nam, benefitting 50 000 households. Implementation of the project has the following foreseen impacts: (1) rehabilitation of the seagrass meadow, (2) reduced consumption of agricultural inputs, (3) reduction in offshore fisheries, and (4) sustainable intensification of aquaculture production.

Data used: The EX-ACT GHG appraisal for this project is carried out for tropical moist climate conditions and a dominant soil type of Low Activity Clay (LAC) soils. Project impacts are estimated over a total period of 20 years after the project begins, considering a six-year period for project implementation and 14 years for capitalization.

Rehabilitation of the seagrass meadow

It is estimated that the project will restore 83 000 hectares of seagrass meadow from a state of degradation of 50 percent lost biomass to 30 percent lost biomass.

Reduced consumption of agricultural and energy inputs

It is estimated that the average annual consumption of limestone and fungicides will decrease by 30 percent under the project due to the more sustainable aquaculture production practices. Use of urea (51 tonnes per year) will be replaced with other forms of nitrogen fertilizers (31 tonnes per year). Electricity consumption will decrease by 30 percent and gas/oil consumption by 10 percent. The actual annual consumption of lime is 2 400 tonnes, fungicides 2 400 tonnes, electricity 141 750 MWh and diesel 50 000 m^3.

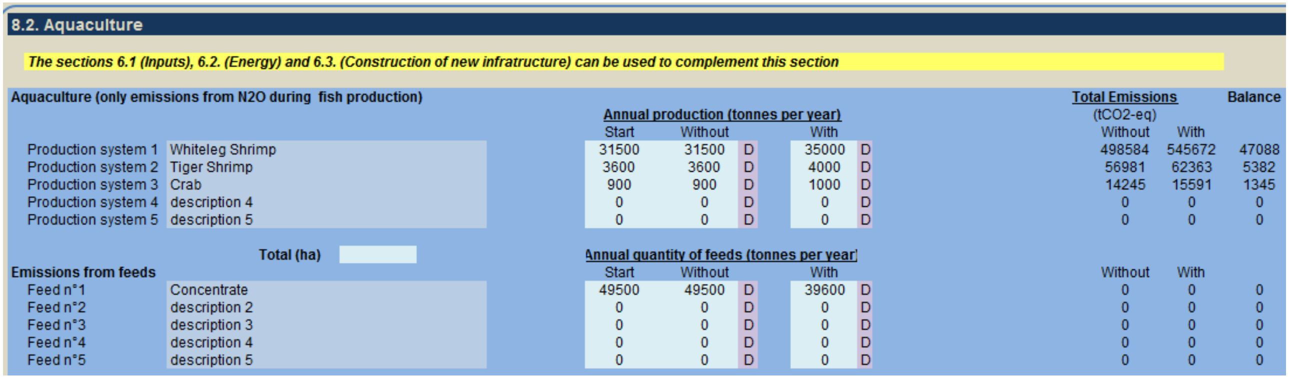
Reduced fishing volume of near-shore fisheries

As a result of livelihood diversification measures and improved income potential from aquaculture production, it is expected that the volume of near-shore fisheries will reduce by 10 percent (compared to the business-as-usual scenario). The main target species are crustaceans and finfish captured using gillnets. Actual annual production is 7 500 tonnes of crustaceans per year and 122 500 tonnes of finfish per year, of which 50percent is preserved on ice onboard the vessels. With the project, upgrading of coastal infrastructure will allow an increased production of ice preserving up to 90 percent of the catch.

Sustainable intensification of aquaculture production

Aquaculture production is foreseen to be sustainably intensified in future. This will provide alternative revenue sources for beneficiaries that do not harm the regeneration of near-shore fish stocks. Fish production will increase as along with associated GHG emissions from the excretion of ammonia, yet feed consumption will be reduced by 10 percent in order to combat the excessively high feeding rates in current systems. Data are entered in the following screenshot:

Figure 11: EX-ACT screenshot of the aquaculture module



8.2. Aquaculture

The sections 6.1 (Inputs), 6.2. (Energy) and 6.3. (Construction of new infratructure) can be used to complement this section

Aquaculture (only emissions from N2O during fish production)		Annual production (tonnes per year) Start	Without		With		Total Emissions (tCO2-eq) Without	With	Balance
Production system 1	Whiteleg Shrimp	31500	31500	D	35000	D	498584	545672	47088
Production system 2	Tiger Shrimp	3600	3600	D	4000	D	56981	62363	5382
Production system 3	Crab	900	900	D	1000	D	14245	15591	1345
Production system 4	description 4	0	0	D	0	D	0	0	0
Production system 5	description 5	0	0	D	0	D	0	0	0

Total (ha)

Emissions from feeds		Annual quantity of feeds (tonnes per year) Start	Without		With		Without	With	
Feed n°1	Concentrate	49500	49500	D	39600	D	0	0	0
Feed n°2	description 2	0	0	D	0	D	0	0	0
Feed n°3	description 3	0	0	D	0	D	0	0	0
Feed n°4	description 4	0	0	D	0	D	0	0	0
Feed n°5	description 5	0	0	D	0	D	0	0	0

Project GHG Appraisal Results

When aggregating the impacts of all the project activities identified above, the project provides an annual GHG benefit of 72 555 tCO_2e.

Figure 12 : EX-ACT result – GHG balance

Components of the project	Gross fluxes Without	 With	 Balance
	All GHG in tCO2eq Positive = source / negative = sink		
Land use changes			
Deforestation	0	0	0
Afforestation	0	0	0
Other LUC	0	0	0
Agriculture			
Annual	0	0	0
Perennial	0	0	0
Rice	0	0	0
Grassland & Livestocks			
Grassland	0	0	0
Livestocks	0	0	0
Degradation & Management	0	0	0
Coastal wetlands	-1,112,338	-1,557,274	-444,935
Inputs & Investments	4,671,222	3,924,980	-746,243
Fishery & Aquaculture	5,058,431	4,798,507	-259,923
Total	8,617,315	7,166,214	**-1,451,101**
Per hectare	104	86	-17
Per hectare per year	5.2	4.3	-0.9

Over the full 20 year analysis period a total of 1.5 million tCO_2e are mitigated. Thirty percent of these mitigation benefits derive from increased carbon stocks, while 70 percent are due to reduced GHG emissions.

Figure 12 shows that the reductions in agricultural inputs and energy use account for 51 percent of the overall mitigation benefits. The restoration of seagrass meadows contribute 31 percent, while the combined impacts of reducing off-shore fisheries and increasing aquaculture production contribute 18 percent.

EX-ANTE CARBON-BALANCE TOOL [EX-ACT]

The EX-Ante Carbon-balance Tool (EX-ACT) is an appraisal system developed by FAO providing estimates of the impact of agriculture and forestry development projects, programmes and policies on the carbon-balance. The tool helps project designers estimate and prioritize project activities with high benefits in terms of economic and climate change mitigation, and it helps decision-makers to decide on the right course to mitigate climate change in agriculture and forestry and to enhance environmental services.

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