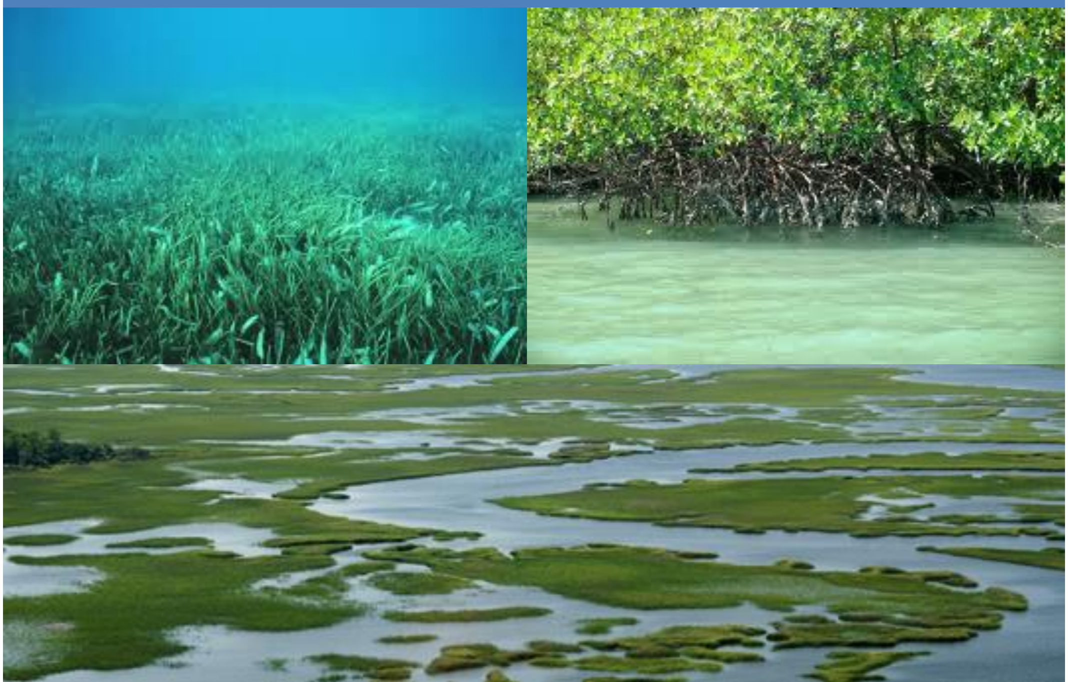
Food and Agriculture Organization of the United Nations

IRD Institut de recherche pour le développement

EX-ACT Manual for Blue Carbon, Fisheries & Aquaculture management project



Estimating and targeting greenhouse Gas mitigation in Coastal Wetlands, fishery and aquaculture

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, programs and policies on the carbon balance. The carbon-balance is defined as the net balance from all greenhouse gases (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 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 tons 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 others projects on climate change mitigation, watershed development, production intensification, food security, livestock, forest management or land use change, but also on management activities within coastal wetlands, and from the fisheries and aquaculture sector. Furthermore, it is cost effective, requires a relatively small amount of data, and has resources (tables, maps) which can help in finding the required information. While EXACT is mostly used at project level it may easily be scaled-up to the program/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

Acknowledgments

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Contents

Users not familiar with the tool EX-ACT are advised to consult the quick guidance for an overview and understanding of its methodology (part 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. 2011) for details on its calculations.

Chapter 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 projects GHG balance. 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 analysis.

1. Background

Marine and coastal ecosystems are being increasingly degraded or destroyed by human activities. Pollution of coastal and marine waters, eutrophication, harmful algal bloom and over-fishing are some of the threats to marine ecosystems. Climate change is also expected to add cumulative or synergistic impacts on marine ecosystems, aquaculture and fisheries, therefore on food security and livelihoods of human population (Cochrane et al. 2009; Shelton 2014; Gattuso et al. 2015). Increasing sea level is affecting the low lying areas and islands more severely, increasing the risk of contamination of groundwater and salt water intrusion in deltaic fish-farming (De Silva & Soto 2009; Wong et al. 2014). Ocean and atmospheric temperature change is affecting the distribution of marine and freshwater species, fish and molluscs physiological processes, and altering the food webs which requires changes in fishing operations and aquaculture practices, and livelihoods strategies (Cochrane et al. 2009, Gazeau et al. 2014; Yusuf et al. 2015). CO_2 uptake from the ocean is increasing the 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…) which will also affect 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 from algal blooms could subsequently undergo microbial respiration, adding CO_2 and decreasing the pH of local waters, (Cai et al. 2011).

The coastal ocean, at the boundary between the land, the open ocean and the atmosphere, is one of the most biogeochemically active areas, receiving carbon and nutrients inputs from the land and exchanging flow and materials through the continental slope with the open ocean. Tidal marsh, mangrove and seagrass meadow are some of the major coastal ecosystems that provide a wide variety of regulating, provisioning, supporting and cultural services. These services include carbon cycling, fishery resources, nursery ground for coastal fish and crustaceans, improvement of water quality, protection from storm and stabilization of the shoreline and 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, with a current conversion rate from 0.7 to 3% per year (Pendelton et al. 2012). Globally, mangrove lost 35% of their coverage, and seagrass 29% (Valiela et al. 2001; Waycott et al. 2009). Drivers of their loss include aquaculture with conversion to shrimp ponds and fisheries activities, with 40% of the mangrove degradation in West Africa originating from post-production of fisheries processes and fish smoking. Industrial pollution, urban, coastal and tourism development, over-harvesting for fuelwood and timber extraction, land clearing for agriculture and conversion into rice fields, and climate change are also strongly implicated in loss of coastal ecosystems (Gilman et al. 2008; Giri et al. 2008; Waycott et al. 2009; Ajonina et al. 2014).

2. What is the blue carbon?

Coastal ecosystems have a natural capacity to sequester organic carbon termed "blue carbon" within the soil, the above-ground & below-ground living biomass, litter and dead wood (Herr et al. 2011) and collectively tidal marsh, mangrove and seagrass meadow 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 the soil compartment. 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 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 5 times more carbon in the soil than tropical forests (Chmura et al. 2003; Alongi 2014).

Together with the wide range of ecosystems services they provide, their capacity to store and sequester the carbon make coastal ecosystems important in term of mitigation and conservation. When coastal ecosystems are disturbed, degraded or converted, the carbon (C) stock in the biomass as well as the 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% to carbon emission from tropical deforestation (Pendelton et al. 2012; Alongi & Mukhopadhyay 2014). Conservation and restoration of these coastal ecosystems is then significant to maintenance of coastal biodiversity, coastal protection and communities' livelihood and climate change mitigation.

3. Fisheries & aquaculture

Fisheries and aquaculture contribute to global GHG emissions during fish capture or fish-farming, processing, transportation and storage. Energy consumption in the fishery sector depends on many factors, *e.g.* the structure and the 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 major share of 75-90% 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 used primarily for the vessel propulsion, but in some particular cases can include on-board processes like refrigeration and freezing. The remaining 10 to 25% are energy from electricity for ice production ashore and embodied energy as for the vessel construction and its maintenance, fishing gears, 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 & Tyedmers 2014).

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

Environment degradation, habitat destruction, loss of biodiversity, overexploitation of fish stocks, fleet overcapacity, loss in post-production processes are all contributing to the unsustainable exploitation of the marine and freshwater ecosystems. Fisheries and aquaculture do not emit as much GHG 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 or changing fishing practices, lower feed conversion ratio in aquaculture would reduce emissions from fishing and farming activities, and could also decrease damage to aquatic environments (Gulbrandsen 1986, Suuronen et al 2012, Shelton 2014). Moreover it has been highlighted recently that marine vertebrates (fish, mammals, turtles) might be active actors in the marine carbon cycle, either in carbon sequestration and/or protecting against ocean acidification but also in safeguarding blue carbon stocks in coastal ecosystems if fish stock are kept intact (Lutz & Martin 2014; Atwood et al. 2015).

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

4. Why developing a blue carbon, fisheries &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 others methodologies (for further details refer to Bernoux et al. 2011). 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 GHG from wetlands and drained soils. Chapter 4 of the IPCC 2014 is focusing on mangrove, tidal marsh and seagrass, giving adapted default value and provided 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 in a land use change. These activities of concerned are extraction and drainage of the soil, and processes of restoration and revegetation within these 3 coastal ecosystems.

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

Chapter 2: Data Requirements and Data Collection

The scope of this manual is to give user guidance on the selection and use of the different modules necessary for projects related to coastal ecosystems, fishery and aquaculture sector only. **Users not familiar with the tool EX-ACT are advised to consult the quick guidance for an overview and understanding of its methodology (part 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. 2011) for details on its calculations.**

This chapter describes the data that needs to be collected in order to use EX-ACT and offers guidance on methods of data collection. Data collection designs may vary with differences in data quality and precision as well as time intensity and cost. The purpose here is to provide users with an overview of data collection methods, while leaving it to individual users to make informed decisions about which methods to use.

1. Choosing the relevant modules for coastal wetlands activities, fishery and aquaculture sector

EX-ACT does not necessarily require a full inventory of all land-uses or management activities in the project area, but is mainly concerned with all land areas or sectors (i.e. fishery and aquaculture) that are altered due to the proposed project. Data is needed on all those areas or activities in which **change is observed between project start and end of the capitalization phase** as well as on those areas or activities **where such alterations would have been observed in case of the business-as-usual scenario**.

Given that for each specific project it will be only necessary to fill a limited subset of EX-ACT topic modules. Table 1 lists typical development projects by type for blue carbon, fisheries and aquaculture projects and identifies which are the most relevant EX-ACT modules that need to be completed in order to calculate the GHG-balance. EX-ACT is a flexible tool based on project impacts rather than objectives, implying that one type of project can involve several modules.

If the project activities are covering other sectors than those treated here, e.g. agriculture, forestry and land use change, the EX-ACT User manual provides information on data needs and module to be completed for estimation of the GHG balance.

2. Overview of data needs

In the following the reader is provided with concrete specifications of the data needs for coastal wetlands, fisheries and aquaculture in EX-ACT (Table 2). It is 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 in the analysis. This reflects the difference between using the Tier 1 coefficients provided by the IPCC 2006 and 2014 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 level of precision chosen in other parts of the project analysis and should be aligned to the overall purpose of engaging in the carbon-balance appraisal.

Tier 2 data instead concerns location specific variables that offer specifications of the carbon content and stock changes in all five carbon pools as well as the emission factors for selected practices. While all tier 2 data needs that can be accommodated in EX-ACT are fully listed in the annex of the *User Manual*. The present manual list tier 2 data needs for the blue carbon, fishery & aquaculture in their respective chapters.

The collection of Tier 2 data is especially advised for core project components that are expected to be stronger sources or sinks of GHGs. This logic may be understood as a good practice leading to a reasonable combination of Tier 2 and Tier 1 data. Data collection of Tier 2 variables is thereby often difficult and it will for this reason never be possible to collect Tier 2 information for all considered variables as part of conventional project planning.

Blue carbon and Fishery & Aquaculture modules are detailed in the next chapters. The following sections describe some unique features which can be of used when analysing a blue carbon and/or fishery & aquaculture project. This is also the reason why users should consult the *User Manual* and the *EX-ACT Technical guidelines* for a better understanding of the tool and its methods used for calculations.

Table 1: Modules to be used according to 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 occurring with or without project?** *Go to* →	
	IF mangrove biomass removal without any change on the soil ○ Harvest, wood removal, fuelwood removal, charcoal production…	Land Use Change (*Deforestation*)
	IF Management practices in Mangrove degradation, i.e. The degradation level of the mangrove will be positively or negatively affected by the project. In both case the soil is not drained.	Management & degradation (*Forest degradation and management*)
	IF Burning or improved techniques for burning less of **harvest wood products**	Inputs & Investments
	IF Extraction of coastal wetlands soil ○ For excavation to urban and marine development construction (harbour, marina…) ○ For dredging to facilitate raising the elevation of land ○ For construction of Aquaculture pond and salt production	Coastal Wetlands (*extraction and excavation*)
	IF Drainage of tidal marsh 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 & Aquaculture (*Aquaculture*)
	IF Aquaculture management with inputs ○ Pesticides, herbicides, lime, fertilizers	Inputs & Investments
	IF Fisheries management with ○ Fuel use during harvest ○ Ice production for preservation of catch ○ On-Board refrigerant for preservation of the catch	Fisheries & Aquaculture (*Fisheries*)
	IF Energy consumption for ice production ashore, for motors for pumps and aeration systems in aquaculture, for fuel for transport	Inputs & Investments
	IF Investment in buildings, roads, storages	Inputs & Investments

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

Obligatory	**Description module**	
	• Sub-continent	• Dominant regional soil type[1]
	• Type of climate	• Project duration
	• Moisture regime	
Only if project related	**Land use change module**	
	• Deforestation	
	• Area of mangrove deforested	• Final land use after conversion[2]
	• Quantity of Harvested wood products	• Burning during conversion?
	Coastal wetlands module	
	• Extraction and/or drainage	
	• Wetlands type and area concerned by Extraction and/or drainage	
	• Rewetting (i..e restoration)	
	• Wetlands type and area concerned by Rewetting, i.e. restoration	• % of nominal biomass restored
	Management & Degradation module	
	• Forest degradation and management	
	• Dynamic of mangrove degradation (positive or negative) and size	
	Fisheries and Aquaculture module	
	• Fishery	
	• Fish category, gear-type and data on catch	• Proportion of catch preserved on-board with refrigerant system • Proportion of catch preserved on ice produced ashore and brought on-board
	• Aquaculture	
	• Fish production	• Carbon footprint of the feed
	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)	

2.1 Description module

EX-ACT users first need to fill in 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 important agro-ecological variables of that are listed in table 2. These information are obligatory, even for fisheries and aquaculture projects, as they will set up Tier 1 data used for the computations in the different EX-ACT modules. All Tier 1 data can be refine at a Tier 2 level.

Soil information provided in the description module sets up the default values for soil organic carbon stocks for mineral soils down to a depth of 30 cm. These values are of used in the case of coastal ecosystems only for the *deforestation* module and the *forest degradation and management* module. The coastal wetlands module used specific soil carbon stock down to 1 m depth (refer to the *EX-ACT technical guidelines* for methods). The dominant soil type to be considered 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.

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[1] User should choose the soil type of the adjacent land mass for coastal wetlands projects.
[2] Should be set up as degraded or set aside

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

2.2 Land use change – Deforestation module

This module concerns **only deforestation of mangrove** with no further activities such as extraction or drainage that are accounted for directly in the coastal wetland module (see below). In the *deforestation* module, only areas at the start, the without and with project situation are required, and the final use of the area after deforestation, i.e. set aside or degraded. In the contrary the IPCC 2014 does provide for the moment only deforestation associated with extraction and drainage which are part of the *Coastal Wetland* modules and should be treated there (see next chapter).

Data can be refined (Tier 2) for above- and belowground biomass, dead organic matter and litter carbon stock, and soil carbon content (30 cm depth).

2.3 Management and degradation module - Mangrove management practices

This module concerns management activities that will lead to a change, positive or negative, of the degradation level of mangrove. It supposed that the soil is undrained and already covered by 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 situation. In this module, only the surface area covered by the mangrove and the degradation level at the initial state, and the without and with-project scenario are required. Data can be refined (Tier 2) for above- and belowground biomass, dead organic matter and litter carbon stock, and soil carbon content (30 cm depth).

Chapter 3: Coastal wetlands module

The Coastal wetlands module covers issues of management of coastal wetlands, i.e. extraction/excavation of soil with removal of the above-ground biomass, drainage, and rewetting that is defined as the restoration of the hydrology or water quality of a drained soil and additional replanting.

1. Extraction & Excavation and/ or Drainage activities

For both of these activities, user will have to specify only the area of concern at the start of the project as the baseline scenario, the percentage of area in the without and with-project scenario undergoing extraction/excavation in the "Extraction and Excavation" sub-module. This information will set up the remaining area available for drainage activities, i.e. in % 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 types of information will be needed:

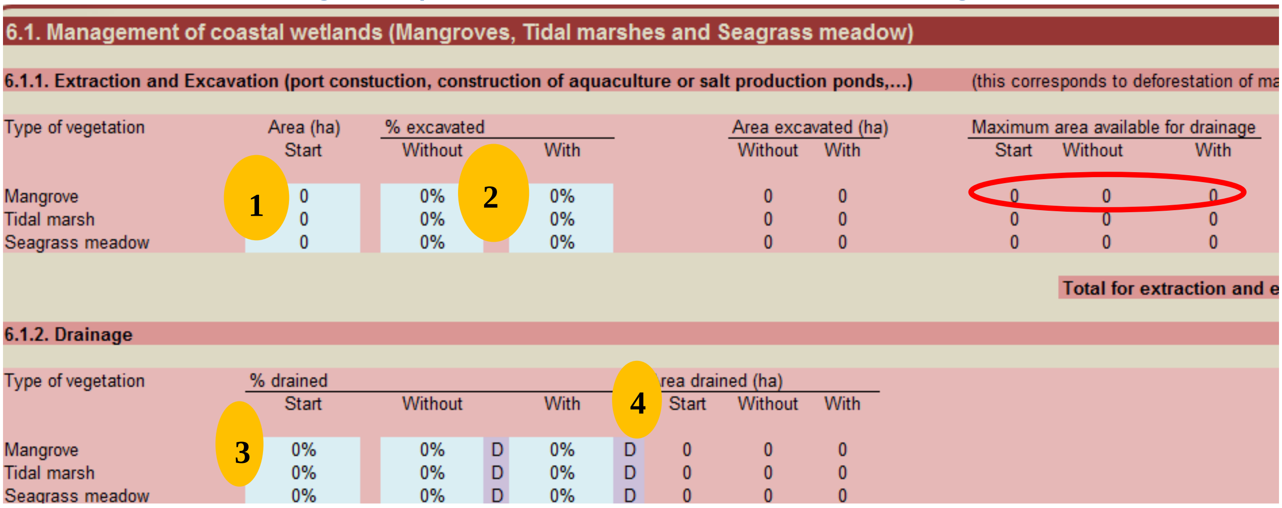
1 **The area of concern for Extraction <u>and</u> Drainage**: at the start of the project as the baseline scenario, the % of surface area in the without and with-project scenario undergoing extraction/excavation and/or drainage.

2 **The percentage of the project's surface area undergoing extraction/excavation** for the without and with-project situation. This will set up the surface area remained for drainage activities (indicated in the red circle).

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

4 **Dynamic of change**: in case of any changes in the surface area between the without- and with project scenario. The dynamic of these parameters can be specified by user either as linear (default), immediate or exponentially taking place

EX-ACT Screenshot 2: Management of coastal wetlands with Extraction and/or Drainage



6.1. Management of coastal wetlands (Mangroves, Tidal marshes and Seagrass meadow)

6.1.1. Extraction and Excavation (port constuction, construction of aquaculture or salt production ponds,...) (this corresponds to deforestation of ma

Type of vegetation	Area (ha)	% excavated		Area excavated (ha)		Maximum area available for drainage		
	Start	Without	With	Without	With	Start	Without	With
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

Total for extraction and e

6.1.2. Drainage

Type of vegetation	% drained					rea drained (ha)		
	Start	Without		With		Start	Without	With
Mangrove	0%	0%	D	0%	D	0	0	0
Tidal marsh	0%	0%	D	0%	D	0	0	0
Seagrass meadow	0%	0%	D	0%	D	0	0	0

In the above screenshot (fictive scenario), the totale surface area of the project is 100 ha. Without the project, no extraction activities occur, but the whole surface area, i.e. 100 ha, will undergo drainage activities with associated complete removal of the biomass. With the project, 30% of the project's surface is being excavated, i.e. 300ha, and 50% of the remaining surface (70 ha) undergoes drainage, i.e. 35 ha.

Tier 2 options for extrcation and drainage

Estimations can be refined (Tier 2) by entering specific coefficients such as (*cf.* screenshot 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 (t C 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 mangrove.
- The percentage of carbon lost after excavation:
  In the mangrove carbon stock 4% of it is considered refractory and was considered also as default value for tidal marsh and seagrass meadow ecosystems.
- The emission factor for loss of C associated with drainage in the soil (t C ha^{-1} yr^{-1})

EX-ACT Screenshot 3: Extraction and drainage activities, Tier 2.

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		Below-ground		Litter		Dead wood	
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	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 consider 1 m depth)		% of C lost after excavation	
		Default	Tier 2	Default	Tier 2
Mangrove	NO	0		96%	
Tidal marsh	YES	0		96%	
Seagrass meadow		0		96%	

6.1.2. Drainage

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

Type of vegetation	Above-ground		Below-ground		Litter		Dead wood	
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	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 consider 1 m depth)		Emission factor (t C /ha/yr)	
		Default	Tier 2	Default	Tier 2
Mangrove	YES	0		0	
Tidal marsh	YES	0		0	
Seagrass meadow		0		0	

2. Restoration & revegetation (rewetting)

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

EX-ACT Screenshot 3: Rewetting activities

6.1.3. Rewetting

Type of vegetation	Area rewetted (ha)					Percentage of nominal biomass restored	
	Start	Withou		With		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 as the baseline scenario, and the area of concerned with- and without the project

2 **Dynamic of change**: in case of any changes in the surface area between the without- and with project scenario. The dynamic of these parameters can be specified by user either as linear (default), immediate or exponentially

3 **The percentage of biomass gain due to rewetting**: at the start of the project, the without- and with project scenario.

Tier 2 options for the restoration & revegetation

Users can refine the results using Tier 2 data. The variables that can be specified by location specific coefficients in the *Rewetting* section of the Coastal wetlands module are the following (screenshot below):

- 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})
- 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.
- The emission factor of CO_2 associated with rewetting in the soil (t C ha^{-1} yr^{-1}).
- The emission factor of CH_4 associated with rewetting in the soil (kg CH_4 ha^{-1} yr^{-1}), independently of the salinity.

EX-ACT Screenshot 4: Rewetting activities, Tier 2.

6.1.3. Rewetting

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

Type of vegetation	Above-ground		Below-ground		Litter		Dead wood	
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	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)		CH4 Emission Factor (kg CH4 /ha /yr)	
	Default	Tier 2	Default	Tier 2
Mangrove	-1.62		0	
Tidal marsh	-0.91		0	
Seagrass meadow	-0.43		0	

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

The project aimed at the conservation and protection of coastal resources, i.e. mangroves, seagrass and coral reefs, with as components restoration of mangrove (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 mangrove and shelterbelt plantations are proposed in areas that do not have any forest cover for a long time, we use the afforestation module for the shelterbelt plantation while the rewetting module is used for mangrove plantation. Without intervention of the project, areas remained degraded and devoid of vegetation. With the various activities within the project we assume that of the 16,100 ha of replanted mangrove, but 80% of the area will be covered by biomass at the end of the project duration, 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 GHGs sequestration and the share of the balance per GHG from above scenario. Results are given in tonne CO_2 equivalent (tCO_2-e). Positive numbers represent sources of CO_2-e emission while negative numbers represent sinks. The left table section summarizes estimated CO_2-e emissions and sinks from the scenario without-project (left column), from the scenario with-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 without and with-project implementation.

In term of climate mitigation, restoration of mangrove and shelterbelt plantation on about 18,000 ha represent a potential net carbon sequestration of -5,000,000 tCO_2-e over 20 years (6 years implementation and 14 years of capitalization), i.e. -14 tCO_2-e yr^{-1} ha^{-1} (left table). The biomass and soil pools account for respectively -3.6 million tCO_2-e and 1.4 of the sequestered carbon.

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

Chapter 5: Fisheries & Aquaculture module

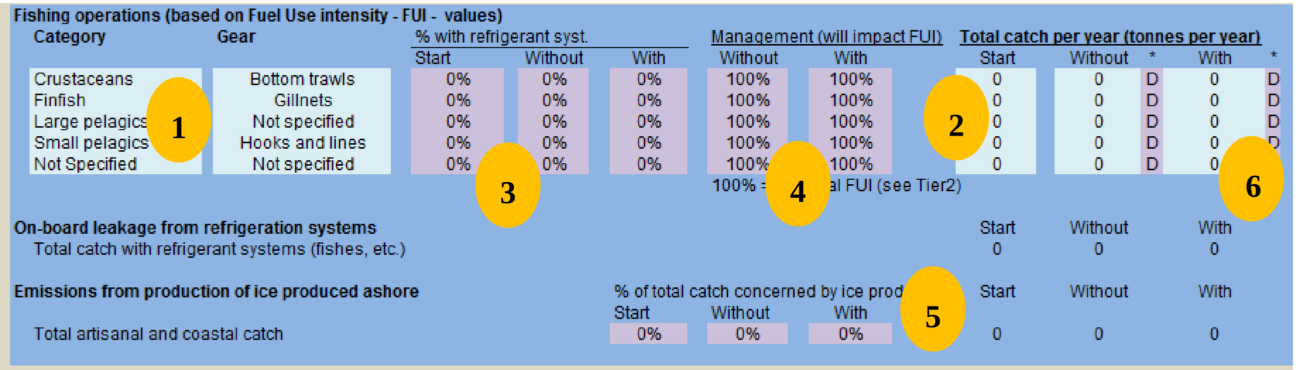
1. Management activities within the fisheries sector

GHG emissions accounted for in the module fisheries of EX-ACT are from: (1) fuel use for wild-capture fisheries during the harvest phase (2) on-board leakage from the refrigerant, excluded in the artisanal fishery (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 the section 7.2 Energy inputs.

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

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

EX-ACT Screenshot 5: Fisheries sub-module



1 **Users select the fish category and associated gear** following options in the drop-down list:

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

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

2 **Total Catch per year** (in tonne per year): In the second step users then specify the initial catch as a baseline scenario, expected total catch without and with project.

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

4 **Management activities**: Users have the possibility to specify any changes (in %) that will affect the Fuel Use Intensity with- and without project.

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

6 **Dynamic of change**: in case of any changes in the total catch between the start and either the outcome of the project or baseline scenario. The dynamic of these parameters can be specified by user either as linear (default), immediate or exponentially taking place.

Tier 2 specifications in the fisheries module

Also in this module, users may replace selected variable with location specific values by clicking on the violet “Tier 2” button. Variables that may be specified are:

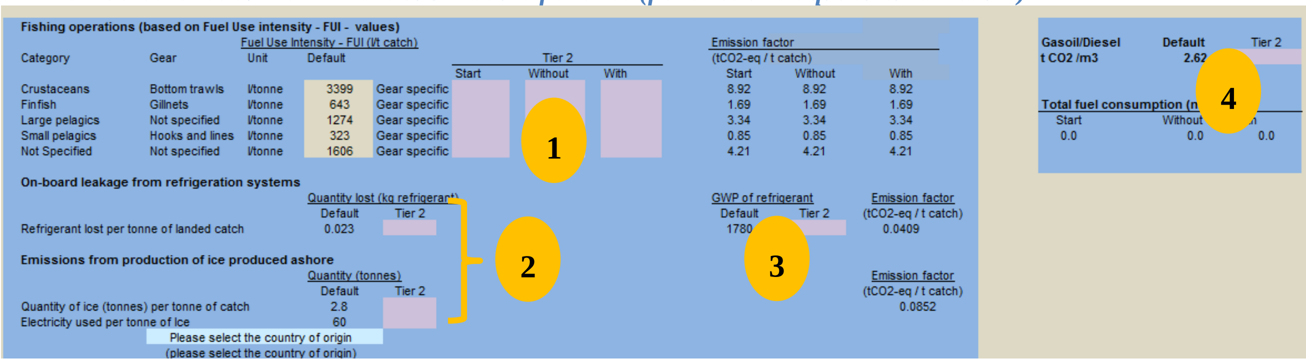
1 - The FUI, with values according to the species catch and the gear-type in use in l $tonne^{-1}$

2 - The quantity of ice (in tonne) 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)
  - The country of origin for the electricity production

3 - The refrigerant’s Global Warming Potential (GWP)

4 - The emission factor for gasoil/diesel used on board

EX-ACT Screenshot 6: Tier 2 in the sub-module fisheries (fisheries and aquaculture module)

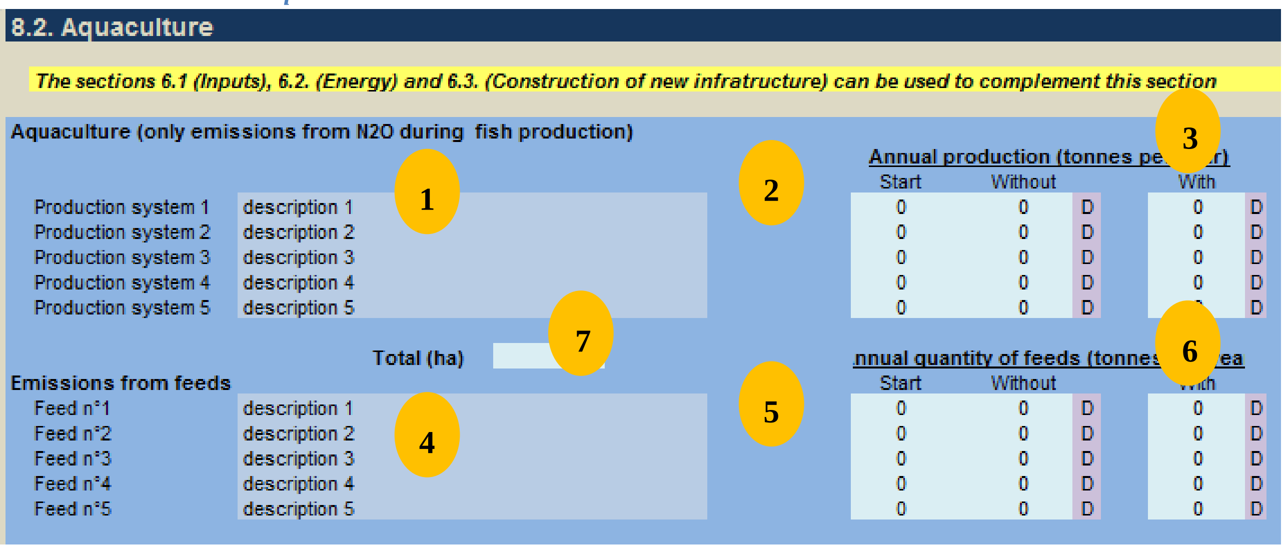


2. Aquaculture

Tables 1 and 2 from the previous chapter give information about required data and the different modules which can be of used when analyzing an aquaculture project. The present section decsribehow 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. It is also important to take into account in the total production the percentage of dead fish before the harvest phase, as they contribute to the built up of $N\text{-}N_2O$ content in the water.

EX-ACT Screenshot 7: Aquaculture sub-module



To fill the aquaculture sub-module, users need to specify:

For the fish production:

1 **Users fill up the description of the production**

2 **Annual fish production** (in tonne per year): In the second step users then specify the initial fish production as a baseline scenario, the fish production without and with project.

3 **Dynamic of change**: in case of any changes in fish production between the start and either the outcome of the project or baseline scenario, the dynamic of this production can be specified by user either as linear (default), immediate or exponentially taking place.

For the emissions from feed (carbon footprint):

4 **Users fill up the description of the feed**

5 **Annual feed quantity used** (in tonne per year): In the second step if users have then specify the initial quantity of feed used as a baseline scenario, the feed quantity used without and with project. It is necessary that user enters at Tier 2 the carbon footprint of the feed in use, as EX-ACT does not yet provide a default data.

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

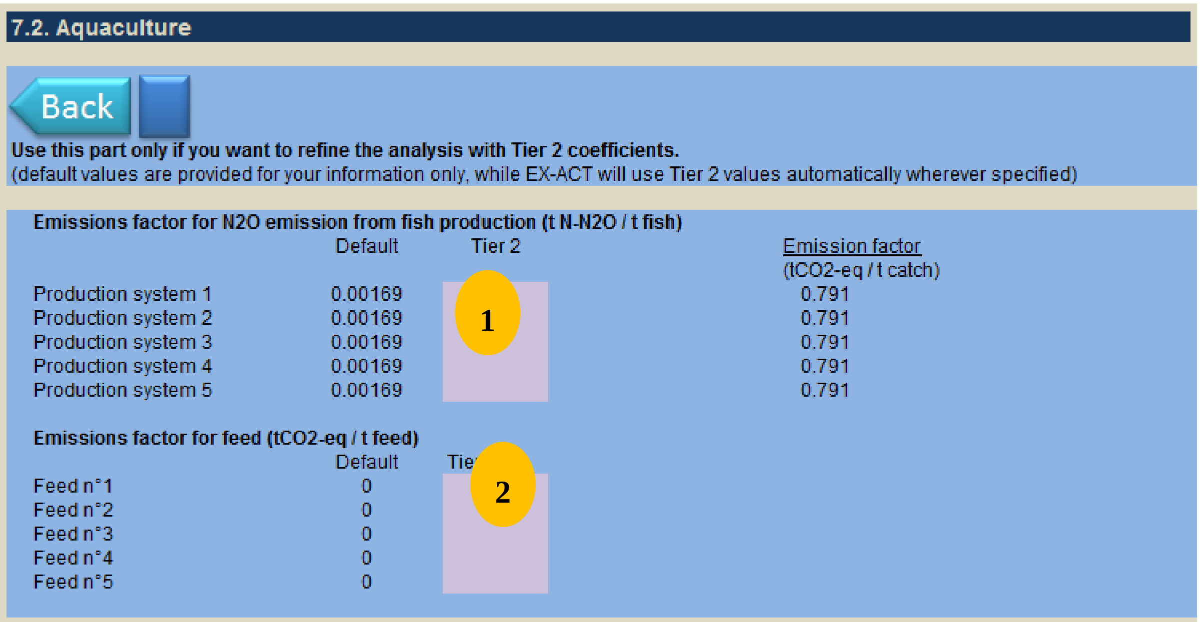
7 **The total surface area** (ha) occupied by feed fed fish farming system of the project **if** the surface of the pond is not already accounted for in others EX-ACT modules, e.g. the surface of a pond created from excavation on coastal wetlands, conversion from rice paddies to shrimp ponds are already taken into account in EX-ACT computations, thus inserting in this case the surface in the aquaculture module will lead to double the total surface area of the project in the final carbon balance.

3. Tier 2 specifications in the Aquaculture module

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

- The emission factor for N_2O emissions from fish production (t N-N_2O / t fish)
- The emission factor for feed (t CO_2-eq / t feed)

EX-ACT Screenshot 8: Tier 2 for the aquaculture sub-module



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Appendix 1 - Case study: Aquaculture project and coastal wetland management in Mozambique

The project development objective is to pilot an inclusive out-grower scheme in Mozambique and increase shrimps production. The project is taking place near the bank of a river, on site previously devoted to salt production. The project's surface area currently comprises mostly dry saline mudflat and short saline grassland, closely located to mangrove and inter-tidal mudflat along the banks. The saline mudflats infrequently wetted are converted into aquaculture ponds. The project also include mangrove plantation in the vicinity of the shrimp farm.

The 3 main components of the project are (1) excavation activities in the mudflat; (2) the improvement of the shrimps production, and (3) mangrove plantation in the vicinity of the shrimp farm on a surface area equivalent of 40% of the excavated one.

EX-ACT inputs

Table 1: 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)[(1)]	350
Mangrove plantation (ha)	176

(1) i.e. for the annual shrimp production, thus for 1 ha. The kWh cost 0,07$ in Mozambique (data retrieved from http://www.doingbusiness.org/data/exploreeconomies/mozambique/getting-electricity/)

An EX-ACT analysis is performed according to inputs data from table 1. We use the management of coastal wetlands module (excavation & rewetting), the inputs module for electricity consumption for on-farm activities and fishery modules of EX-ACT, considering the following as without- and with project scenario: (1) In the absence of project, no management activity on mudflat and shrimp farming is performed and the environment remains intact; (2) for the with-project situation we consider excavation of 440 ha of mudflat for the construction of shrimp pond-farming and associated parameters (table 1) and mangrove plantation of 176 ha.

While the project is implemented over a period of 5 years (for the progressive extraction in 440 ha of mudflat), EX-ACT takes into account an additional period of capitalization of 15 years associated to the occupation time of shrimp pond-farming.

We also use the tier 2 approach in EX-ACT, with carbon stocks in the litter, the deadwood and the above- and belowground pools set up to zero as to take into account the absence of woody vegetation. The soil carbon content is corrected according to several assumptions not detailed here (EX-ACT screenshot 1).

EX-ACT screenshot 1: Tier 2 application to excavation of mudflat (total area of 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		Below-ground		Litter		Dead wood	
	Default	Tier 2	Default	Tier 2	Default	Tier 2	Default	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)		% of C lost after excavation	
		Default	Tier 2	Default	Tier 2
Mangrove	NO	286	56.5	96%	
Tidal marsh	YES	340		96%	
Seagrass meadow		108		96%	

The following screenshot 2 summarizes the GHGs sequestration and the share of the balance per GHG. Results are given in tonne CO_2 equivalent (tCO_2-e). Positive numbers represent sources of CO_2-e emission while negative numbers represent sinks. The left table section summarizes estimated CO_2-e emissions and sinks from the scenario without-project (left column), from the scenario with-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, GHG associated to agricultural and energy input and GHG from pond-farming activities and mangrove plantations. The right table details annual CO_2-e fluxes for the different activities without and with-project implementation.

EX-ACT Screenshot 2: EX-ACT results including mangrove reforestation, gross fluxes and balance of greenhouse gases (GHG) of the without- and with-project scenario, share of GHG of the balance 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 CO_2 Biomass	 CO_2 Soil	 CO_2 Other	 N_2O	 CH_4	Result per year Without	 With	 Balance
	All GHG in tCO2eq Positive = source / negative = sink			All GHG in tCO2eq							
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 the mudflat, and revegetation) after 20 years largely counterbalances emissions associated to the mudflat excavation, via carbon sequestration in the biomass and soil. While the excavation leads to the oxidation of organic matter in soil of 87,500 tCO_2-e (it is assumed that all the carbon is oxidized during the 1^{st} year), mangrove plantations sequester about -109,000 tCO_2-e. The final carbon balance is also significantly changed over 20 years is of -0.7 tCO_2-e ha^{-1} yr^{-1}.

Appendix 2 - Case study from a real project: Fisheries management and seagrass restoration in Vietnam

The co-existence of rapid growth and high vulnerability applies to Viet Nam's fisheries sector, including both marine fisheries and aquaculture. There is evident signs that the capture fisheries is unsustainable as characterized by over-capacity of the fleet and overfishing which results in a declining of the production and increasing landing of the proportion of trash fish and small sized fish. The aquaculture sector is frequently facing high mortality rate from viral disease and environmental pollution from overconsumption of agricultural inputs. The general objective of the project is to improve the sustainable management of coastal fisheries and aquaculture which will benefit to 50,000 households. Implementation of the project has as foreseen impacts: (1) rehabilitation of the seagrass meadow, (2) reduced consumption of agricultural inputs, (3) reduction of the offshore fisheries, and (4) sustainable intensification of the aquaculture production.

Data used: The EX-ACT GHG assessment 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 during a total period of 20 years after project start, considering a six-year period for project implementation and 14 years for capitalization.

Rehabilitation of the Seagrass meadow

As a consequence of project implementation it is estimated that 83,000 hectares of seagrass meadow are restored from a state of degradation of 50 percent lost biomass to 30 percent lost biomass.

Reduced consumption of agricultural and energy inputs

The project estimates that the average annual consumption of limestone and fungicides will decrease by 30 percent due to more sustainable practices of aquaculture production. Use of urea (51 n per year) will be replaced with other forms of nitrogen fertilizers (31 tonnes per year). Indeed electricity consumption will decrease by 30 percent and gasoil 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 form aquaculture production, it is expected that the volume of near-shore fisheries will reduce by 10 percent as compared to the business-as-usual situation. Main target species are crustaceans and finfish capture by mean of gillnets. The actual annual production is of 7500 tonnes per year and 122500 tonnes of finfish per year, of which 50% is preserved on ice on board of the vessels. With the project, upgrading of coastal infrastructure will allow to increase production of ice to preserve up to 90% of the catch.

Sustainable intensification of aquaculture production

Aquaculture production is foreseen to be sustainably intensified in order to provide alternative revenue potentials to beneficiaries that do not harm the regeneration of near-shore fish stocks. While fish production will increase as well as associated GHG emissions from excretion of ammonia, feed consumption will be reduced by 10 percent as a measure to reverse too high feeding rates in current systems. Data are entered in the following screenshot:

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)					Total Emissions (tCO2-eq)		Balance
		Start	Without		With		Without	With	
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

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

Project GHG Appraisal Results

As a combination of the joined project impacts identified above, the project provides annual GHG benefits of 72,555 tCO_2e.

Over the full analysis period of 20 years a total of 1.5 million tCO_2e are mitigated. 30 % of these mitigation benefits are due to increased carbon stocks, while 70 % are due to reduced GHG emissions.

The table below shows that the reduction in agricultural input and energy use contribute 51 % of the overall mitigation benefits. The restoration of seagrass meadow contributes 31 %, while the combined impact of reducing off-shore fisheries and increasing aquaculture production contributes 18 % to the overall mitigation benefits.