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 C-balance tool (EX-ACT)

EASYPol

Resources for policy making

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Application of the EX-Ante C-balance tool (EX-ACT)

by

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for the

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, FAO

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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. The projected 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 contributing to mitigate climate change. Thus it reflects possible synergies between mitigation and rural development goals through 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 row data collected during field mission. Due to the fact that this exercise puts the user in a situation somehow similar to the reality faced by Carbon Balance Appraisal, it can be used in a training course, where there is no possibility to organize field visits to gather data for a practical applications of the EX-ACT software.

Target audience

This document particularly aims at current or future practitioners who work on the formulation and analysis of investment projects, on climate change issues and who work in public administrations, in NGO's, professional organizations or consulting firms. Academics can also find this material useful to support their courses in Carbon Balance Analysis and development economics.

Required background

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[2].

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

a) training paths are shown in **underlined bold font**

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%. The ensuing rise of population density has put pressure on the physical environment and induced 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 above 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 the rain fed agricultural production of small, semi subsistence, and fragmented farms.

Agriculture is the backbone of Rwanda's economy, accounting for 41.7% of GDP and sustaining almost 90% of the population (CIA, 2009). Rwanda's agricultural strategy, as developed by the Ministry of Agriculture and Animal Resources (MINAGRI) is aligned around four strategic programs: (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 (World Bank, 2009).

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. High density population zones are currently characterised by overexploitation of lands and a vegetal cover severely altered. Erosion and landslides processes are advanced. This situation explains the present migratory dynamic of people from the most densely populated provinces in the North and the South towards the least populated provinces especially in the East and South East in search of a new land for agriculture and livestock. These migrating populations are already economically vulnerable and this vulnerability is increased by the high risk of drought and desertification of the zone that receives them (Harding, 2009).

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. (IAASTD, 2009; Jones and Thronton, 2009).

In efforts to address the impact of climate change, the Government of Rwanda has prepared the National Adaptation Program of Action (NAPA) with the following objectives: evaluating current vulnerabilities to climate change in consideration of

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b) other EASYPol modules or complementary EASYPol materials are in ***<u>bold underlined italics</u>***;
c) links to the glossary are in **bold**; and
d) external links are in *italics*.

[2] This module is part of the EASYPol Resource Package: **<u>MACROECONOMIC, AGRICULTURAL, TRADE AND DEVELOPMENT POLICY, MODULE 1: MACROECONOMICS AND INSTRUMENTS OF PROTECTION</u>**

socioeconomic aspects and land use that exacerbate these vulnerabilities; identifying most vulnerable population groups, regions and sectors; determining priority adaptation options; selecting urgent and immediate project activities to be implemented as well as defining their profiles. The identified vulnerabilities to climate change focus especially on the high degradation of arable land due to erosion, following torrential regime of rains in Northern regions (Gisenyi, Ruhengeri and Byumba), Centre/West (Gitarama, Kibuye, Gikongoro) and floods in their downhill slope; the desertification trend in agro-bioclimatic regions of the East and South-East; the lowering of level of lakes and water flows due to pluviometric deficit and prolonged droughts; and the degradation of forests (Republic of Rwanda, 2006) Rwanda can gain long-term economic, environmental and social benefits through moving on 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 (SEI, 2009).

In order not to increase GHGs in Rwanda, the intensification of agriculture production targeted by national ambition needs to consider good nutrient management (method and timing of fertilizer application to improve nitrogen use efficiency), low impact farming measures (reduced tillage, reducing biomass burning), and ways of ensuring carbon storage in soils is maintained / enhanced. It is worth noticing that increasing population and growing income should lead to increasing livestock demand. Thus, careful management of an increasing livestock herd will be needed to minimize methane (CH_4) emissions per unit of livestock production, and measures promoting better feeding and breeding practices are considered (SEI, 2009). In Rwanda, increased or more effective irrigation is expected to enhance carbon storage in soils through increased yields and residue returns. Rice management is also targeted to reduce CH_4 emissions through various practices including draining and using alternative rice varieties. Last, 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 ensure Rwandan agriculture remains and moves further to being a lower GHG sector in the future whilst 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 conduct actions to tackle climate change. EX-ACT (EX-Ante Carbon-balance Tool) is one of such models 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 agriculture (and forestry) sector to CC mitigation (see next section 1.3). The tool is now going through a testing process: case studies have been selected with the aim of representing a wide range of different ecosystems worldwide (e.g. tropical, temperate, semi-arid), agriculture activities (e.g. annual/perennial crops, forestry, livestock, grasslands[3]) 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 to notice that the results could be subject to change as a result of possible adjustments regarding data collection and in the methodology adopted in further development of the tool.

The report is organized as follows. Next section 3.3 provides a description of EX-ACT and its methodology. Chapter 4 provides a short description of the proposed LWH while 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. In annex 1 the map of project area is shown, while annex 2 reports the relevant EX-ACT tables with detailed results of the analysis.

3.3 The EX-Ante carbon-balance Tool (EX-ACT)

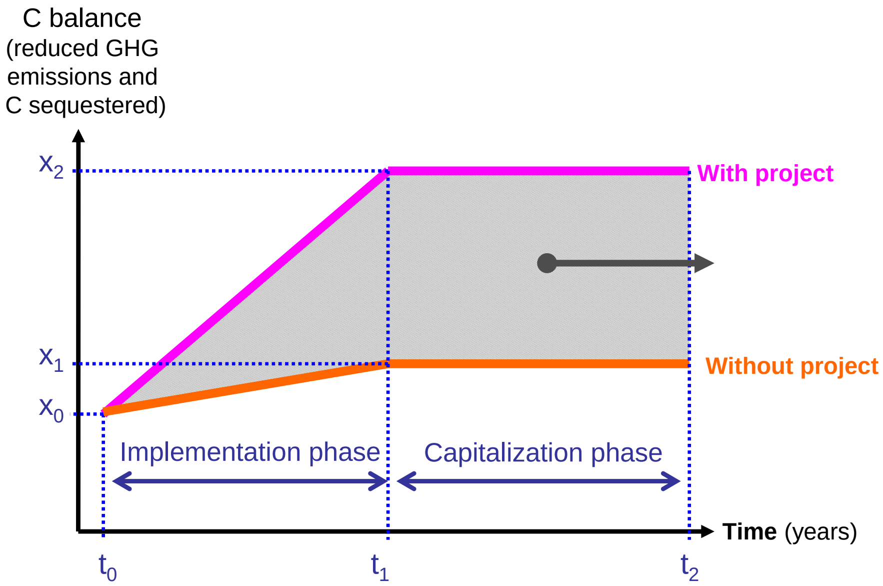
EX-ACT is a tool developed by FAO and aimed at providing ex-ante measurements of the impact of agriculture (and forestry) development projects on GHG emissions and C sequestration, indicating its effects on the C-balance[4] , which is selected as an indicator of the mitigation potential of the project (EX-ACT 2010). EX-ACT can be used in the context of ex-ante project formulation and it 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”. Main output of the tool consists of the C-balance resulting from the difference between these two alternative 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 a project level but it can easily be up-scaled at program/sector or national level (Bernoux et al. 2010a.).

[3] 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.

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

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 (IPCC, 2006) complemented with other methodologies and review of default coefficients for mitigation option as a base. Most calculations in EX-ACT use a Tier 1 approach[5] 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. It should be highlighted that EX-ACT also allows users to incorporate specific coefficients (e.g. from project area) in case they are available, therefore working at Tier 2 level too. EX-ACT measures C stocks and stock changes per unit of land, as well as Methane (CH4) and Nitrous Oxide (N2O) emissions expressing its results in tonnes of Carbon Dioxide equivalent per hectare (t CO_2e ha-1) and in tonnes of Carbon Dioxide equivalent per year (t CO_2e yr-1).

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 in 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 in 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 adopting a different dynamic of change, e.g. "immediate" or "exponential" (figure 2), depending on the characteristics of the specific

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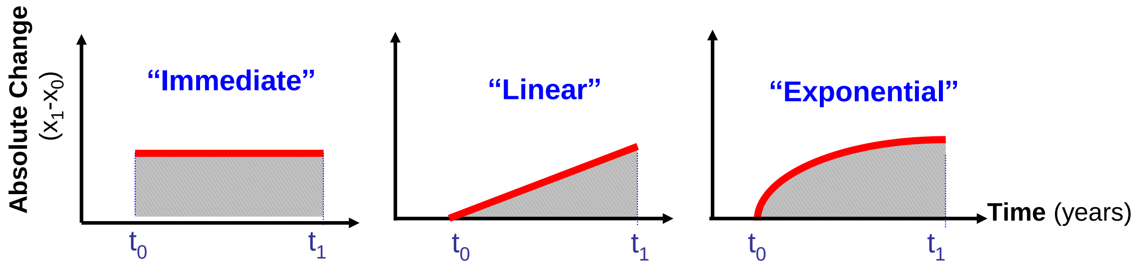
[5] IPCC Guidelines provide three methodological tiers varying in complexity and uncertainty level: Tier1, simple first order approach which uses data from global datasets, simplified assumptions, IPCC default parameters (large uncertainty); Tier 2, a more accurate approach, using more disaggregated activity data, country specific parameter values (smaller uncertainty); Tier 3, which makes reference to higher order methods, detailed modeling and/or inventory measurement systems driven by data at higher resolution and direct measurements (much lower uncertainty).

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 project area together with basic data on land use, land use change and land management practices foreseen under projects' activities as compared to a business as usual scenario (Bernoux et al. 2010a).

4 Project Description

The Government of Rwanda has developed a plan to increase agricultural productivity and commercialization of hillside agriculture in 101 pilot watersheds covering 30,250 hectares (of which 12,000 irrigated) of land especially in 5 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 WB-financed LWH project of the Government of Rwanda.

The primary beneficiaries of the LWH include female and male smallholder farmers producing either irrigated or (in majority) rain fed crops within the project sites who crop an average area of somewhat less than 1 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 among three components (see table 1):

(i) Capacity development and institutional strengthening for hillside intensification
(ii) Infrastructure for hillside intensification
(iii) Project management trough 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 the 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 L, the W and the H of LWH. This component will support the development of participatory and comprehensive land husbandry practices throughout the sub-watershed to improve productivity for rainfed and irrigated areas.

Component C (Project management trough 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 programs and projects at MINAGRI.

Table 1: Profile of the LWH project

<table>
<tr><th></th><th>Component A</th><th>Component B</th><th>Component C</th></tr>
<tr><td></td><td>Capacity Development and Institutional Strengthening for Hillside Intensification</td><td>Infrastructure for Hillside Intensification</td><td rowspan="2">Implementation through the Ministerial SWAp Structure</td></tr>
<tr><td>Sub component</td><td>A1 Strengthening Farmer Organizations;
A2 Extension;
A3 Marketing and Finance;
A4 Capacity Development and Institutional Strengthening: MINAGRI and its Agencies</td><td>B1 Land husbandry infrastructure;
B2 Water harvesting infrastructure;
B3 Hillside irrigation infrastructure</td></tr>
<tr><td>Total Costs</td><td>US$13.85</td><td>US$20.75</td><td>US$10.47</td></tr>
</table>

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 to take into consideration the different project activities and the 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. Since the area targeted by project activities shows significant differences in terms of climatic conditions (see annex 1), data used to describe climate patterns and soil characteristics cannot take into account the considerable variability of existing soil and climatic conditions and 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 areas targeted. 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 is affecting, for example, the level of CH4 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) – project area is characterized essentially by Low Activity Clay (LAC) soils which are highly weathered soils and dominated by 1:1 silicate clay minerals[6] (Bernoux et al. 2010b).

The analysis will consider an implementation phase of five years, followed by a capitalization phase of fifteen years, which will represent a period where the benefits of the investment are still occurring and may be attributed to the changes in land use and management induced by the adoption of the project (see section 1.3). In the analysis it is assumed that the implementation phase will happen according 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[7] , the present analysis uses the same values as those adopted within the Clean Development Mechanism (CDM), i.e. 21 for CH_4 and 310 for N_2O.

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

[6] 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.

[7] 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 which compares the gas in question to that of the same mass of carbon dioxide (whose GWP is by convention equal to 1).

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 will 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 upstream sides of the reservoir and planning perennial commercial trees in all immediate upstream sites of the forage legume area, afforestation of most vulnerable upstream portions of watersheds), 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 in proximity of the irrigated area, and introducing sustainable practices in the catchment's 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's sections: reforestation and soil protection in the upper catchment's area; sustainable agricultural management practices in the rain fed and command area; intensive (annual and perennial) cropland in the downstream part of the rainfed catchment's area (irrigated)[8] .

Therefore the analysis considers that in the "with project" scenario: 2/3 of the existing annual cropland in the irrigated area will 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's area (which includes all the land with slope over 40%) will be converted to forest land; annual cropland in the rain fed area will decrease by the size of the reservoir (which will in fact occupy that land). Also, in the command area, trees will be planted along the contour lines: given that trees will be planted every 5 meters, it is estimated that 1% of annual cropland in the rain fed area will be converted to perennials. While bush and shrub land will not be subject to any change with the project, grasslands is considered as degraded land which will be converted to non-degraded as a consequence of the implementation of the sustainable land management practices. Existing natural forest is conserved (no change) while planted forest will increase (conversion from annual cropland in upper catchment's area, as already mentioned above). The owners of the land which will become part of the reservoir will be resettled and move to existing annual cropland area, therefore implying no land use change.

[8] This strategy is expected to have many benefits in terms of improved soil and water conservation and overall soil fertility thus resulting in 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 program of environmental protection, combining strict laws to reduce damage with projects that will enable Rwandan to gain immediate benefits from conservation (King, 2007).

The analysis takes also into account that: the project will promote the adoption of improved cropland management on annual crops: improved agronomic practices, better water management and manure application; the new management will stop the practice of residue burning and will promote improved residue management; and a low energy irrigation system will be put in place in the irrigated area. Last, the following assumptions about the input use in the "with project" scenario are made: Some sites of the projects 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 the double of this quantity will be applied to integrate two project sites receiving fertilizers. Compost will be applied at a rate of 10t per hectare on all sites reaching a total amount of compost of 35 659 tons (2 830 tons for Gatsibo 8, 12 588 tons for Karongi 13, 10 120 tons for Nyanza 23, and 10 120 tons for Karongi 12 according to land husbandry reports). We assume that the final percentage of nitrogen in compost is 2%[9] . 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, as summarized in what follows: it is assumed that there will be no expansion of perennial crops on existing annual cropland (therefore overall perennial area equals 0); marginal land (bush and shrub lands) remains unchanged, as well as planted forest area. It is also assumed that intensification promoted within 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 will be converted to annual crops. Such assumption implies to establish the link between the yield increases in intensified area with a potential land-sparing. Although there is no consensus about the possible rate of substitution (Rudela et al. 2009), it has been decided to follow the same procedure as described 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% per year is estimated. Also, since households are expanding cultivation at the expense of grasslands and forestland (Kangasniemi, 1998), it is assumed that grasslands and natural forests will be converted to annual cropland at the annual growth rate of 1.7%, i.e. 8.5% over 5 years. This is consistent with the data available at national level (Vision 2020; ROR 2004[10]) .

In the "without project" scenario is also assumed that: about 30% of farmers will abandon the practice of residue burning and introduce manure management; and that no investments (irrigation schemes) will be realized. Also, the following assumptions about the input use in the "without project" scenario are made: on farm use of inorganic

[9] http://www.calrecycle.ca.gov/Organics/CompostMulch/CompostIs.htm; http://soilplantlab.missouri.edu/soil/compost.aspx

[10] Statistics from the Forest department show that the country experienced a loss of approximately 64% of forests in between 1960 and 2007, which is about than 1.3% per year (Republic Of Rwanda, 2004)

fertilizer remained extremely low (less than 4,000 t/year, equivalent to 1-2 kg/ha) (Clay & al, 2001[11]). Thus we assumed that currently and without project farmers apply only 1.5 kg of urea/ha/year. As mentioned above we also considered that some farmers will introduce manure management. Thus an area of 456 ha will 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% farmers still use residue burning 30% farmers abandon residue burning and introduce manure	Residue burning stopped 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

[11] 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		Nya
START		**START**		**START**		**S**
Annual on irrigated	83.23	Annual on irrigated	234.99	Annual on irrigated	376.08	Annual on i
Annual rainfed	173.25	Annual rainfed	165.03	Annual rainfed	266.14	Annual rain
Annual upper catchment	2.42	Annual upper catchment	314.98	Annual upper catchment	575.18	Annual upp
Perennial	0	Perennial	0	Perennial	0	Perennial
Bush and Shrubland	32.07	Bush and Shrubland	101	Bush and Shrubland	183.6	Bush and S
Grassland	89.81	Grassland	84	Grassland	21	Grassland
Natural forest	92.73	Natural forest	62	Natural forest	131.5	Natural fore
Planted forest	26.1	Planted forest	207	Planted forest	195.7	Planted fore
Riverine vegetation	28.12	Riverine vegetation	0	Riverine vegetation	0	Riverine ve
Urban/settlement	10.39	Urban/settlement	3	Urban/settlement	1.1	Urban/settle
Total	538.12	Total	1172	Total	1750.3	Total

WITH PROJECT		**WITH PROJECT**		**WITH PROJECT**		**WITH I**
Annual on irrigated	20.8075	Annual on irrigated	58.7475	Annual on irrigated	94.02	Annual on i
Annual rainfed	161.5175	Annual rainfed	156.3797	Annual rainfed	252.4786	Annual rain
Annual upper catchment	1.21	Annual upper catchment	157.49	Annual upper catchment	287.59	Annual upp
Reservoir	10	Reservoir	7	Reservoir	11	Reservoir
perennial in rainfed	1.7325	perennial in rainfed	1.6503	perennial in rainfed	2.6614	perennial in
perennial irrigated	62.4225	perennial irrigated	176.2425	perennial irrigated	282.06	perennial ir
Bush and Shrubland	32.07	Bush and Shrubland	101	Bush and Shrubland	183.6	Bush and S
Grassland	89.81	Grassland	84	Grassland	21	Grassland
Natural forest	92.73	Natural forest	62	Natural forest	131.5	Natural fore
Planted forest	27.31	Planted forest	364.49	Planted forest	483.29	Planted fore
Riverine vegetation	28.12	Riverine vegetation	0	Riverine vegetation	0	Riverine ve
Urban/settlement	10.39	Urban/settlement	3	Urban/settlement	1.1	Urban/settle
Total	538.12	Total	1172	Total	1750.3	Total

WITHOUT PRJ		**WITHOUT PRJ**		**WITHOUT PRJ**		**WITH**
Perennial	0	Perennial	0	Perennial	0	Perennial
Annual	274.4159	Annual	727.41	Annual	1230.363	Annual
Bush and Shrubland	32.07	Bush and Shrubland	101	Bush and Shrubland	183.6	Bush and S
Grassland	82.17615	Grassland	76.86	Grassland	19.215	Grassland
Natural forest	84.84795	Natural forest	56.73	Natural forest	120.3225	Natural fore
Planted forest	26.1	Planted forest	207	Planted forest	195.7	Planted fore
Riverine vegetation	28.12	Riverine vegetation	0	Riverine vegetation	0	Riverine ve
Urban/settlement	10.39	Urban/settlement	3	Urban/settlement	1.1	Urban/settle
Total	538.12	Total	1172	Total	1750.3	Total

5.2 The Carbon-balance analysis

- **Afforestation and reforestation activities**

It is estimated that in the upper catchment area with slope over 40% 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 to store **82 905 t CO_2e** in twenty years, in comparison to a situation without any project intervention in which the annual cropland would have remained.
This activity of reforestation implies a sink of CO_2e that is especially due to the development of forestry biomass as well as an increase of carbon in soils.
The activity of reforestation is central in 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 plantation of perennial crops. First the project will establish the plantation of perennials in the irrigated command area of project sites. Then farmers are advised to plant fruit trees and other perennial crops in between live terraces to minimize the disturbances of the soil in order to maintain the live terraces established with the LWH project and cope with soil erosion phenomenon. The development of perennials implies a sink of GHG reaching **77 141 t CO_2e** in twenty years, mainly due to the biomass carbon pool. Those two activities will imply land use change from annual cropland to valuable cash perennial crops (e.g avocado, mango, coffee, tea, ananas) whose impacts are calculated among the Non forest land use change of EX-ACT. Without the implementation of the project, it is assumed that no perennial cropland will be developed.
Activities dealing with perennials put forward synergies between mitigation to climate change, economic development of the project sites (cash crops), and sustainable land management. Indeed it allows for protecting newly implemented infrastructure with better management of natural resources.

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

Currently we assumed that the majority of annual cropland is following a traditional management in which no specific improvements are conducted, residue is burnt to comply with the farmer calendar (most of time the residue is spread on soils but do not have time to decompose making the farmer burning it).
In the future without project we assumed that some of the annual cropland will remain under traditional management (430.9 ha) and that some farmers will stop the residue burning and introduce manure (1005.5 ha).
The project recommends the adoption of improved practices that should lead to expand crop rotation and diversification, intercrop legumes, use improved seeds, manure and improved compost.
The annual crops in the irrigated command area should also receive a better water management additionally to the previous improvements quoted previously. The land

that is converted to other land uses due to the adoption of the project is considered to be under the 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) increase production and productivity.
The impacts of activities implemented in annual cropland in the project in comparison to a situation without project are of interest, they contribute to create a sink reaching **73 308 t CO_2e** in twenty years, essentially due to the adoption of more sustainable management including soil and water conservation practices.

- **Non forest land use changes**

As described previously the main land use changes will occur with the implementation of the project, by developing perennials and building reservoir on existing annual cropland. Without the implementation of the project, the grassland will 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_2e** 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 implementation of the project it has been considered that the current moderately degraded grassland will become severely degraded.
The proposed improvements in grassland may have huge potential to sequester carbon and imply a sink reaching **21 670 t CO_2e.**

- **Avoiding deforestation**

Without the implementation of the project it has been assumed that there will be an expansion on annual cropland on current 439 ha of natural forest land.
The adoption of the project should imply the conservation of the current forested area. In this scenario the project contribute to reduce pression 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_2e**.

- **Installation of new irrigation systems**

The project foresees the installation of irrigated perimeters that will 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 is implementing an entirely gravity fed system with no energy source used. Therefore this activity has no impact on the GHG balance.

- **Use of inputs**

The project will accompany farmers to produce and apply 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 sites of the project, inputs access will be improved. For example in Karongi 12, a quantity of 12 207 kg of NPK fertilizers (17,17,17) will be distributed allowing farmers to reimburse the input providers when they will be able to sell their production.

Currently the use of fertilizers is really 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 or association or program they generally do not use fertilizers as it is really difficult to obtain inputs for average 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 fertilizer selling to private entities.
At the moment information could have not been gathered to set the quantity of inputs that farmers could use with the adoption of this new plan. Consequently it has been assumed that the current situation will remain in the future 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. In a very conservative approach it was assumed that it will remain the same in the future without project.
The expected increase in input use in the project sites will lead to a total emission of **64 352 t CO_2e** 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 (5 years of implementation phase and 15 years of capitalization phase). The project is in fact able to sequester 294,199 tCO_2e while emitting 64,352 tCO_2e so that the net effect of project activities is to create a sink of almost 0.23 MtCO_2e.

Table 3: C-balance of the LWH

C-balance elements	tCO_2e 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, plantation of perennial crops and the 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 the best practices on cropland.

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

EX-ACT modules	tCO_2e 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 protection of the watershed such as plantation of forests and expansion of perennial crops contribute to more than a 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 of sequestering carbon per hectare improved. Last, 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. Since the area interested by project activities shows significant differences in terms of climatic conditions (see annex 1), data used to describe climate patterns and soil characteristics cannot take into account the considerable variability of existing soil and climatic conditions in all project sites and the results of the analysis should therefore be considered only as an average for the whole area.

A sensitivity analysis has therefore 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

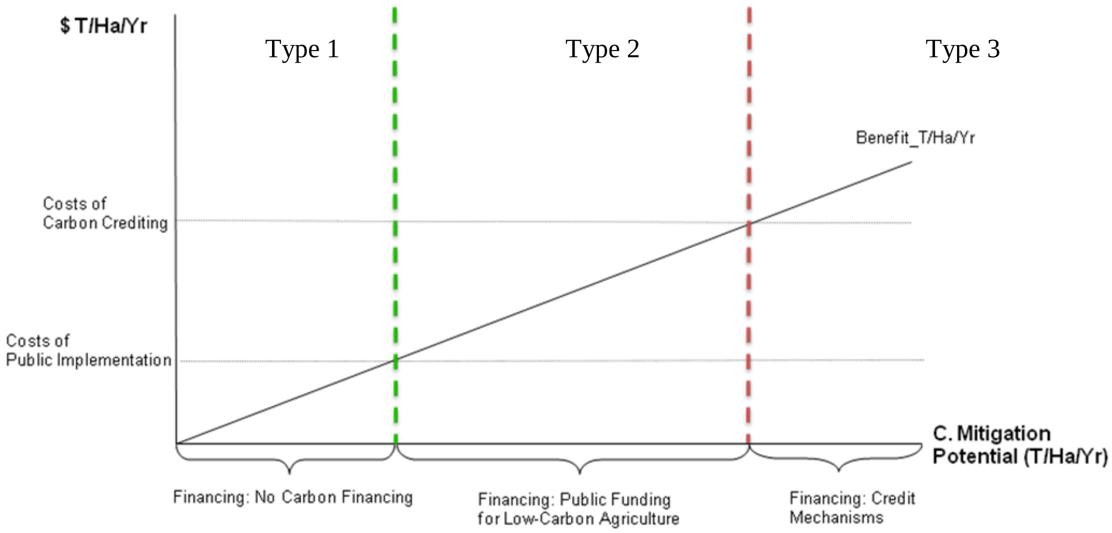
Scenarios	Climate	Moisture regime	Carbon balance	Difference
			tCO_2e sequestered over 20 years	%
Base scenario	Tropical montane	Moist	229,775	-
Alternative 1	Warm temperate	Moist	309,955	35
Alternative 2	Tropical	Moist	431,718	88
Alternative 3	Tropical montane	Dry	181,593	-21
Alternative 4	Warm temperate	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 (Branca et al. 2010).

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 they 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, so that there would be no space 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 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).

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 (Cacho et al. 2005; Lipper at al. 2010; Mooney et al. 2004). 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 (Cacho and Lipper 2006).

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_2e/ha per year. It could be valued using a price of 3 US$/t CO_2e, which is the average C price for agricultural soil C at retail level on the voluntary C market in 2008 (Hamilton et al. 2009). Therefore, the value of the average mitigation potential of the LWH amounts to about 8 US$/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 type 2 project and would probably be suitable for being financed on the public C sector.

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 $MtCO_2e$ 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_2e/ha per year) which is reasonable taking into account the type of activities implemented and in line with similar cases (EX-ACT, 2010). Such potential would make the project worth for being financed by the public C sector.

Also, 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 project appraisal. The uncertainty in the data availability and the significant number of assumptions made is 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%, and the unitary mitigation potential would amount only to 2 t CO_2e/ha/year. This makes monitoring a key element to ensure the delivery of the environmental benefits estimated.

The sensitivity analysis showed that in all alternative scenarios the project will 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 keep into account the different environmental characteristics of targeted areas.

7 Links to other EASYPol materials

- An Application to the Rio de Janeiro Sustainable Rural Development Project in Brazil [EASYPol Module 260]
- An Application to the Santa Catarina Rural Competitiveness Project in Brazil [EASYPol Module 261]
- Irrigation and Watershed Management Case Study in Madagascar [EASYPol Module 263]
- EX-ACT Software, Technical Guidelines & EX-ACT Brochure [EASYPol Module 210]
- Policy brief: Mainstreaming Carbon Balance Appraisal of Agriculture Projects and Policies. A Tool for Measuring Carbon-Balance in Ex-Ante Project - Programme Impact Appraisal

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