



The EX Ante  
Carbon-balance  
Tool



**EASYPol**  
Resources for policy making

# The Carbon Balance of the World Bank-financed Land Husbandry, Water Harvesting and Hillside Irrigation (LWH) Project of the Government of Rwanda

## Application of the EX-Ante Carbon-balance tool (EX-ACT)

by

**G. Branca<sup>1</sup>, M. Tinlot<sup>2</sup>**

<sup>1</sup> Economist, Agricultural Development Economics Division, FAO

<sup>2</sup> Consultant, Policy Assistance Support Service, FAO

for the

**FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, FAO**



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**About EX-ACT:** The *Ex Ante* Appraisal Carbon-balance Tool aims at providing *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.

See EX-ACT [website: www.fao.org/tc/exact](http://www.fao.org/tc/exact)

### Related resources

- EX-ANTE Carbon-Balance Tool (EX-ACT): (i) [Technical Guidelines](#); (ii) [Tool](#); (iii) [Brochure](#)
- See all EX-ACT resources in EASYPol under the Resource package, [Investment Planning for Rural Development, EX-Ante Carbon-Balance Appraisal of Investment Projects](#)

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## Acronyms

C	Carbon
CC	Climate Change
CDM	Clean Development Mechanism
CH <sub>4</sub>	Methane
CO <sub>2</sub>	Carbon Dioxide
DAP	Diammonium Phosphate
FAO	Food and Agricultural Organization
GDP	Gross Domestic product
GHG	Greenhouse Gas
GWP	Global Warming Potential
HAC	High Activity Clay
IPCC	Intergovernmental Panel on Climate Change
IRSS	Irrigation runoff returns system
LULUCF	Land use, land use change and forestry
LWH	Land husbandry, Water harvesting and Hillside irrigation
MINAGRI	Ministry of Agriculture and Animal Resources
Mt	Million tons
NAPA	National Adaptation Programme of Actions
N <sub>2</sub> O	Nitrous Oxide
PAD	Project Appraisal Document
ROR	Republic of Rwanda
SLM	Sustainable Land Management
CO <sub>2</sub> e	Carbon Dioxide equivalent
t CO <sub>2</sub> e ha <sup>-1</sup>	Tonnes of Carbon Dioxide equivalent per hectare
t CO <sub>2</sub> e yr <sup>-1</sup>	Tonnes of Carbon Dioxide equivalent per year
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank

## 1. SUMMARY

Agriculture can play an important role in climate change mitigation while contributing to increased food security and reductions in rural poverty.

The Ex-Ante Carbon-balance Tool (EX-ACT) can estimate the mitigation potential of rural development projects generated from changes in farming systems and land use.

The study presents and discusses the EX-ACT analysis performed on the World Bank-financed Land Husbandry, Water Harvesting and Hillside Irrigation Project of the Government of Rwanda. Estimates of the impact of project activities on greenhouse gas emissions and carbon sequestration demonstrate that the implementation of the LWH project will provide additional environmental benefits by helping to mitigate climate change. Thus it reflects possible synergies between mitigation and rural development goals through a watershed approach.

## 2. INTRODUCTION

**Objectives** : This paper identifies and interprets the main project impacts on climate change mitigation. It shows the results issued from a real case project (although simplified), starting with raw data collected during field mission. This exercise could be used in a training course, particularly when it is not possible to organize field visits to gather data for practical applications of the EX-ACT software, since it puts the user in a situation similar to that of the carbon balance appraisal.

**Target audience** : This document is designed in particular for people who work on developing and analyzing investment projects as well as climate change issues. It is also aimed at people working in public administration, NGOs, professional organizations or consulting firms. Academics may also find this material useful to support their course work in carbon balance analysis and development economics.

**Required background** : To fully understand the content of this module users 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<sup>1</sup>. See also the list of EASYPol links included at the end of this module.

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<sup>1</sup> 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. BACKGROUND

#### 3.1. Critical climatic change issues in the agricultural sector of Rwanda

Rwanda has a population of 10.7 million with a growth rate of 2.8 percent. Increased population density has put pressure on the physical environment and sparked labour migration between rural areas as well as from the countryside to urban areas. The country has a total land area of 24,668 square kilometres. Of this, slightly more than 1.5 million hectares are suitable for producing annual and perennial crops, 90 percent of which is found on hillsides. Of the estimated arable land, the large majority is based on rain-fed agricultural production of small, semi subsistence and fragmented farms.

Agriculture is the backbone of Rwanda's economy, accounting for 41.7 percent of GDP and sustaining almost 90 percent of the population<sup>2</sup>. Rwanda's agricultural strategy, as developed by the Ministry of Agriculture and Animal Resources (MINAGRI) is aligned around four strategic programmes: (i) physical resources and food production – intensification and development of sustainable production systems; (ii) producer organization and extension – support to the professionalization of producers; (iii) entrepreneurship and market linkages – promotion of commodity chains and the development of agribusiness; and (iv) institutional development – strengthening the public sector and regulatory framework for agriculture<sup>3</sup>.

According to the Rwandan Vision 2020, Rwanda's land resources are used in an inefficient and unsustainable manner, which limits the profitability of land and infrastructure. Zones with a high population density are currently characterised by overexploited lands and severely altered vegetal cover. Erosion and landslide processes are advanced. This situation explains the current migration of people from the most densely populated provinces in the North and the South to the least populated provinces, especially those in the East and South East, in search of new land for agriculture and livestock. These migrating populations are already economically vulnerable; this vulnerability is heightened by the high risk of drought and desertification in the zones receiving them<sup>4</sup>.

Changes in land use and management are a fundamental element that must be taken into account when considering the effects of climatic changes (CC) on agricultural production, agribusiness investments and regional prosperity.<sup>5</sup>

In an effort to address the impact of climate change, the Government of Rwanda prepared the National Adaptation Program of Action (NAPA) with the following objectives: evaluate current vulnerabilities to climate change in consideration of socioeconomic aspects and land use that exacerbate these vulnerabilities; identify most vulnerable population groups, regions and sectors; determine priority adaptation

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<sup>2</sup> CIA, 2009.

<sup>3</sup> World Bank, 2009.

<sup>4</sup> Harding, 2009.

<sup>5</sup> IAASTD, 2009. Jones and Thornton.

options; select urgent and immediate project activities to be implemented and define their profiles. The vulnerabilities to climate change focus particularly on: the significant degradation of arable land due to erosion, following torrential rains in the northern regions (Gisenyi, Ruhengeri and Byumba) and centre/western regions (Gitarama, Kibuye, Gikongoro) and flooding from hillside runoff; the desertification trend in agro-bioclimatic regions in the East and South-East; lowered lake levels and water flows due to deficits in rainfall and prolonged droughts; and the degradation of forests (Republic of Rwanda, 2006). Rwanda can gain long-term economic, environmental and social benefits by moving to a low-carbon growth path, combined with climate resilient growth. Agriculture and forestry mitigation options identified in Rwanda focus especially on the reduction of emissions through livestock, grazing and cropland management, pasture improvement, restoration of degraded lands, forest protection, afforestation and agro forestry<sup>6</sup>.

In order not to increase GHGs in Rwanda, the country's intention to intensify agriculture production needs to consider good nutrient management (method and timing of fertilizer application to improve nitrogen use efficiency), low impact farming measures (reduced tillage, reduced biomass burning) and ways of ensuring carbon storage in soils is maintained and enhanced. It is worth noting that a rising population and growing income should lead to increased livestock demands. Thus, careful management of an increasing livestock herd will be needed to minimize methane (CH<sub>4</sub>) emissions per unit of livestock production, and measures promoting better feeding and breeding practices considered<sup>7</sup>. In Rwanda, increased or more effective irrigation is expected to enhance carbon storage in soils through higher yields and residue returns. Rice management is also targeted to reduce CH<sub>4</sub> emissions through various practices including draining and using alternative rice varieties. Finally, the management of organic/peaty soils needs to be accounted as it contains huge stocks of carbon. Emissions from those cultivated organic soils can be reduced by practices such as avoiding row crops and tubers, avoiding deep ploughing, and avoiding the drainage of these soils or re-establishing a high water table. Developing a low carbon strategy in tandem with any adaptation strategy will be key to ensuring that Rwandan agriculture remains and moves closer to being a lower GHG sector in the future, while still coping with climate impacts.

### 3.2. Objectives and structure of the document

In this context, models are being developed to estimate the resilience of agricultural systems and the mitigation potential from changes in farming systems, and to support project managers on CC mitigation decision making, helping to carry out actions to tackle climate change. EX-ACT (EX-Ante Carbon-balance Tool) is one such model, developed by the Food and Agriculture Organization of the United Nations (FAO), to provide an ex-ante evaluation of the impact of rural development projects on greenhouse gas (GHG) emissions and carbon (C) sequestration, thus estimating the potential contribution of the agriculture (and forestry) sector to CC mitigation (see Section 5.3). The tool is now being tested: case studies have been selected to represent a

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<sup>6</sup> SEI, 2009.

<sup>7</sup> SEI, 2009.

wide range of different ecosystems worldwide (e.g. tropical, temperate, semi-arid), agriculture activities (e.g. annual/perennial crops, forestry, livestock, grasslands<sup>8</sup>) and geographic coverage.

The objective of this report is to present the results of the EX-ACT test on the World Bank (WB)-financed Land Husbandry, Water Harvesting and Hillside Irrigation (LWH) Project of the Government of Rwanda. It is worth noting that the results could be subject to change as a result of possible adjustments regarding data collection and in the methodology adopted in the further development of the tool.

The report is organized as follows: Section 3.3 provides a description of EX-ACT and its methodology; Chapter 4 provides a short description of the proposed LWH; Chapter 5 presents the EX-ACT analysis for the specific case study, reporting the main findings in terms of LWH mitigation potential and the results of the sensitivity and economic analyses. Annex 1 provides a map of the project area, while Annex 2 presents the relevant EX-ACT tables with detailed results of the analysis.

### **3.3. The EX-Ante carbon-balance Tool (EX-ACT)**

EX-ACT is a tool developed by FAO aimed at providing ex-ante measurements of the impact of agriculture (and forestry) development projects on GHG emissions and C sequestration, noting their effects on the C-balance<sup>9</sup>, which is used as an indicator of the project's mitigation potential<sup>10</sup>. EX-ACT can be used in the context of ex-ante project formulation and is capable of covering the range of projects relevant for the land use, land use change and forestry (LULUCF) sector. It can compute the C-balance by comparing two scenarios: "without project" (i.e. the "business as usual" or "Baseline") and "with project". The tool's main output consists of the C-balance resulting from the difference between these two scenarios (Figure 1).

The model takes into account both the implementation phase of the project (i.e. the active phase of the project commonly corresponding to the investment phase), and the so-called "capitalization phase" (i.e. a period where project benefits are still occurring as a consequence of the activities performed during the implementation phase). Usually, the sum of the implementation and capitalization phases is set at 20 years. EX-ACT was designed to work at project level but it can easily be scaled up at programme/sector or national level.<sup>11</sup>

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<sup>8</sup> For the purposes of this analysis, the term grasslands is used in the report in its wider meaning to indicate areas where the vegetation is dominated by grasses and other herbaceous and woody plants, including shrub lands, scrubby grassland or semi-wooded grassland.

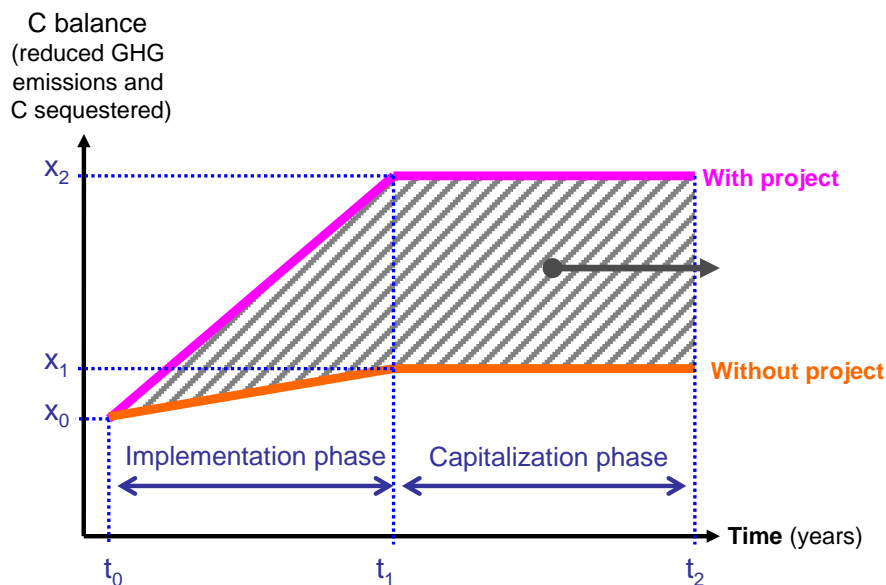
<sup>9</sup> C-balance = GHG emissions - C sequestered above and below ground.

<sup>10</sup> EX-ACT 2010.

<sup>11</sup> Bernoux et al. 2010°.



**Figure 1: Quantifying C-balance “with” and “without project” using EX-ACT**



Source: Bernoux et al. 2010b

EX-ACT has been developed using mostly the Guidelines for National Greenhouse Gas Inventories<sup>12</sup> complemented with other methodologies and a review of default coefficients for mitigation option as a base. Most calculations in EX-ACT use a Tier 1 approach<sup>13</sup> as default values are proposed for each of the five pools defined by the Intergovernmental Panel on Climate Change (IPCC) Guidelines and the United Nations Framework Convention on Climate Change (UNFCCC): above-ground biomass, below-ground biomass, soil, deadwood and litter. EX-ACT also allows users to incorporate specific coefficients (e.g. from project area) in case they are available, therefore working at a Tier 2 level, too. EX-ACT measures C stocks and stock changes per unit of land, as well as methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions expressing its results in tonnes of carbon dioxide equivalent per hectare (t CO<sub>2</sub>e ha<sup>-1</sup>) and in tonnes of carbon dioxide equivalent per year (t CO<sub>2</sub>e yr<sup>-1</sup>).

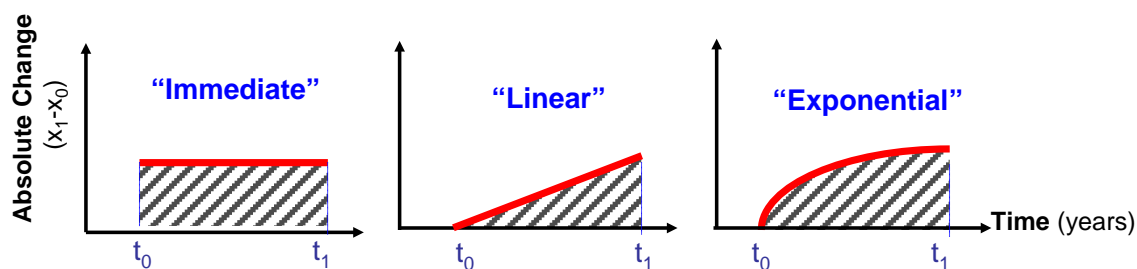
In terms of dynamics, land use changes associated with the establishment of project activities and the rate of adoption of land management options occur only during the implementation phase. Therefore, it is assumed that all project activities will be completed in the project timeframe and that no additional change in land use and management will take place during the capitalization phase. The EX-ACT default assumption for the land use and management change is a “linear” function over time, although the software allows for a different dynamic of change to be adopted, e.g.

<sup>12</sup> IPCC, 2006.

<sup>13</sup> IPCC Guidelines provide three methodological tiers varying in complexity and uncertainty: Tier 1, simple first order approach using data from global datasets, simplified assumptions, IPCC default parameters (large uncertainty); Tier 2, a more accurate approach, using more disaggregated activity data, country specific parameter values (smaller uncertainty); Tier 3, making reference to higher order methods, detailed modeling and/or inventory measurement systems driven by data at higher resolution and direct measurements (much lower uncertainty).

“immediate” or “exponential” (Figure 2), depending on the characteristics of the specific project activity and on the information available on the adoption rate of the selected practice among project participants. This aspect is often considered in the sensitivity analysis where different rates of adoption are taken into account.

**Figure 2: Schematic representation of the dynamics of change in the implementation phase**



Source: Bernoux et al. 2010b

EX-ACT consists of a set of Microsoft Excel sheets in which project designers insert information on dominant soil types and climatic conditions of the project area together with basic data on land use, land use change and land management practices foreseen under project activities as compared to a business-as-usual scenario<sup>14</sup>.

#### 4. PROJECT DESCRIPTION

The Government of Rwanda has developed a plan to increase the agricultural productivity and commercialization of hillside agriculture in 101 pilot watersheds covering 30,250 hectares (of which 12,000 irrigated) of land mainly in five regions (Karongi, Nyanza, Bugesera, Kayonza, Gatsibo). Four preliminary sites (Gatsibo 8, Nyanza 23, Karongi 12, and Karongi 13) were identified for being developed through the Government of Rwanda’s WB-financed LWH project.

The primary beneficiaries of the LWH include female and male smallholder farmers who produce either irrigated or, in most cases, rain-fed crops within the project sites, with an average crop area of somewhat less than one hectare (about 65 percent of the households own less than 0.5 ha). Overall, the project sites considered in this analysis will involve the development of 4 163.3 ha.

The LWH project uses a modified watershed approach to introduce sustainable land husbandry measures for hillside agriculture on selected sites as well as developing hillside irrigation for sub-sections of each site. The LWH will be implemented over a period of five years and is structured around three components (see Table 1):

- (i) Capacity development and institutional strengthening for hillside intensification
- (ii) Infrastructure for hillside intensification

<sup>14</sup> Bernoux et al. 2010°.

(iii) Project management through the SWAp structure

A short description of the main activities planned under each component is described below.

***Component A (Capacity development and institutional strengthening for hillside intensification) US\$13.85 million***

The objective is to develop the capacity of individuals and institutions for improved hillside land husbandry, stronger agricultural value chains and expanded access to finance. It covers the capacity development and institutional strengthening for both production and marketing, including access to finance issues that can constrain both. This component will finance technical assistance, training workshops and meetings, surveys and studies, works related to post-harvest infrastructure and goods.

***Component B (Infrastructure for hillside intensification) US\$20.75 million***

The objective of this component is to provide the essential “hardware” for hillside intensification to accompany the capacity development and institutional strengthening activities of Component A. Its three sub-components are organized around the land husbandry, water harvesting and hillside irrigation of the LWH project. This component will support the development of participatory and comprehensive land husbandry practices throughout the sub-watershed to improve productivity in rain-fed and irrigated areas.

***Component C (Project management through the SWAp structure) US\$10.47 million***

The objective of Component C is to ensure that project activities are effectively managed within the new SWAP structure for Ministerial implementation of programmes and projects at MINAGRI.

**Table 1: Profile of the LWH project**

	Component A	Component B	Component C
	Capacity Development and Institutional Strengthening for Hillside Intensification	Infrastructure for Hillside Intensification	
Sub component	A1 Strengthening Farmer Organizations; A2 Extension; A3 Marketing and Finance; A4 Capacity Development and Institutional Strengthening: MINAGRI and its Agencies	B1 Land husbandry infrastructure; B2 Water harvesting infrastructure; B3 Hillside irrigation infrastructure	Implementation through the Ministerial SWAp Structure
Total Costs	US\$13.85 million	US\$20.75 million	US\$10.47 million

Source: World Bank 2009.

## 5. POTENTIAL MITIGATION IMPACT OF PROJECT ACTIVITIES

This section describes the analysis of the potential impact of project activities on GHG emissions and C sequestration. We describe here the methodology followed that takes into consideration the different project activities and results obtained from the EX-ACT analysis.

### 5.1. Structure and basic assumptions of the analysis

#### 5.1.1. Fixed parameters of the carbon appraisal

The analysis takes into account the activities related to the implementation of land husbandry practices, water harvesting and hillside irrigation infrastructures. Data used to describe climate patterns and soil characteristics cannot take into account the considerable variability of existing soil and climatic conditions in the area where project activities will be carried out (see Annex 1). The results of the analysis should therefore be considered only as an average for the whole area. The impact of using average climatic data on the overall carbon-balance results is shown in the sensitivity analysis.

Average climate is considered as “tropical mountain” with a mean annual temperature equal to 20 degrees Celsius and a moisture regime classified as “moist”. These settings correspond to average temperature and rainfall for the targeted areas. Such information is essential as most coefficients used in the analysis can change drastically according to the climate. This is particularly true for the moisture regime, but also for the mean annual temperature which affects, for example, the level of CH<sub>4</sub> emissions from manure management.

As for the soil characteristics – and with reference to the simplified IPCC classification where only six soil categories are listed (sandy soils, spodic soils, volcanic soils, wetland soils, high activity clay soils and low activity clay soils) – the project area is characterized essentially by low activity clay (LAC) soils, which are highly weathered soils, dominated by 1:1 silicate clay minerals<sup>15 16</sup>.

The analysis will consider an implementation phase of five years, followed by a capitalization phase of 15 years, representing a period where the benefits of the investment are still occurring and may be attributed to changes in land use and management brought on by adoption of the project (see Section 1.3). In the analysis it is assumed that the implementation phase will happen according to a linear dynamic of change (see figure 2), as no specific information is available about the adoption rate of the project activities among project participants. As concerns the Global Warming Potential (GWP) coefficients<sup>17</sup>, the current analysis uses the same values as those

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<sup>15</sup> In the World Reference Base for Soil Resources classification LAC soils include: Acrisol, Anthrosol, Cryosol, Durisol, Ferralsol, Fluvisol, Lixisol, Nitisol, Planosol, Plinthosol, Solonchak, Stagnosol, Technosol. In USDA classification LAC soils include: Ultisols, Oxisols, acidic Alfisols.

<sup>16</sup> Bernoux et al. 2010b.

<sup>17</sup> The GWP is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale that compares the gas in question to that of the same mass of carbon dioxide (whose GWP is by convention equal to 1).

adopted within the Clean Development Mechanism (CDM), i.e. 21 for CH<sub>4</sub> and 310 for N<sub>2</sub>O.

The analysis is based on the identification of two alternative land use and management scenarios, i.e. “with” and “without” project.

#### 5.1.2. Assumptions for the “with project” scenario

The “with project” scenario is built on the basis of the activities that the project will be implementing. Project interventions will focus on four sites (Gatsibo 8, Nyanza 23, Karongi 12, and Karongi 13) and promote the adoption of soil conservation measures and land husbandry to reduce erosion and maintain/restore soil fertility (terraces and bunding, green manuring, terraces, liming, creation of silt trap zone for sediment reduction in the reservoir, fencing reservoirs, planting perennial forage legumes on the upstream sides of the reservoir and planting perennial commercial trees in all immediate upstream sites of the forage legume area, afforestation of the most vulnerable upstream portions of watersheds), and the building of dams and water conveyance structures for hillside irrigation. These activities are essentially aimed at developing irrigated cropland production in the downstream part of the watershed, building a reservoir near the irrigated area and introducing sustainable practices in the catchment area (both in the so-called “command area” surrounding the reservoir and the upper watershed area).

This is in line with the expected land use in the watersheds, after project implementation, depending on the different catchment sections: reforestation and soil protection in the upper catchment area; sustainable agricultural management practices in the rain-fed and command area; intensive (annual and perennial) cropland in the downstream part of the rain-fed catchment area (irrigated)<sup>18</sup>.

Therefore the analysis considers that in the “with project” scenario, two-thirds of the existing annual cropland in the irrigated area would be converted to perennial (essentially fruit trees – e.g. peach trees, and coffee and tea as valuable cash crops); half of the annual cropland in the upper catchment area (which includes all the land with slope over 40 percent) would be converted to forest land; and annual cropland in the rain-fed area would decrease by the size of the reservoir (which will in fact occupy that land). Also, in the command area, trees would be planted along the contour lines. Given that trees would be planted every five meters, it is estimated that 1 percent of annual cropland in the rain-fed area would be converted to perennials. While bush and shrub land would not be subject to any change with the project, grasslands is considered as degraded land which would be converted to non-degraded as a consequence of the implementation of the sustainable land management practices. Existing natural forest is

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<sup>18</sup> This strategy is expected to have many benefits in terms of improved soil and water conservation and overall soil fertility thus resulting in an overall production increase. In fact, in many areas of the country, intensive crop cultivation is being practiced on land that cannot sustain such practices or land that should be set aside for environmental conservation. This trend is most evident in hilly areas, where every slope is intensively cultivated, even very steep slopes (Chew, 1990). Over the past years the Rwandan government has implemented an ambitious programme of environmental protection, combining strict laws to reduce damage with projects that will enable Rwanda to gain immediate benefits from conservation (King, 2007).

conserved (no change) while planted forest would increase (conversion from annual cropland in upper catchment area, as already mentioned above). The owners of the land, which would become part of the reservoir, be resettled and move to the existing annual cropland area, therefore implying no land use change.

The analysis also takes into account the project's role in promoting the adoption of improved cropland management on annual crops: improved agronomic practices, better water management and manure application. The new management would stop the practice of residue burning and promote improved residue management, and a low energy irrigation system would be put in place in the irrigated area. Finally, it is assumed that with respect to input use in the "with project" scenario, some project sites are targeted to be characterized by organic farming, while only Karongi 12 and another site not yet identified should receive N,P,K fertilizers. The quantity of inputs ordered at Karongi 12 reaches 12 207 kg of N,P,K (17,17,17) per year. We assume that double this amount would be applied to integrate two project sites receiving fertilizers. Compost would be applied at a rate of 10t per hectare on all sites reaching a total amount of compost of 35 659 tonnes (2 830 tonnes for Gatsibo 8, 12 588 tons for Karongi 13, 10 120 tonnes for Nyanza 23, and 10 120 tonnes for Karongi 12 according to land husbandry reports). We assume that the final percentage of nitrogen in the compost is 2 percent<sup>19</sup>. Lime application is also expected on three sites at a rate of 7t/ha, on 332 hectares totally.

### 5.1.3. Assumptions for the "without project" scenario

The second part of the analysis concerns the identification of the baseline scenario (the so-called "without project" case). Several assumptions regarding land use, land use changes, use of inputs and other investments are made. It is assumed that there would be no expansion of perennial crops on existing annual cropland (therefore overall perennial area equals 0); marginal land (bush and shrub lands) would remain unchanged, as well as planted forest area. It is also assumed that intensification promoted within the LWH project could avoid the expansion of cropland on grasslands and natural forest areas. Therefore, in the "with project" scenario, part of the grasslands and natural forests would be converted to annual crops. Such an assumption implies the linking of yield increases in an intensified area with potential land-sparing. Although there is no consensus about the possible rate of substitution<sup>20</sup>, it has been decided to follow the same procedure as described by Burney et al. (2010): expansion patterns by crop between 2000 and 2005 have been derived from FAOSTAT and an average crop growth rate of 1.7 percent per year is estimated. Also, since households are expanding cultivation at the expense of grasslands and forestland<sup>21</sup>, it is assumed that grasslands and natural forests would be converted into annual cropland at the annual growth rate of

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<sup>19</sup><http://www.calrecycle.ca.gov/Organics/CompostMulch/CompostIs.htm>;  
<http://soilplantlab.missouri.edu/soil/compost.aspx>

<sup>20</sup> Rudela et al. 2009.

<sup>21</sup> Kangasniemi, 1998.

1.7 percent, i.e. 8.5 percent over five years. This is consistent with the data available at national level<sup>22 23</sup>.

In the “without project” scenario, it is also assumed that about 30 percent of farmers would abandon the practice of residue burning and introduce manure management, and that no investments (irrigation schemes) would be made. It is also assumed the with respect to input use in the “without project” scenario that on farm use of inorganic fertilizer would remain extremely low (less than 4,000 t/year, equivalent to 1 to 2 kg/ha)<sup>24 25</sup>. Thus we assumed that currently without project farmers apply only 1.5 kg of urea/ha/year. As mentioned above we also considered that some farmers would introduce manure management. Thus an area of 456 ha would receive 10t of compost per year.

**Table 2: Main differences between the without and with project scenario**

Future without project	Future with project
No perennial expansion on current annual crops	Perennial expansion on current annual crops
Cropland expansion on current grassland and forested zones	No cropland expansion due to intensification
70 percent of farmers still use residue burning	Residue burning stopped
30 percent of farmers abandon residue burning and introduce manure	Improved practices on cropland
Low input use	Increased input use (lime, fertilizers)
No investment in irrigation systems	Development of irrigation
No increase in forested zones	Forest plantations in upper catchment

<sup>22</sup> Statistics from the Forest department show that the country experienced a loss of approximately 64 percent of forests in between 1960 and 2007, which is about than 1.3 percent per year (Republic Of Rwanda, 2004)

<sup>23</sup> Vision 2020; ROR 2004.

<sup>24</sup> Clay & al, 2001.

<sup>25</sup> [http://www.aec.msu.edu/fs2/rwanda/input\\_use.pdf](http://www.aec.msu.edu/fs2/rwanda/input_use.pdf)

Table 3: Summary table of the land uses in the three situations start/future with/ future without project (data in ha)

gatsibo 8		Karongi 12		Karongi 13		Nyanza 23		TOTAL	
START		START		START		START		START	
Annual on irrigated	83.23	Annual on irrigated	234.99	Annual on irrigated	376.08	Annual on irrigated	120.55	Annual on irrigated	814.85
Annual rainfed	173.25	Annual rainfed	165.03	Annual rainfed	266.14	Annual rainfed	259.87	Annual rainfed	864.29
Annual upper catchment	2.42	Annual upper catchment	314.98	Annual upper catchment	575.18	Annual upper catchment	11.57	Annual upper catchment	904.15
Perennial	0	Perennial	0	Perennial	0	Perennial	0	Perennial	0
<b>Bush and Shrubland</b>	32.07	Bush and Shrubland	101	Bush and Shrubland	183.6	Bush and Shrubland	63.39	<b>Bush and Shrubland</b>	380.06
<b>Grassland</b>	89.81	Grassland	84	Grassland	21	Grassland	84.54	<b>Grassland</b>	279.35
<b>Natural forest</b>	92.73	Natural forest	62	Natural forest	131.5	Natural forest	62.95	<b>Natural forest</b>	349.18
<b>Planted forest</b>	26.1	Planted forest	207	Planted forest	195.7	Planted forest	50.67	<b>Planted forest</b>	479.47
<b>Riverine vegetation</b>	28.12	Riverine vegetation	0	Riverine vegetation	0	Riverine vegetation	49.37	<b>Riverine vegetation</b>	77.49
<b>Urban/settlement</b>	10.39	Urban/settlement	3	Urban/settlement	1.1	Urban/settlement	0	<b>Urban/settlement</b>	14.49
<b>Total</b>	538.12	<b>Total</b>	1172	<b>Total</b>	1750.3	<b>Total</b>	702.91	<b>Total</b>	4163.33
WITH PROJECT		WITH PROJECT		WITH PROJECT		WITH PROJECT		WITH PROJECT	
Annual on irrigated	20.8075	Annual on irrigated	58.7475	Annual on irrigated	94.02	Annual on irrigated	30.1375	Annual on irrigated	203.7125
Annual rainfed	161.5175	Annual rainfed	156.3797	Annual rainfed	252.4786	Annual rainfed	210.2713	Annual rainfed	780.6471
Annual upper catchment	1.21	Annual upper catchment	157.49	Annual upper catchment	287.59	Annual upper catchment	5.785	Annual upper catchment	452.075
Reservoir	10	Reservoir	7	Reservoir	11	Reservoir	47	Reservoir	75
perennial in rainfed	1.7325	perennial in rainfed	1.6503	perennial in rainfed	2.6614	perennial in rainfed	2.5987	perennial in rainfed	8.6429
perennial irrigated	62.4225	perennial irrigated	176.2425	perennial irrigated	282.06	perennial irrigated	90.4125	perennial irrigated	611.1375
<b>Bush and Shrubland</b>	32.07	Bush and Shrubland	101	Bush and Shrubland	183.6	Bush and Shrubland	63.39	<b>Bush and Shrubland</b>	380.06
<b>Grassland</b>	89.81	Grassland	84	Grassland	21	Grassland	84.54	<b>Grassland</b>	279.35
<b>Natural forest</b>	92.73	Natural forest	62	Natural forest	131.5	Natural forest	62.95	<b>Natural forest</b>	349.18
<b>Planted forest</b>	27.31	Planted forest	364.49	Planted forest	483.29	Planted forest	56.455	<b>Planted forest</b>	931.545
<b>Riverine vegetation</b>	28.12	Riverine vegetation	0	Riverine vegetation	0	Riverine vegetation	49.37	<b>Riverine vegetation</b>	77.49
<b>Urban/settlement</b>	10.39	Urban/settlement	3	Urban/settlement	1.1	Urban/settlement	0	<b>Urban/settlement</b>	14.49
<b>Total</b>	538.12	<b>Total</b>	1172	<b>Total</b>	1750.3	<b>Total</b>	702.91	<b>Total</b>	4163.33
WITHOUT PRJ		WITHOUT PRJ		WITHOUT PRJ		WITHOUT PRJ		WITHOUT PRJ	
Perennial	0	Perennial	0	Perennial	0	Perennial	0	Perennial	0
<b>Annual</b>	274.4159	<b>Annual</b>	727.41	<b>Annual</b>	1230.363	<b>Annual</b>	404.5267	<b>Annual</b>	2636.715
<b>Bush and Shrubland</b>	32.07	<b>Bush and Shrubland</b>	101	<b>Bush and Shrubland</b>	183.6	<b>Bush and Shrubland</b>	63.39	<b>Bush and Shrubland</b>	380.06
<b>Grassland</b>	82.17615	<b>Grassland</b>	76.86	<b>Grassland</b>	19.215	<b>Grassland</b>	77.3541	<b>Grassland</b>	255.6053
<b>Natural forest</b>	84.84795	<b>Natural forest</b>	56.73	<b>Natural forest</b>	120.3225	<b>Natural forest</b>	57.59925	<b>Natural forest</b>	319.4997
<b>Planted forest</b>	26.1	<b>Planted forest</b>	207	<b>Planted forest</b>	195.7	<b>Planted forest</b>	50.67	<b>Planted forest</b>	479.47
<b>Riverine vegetation</b>	28.12	<b>Riverine vegetation</b>	0	<b>Riverine vegetation</b>	0	<b>Riverine vegetation</b>	49.37	<b>Riverine vegetation</b>	77.49
<b>Urban/settlement</b>	10.39	<b>Urban/settlement</b>	3	<b>Urban/settlement</b>	1.1	<b>Urban/settlement</b>	0	<b>Urban/settlement</b>	14.49
<b>Total</b>	538.12	<b>Total</b>	1172	<b>Total</b>	1750.3	<b>Total</b>	702.91	<b>Total</b>	4163.33



## 5.2. The Carbon-balance analysis

- **Afforestation and reforestation activities**

It is estimated that in the upper catchment area with slope over 40 percent, the project will lead to a land use change from current annual cropland converted to forest land. It corresponds to a total area of 452 ha that should allow **82 905 t CO<sub>2</sub>e** to be stored in twenty years, compared to a situation without any project intervention in which the annual cropland would have remained.

The reforestation implies a sink of CO<sub>2</sub>e that is due particularly to the development of forestry biomass as well as an increase of carbon in soils.

The reforestation is central to the watershed approach. That could help to regulate and clean water flows, reduce and prevent erosion impacts and thus reduce the vulnerability of production systems to natural risks.

- **Development of perennial crops**

Two different foreseen activities refer to the planting of perennial crops. First the project would establish the planting of perennials in the irrigated command area of project sites. Then farmers would be advised to plant fruit trees and other perennial crops in between live terraces to minimize soil disturbances in order to maintain the live terraces established with the LWH project and to cope with soil erosion. The development of perennials implies a sink of GHG reaching **77 141 t CO<sub>2</sub>e** in twenty years, mainly due to the biomass carbon pool. Those two activities would imply land use change from annual cropland to valuable cash perennial crops (e.g avocado, mango, coffee, tea, bananas) whose impacts are calculated among the non forest land use change of EX-ACT. Without the project, it is assumed that no perennial cropland would be developed.

Activities dealing with perennials could create synergies among climate change mitigation, economic development of the project sites (cash crops) and sustainable land management. Indeed it would allow for newly implemented infrastructure to be protected with better management of natural resources.

- **Impacts of the management in annual croplands**

Currently we assume that the majority of annual cropland would following traditional management in which no specific improvements were conducted and residue was burned to comply with the farmer calendar (most of time the residue is spread on soils but does not have time to decompose, forcing the farmer to burn it).

In the future, without the project, we assume that some of the annual cropland would remain under traditional management (430.9 ha) and that some farmers would stop the residue burning and introduce manure (1005.5 ha).

The project recommends the adoption of improved practices that should lead to expanded crop rotation and diversification, the intercropping of legumes and the use improved seeds, manure and improved compost.

The annual crops in the irrigated command area should also receive better water management in addition to the other improvements previously mentioned. The land that is converted to other land uses due to the adoption of the project is considered to be under traditional management as well.

All the improved practices should be implemented to: i) enhance the general fertility status of soils; ii) improve water holding capacity, nutrient efficiency; iii) launch physical soil conservation measures; iv) and increase production and productivity.

The impacts of activities carried out in the annual cropland, compared to a situation without the project, are of interest. They contribute to creating a sink reaching **73 308 t CO<sub>2</sub>e** in twenty years, essentially due to the adoption of more sustainable management, including soil and water conservation practices.

- **Non forest land use changes**

As previously described the main land use changes would occur with the project, by developing perennials and building a reservoir on existing annual cropland. Without the project, the grassland would reduce to the advantage of annual cropland, reflecting an expansion of agriculture land.

The land use changes expected should lead to a sink reaching **30 242 t CO<sub>2</sub>e** in twenty years.

- **Improvements on grasslands**

The adoption of the LWH should help to improve existing grasslands through the adoption of sustainable land management practices improving the feeding of livestock. Without the project the current moderately degraded grassland would likely become severely degraded.

The proposed improvements in grassland may have a huge potential to sequester carbon and result in a sink reaching **21 670 t CO<sub>2</sub>e**.

- **Avoiding deforestation**

Without the project it has been assumed that there would be an expansion on annual cropland on current 439 ha of natural forest land.

The adoption of the project should result in the conservation of the current forested area. In this scenario the project contributes to reducing pressure on forested land in the project sites. Avoiding additional deforestation with the adoption of the LWH project should reduce the emission of **8 935 t CO<sub>2</sub>e**.

- **Installation of new irrigation systems**

The project foresees the installation of irrigated perimeters that would be supplied by reservoirs with run-off systems on a total area reaching 813 ha for the four studied sites. This activity should allow for controlling water supply and increase agricultural production through less dependency on natural rain. Nevertheless, the LWH project uses an entirely gravity fed system with no energy source. Therefore this activity has no impact on the GHG balance.

- **Use of inputs**

The project would assist farmers in producing and applying improved organic compost in the project sites. The average rate of application per year is 10t/ha. The total amount of compost used should be 34,969 t of compost.

To cope with soil acidification in some project sites, lime applications are foreseen at a rate of 7t/ha on 332 hectares. In about two project sites, inputs access would be improved. For example in Karongi 12, a quantity of 12 207 kg of NPK fertilizers

(17,17,17) would be distributed allowing farmers to reimburse the input providers once they were able to sell their production.

Currently the use of fertilizers is limited as there are few to no agro-dealers except in large market areas or cities in Rwanda. Indeed, unless farmers are in a government-approved cooperative, association or programme they generally do not use fertilizers as they are difficult to obtain for average the farmer. Before 2010, the Government attempted to sell fertilizer through sector-level agronomists, but sales were low and ineffective hence the switch to the Governments’ new plan to outsource the sale of fertilizer to private entities.

At the moment there is little information about the quantity of inputs that farmers could use with the adoption of this new plan. Consequently it has been assumed that the current situation would, in the future, remain without the intervention of the LWH. According to Clay and al, farmers may use an average quantity of 1.5 kg of urea per hectare per year. It is likely the figures would remain the same in the future without the project.

The expected increase in input use in the project sites will lead to a total emission of **64 352 t CO<sub>2</sub>e** in twenty years.

### 5.3. The project mitigation potential

Table 3 summarizes the overall C balance of the project, computed as the difference between C sinks and sources over 20 years (five years of implementation phase and 15 years of capitalization phase). The project is in fact able to sequester 294 199 tCO<sub>2</sub>e while emitting 64 352 tCO<sub>2</sub>e so that the net effect of project activities is to create a sink of almost 0.23 MtCO<sub>2</sub>e.

**Table 3: C-balance of the LWH**

C-balance elements	tCO <sub>2</sub> e over 20 years
Total GHG mitigated	294 199
Total GHG emitted	64 352
C-balance	229 848

*Source: our calculations using EX-ACT (2010)*

Table 4 shows the mitigation potential of the project by category of land use change (corresponding to the EX-ACT modules). Mitigation potential is linked to the activities of reforestation, the planting of perennial crops and changes in the management of annual cropland and grasslands (improved agronomic practices, soil and water conservation), while most GHG emissions are determined by the increase in input use associated with the scaling up of best practices on cropland.

**Table 4: Mitigation potential of LWH, by EX-ACT module**

EX-ACT modules	tCO <sub>2</sub> e over 20 years	% of total GHG mitigated	% of total GHG emitted
Reforestation	82 905	28	
Agroforestry/Perennial crops	77 141	26	
Annual crops	73 308	25	
Non forest land use changes	30 241	10	
Grassland	21 670	7	
Avoided deforestation	8 935	3	
Total GHG mitigated	294 199	100	
Inputs	64 352		100
Total GHG emitted	64 352		100
C-balance	229 848		

Source: our calculations using EX-ACT (2010)

Activities linked to the protection of the watershed such as the planting of forests and the expansion of perennial crops contribute to more than one half of project mitigation potential, while management of annual crops recommended by the project is responsible for one quarter of the project mitigation potential. Restoring grassland also has relevant potential for sequestering carbon per hectare improved. Finally, the project promotes intensification of existing agricultural land and should avoid future probable expansion of agriculture lands on deforested land. The use of inputs (fertilizers, lime, and compost) is a source of emissions which are offset by C sequestered through other project activities.

#### 5.4. Sensitivity analysis

The Carbon-balance analysis has been conducted at project level. Data used to describe climate patterns and soil characteristics could not take into account the considerable variability of existing soil and climatic conditions in all of the project sites (see Annex 1). Therefore, the results of the analysis should be considered only as an average for the whole area.

A sensitivity analysis has been conducted in order to estimate the impact of using average climatic data on the overall carbon-balance results. Results show that in all alternative scenarios the project is always found to be a net carbon sink, as in the base scenario. Nevertheless, the quantity of carbon sequestered increases when warmer climates are considered (warm temperate and tropical), and decreases when a drier moisture regime is taken into account (see Table 5).

**Table 5: Sensitivity analysis**

Scenarios	Climate	Moisture regime	Carbon balance	Difference
			tCO <sub>2</sub> e sequestered over 20 years	%
Base scenario	Tropical montane	Moist	229,775	-
Alternative 1	Warm temperate	Moist	309,955	35
Alternative 2	Tropical	Moist	431,718	88
Alternative 3	Tropical montane	Dry	181,593	-21
Alternative 4	Warm temperate	Dry	222,117	-3
Alternative 5	Tropical	Dry	329,784	44

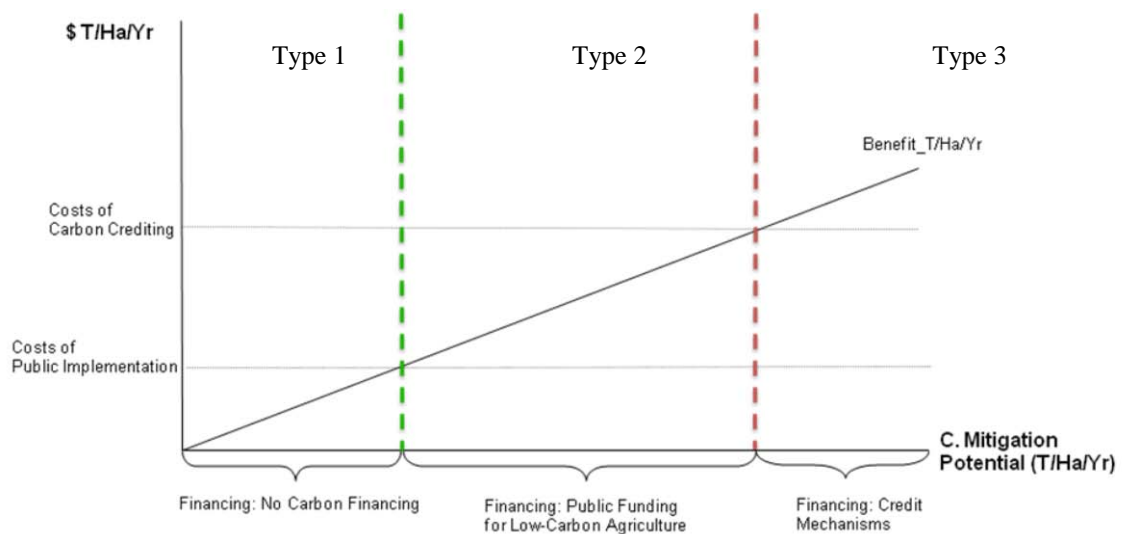
### 5.5. Economic analysis

Mitigation public and private financing for agriculture can play two important roles: providing increased investment flows to the agricultural sector of developing countries, and/or providing increased incomes to farmers in the form of C payments. Mitigation finance could be either public or market-based and integrated with existing official development assistance (ODA). Rural development projects involving the implementation of sustainable land management practices could therefore obtain funds from C finance related to mitigation benefits<sup>26</sup>.

It is possible to classify projects which are of interest for agricultural development in four categories depending on their mitigation potential. Type 0 projects have no mitigation potential (e.g. they are a net source of GHG emissions) and cannot benefit from any additional financing from the C sector. Type 1 projects have a low mitigation potential so that the mitigation benefits are smaller than the costs for monitoring, reporting and verifying (MRV) C mitigation activities. There would be no room for additional project financing from C mitigation sources (ODA public funds remain the main financing source for this category of projects). For type 2 projects, the benefits of pursuing low-C agricultural strategies may be greater than the costs associated with the adoption of basic MRV for public implementation. In this case, public funding may be a possible financing source which could integrate ODA funds, as project offsets are considered as public goods and therefore purchased by a public institution. For type 3 projects, mitigation benefits are greater than the costs of adopting and meeting C crediting MRV requirements (presumably higher than MRV for public sector options) so that C crediting mechanisms are a suitable source of financing for this category of projects. This is the case, for example, of projects aimed at producing C credits from agriculture in developed countries to be sold on the (voluntary or mandatory) C markets (see Figure 3).

<sup>26</sup> Branca et al. 2010.

**Figure 3: Financing options for agriculture development and mitigation projects**



Source: adapted from FAO 2009.

It is not easy to estimate the transaction costs related to the accounting of C activities at public or market level, given the lack of information and the fact that data available are not in standard format to allow accurate comparison. Therefore more research is needed on this topic. Nevertheless, for the purpose of this note, it is assumed that the transaction costs for public implementation are equal to 4 US\$/ha (per year) which is an arbitrary but plausible value based on some literature available<sup>27</sup>. The transaction costs for selling C credits on the market will be obviously higher, given the number and type of requirements, e.g. establish baseline and C flows of the project, design monitoring plan, establish permanent sampling plots, prepare project design document, design individual farm plans, monitor C stocks reported by farmers, verification and certification<sup>28</sup>.

Using the preliminary estimates from EX-ACT shown above, it can be derived that the average mitigation potential of the LWH is equal to 2.8 tCO<sub>2</sub>e/ha per year. It could be valued using a price of 3 US\$/t CO<sub>2</sub>e, which is the average C price for agricultural soil C at retail level on the voluntary C market in 2008<sup>29</sup>. Therefore, the value of the average mitigation potential of the LWH amounts to about 8 US\$/ha. Since this value is well above the level of transaction costs for public implementation 4 US\$/ha (see above), the LWH can be classified as a type 2 project and would probably be suitable for being financed by the public C sector.

<sup>27</sup> Cacho et al. 2005; Lipper et al. 2010; Mooney et al. 2004.

<sup>28</sup> Cacho and Lipper 2006.

<sup>29</sup> Hamilton et al. 2009.

## 6. CONCLUSIONS

The paper describes the ex-ante C-balance analysis performed for the WB-financed LWH project of the Government of Rwanda, using the EX-ACT methodology. Preliminary results show that overall the net effect of LWH is to create a C sink of 0.3 MtCO<sub>2</sub>e over 20 years, which represents the balance between the GHG emitted (mainly as a consequence of the use of agro-chemicals) and C sequestered (essentially through the expansion of forests and perennial crops and the adoption of improved agronomic practices on agricultural area). The project is therefore shown to deliver environmental co-benefits in terms of climate change mitigation.

LWH has a relevant unitary mitigation potential (2.8 tCO<sub>2</sub>e/ha per year), which is reasonable taking into account the type of activities implemented and in line with similar cases<sup>30</sup>. Such potential would make the project worth being financed by the public C sector.

Also, the project approach optimizes land use and management at watershed level, promoting activities aimed at restoring soil fertility. Once the soil fertility will be recovered the use of inputs is planned to be reduced to progressively implement organic agriculture that may be better valued at sub regional markets. This may have a positive effect on the C balance as GHG emissions from input use are expected to be reduced in the future, and the mitigation potential could further increase.

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 the project appraisal. The uncertainty in the data availability and the significant number of assumptions made are inevitably reflected in the results discussed.

The analysis could therefore be revised and expanded at a more advanced project stage, on the basis of the activities effectively implemented in project sites and on the projected upscale of project activities to a higher number of sites. Indeed the choice of crops may imply different results, especially if it concerns annual and perennial. And the adoption of recommended practices is important in the final results. For example, it has been estimated that if farmers do not implement the recommended practices as planned by the project (and considered in the analysis) mitigation potential would decrease by about 40 percent, and the unitary mitigation potential would amount only to 2 t CO<sub>2</sub>e/ha/year. This makes monitoring a key element for ensuring the delivery of the estimated environmental benefits.

The sensitivity analysis showed that in all alternative scenarios the project would represent a Carbon sink as in the base scenario, but confirmed that carbon-balance results are quite sensitive to changes in climate conditions and moisture regime. The analysis could therefore be replicated at project site level, in order to take into account the different environmental characteristics of the targeted areas.

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<sup>30</sup> EX-ACT, 2010.

## 7. LINKS TO OTHER EASYPOL MATERIALS

This module belongs to a set of EASYPol modules and other related documents. See EASYPol Module 101 below:

- [EX-ante Carbon-Balance Tool : Software](#)
- [EX-ante Carbon-Balance Tool : Technical Guidelines](#)
- [EX-ante Carbon-Balance Tool : Brochure](#)

See all EX-ACT resources in EASYPol under the Resource package, [Investment Planning for Rural Development - EX-Ante Carbon-Balance Appraisal of Investment Projects](#)

See also:

- ◆ [An Application to the Rio de Janeiro Sustainable Rural Development Project in Brazil](#) [EASYPol Module 109]
- ◆ [An Application to the Santa Catarina Rural Competitiveness Project in Brazil](#) [EASYPol Module 110]
- ◆ [Irrigation and Watershed Management Case Study in Madagascar](#) [EASYPol Module 112]
- ◆ Policy brief: [Mainstreaming Carbon Balance Appraisal of Agriculture Projects and Policies. A Tool for Measuring Carbon-Balance in Ex-Ante Project - Programme Impact Appraisal](#), EASYPol Module 099

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