The EX Ante Carbon-balance Tool

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ISSUE PAPERS **EASYPol Module xxx**

The Kirehe Community-based Watershed Management Project (KWAMP) in Rwanda

Carbon balance appraisal with the EX-ACT tool

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by

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ABBREVIATIONS

AGB:	Above Ground Biomass
BGB:	Below Ground Biomass
C:	Carbon
CO2e:	Carbon dioxide equivalent
DM:	Dry Matter
EX-ACT:	Ex-Ante Carbon balance Tool
FM:	Fresh Matter
GDP:	Gross Domestic Product
GHG:	Green House Gas
KWAMP:	Kirehe Community-based Watershed management Project
Mt CO2e:	million of tons CO2 equivalent
PAPSTA:	Support Project for the Strategic Transformation of Agriculture
SOC:	Soil Organic Carbon
PSTA:	Strategic Plan for Agricultural Transformation
SWC:	Soil & water Conservation

1 SUMMARY

This module presents a case study of Carbon-Balance Appraisal for an investment project. It is useful for people who wish to improve their skills on how to estimate climate change mitigation potential of agricultural programs/projects and to integrate it in economic analysis of projects. It is part of a set of documents aimed at driving project developers in the process of learning and applying the EX-Ante Carbon balance Tool (EX-ACT). Specifically, this case study has been developed as a result of the application of EX-ACT to an IFAD Project in Rwanda.. The case study consists of a brief description of the project and the EX-ACT analysis with a discussion of the results.

2 INTRODUCTION

Objective: This paper analyzes the carbon balance of the KWAMP project in Rwanda. The appraisal is done with the EX-ACT tool. The assessment takes into account the different activities planned within the project that can have an impact on the GHG emissions. It will enable to calculate the mitigation potential of the KWAMP project. A sensibility study has been done to analyse the impact on the results depending on the assumptions.

Target audience: This paper targets the national agriculture sector, forestry and food security policy makers, institution-based, agency and donor decision-makers.

Required background: In order to fully understand the content of this module the user must be familiar with:

- Concepts of climate change mitigation and adaptation
- Concepts of land use planning and management
- Elements of project economic analysis

Readers can follow links included in the text to other EASYPol modules or references[1]. See also the list of EASYPol links included at the end of this module.

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[1] EASYPol hyperlinks are shown in blue, as follows:

a) training paths are shown in **underlined bold font**
b) other EASYPol modules or complementary EASYPol materials are in ***bold underlined italics***;
c) links to the glossary are in **bold**; and
d) external links are in *italics*.

3 THE POSITION OF AGRICULTURE IN RWANDA AND THE KWAMP PROJECT

3.1 Background

Rwanda has launched his Vision 2020 which aims at transforming it from a low-income country into a middle-income country by the year 2020. This ambition would be realized around six pillars, one of them being a productive and market orientated agriculture. The Strategic Plan for Agricultural Transformation (PSTA) forms the framework for enhancing agricultural development. The agricultural sector in Rwanda is indeed the most important in terms of contribution to gross domestic product (GDP), employment and foreign exchange earnings. Agriculture accounts for 42% of GDP in real terms, and in 2005 approximately 90% of the economically active population was employed in the primary sector.

The Kirehe Community-based Watershed Management Project (KWAMP) as well as others projects, are a first step toward the full implementation of the PSTA strategy. They will be used to ensure that the Government's program of investment in agriculture is planned in a systematic and coordinated manner and in consistency with long-term national development objectives. The Support Project for the Strategic Transformation of Agriculture (PAPSTA) overall objective is to increase the agricultural income and improve the nutrition of poor rural population by implementing the PSTA within the frame of innovative partnerships with stakeholders. There are six pilot zones scattered across the country within this project, one of the zone being Kirehe. So the KWAMP project falls under this broader PAPSTA project.

3.2 Presentation of the KWAMP project

The Kirehe Community-based Watershed Management Project aims to promote poor smallholders of Kirehe district to overcome their food insecurity and low agricultural incomes, to arrest land degradation and to restore soil fertility.

It started in 2009 and is expected to be completed by August 2016. It will directly concern 22 500 households. The total project cost is USD 49.32 million, funded at 50% by IFAD with other stakeholders (World Food Program, German Development Services, government of Rwanda, beneficiaries, private sector partners).

The project is intended to result in:

- an increased level of marketed production of crops and livestock products, leading to increases in incomes derived from gains in productivity, farming efficiency and cash returns to effort;
- the operation and maintenance of affordable irrigation facilities made available to a large proportion of the active poor and landless farmers in the District, reducing dependence on increasingly erratic rains and permitting a shift to higher value crops in response to market demand
- a steady improvement in the natural resource base in selected watersheds to enable production in the future, reversing the present negative trends of soil erosion and nutrient depletion coupled with failure to put available water to productive use.

The project consists in the following 4 components:

- **Local institutional development**
  - Support to agricultural transformation by providing knowledge and experience to the farmers on Soil and Water Conservation (SWC). It seeks to build up the capacity of the governmental and community institutions in Kirehe to support a rapid and sustained increase in profitable smallholder agriculture in the District.
  - Water and land use management: after having selected the watersheds, their management and planning would be undertaken in a participatory manner.

- **Agricultural intensification**
  - Soil and water conservation: 300 farmers would be trained on SWC measures. The farmers so trained would in turn train other farmers, and eventually involve about 22 500 farm households
  - Crop and livestock intensification: the crop intensification part would concentrate on the promotion of cropping and agronomic practices, improvement of planting material and in-field rainwater management for dry-land cropping. The livestock intensification would engage in activities related to livestock improvement, feed and feeding development, and capacity-building
  - Irrigation development: within this sub-component, institutional support for irrigation and development of marshland and hillside irrigation would be brought to the local population
  - Value chain development: the approach is to combine an increase in the value of trade taking place with the strengthening of the economic, social and organizational capacities of the poor to give them a fair share of the profits generated

- **Feeder roads**: the third component addresses the ongoing and increasing need for fully functional feeder roads to provide physical access for farmers to enable trade in both inputs and produce

- **Project coordination**: it provides managerial and administrative support services needed to implement the substantive components.

All the sub-components of the agricultural intensification part, as well as the feeder roads component, which can be seen as a mean to develop value-chains, will have an impact on the carbon balance of the project and will thus be assessed with the EX-ACT tool. On request, we also added the Hilltop Reforestation Initiative, which is now part of PAPSTA. Under this program, 1 500 ha of degraded lands in Kirehe District are planned to be reforested, with a future total potential of 7 000 ha.

4 Measuring the mitigation potential of the project: an application of EX-ACT

4.1 Surface areas and activities concerned by the appraisal

EX-ACT aims at providing ex-ante estimates of the impact of agriculture and forestry development projects on GHG emissions and C sequestration, indicating its effects on the C-balance[2], which is selected as an indicator of the mitigation potential of the project. It can compute the C-balance by comparing two scenarios: "without project" (i.e. the "Business As Usual" or "Baseline") and "with project". Main output of the tool consists of the C-balance resulting from the difference between these two alternative scenarios.

To build the "without" scenario, the assumption made is that the situation will remain the same as currently, i.e. business as usual, without the implementation of the KWAMP project.

The different activities taken into account in the appraisal and the surface areas concerned are presented in the following drawing and table 1.

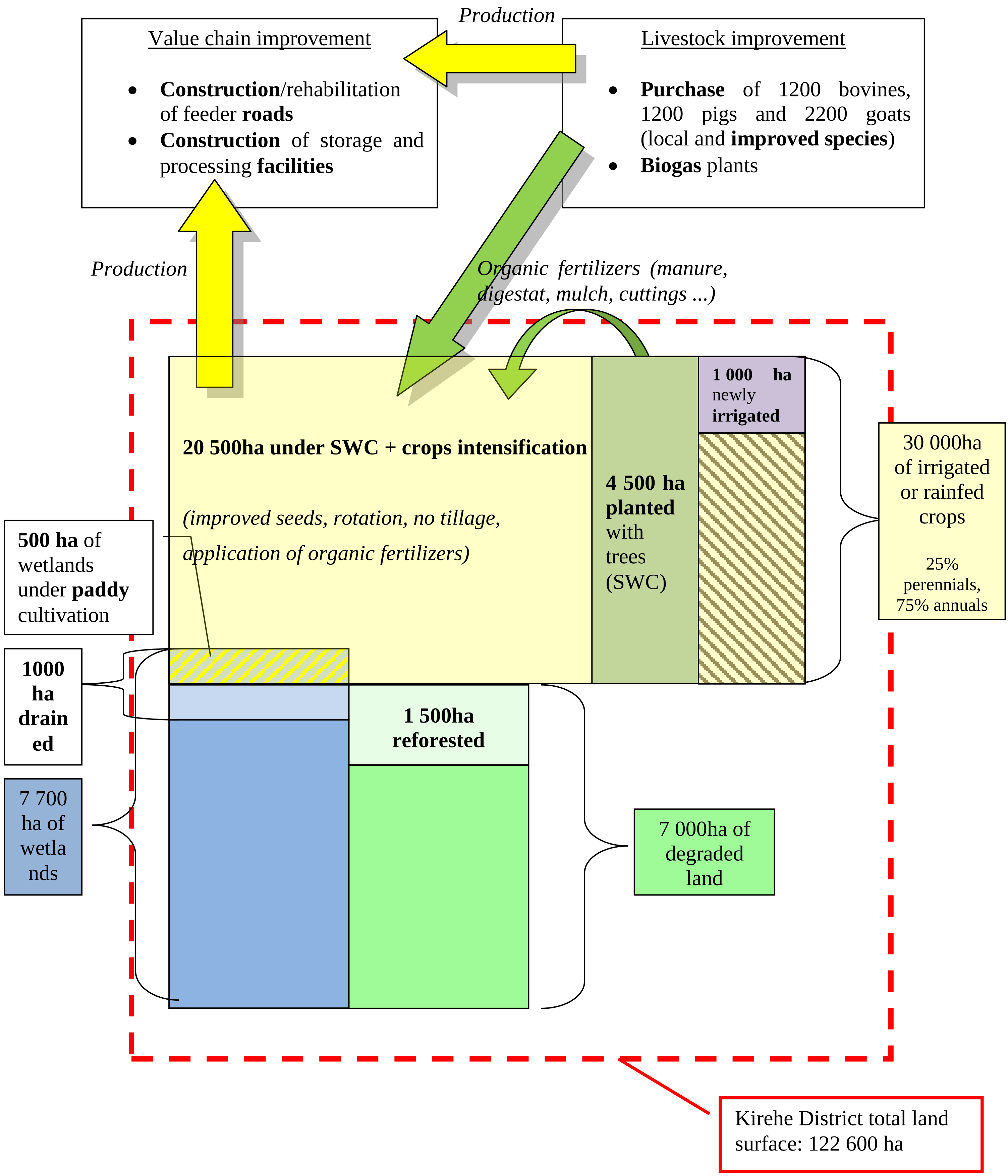
The appraisal concerns 28 000ha, of which 1 000 are wetlands (including the 500ha of paddy rice) and 1 000ha are newly irrigated.

Table 1: Land Use within the KWAMP project

	Without scenario	With scenario
Traditional annual crops	25 000	0
Improved annual crops	0	20 500 with 1 000ha newly irrigated
Perennials	0	4 500
Traditional rice (also included in the wetlands)	500	0
Improved rice (also included in the drained wetlands)	0	500
Wetlands	1 000	0
Drained wetlands	0	1 000
Degraded lands	1 500	0
Forest plantation	0	1 500
TOTAL	***28 000***	***28 000***

[2] C-balance = GHG emissions - C sequestered above and below ground.

Figure 1: Schematic representation of the KWAMP activities to take into account in EX-ACT



4.2 Biophysical characteristics of Kirehe District

The project takes place in the Kirehe District, in the South-East of Rwanda, as shown in figure 2. The district is located on two of the three main altitudinal regions of Rwanda (*figure 3*): the lowlands (1000-1500m) and the middle altitudes of the central plateau (1500-2000m). The average climate is a tropical temperate climate, with average temperatures of 20-21°C on the plateau and more than 21°C in the lowlands (*figure 4*). The north of the district is drier than the south, with an average rainfall precipitation of less than 900mm compared to 900-1100mm (*figure 5*). As a result, the climate of Kirehe is between **tropical montane dry in the north** and **tropical montane moist in the south**. This is why two assessments will be conducted, one with a dry temperate montane climate and one with a moist temperate montane climate, to compare the results and see how the choice of the climate impacts the carbon balance.

Figure 2: Localization of Kirehe District within Rwanda

Figure 3: Altitudinal regions of Rwanda

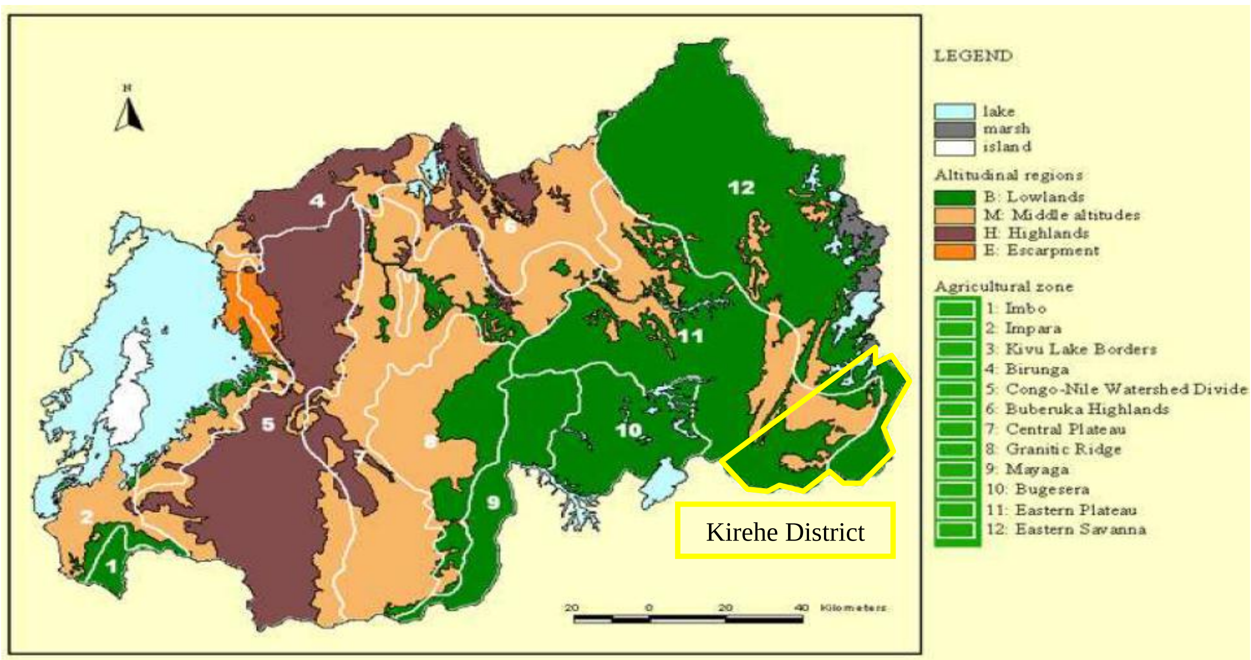


Figure 4: Rainfall distribution

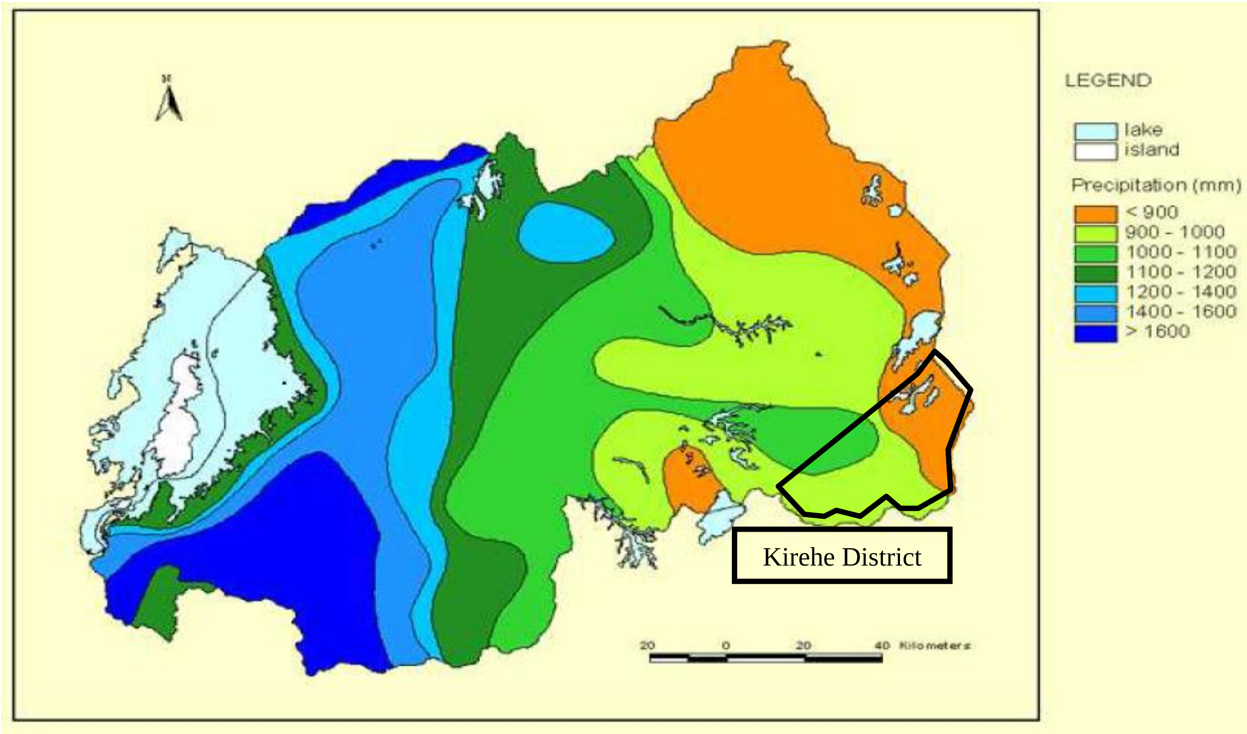
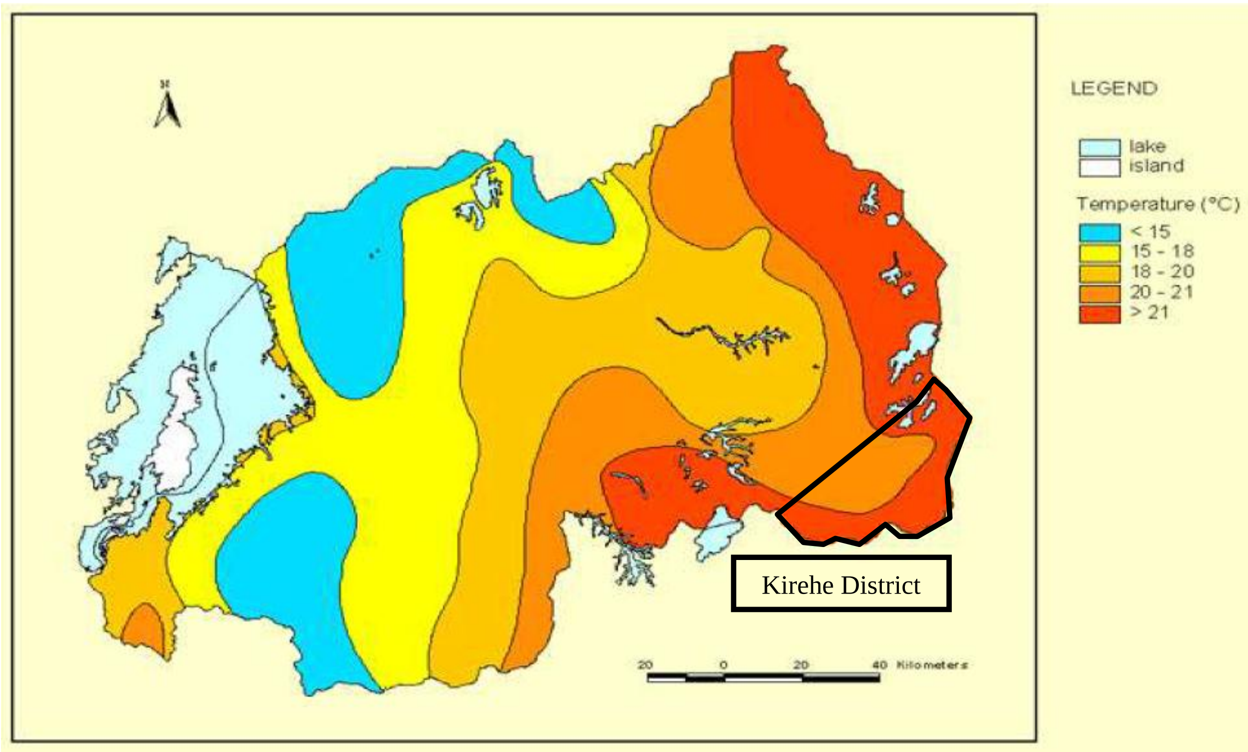


Figure 5: Temperature distribution



Sources: Working Paper 5: Agriculture and Water development, Maps

The soils on steep slopes are predominantly **fertile volcanic soils**, but they are fragile and vulnerable to deterioration and/or erosion.

The length of **implementation is 7 years** (2009-2016), so the duration of the capitalization phase is 13 years, to have a **total duration of 20 years**, which is the transition period before the SOC content (Soil Organic Carbon) reaches the equilibrium.

The EX-ACT module "description" can be filled in as follow:

Figure 6: Ex-ACT module "Description"

Description of the project			
Project Name	*KWAMP project in Rwanda*		
Continent	Africa		
Climate	Tropical Montane		
Moisture regime	Dry		
	See "Climate" for Help		
Dominant Regional Soil Type	Volcanic Soils		
	See "Soil" for Help		
Duration of the Project (Years)	Implementation phase	7	
	Capitalisation phase	13	
	Duration of accounting	20	

GWP (choose values)	
Official-CDM	
CO_2	1
CH_4	21
N_2O	310

4.3 Hilltop Reforestation Initiative

The reforestation aims at addressing both the risk of erosion of degraded lands as well as guarantees an increased wood production for the communities involved.

The first reforestations in the Kirehe district may cover approximately 1 500 ha. However, the National Forest Authority has identified an area of around 7000 ha for reforestation in the district but lacks of means for implementation. The tree species will be determined in the course of consultation processes with local villages. For the estimations of the projects' carbon sequestration we assume reforestation with 30% of *Acacia mearnsii*, 40% of *Eucalyptus spp* and 30% of *Pinus spp* at a density 1,111 plants per ha. Trees will be planted on degraded lands.

The amount of carbon sequestered in the above and below ground biomass (AGB and BGB) thanks to this afforestation has already been calculated by the World Bank Carbon Finance Business; it reaches 356 340 t CO2e on a 20 years basis. However, the carbon stock has been recalculated with EX-ACT since the tool takes into account not only AGB and BGB but also the stocks in the dead wood, the litter and the soil.

The AGB for each species is derived from the results of the World Bank. The average carbon sequestration rates obtained are respectively 10.3, 8.8 and 17 tCO2/ha/year for Eucalyptus, Acacia and Pinus. The root-shoot ratio is 0.27; the relation between the quantity of carbon and the biomass is 0.47 t C/t DM. This means that the biomass growth is as follow:

Figure 7: Biomass growth and carbon content of the tree species used for afforestattion

	Eucalyptus spp	Acacia mearnsii	Pinus spp	Weighted average
Total biomass in t DM/ha/year	5.97	5.11	9.86	6.88
AGB in tDM/ha/year	4.71	4.02	7.77	5.42
BGB in tDM/ha/year	1.27	1.09	2.10	1.46

The litter and soil C content were taken as in a tropical montane forest. (*see figure 8 below*).

The carbon balance of the afforestation of 1 500ha is a sink of about 0.460 Mt CO2e for a total period of 20 years. This result is a little higher than the WB calculation, because the litter and soil stocks were taken into account.

Figure 8: EX-ACT module "A-R" for the emissions of the reforestation on degraded lands

	Suggested Default Values per hectare (/ha)										
	Up to 20 year-old				After 20 year-old						
	Above-Ground Biomass Growth		Below-Ground Biomass gr		Above-Ground Biomass Gr		Below-Ground Biomass g		Litter total	Dead Wood	Soil C
	tonnes dm	t C	tonnes dm	t C	tonnes dm	t C	tonnes dm	t C	t C	tC	tC
Specific Vegetation 2 refo euca,	5.42	2.55	1.46	0.69	5.42	2.55	1.46	0.69	3.65	0	50

GHG emissions																
Vegetation Type	Afforested or reforested Area (ha)					Biomass Gain		Biomass Loss		Soil		Fire		Total Balance		Difference
	Start	Without Project		With Project		Without	With	Without	With	Without	With	Without	With	Without	With	
	t0	End	Rate	End	Rate	tCO2	tCO2	tCO2	tCO2	tCO2	tCO2	tCO2	tCO2	tCO2	tCO2	tCO2
A/R1	0	0	Linear		Linear	0	0	0	0	0	0	0	0	0	0	0
A/R2	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0	0	0
A/R3	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0	0	0
A/R4	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0	0	0
A/R5	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0	0	0
A/R6	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0	0	0
A/R7	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0	0	0
A/R8	0	0	Linear	1500	Linear	0	-313669	0	5500	0	-152006	0	0	0	-460175	-460175
A/R9	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0	0	0
A/R10	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0	0	0
A/R Total														0	-460175	-460175

According to information provided above, you should provide informations in the following module:

4.4 Livestock development

There are two components within this objective. The first one is the introduction of improved animals and the second one is the anaerobic digestion of the animals' dejections to produce biogas.

4.4.1 Improving the quality of livestock through the introduction of improved animals

Even if an ever-increasing proportion of the rural population own livestock (70% in 2006), whose husbandry brings a good income, the livestock production is still not very competitive. The main issues identified are the lack of grazing land and good forage quality, the lack of veterinary, breeding and extension services and the lack of good-quality livestock types. This is why one of the components of the KWAMP project is to enhance the productivity of the mixed farming production through introduction of improved animals into the integrated crop-livestock resource management production system.

The number of local or improved animals purchased is presented in table 2. We assume that the rate of increase in the size of the livestock will be the same with and without the project. The "with scenario" will only take into account the animals purchased.

Table 2: Number of additional animals introduced with the project

Type of animals	Local species purchased	Improved species introduced	Total additional animals
Dairy cow	0	1000	1000
Buffalo	200	0	200
Goats	2000	200	2200
Pigs	1000	200	1200

Figure 9: EX-ACT module "Livestock" for the emissions of the animals

Methane emissions from enteric fermentation

Choose Livestocks:	IPCC factor	Specific factor	Default Factor	Head Number: Start t0	Without Project: End	Without Project: Rate	With Project: End	With Project: Rate	Emission (t CO2eq) per year: Start	End: Without	End: With	Total Emission (tCO2eq) All Period: Without	All Period: With	Difference
Dairy cattle	40		YES	0	0	Linear	1000	Linear	0	0	840	0	13 860	13 860
Other cattle	31		YES	0	0	Linear	200	Linear	0	0	130	0	2 148	2 148
Buffalo	55		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Sheep	5		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Swine (Market)	1,5		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Swine (Breeding)	1,5		YES	0	0	Linear	1200	Linear	0	0	38	0	624	624
Goats	5		YES	0	0	Linear	2200	Linear	0	0	231	0	3 812	3 812
Please select	0		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Please select	0		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
User Defined- Specified value -------------		5	NO	0	0	Linear	0	Linear	0	0	0	0	0	0
User Defined- Specified value -------------		6	NO	0	0	Linear	0	Linear	0	0	0	0	0	0
								Sub-Total	0	0	1239	0	20 444	20 444

PLEASE SPECIFY INFORMATION BELOW IF AVAILABLE

Country "Type"	Developing
Mean Annual Temperature (MAT*) in °C	21

Possible

*MAT affects Methane emission from manure management

Methane emissions from manure management

Livestocks:	IPCC factor	Specific factor	Default Factor	Head Number: Start t0	Without Project: End	Without Project: Rate	With Project: End	With Project: Rate	Emission (t CO2eq) per year: Start	End: Without	End: With	Total Emission (tCO2eq) All Period: Without	All Period: With	Difference
Dairy cattle	1		YES	0	0	Linear	1 000	Linear	0	0	21	0	347	347
Other cattle	1		YES	0	0	Linear	200	Linear	0	0	4	0	69	69
Buffalo	1		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Sheep	0,15		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Swine (Market)	1		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Swine (Breeding)	1		YES	0	0	Linear	1 200	Linear	0	0	25	0	416	416
Goats	0,17		YES	0	0	Linear	2 200	Linear	0	0	8	0	130	130
Please select	0		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Please select	0		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
User Defined- Specified value -------------->			NO	0	0	Linear	0	Linear	0	0	0	0	0	0
User Defined- Specified value -------------->			NO	0	0	Linear	0	Linear	0	0	0	0	0	0
								Sub-Total	0	0	58	0	961	961

Nitrous Oxide emissions from manure management

Livestocks:	IPCC factor	Specific factor	Default Factor	Annual amount of N manure* (t N per year): Start t0	Without Project: End	Without Project: Rate	With Project: End	With Project: Rate	Emission (t CO2eq) per year: Start	End: Without	End: With	Total Emission (tCO2eq) All Period: Without	All Period: With	Difference
Dairy cattle	0,01		YES	0	0	Linear	60	Linear	0	0	293	0	4 841	4 841
Other cattle	0,01		YES	0	0	Linear	8	Linear	0	0	39	0	640	640
Buffalo	0,01		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Sheep	0,01		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Swine (Market)	0,01		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Swine (Breeding)	0,01		YES	0	0	Linear	7	Linear	0	0	33	0	542	542
Goats	0,01		YES	0	0	Linear	33	Linear	0	0	161	0	2 653	2 653
Please select	0,01		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Please select	0,01		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
User Defined- Specified value -------------->			NO	0	0	Linear	0	Linear	0	0	0	0	0	0
User Defined- Specified value -------------->			NO	0	0	Linear	0	Linear	0	0	0	0	0	0
see equation 10.30								Sub-Total	0	0	526	0	8 675	8 675

Total "Livestocks"	**0**	**30080**	**30 080**

The introduction of 4 600 animals will lead to a positive carbon balance of 30 080 tCO2e for 20 years.

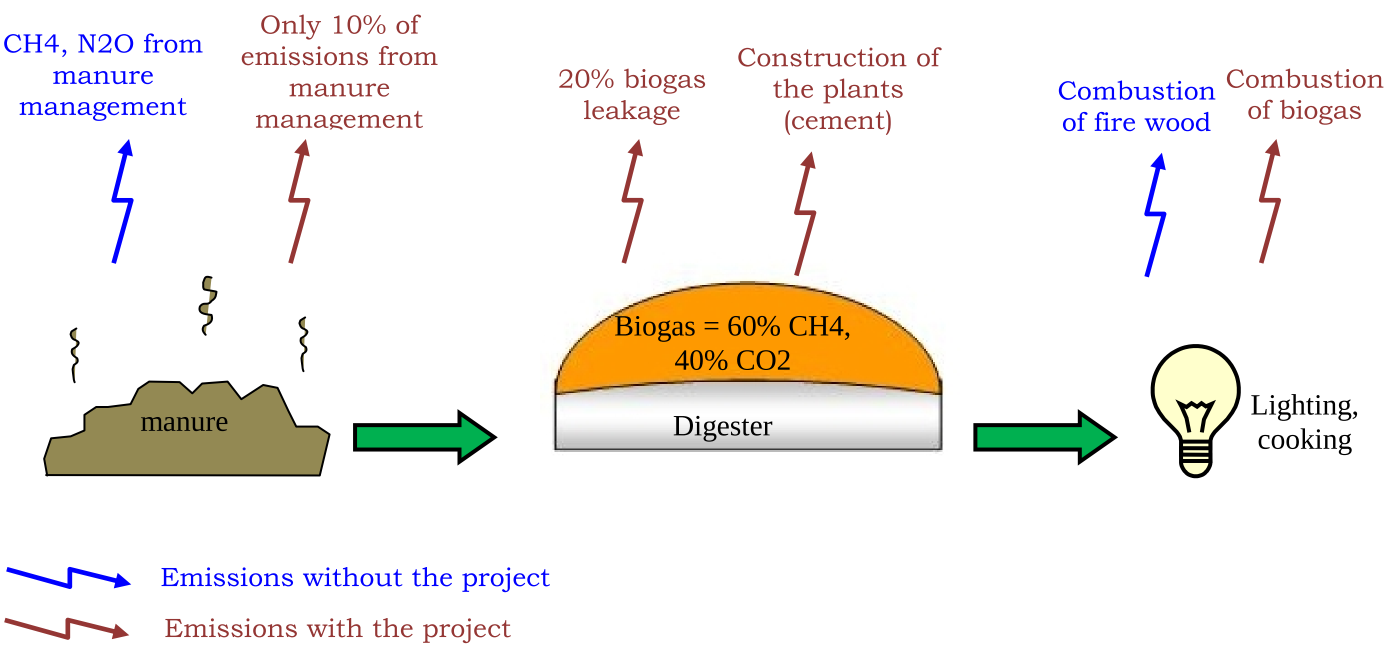
4.4.2 Biogas production

The increase in livestock ownership provides an opportunity for the introduction of appropriate and affordable biogas technology. 2 000 small low-cost household biogas plants will be built, dimensioned for the dung produced by one cow (2-3 t of manure per year)[3]. The advantages of the digesters are to provide good quality organic fertilizers (the digestat), cooking and lighting energy that are going to replace fuel woods.

The implementation of biogas plants will have different effects on the carbon balance, as shown in figure 10:

- Emissions from the construction of the plants
- Emissions from biogas leakages
- Emissions from the combustion of biogas
- Avoided emissions from the non use of fire wood
- Avoided emissions from manure management

Figure 10: schematic representation of the impact of biogas plants on GHG emissions



We suppose that small biogas plants of $1m^3$ will be built, as the example in figure 11. The GHG emissions from the construction mainly come from the cement (≈110 kg/plant).[4] As the production

[3] Working Paper 4: Livestock development, p.7
[4] Evaluation of small-scale biogas systems for the treatment of faeces and kitchen waste - Case study Kochi, South India, Nicolas Estoppey, May 2010, p.16

of 1t of cement emits 990 kg CO2e[5], the total emissions from the construction of 2 000 biogas plants are about 218 t CO2e (*figure* 12).

Figure 11: A one cubic meter floating-dome biogas plant, installed by BIOTECH in a home in South India.

Source: http://www.ashdenawards.org/biogas

Figure 12: EX-ACT module "Other investment" for the emissions of the biogas plants construction

Released GHG associated with building of infrastructure

Type of construction or infrastructure	Default value t CO2 /m2	Specific Value	Default Factor	surface (m2)		Emission (t CO2eq)	
				Without	With	Without	With
Other (concrete)	0.550	0.99	NO	0	220	0.0	217.8
Please select	0.000		YES			0.0	0.0
Please select	0.000		YES			0.0	0.0
Please select	0.000		YES			0.0	0.0
Please select	0.000		YES			0.0	0.0
Please select	0.000		YES			0.0	0.0
Please select	0.000		YES			0.0	0.0
			Subtotal	0.0	217.8	*Difference*	*217.8*

The biogas is a mix of CH4 (60-65%) and CO2 (35-40%). 1m^3 (or 1t) of cattle manure digested produced on average 22 m^3 of biogas[6]. The biogas released in the atmosphere contributes to climate change with a warming power of 9.3 kg CO_{2e}/m^3 biogas. It has been calculated with the following formula:

$$WP\ of\ biogas = 60\% * \rho_{CH4} * WP_{CH4} + 0.4 * \rho_{CO2} * WP_{CO2}$$

With ρ_{CH4} = volumic mass of methane at 15°C = 0.68 kg/m3

http://www.eawag.ch/forschung/sandec/publikationen/swm/dl/evaluation_biogas.pdf

[5] ADEME, Bilan Carbone, Guide des facteurs d'émissions V.6.1, Chapitre 5 – Prise en compte des matériaux de base entrants et des services tertiaires achetés, juin 2010, p.22

[6] http://www.folkecenter.net/default.asp?id=41047 and Biogas Digest Volume III, GTZ, p.31 http://www.gtz.de/de/dokumente/en-biogas-volume3.pdf

ρ_{CO2} = volumic mass of carbon dioxyd at 15°C = 1.87 kg/m3
WP_{CH4} = warming power of methane = 21
WP_{CO2} = warming power of carbon dioxide = 1

We make the assumption that domestic biogas plants are not perfect and that there is 20% of leaks (*figure 13*). The amount of CO_{2e} released because of this leakage is

*Number of digester * WP of biogas * volume of biogas produced by one digester * 20% = 2 000 * 9.32 * 22 * 0.2 = 82 t CO2e/year*

The combustion of biogas emits 1.8 kg CO_{2e}/m^3 of biogas.[7] The amount of CO_{2e} released because of biogas combustion is (*figure 13*):

*EF from combustion * number of digesters * volume of biogas produced by one digester * (1-% leakage) = 1.8 * 2 000 * 22 * 0.8 = 63.4 t CO2e/year.*

Figure 13: EX-ACT module "Other investments" for the emissions from the leaks and the combustion of biogas

OPTION 2 (Based on Annual Fuel consumption at the beginning and according to dynamic changes)

Type of Fuel	Default value t CO2 /m3	Specific Value	Default Factor	Annual Fuel Consumption (m3/yr) Start t0	Without Project End	Without Project Rate	With Project End	With Project Rate	Emission (t CO2eq) All Period Without	Emission (t CO2eq) All Period With
Gasoil/Diesel	2.63		YES	0	0	Linear	0	Linear	0	0
Gasoline	2.85		YES	0	0	Linear	0	Linear	0	0
Gas (LPG/ natural)	1.69		YES	0	0	Linear	0	Linear	0	0
Propane	1.53		YES	0	0	Linear	0	Linear	0	0
biogas combustion	1.76	0.0018	NO	0	0	Linear	35200	Linear	0	1045
User defined	biogas leakage	0.0093	NO	0	0	Linear	8800	Linear	0	1353
	t CO2/t dry matter			Annual Consumption in t dry matter						
Wood	0.010		YES	406.153792	406.1538	Linear	0	Linear	83	14
Peat	0.003		YES	0	0	Linear	0	Linear	0	0

OPTION1 + OPTION2	Sub-Total Without	82.5	Sub-Total With	2413.1	Difference	2330.6

These emissions will be compensated by the fact that fire woods will not be used anymore. $1m^3$ of biogas has an energy content of 6 kWh (at 60% methane), wood has an energy content of 5.2 kWh/kg dry matter (totally dry)[8]. In a word, $1m^3$ of biogas is equivalent to 1.15 kg DM of wood. As the biogas plants will produce annually 0.8*20 000*22 = 352 $000m^3$ of biogas (80% in order to account for the leakages), it will replace the use of 406 154 kg DM of wood, thus preventing the emissions of 4.1 t CO2e/year (see *figure 13*)

However, the anaerobic digestion of manure also prevents the methane and nitrous oxide emissions from manure management. The assumption is that 90% of the emissions from manure management are prevented thanks to the biogas plants (the manure will still be stored for a short period before entering the digester). EX-ACT can calculate these avoided emissions if we add 1 800 dairy cows (90% of 2 000) in the "without" scenario and 0 dairy cows in the "with" scenario. However, we have to use an emission factor of 0 for the enteric fermentation since it is only the emissions from manure management that are concerned (see *figure 14*)

[7] Cow power: the energy and emissions benefits of converting manure to biogas, p.4 http://iopscience.iop.org/1748-9326/3/3/034002/fulltext
[8] http://energy.saving.nu/biomass/guidelines.shtml

Figure 14: EX-ACT module "Livestock" for the avoided emissions of manure management

Methane emissions from enteric fermentation

Choose Livestocks:	IPCC factor	Specific factor	Default Factor	Head Number: Start t0	Without Project End	Without Project Rate	With Project End	With Project Rate	Emission (t CO2eq) per year: Start	End Without	End With	Total Emission (tCO2eq) All Period Without	All Period With	Difference
Dairy cattle	40		YES	0	0	Linear	1000	Linear	0	0	840	0	13,860	13,860
Other cattle	31		YES	0	0	Linear	200	Linear	0	0	130	0	2,148	2,148
Buffalo	55		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Sheep	5		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Swine (Market)	1.5		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Swine (Breeding)	1.5		YES	0	0	Linear	1200	Linear	0	0	38	0	624	624
Goats	5		YES	0	0	Linear	2200	Linear	0	0	231	0	3,812	3,812
Please select	0		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Please select	0		YES	*0*	*0*	Linear	*0*	Linear	0	0	0	0	0	0
*manure for biogas=0,9*20 000 cows*		0	NO	*1800*	*1800*	Linear	*0*	Linear	0	0	0	0	0	0
User Defined- Specified value ----------		6	NO	*0*	*0*	Linear	*0*	Linear	0	0	0	0	0	0
								Sub-Total	0	0	1,239	0	20,444	20,444

PLEASE SPECIFY INFORMATION BELOW IF AVAILABLE

Country "Type"	*Developing*
Mean Annual Temperature (MAT*) in °C	21

Possible

*MAT affects Methane emission from manure management

Methane emissions from manure management

Livestocks:	IPCC factor	Specific factor	Default Factor	Head Number: Start t0	Without Project End	Without Project Rate	With Project End	With Project Rate	Emission (t CO2eq) per year: Start	End Without	End With	Total Emission (tCO2eq) All Period Without	All Period With	Difference
Dairy cattle	1		YES	0	0	Linear	1,000	Linear	0	0	21	0	347	347
Other cattle	1		YES	0	0	Linear	200	Linear	0	0	4	0	69	69
Buffalo	1		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Sheep	0.15		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Swine (Market)	1		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Swine (Breeding)	1		YES	0	0	Linear	1,200	Linear	0	0	25	0	416	416
Goats	0.17		YES	0	0	Linear	2,200	Linear	0	0	8	0	130	130
Please select	0		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Please select	0		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
manure for biogas=0,9*20 000 cows		1	NO	1,800	1,800	Linear	0	Linear	38	38	0	756	132	-624
User Defined- Specified value ---------------->			NO	0	0	Linear	0	Linear	0	0	0	0	0	0
								Sub-Total	38	38	58	756	1,093	337

Nitrous Oxide emissions from manure management

Livestocks:	IPCC factor	Specific factor	Default Factor	Annual amount of N manure* (t N per year): Start t0	Without Project End	Without Project Rate	With Project End	With Project Rate	Emission (t CO2eq) per year: Start	End Without	End With	Total Emission (tCO2eq) All Period Without	All Period With
Dairy cattle	0.01		YES	0	0	Linear	60	Linear	0	0	293	0	4,841
Other cattle	0.01		YES	0	0	Linear	8	Linear	0	0	39	0	640
Buffalo	0.01		YES	0	0	Linear	0	Linear	0	0	0	0	0
Sheep	0.01		YES	0	0	Linear	0	Linear	0	0	0	0	0
Swine (Market)	0.01		YES	0	0	Linear	0	Linear	0	0	0	0	0
Swine (Breeding)	0.01		YES	0	0	Linear	7	Linear	0	0	33	0	542
Goats	0.01		YES	0	0	Linear	33	Linear	0	0	161	0	2,653
Please select	0.01		YES	0	0	Linear	0	Linear	0	0	0	0	0
Please select	0.01		YES	0	0	Linear	0	Linear	0	0	0	0	0
manure for biogas=0,9*20 000 cows		0.01	NO	108	108	Linear	0	Linear	526	526	0	10,522	1,841
User Defined- Specified value ---------------->			NO	0	0	Linear	0	Linear	0	0	0	0	0
								Sub-Total	526	526	526	10,522	10,517

see equation 10.30

Total "Livestocks"	11278	32054	20,775

The carbon balance of manure management linked with anaerobic digestion of the dejections is -9 305 t CO2e. (-8 681 + -624)

As a result, the anaerobic digestion of the manure will decrease the GHG emissions by 6 756 t CO2e for 20 years. (-9 305 + 2 331 + 218).

4.5 Soil and Water Conservation (SWC) measures and crops intensification

One of Kirehe District main issue is the decline in agricultural productivity. Rapid population growth has led to land fragmentation; land scarcity prompts farmers to expand cultivation on marginal land, where erosion and loss of soil fertility reduce productivity levels. Farmers will be trained to adopt better management practices, thus limiting the erosion and increasing the yields.

Two main types of SWC activities will occur, on 25 000ha:

- Vegetative measures: cover crops — investigating the sequential and intercropping system and crop characteristics, practices on improving organic matter such as crop rotation, applying manure, green manure such as leguminous crops and trees, mulching, and planting grass barrier strips such as *Pennissetum purpureum, Panicum maximum.*
- Physical measures — bench terracing, trenches (*Fanya Juu*), trash lines, roadbeds and furrows, conservation tillage, zero or minimum tillage.

4.5.1 Planting of grass or shrubby barrier strips

It is proposed to establish forage trees such as *Gliricidia*, *Calliandra*, *Crevelia*, *Acacia meanci* and *Leucaena diversifolia* along the trenches and other anti-erosion structures.

In each household, 0.2 ha of lands will be planted to create hedges and thus protect SWC structures. As 22 500 households will be concerned, it represents a surface area of 4 500ha with a density of 2 500 trees/ha. Planting of grass strips on the edges and crop separation lines, with Pennissetum (60 000 cuttings) and Gliricidia will also be implemented.

These actions will provide every household an area for fuel wood and fodder for their farm animals.

The assumption makes here is that the 4 500ha of Gliricidia will be planted on 4 500ha of annual crops. Thus the "non forest land use change" module of EX-ACT should be filled in (*figure 15*). It will also have an impact on the "perennials" module.

Tier 2 coefficients have been found for the Gliricidia specie: a mean above ground biomass growth of 4.8 t DM/ha[9], i.e. 2.26 t C/ha and a root-shoot ratio of 0.49[10], thus giving a below ground biomass of 2.35 t DM/ha, i.e. 1.11 t C/ha.

Figure 15: EX-ACT module "non forest land use change" and "perennials" for the carbon storage due to Gliricidia plantations

Name	Your Name	Description of LUC: Initial Land Use	Final Land Use	Alert	Burnt before conversion
LUC-1	plantation of Glyricidia on annual crops	Annual Crop	Perennial/Tree Crop		NO
LUC-2		Select Initial Land Use	Select Final Land Use	Fill initial LU	NO
LUC-3		Select Initial Land Use	Select Final Land Use	Fill initial LU	NO
LUC-4		Select Initial Land Use	Select Final Land Use	Fill initial LU	NO

GHG emissions		Area concerned by LUC				Biomass Change		Soil Change	
Vegetation Type		Without Project		With Project		Without	With	Without	With
		Area	Rate	Area	Rate	tCO2	tCO2	tCO2	tCO2
LUC-1	plantation of Glyricidia on annual crops	0	Linear	4500	Linear	0	52800	0	-245025
LUC-2		0	Linear	0	Linear	0	0	0	0
LUC-3		0	Linear	0	Linear	0	0	0	0

---

9 Above ground biomass production and nitrogen content in Gliricidia sepium (JACQ.) walp under several pruning regimes, 2005, table 1
http://www.scielo.org.ve/scielo.php?script=sci_arttext&pid=S0378-18442005000300008&lng=es&nrm=iso&tlng=en
Competition between six hedgerow tree species and mung bean (Vigna radiate (L.) Wilczek) in the mid-country intermediate zone, 2000, p.7
http://thakshana.nsf.ac.lk/pdf/JNSF26-34/JNSF28_2/JNSF28_2_113.pdf

10 Temporal change in carbon stocks of cocoa–gliricidia agroforests in Central Sulawesi, Indonesia, 2008, p.4
http://www.worldcocoafoundation.org/scientific-research/research-library/documents/Smiley2008.pdf

Fire		Total Balance		Difference
Without	With	Without	With	
tCO2	tCO2	tCO2	tCO2	tCO2
0	0	0	-192225	-192225
0	0	0	0	0
0	0	0	0	0

Agroforestry/Perennial/tree Crops Back to Description

	Your description	Residue/Biomass Burning	Interval (yr)	Tons dm/ha	Aboveground Biomass Growth rate (tC/ha) Default	Specific	Belowground Biomass Growth rate (tC/ha) Default	Specific	Soil Effect Default t CO2/ha/yr	User default available	tCO2/ha/yr	CH4 kg	N2O kg	CO2eq t
Reserved system P1	From Deforestation	NO	1	10	1,8		0		0,33	NO		0	0	0,0
Reserved system P2	Converted to A/R	NO	1	10	0		0		0,33	NO		0	0	0,0
Reserved system P3	OLUC to Perennial	NO	1	10	1,8	2,26	0	1,11	0,33	NO		0	0	0,0
Reserved system P4	Perennial to OLUC	NO	1	10	0		0		0,33	NO		0	0	0,0

Mitigation potential

Vegetation Type	Areas Start t0	Without project End	Rate	With Project End	Rate	CO_2 fluxes from Biomass Without	With	CO_2 fluxes from Soil Without	With	CO_2eq emitted from Burn Without	With	Total Balance Without tCO_2	With tCO_2	Difference tCO2eq
System P1	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
System P2	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
System P3	0	0	Linear	4500	Linear	0	-889680	0	-24503	0	0	0	-914183	-914183
System P4	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0

Planting Gliricidia as a mean to protect other anti-erosion infrastructures such as trenches or terraces will store 1 106 408 t CO2e. (192 225 + 914 183)

4.5.2 Better agronomic practices

Other SWC measures concern agronomics practices (crop rotation, application of manure and green fertilizers (biomass from the hedges, mulch, digestat …), reduction of tillage, hardy genetic planting material and seeds that can adapt to climatic change). 20 500ha are concerned (25 000 minus the 4 500 planted with Gliricidia).

Figure 16: EX-ACT module "annual" for the avoided emissions from better agronomic practices on crops

	Your description	User-defined practices	Name	Rate in tC/ha/yr	Improved agro-nomic practic	Nutrient management	NoTillage/residue management	Water managemen	Manure application	Residue/Biomass Burning	t dm/ha
Reserved system A1	from Deforestation	NO			?	?	?	?	?	NO	10
Reserved system A2	Converted to A/R	NO			?	?	?	?	?	NO	10
Reserved system A3	Annual From OLUC	NO			?	?	?	?	?	NO	10
Reserved system A4	Converted to OLUC	NO			?	?	?	?	?	NO	10
Annual System1	Current system "	YES	Equilibrium	0	A conservative approach is to consider this system at equilibrium or decreasin					NO	10
Annual System2	traditionnal crops	NO			?	?	?	?	?	NO	10
Annual System3	SWC crops	NO			Yes	?	Yes	?	Yes	NO	10

Mitigation potential

Vegetation Type	Areas Start t0	Without project End	Rate	With Project End	Rate	Soil CO2 Change Without tCO2	With tCO2	CO2eq emitted from Burnin Without tCO2	With tCO2	Total Balance Without tCO2	With tCO2	Difference tCO2
System A1	0	0	Linear	0	Linear	0	0	0	0	0	0	0
System A2	4500	4500	Linear	0	Linear	0	0	0	0	0	0	0
System A3	0	0	Linear	0	Linear	0	0	0	0	0	0	0
System A4	0	0	Linear	0	Linear	0	0	0	0	0	0	0
Annual System1	0	0	Linear	0	Linear	0	0	0	0	0	0	0
Annual System2	20500	20500	Linear	0	Linear	0	0	0	0	0	0	0
Annual System3	0	0	Linear	20500	Linear	0	-520905	0	0	0	-520905	-520905
Annual System4	0	0	Linear	0	Linear	0	0	0	0	0	0	0

The better agronomic practices create a carbon sink of 520 905 t CO2e, as presented in figure 16. However, the application of green fertilizers on the crops will emit N_2O. Only the emissions from the application of digested manure have been taken into account, since we have no data about the quantity of biomass from plants (crops, trees). As the use of fertilizers among farmers in Kirehe District is really low, about 0.5% of the smallholders, the emissions for the "without" scenario are negligible. The table below presents the figures[11] used to calculate the amount of N applied on the crops.

Table 3: Nutrients and dry matter content of fresh and digested cow dung

	Fresh cow dung	Digested cow dung
%dry matter (DM)	21.4	2.5
% N on a DM basis	1.5	1.7
Quantity of N in 1t of manure (on a FM-fresh matter basis) kg N/t FM	3.21	0.425

As the quantity of dung produced by one cow is 2.5 t FM/year, and as there are 20 000 biogas plants with an individual capacity of 1 cow's dejections, the total amount of N available to be spread on lands is 21.25 tN/year (2.5*20000*0.425/1000). It will lead to the emission of 1 087 t CO2e during 20 years (*figure 17*).

Figure 17: EX-ACT module "inputs" for the emissions from digested manure application on soils

N_2O emissions from N application on managed soils (except manure management see Livestock Module)

Type of input	IPCC factor	Specific factor	Default Factor	Amount of N Applied (t per year): Start t0	Without Project: End	Without Project: Rate	With Project: 0	With Project: Rate	Emission (t CO2eq) per year: Start	End: Without	End: With	Total Emission (tCO2eq): Without	Total Emission (tCO2eq): With	Difference
Urea	0,01		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
N Fertiliser (other than Urea)	0,01		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
N Fertiliser in non-upland Rice*	0,003		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Sewage	0,01		YES	0	0	Linear	0	Linear	0,0	0,0	0,0	0	0	0
Compost	0,01		YES	0	0	Linear	21	Linear	0,0	0,0	65,9	0	1 087	1087
								Sub-Total I-3	0,0	0,0	65,9	0	1087	1087

*N fertilizer from upland rice should be included above (N fertilizer)

The total net mitigation potential for adapting better agronomic practices is -519 818 tCO2e.

4.6 Irrigation development

Water management, including drainage, rainwater management and irrigation, can provide an opportunity for both intensification -through increases yields and cropping intensity- and diversification.

1 000ha of marshland will undergo low-cost improvements such as drainage and flood protection. Of these 1 000ha, 50% are under annual cultivation (paddy rice); the other 50% are considered as

[11] Biodigester effluent versus manure from pigs or cattle as fertilizer for production of cassava foliage (*Manihot esculenta*), 1998
http://www.fao.org/AG/aGa/agap/FRG/FEEDback/lrrd/lrrd10/3/chau1.htm - these data are similar to other data found in the literature

grassland. Thus, 500ha of paddy will switch from continuously to intermittently flooded, with a cultivation period of 120 days and a flooded pre-season of 30 days.[12] Straws are usually burned.[13]

The "irrigated rice" and "organic soils" modules have to be filled in, as indicated by the following figures.

Figure 18: EX-ACT module "Irrigated rice" for the rice that is drained

Build the Irrigated Rice systems" (upland Rice is treated as "Annual" Agricultural system)

	Your description	Cultivation period (Days)	Water Regime: During the cultivation Period	Water Regime: Before the cultivation period (need help)	Organic Amendment type (Straw or other)	rate tonne
Reserved system R1	from Deforestation	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment	5.5
Reserved system R2	converted to A/R	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment	5.5
Reserved system R3	from OLUC	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment	5.5
Reserved system R4	Rice to OLUC	150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment	5.5
Rice1	paddy in wetland	120	Irrigated - Continuously flooded	Flooded preseason (>30 days)	Straw burnt	5.5
Rice2	paddy drained	120	Irrigated - Intermittently flooded	Flooded preseason (>30 days)	Straw burnt	5.5
Rice3		150	Please select water regime	Please select preseason water regime	Please select type of Organic Amendment	5.5

CH4 emission from rice systems — **Change over the period (t CO2eq)**

Areas (ha) of the different options: Type	Start t0	Without Project End	Without Project Rate	With Project End	With Project Rate	Soil C changes All period Without	Soil C changes All period With	CH4 emitted All period Without	CH4 emitted All period With	Straw burning Without	Straw burning With	Total t CO2 eq Without	Total t CO2 eq With	Difference tCO2eq
System R1	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
System R2	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
System R3	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
System R4	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
Rice1	500	500	Linear	0	Linear	0	0	62244	10893	3450	604	65694	11496	-54197
Rice2	0	0	Linear	500	Linear	0	0	0	28757	0	2846	0	31603	31603
Rice3	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
Rice4	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
Rice5	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
Rice6	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
Rice7	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
Rice8	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
Rice9	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
Rice10	0	0	Linear	0	Linear	0	0	0	0	0	0	0	0	0
Total Systems 1-10	500	500		500										
											Total	65694	43099	-22595

The switch from continuously to intermittently flooded rice avoids the emissions of 22 595 t CO2e.

Figure 19: EX-ACT module "Organic soils" for the wetlands that are drained

Emissions from loss of C associated with drainage of organic soils

Type of Land use	Emission factors (tonnes C ha-1yr-1) IPCC	Specific	Default	Surface of organic soils concerned (ha) Start	Without Project End	Without Project Rate	With Project End	With Project Rate	Emission (t CO2eq) per year Start	End Without	End With	Total Emission (tCO2eq) All Period Without	All Period With	Difference
Managed Forest	1,36		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Annual	20,00		YES	0	0	Linear	500	Linear	0	0	36 667	0	605 000	605 000
Perennial	1,36		YES	0	0	Linear	0	Linear	0	0	0	0	0	0
Grassland	5,00		YES	0	0	Linear	500	Linear	0	0	9 167	0	151250	151250

Total Organic soils	**0**	**756,250**	**756,250**
Total area of organic soils and peatlands (ha)		1000	

The drainage of marshlands will emit 756 250 t CO2e.

[12] Working paper 5: Agriculture & Water development, p.21

[13] Ministry of Agriculture and Animal Resources Republic of Rwanda- Enabling Self Sufficiency and Competitiveness of Rwanda Rice, p.14 http://www.google.co.uk/url?q=http://minagri.gov.rw/index.php%3Foption%3Dcom_docman%26task%3Ddoc_download%26gid%3D23%26Itemid%3D37%26lang%3Den&sa=U&ei=b1BBTojpFYfpObmaqboJ&ved=0CBsQFjAD&usg=AFQjCNHASDo7MchKv-dRlmNXEtpNfFIEfA

Combined with the change in rice production practices, drainage of wetlands leads to a carbon source of 733 655 t CO2e.

1 000ha of hillside lands, with a slope lower than 12% will be newly irrigated, using mini dams, ponds, cisterns, distribution systems. It will be considered as a without IRSS irrigation system within EX-ACT (Irrigation runoff return system).

Figure 20: EX-ACT module "Other investment" for irrigation

Released GHG associated with installation of irrigation systems

Installation of irrigation system	surface (ha)	Type of irrigation system	Associated tCO2eq
Without Project	0	Please select	0.0
With Project	1000	Surface without IRSS	34.0
		Difference	34.0

The irrigation of 1000ha of hillside lands is a carbon source of 34 t CO2e.

The irrigation development component of the KWAMP project is a carbon source of 733 689 t CO2e for 20 years.

4.7 Value-chain development

The market is seen to be the driver of increased incomes from agriculture and livestock husbandry. All project efforts to intensify agriculture in the district will be regarded as part of the value-chain development. The objective is to develop value-chain of on-farm production through more efficient input supply, transport, storage, processing and marketing of agricultural outputs. Within this component of the project, different facilities are going to be built:

- Construction/rehabilitation of 12 supply shops and collection points
- Construction of 6 storage/processing units
- Construction of 60km of new roads (short access roads to storage facilities)
- Rehabilitation of 130 km of roads (feeder and access roads)

To convert the length of the roads into a surface area, we used an average width of 4.3m.[14]

As a result, 560 000 m^2 and 258 462 m^2 of roads need respectively to be rehabilitated and constructed. The assumption is that the emission factor of rehabilitation is equal to 1/3 of the emission factor for construction.

Supply shops and collect points are considered as concrete agricultural building, with an average size of 80m^2. The processing units are supposed to be industrial concrete buildings of 150m^2.

[14] Working Paper 9: Feeder roads, p.6

Figure 21: EX-ACT module "Other investment" for the constructions of infrastructures

IRSS = irrigation runoff return system

Released GHG associated with building of infrastructure

Type of construction or infrastructure	Default value t CO2 /m2	Specific Value	Default Factor	surface (m2) Without	surface (m2) With	Emission (t CO2eq) Without	Emission (t CO2eq) With
Agricultural Buildings (concrete)	0.656		YES	0	960	0.0	629.8
Industrial Buildings (concrete)	0.825		YES	0	900	0.0	742.5
Road for medium trafic (concrete)	0.319		YES	0	258462	0.0	82449.4
Road for medium trafic (concrete)	0.319	0.1063333	NO	0	560000	0.0	59546.7
Please select	0.000		NO	0	0	0.0	0.0
Please select	0.000		YES			0.0	0.0
Please select	0.000		YES			0.0	0.0
			Subtotal	0.0	143368.3	*Difference*	*143,368*

The emissions from these constructions are 143 368 t CO2e.

5 Results of the EX-ACT appraisal and discussions

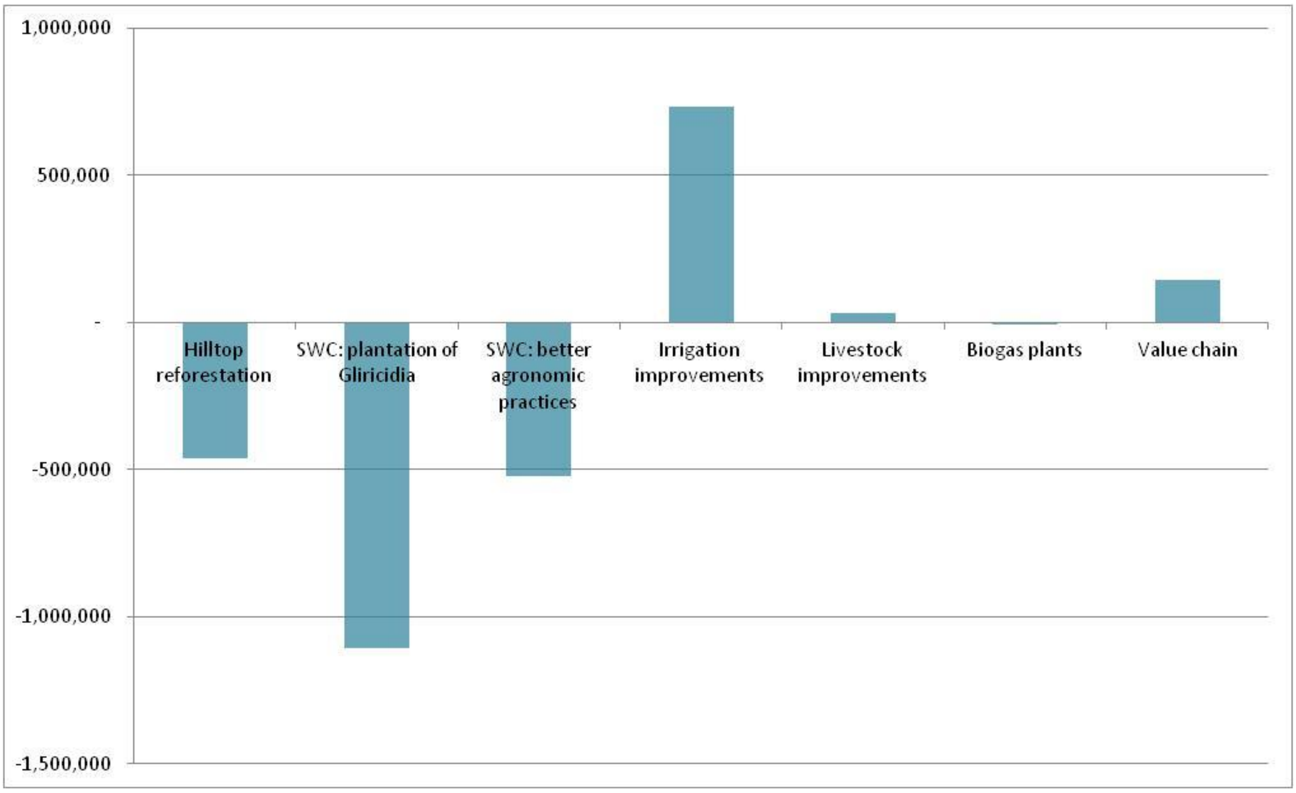
The appraisal concerns 28 000ha, of which 1 000 are wetlands (including the 500ha of paddy rice) and 1 000ha are newly irrigated.

Table 4 presents the results of the assessment, with the repartition in EX-ACT and with the repartition according to the different components of the KWAMP project

Table 4: Carbon balance of the KWAMP project (in 1000 t CO2e)

EX-ACT modules		Project components	
Afforestation, reforestation	-460	-460	Hilltop reforestation
Non forest land use change	-192	/	/
Perennial crops	-914	-1 106	SWC: plantation of Gliricidia
Annual crops	-521	-520	SWC: better agronomic practices
Irrigated rice	-23	/	/
Organic soils and peatlands	+756	+734	Irrigation improvements
Livestock	+21	+30	Livestock improvements
Inputs	+1	-7	Biogas plants
Other investments	+146	+143	Value chain
TOTAL	**-1 186**		

Figure 22: Carbon balance in t CO2e of the KWAMP project for each project components



The Kirehe Community-based Watershed Management project has a negative carbon balance compare to a business as usual scenario, which means that it will avoid GHG emissions by about 1.19 Mt CO2e, i.e. 2.1 t CO2e/ha/year. The principal sinks are the Gliricidia plantations, the better agronomic practices on annual crops and the reforestation, with respectively a contribution of 53%, 25% and 22%. GHG sources are due to 81% to the drainage of wetlands.

The SWC component of the project has really great positive impacts on the environment and the climate, since it fights at the same time against global warming (with the storage of carbon) and against erosion. However, the irrigation improvement component has an important negative impact. Even if this impact is compensated by the SWC measures, it could be worth limiting the extension of agriculture in the marshlands.

6 SENSIBILITY ANALYSIS

The previous assessment has been made for a tropical montane dry climate. Nonetheless, only the north has such climate, the south being more humid. With a tropical montane moist climate, the carbon balance reaches -1.7 Mt CO2e. Table 5 highlights the main discrepancies.

Table 5: EX-ACT results for a dry or a moist tropical montane climate (in 1000 t CO2e)

	dry	moist	Difference in %
Afforestation, reforestation	-460	-460	0%
Non forest land use change	-192	-290	51%
Perennial crops	-914	-944	3%
Annual crops	-521	-942	81%
Irrigated rice	-23	-23	0%
Organic soils and peatlands	+756	+756	0%
Livestock	+21	+21	0%
Inputs	+1	+1	0%
Other investments	+146	+146	0%
TOTAL	**-1 186**	**-1 734**	**44%**

The main differences come from the non forest land use change and the annual crops, thus giving a total carbon balance 44% higher with the moist climate. Indeed, with a moister climate, more carbon is stored in the soil.

This sensitivity analysis underlines the necessity to better know the location of the areas concerned by the project, especially the 15 watersheds to be chosen where the SWC measures will be implemented. Once the selection of the watershed will be finalized, with the participation of all the stakeholders, a more precise C balance could be calculated, splitting the surface areas with a dry climate and the ones with a moister climate.

7 Conclusions

The Kirehe Community-based Watershed Management project, leading by IFAD and the Rwanda government, is going to create a carbon sink of approximately 1.2 million t CO2e for a total period of 20 years. It represents on average 2.1 t CO2e/ha/year. The principal mitigation components are the reforestation, the plantation of Gliricidia trees to fight erosion and the better agronomic practices. The construction of infrastructures, especially the roads, leads to an important amount of GHG emissions, but this component of the project is essential for the development of a more competitive and market orientated agriculture, as wanted by the government development strategy.

An even better mitigation potential could be reach if the drainage of wetlands is avoided. It is indeed necessary to preserve such ecosystems that provide valuable ecological services such as water purification, groundwater replenishment, reservoir of biodiversity, sediments and nutrients retention and exports...However, the current policy of the government is to develop rice cultivation in marshlands, in order to achieve food security.

Nevertheless, the results presented here are only preliminary estimates based on information available (or derived on the basis of working hypotheses) at this stage of project appraisal. The uncertainty in the data availability and the significant number of assumptions made is inevitably reflected in the results discussed. These first estimations could go into detail once the exact location of the watersheds is decided, as well as the tree species used for reforestation or the number of farmers that will effectively implement SWC and better agronomic practices.

8 EASYPol links

EX-ACT Software, Technical Guidelines & EX-ACT Brochure [EASYPol Module 210]

Other case studies in Rwanda:

Land husbandry, Water harvesting and Hillside irrigation (LWH) project

9 References and Further Readings

Republic of Rwanda: Kirehe Community-based Watershed Management Project

- Programme design document, final design – Main report
- Working Paper 3: Soil and Water Conservation and Crops Intensification
- Working Paper 4: Livestock development
- Working Paper 5: Agriculture and Agricultural Water development
- Working Paper 6: Value Chain development
- Working Paper 9: Feeder Roads

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