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Brazil

Greenhouse gas appraisal report for the joint IFAD-GCF project “Planting climate resilience in rural communities of the Northeast (PCRP)” in Brazil

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EX-ANTE CARBON-BALANCE TOOL EX-ACT

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Executive summary

The joint IFAD-GCF project "Planting climate resilience in rural communities of the Northeast (PCRP)" in Brazil has the objective to "transform family farmers' productive systems in the semiarid by increasing production while simultaneously improving their capacity to face the challenges posed by ongoing climate change." The project will take place in the Semiarid region of Northeast Brazil (NEB). The PCRP is co-funded by GCF and IFAD, with a total financing capacity of USD 202 500 000.

The project is currently under design and will have an implementation period of 8 years and a capitalization phase of 12 years. The total lifespan of the project is 20 years. For this report, EX-ACT version 8.5 was used and the total carbon balance of the project ranges between -11 266 144 tCO_2eq and -11 797 804 tCO_2eq over the 20 years period.

1 Project information

The project "Planting climate resilience in rural communities of the Northeast (PCRP)" of Brazil[1], is still under design at the time of this greenhouse gas (GHG) appraisal, and is expected to be implemented end of 2020 or early 2021 over an eight years period.

The Programme Development Objective (PDO) is to "transform family farmers' productive systems in the semiarid by increasing production while simultaneously improving their capacity to face the challenges posed by ongoing climate change." The PCRP project is co-funded by Green Climate Fund (GCF) and IFAD, with a total financing capacity of USD 202 500 000.

Table with the contributions of each institutions

Table 1. Project budget and share among the institutions

Funding source(s)	Amount (in USD)
International Fund for Agricultural Development (IFAD)	30,000,000
Green Climate Fund (GCF)	99,500,000
Brazilian Development Bank (BNDES)	73,000,000

1.1 Project components and activities

The project's objective is to "transform family farmers' productive systems in the semiarid by increasing production while simultaneously improving their capacity to face the challenges posed by ongoing climate change." This will be achieved through three different components:

Component #1 [Budget: USD 76 478 311] aims to implement Climate Resilient Productive System (CRPS), empower beneficiaries to manage sustainably these systems and promote women and youth leadership. Investment strategies are designed to meet diverse demands of family farmers given various land areas sizes, climate-resilience adaptation requirements, target beneficiaries and productive objectives.

Component#2 [Budget: USD 101 803 245] seeks to disseminate practices to capture, harvest, store and use efficiently water to decrease the vulnerability of livestock and crops to rainfall irregularity and prolonged droughts. Beneficiaries will pay attention to addressing issues of efficient water management, good irrigation practices, and techniques for limiting evapotranspiration, and precautions to avoid soil salinization. All pumping systems will use renewable energy, either photovoltaic or wind.

Component#3 [Budget: USD 9 441 911] will support and amplify activities deployed in from the previous components. It will explore for the scaling up and sharing of information through the South-South Cooperation (SSC), the unlocking of policy barriers and the experimentation of the participatory monitoring model (CRPS).

Project Management [Budget: USD 14 776 533]

1.2 Project site

Caatinga is a semiarid region in the Northeast of Brazil covering a total population of 27 million people.[2] The IFAD project "Planting climate resilience in rural communities of the Northeast (PCRP)" is tackling a number of sites in the region. The exact locations of the project area are yet to be defined. The project targets a total of 250 000 households in this region.

The average minimum and maximum temperature of the Caatinga region is 21.2°C and 30.5°C, respectively (European Centre for Medium-Range Weather Forecasts 2016). The average annual precipitation for the region is 722 mm per year (Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS v2) 2017). In consequence, the Caatinga qualifies for a **tropical dry climate**.

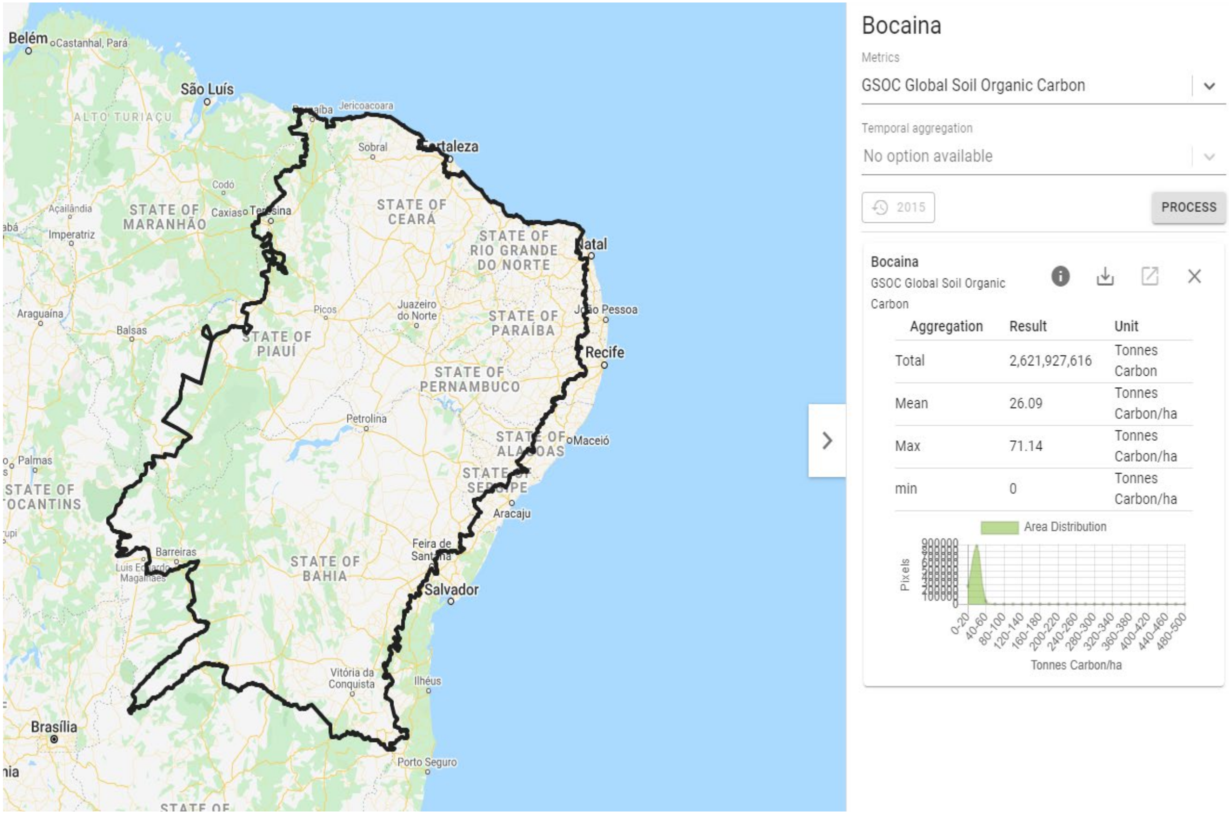
According to the joint UNESCO-FAO soil maps (*see Annex 1*), the area is dominated by five types of soils, namely in descending order Chromic Luvisols, Ferric Luvisols, Orthic Acrisols, Ferrenic Arenosols and Lithosoils. These

[1] Project ID 2000002253

[2] Ministry of Integration webpage, available at: http://www.integracao.gov.br/semiarido-brasileiro

soils can be reclassified according to IPCC's soil classification of 2019: in descending order high activity clay[3], (HAC comprising chromic luvisols, ferric luvisols), sandy soils (orthic acrisols), low activity clay (LAC comprising ferrenic arenosols) and undefined soils (lithosoils). TIER 2 values for the soil organic carbon were applied using FAO's Global Soil Organic Carbon Map (with an average soil organic carbon of 26.09), Figure 1.

Figure 1. Project sites and Global Soil Organic Carbon content in the semiarid region of Northeast Brazil.



Source: FAO, 2020.

[3] HAC soils have appreciable amounts of high-activity clays (e.g. 2:1 layer clays) that promote long-term stabilisation of organic matter, especially in many carbon-rich temperate soils. In contrast, LAC soils (e.g. ferrenic arenosols) have a much lower ability to stabilise carbon, and respond more rapidly to changes in the soil's carbon balance, and include highly-weathered acid soils.

2 Climate mitigation impact

2.1 The EX-Ante Carbon-balance Tool

The Ex-Ante Carbon-balance Tool (EX-ACT) is an appraisal system developed by FAO providing estimates of the impact of agriculture, forestry and fishery development projects, programmes and policies on the carbon-balance. The carbon-balance is defined as the net balance of all GHGs, expressed in carbon dioxide equivalents (CO_2eq), that were emitted or sequestered due to project implementation as compared to a business-as-usual scenario. EX-ACT is a land-based accounting system, estimating carbon stock changes (i.e. emissions or sinks of CO_2) as well as GHG emissions per unit of land, expressed in equivalent tonnes of CO_2 per hectare and year. The tool helps project designers to estimate and prioritize project activities with the greatest economic benefit and potential for climate change mitigation. This GHG mitigation potential may also be used for economic analyses and for allocating additional project funds.

2.2 Data used for the EX-ACT analysis

2.2.1 Agro-ecological variables

The PCRP is expected to affect 84 124 ha covering forest lands, annual croplands, perennial croplands and grasslands. The project area is characterized by a tropical climate with a dry moisture regime. While the project will be implemented about a period of 8 years, EX-ACT will account in addition for a 12 year period of capitalization, which is needed in order to capture the full impact of management and conservation strategies on biomass and soil carbon stocks[4].

A sensitivity analysis was run given the wide diversity of soil. A lower bound analysis is taking into account a region defined with sandy soil, while HAC soil was used in the higher bound analysis.

2.2.2 Activity Data for the GHG appraisal

The main activities with a GHG impact are within component 1 of the project and presented here below, Table 2.

Table 2. Main project components for the GHG appraisal

Project components	Project activities	Without the implementation of the project[5]	With the implementation of the project
Component 1:	Sustainable land management	No improvements	84 124 ha will be sustainably managed
	Eco-stoves installations	No installations	540 eco-stoves installed
	Biodigestor installations	No installations	540 biodigestors installed

Two analysis have been conducted, one taking into account the optimistic scenario with an increased afforestation on degraded grasslands. Assumptions taken for each are described in the next two sections.

2.2.3 Assumptions associated with the activity data for the pessimistic scenario

The sustainable land management can be broken down in following components:

1. 36 000 ha of Caatinga dry forests (24 percent), shrubs (47 percent) and grasslands (28 percent)[6] will be improved through:
   (1) afforestation of shrubs and dry forests on 5 percent of currently degraded grasslands,

[4] The 20 years period (accounting duration) is in line with the idea that even after the point at which a new equilibrium in land use and practices is reached at the end of the implementation phase, further changes may occur as the result of the preceding interventions. For instance, for the soil C estimates, the default values are based on default references for soil organic C (SOC) stocks for mineral soils to a depth of 30 cm (Table 2.3 of IPCC 2006). When SOC changes over time (land use change or management change), it is assumed a default time period for transition between an equilibrium of 20 years. These values are used either in IPCC 1996 or 2006 Guidelines and are gathered from a large compilation of observations and long-term monitoring.

[5] Also named baseline scenario

[6] For a detailed description of the land cover shares, please refer to the Annex and the EX-ACT assessments.

(2) the introduction of live fences, pasture rotation and silage on the 95 percent of remaining grasslands,
(3) an improved management of shrubs and dry forests through live fences.

2. 24 062 ha of Baja-caatinga pastures with declining productivity will be converted into silvopastoral systems (agroforestry).
3. Mono-culture crops will be converted into climate resilient production systems with multiple crops (alley cropping).
4. The installation of 540 biodigestors, together with the installation of 540 eco-stoves and 31 000 solar pumps (the solar pumps were not accounted for in the GHG calculation).
5. Currently, there are 3,750,000 goats present in the project area. This corresponds to the average number of goats by household in the region multiplied by the number of households targeted by the project (250,000). This number is not expected to change in the future with and without the project.

2.2.4 Assumptions associated with the activity data for the optimistic scenario

The sustainable land management can be broken down in following components:

1. 36 000 ha of Caatinga dry forests (24 percent), shrubs (47 percent) and grasslands (28 percent) will be improved through:
   (1) afforestation of shrubs and dry forests on 10 percent of currently degraded grasslands,
   (2) the introduction of live fences, pasture rotation and silage on the 90 percent of remaining grasslands,
   (3) an improved management of shrubs and dry forests through live fences.
2. 24 062 ha of Baja-caatinga pastures with declining productivity will be converted into silvopastoral systems (agroforestry).
3. Mono-culture crops will be converted into climate resilient production systems with multiple crops (alley cropping).
4. The installation of 540 biodigestors, together with the installation of 540 eco-stoves and 31 000 solar pumps (the solar pumps were not accounted for in the GHG calculation).
5. Currently, there are 3,750,000 goats present in the project area. This corresponds to the average number of goats by household in the region multiplied by the number of households targeted by the project (250,000). This number is not expected to change in the future with and without the project.

3 GHG appraisal results

All calculations done in the EX-ACT tool are reported in the results module. After a short reminder of the description module (name of the appraised project, its duration, the continent, the dominant climate, and the soil chosen by the user) including the total area of the project, the following table summarizes the GHGs sequestration and the share of the balance per GHG from the adopted scenario (Figure 3). The balance is the difference of GHG gross fluxes between the with-project situation and the without project situation. Results are given tCO_2eq. Positive numbers represent sources of CO_2eq emissions while negative numbers represent sinks. The left table section summarizes estimated gross fluxes and CO_2eq emissions and sinks from the scenario without-project (left column), from the scenario with-project (middle column) and the total balance (right column). The middle table details the carbon-balance under project implementation, showing the GHG fluxes from the different modules. The right table details annual CO_2eq fluxes for the different activities without and with-project implementation, and for the carbon-balance.

The carbon-balance of the project, which consists in the difference of tCO_2eq emitted or sequestered between a scenario with project and a scenario business-as-usual (BAU or baseline scenario), demonstrates the benefits of implementing the project and its different components in terms of mitigation potential.

The right table describes the carbon balance of each project activity. It covers the activities deployed in the project, which comprise a better forest management, the conversion of annual systems into agroforestry system and some afforestation on degraded lands.

Overall the carbon balance ranges from -11 266 145 tCO_2eq to -11 797 804 tCO_2eq over the 20-years period according to the sensitivity analysis.

In **the "pessimistic" project scenario** GHG mitigation scenario, the accumulated GHG mitigation potential due to project implementation amounts to -6.7 tCO_2eq per hectare per year, or about -11.3 million tCO_2eq over the entire 20-years-period of analysis.

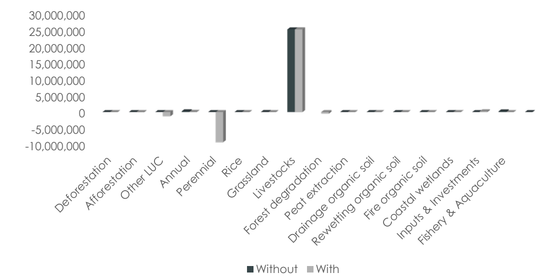
In **the "optimistic" project scenario** GHG mitigation scenario, the accumulated GHG mitigation potential due to project implementation amounts to -7.0 tCO_2eq per hectare per year, or about -11.8 million tCO_2eq over the entire 20-years-period of analysis.

Figure 3. EX-ACT Results for the pessimistic project scenario

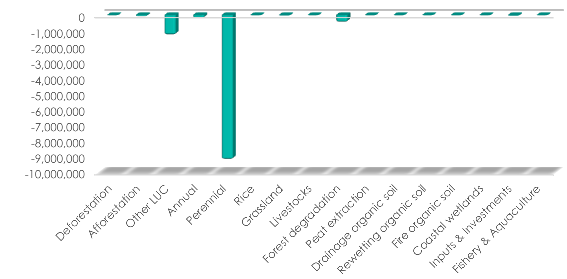
Project Name	*PCR*	**Climate**	*Tropical (Dry)*	**Duration of the Project (Years)**	*20*
Continent	*South America*	**Dominant Regional Soil Type**	*HAC Soils*	**Total area (ha)**	*84124*

Components of the project	Gross fluxes: Without	With	Balance	Share per GHG of the Balance (All GHG in tCO2eq): CO_2 Biomass	CO_2 Soil	CO_2 Other	N_2O	CH_4	Result per year: Without	With	Balance
	All GHG in tCO2eq; Positive = source / negative = sink										
Land use changes											
Deforestation	0	0	0	0	0		0	0	0	0	0
Afforestation	0	-69,064	-69,064	-63,816	-5,248		0	0	0	-3,453	-3,453
Other LUC	0	-1,274,118	-1,274,118	209,011	-1,483,129		0	0	0	-63,706	-63,706
Agriculture											
Annual	237,398	47,480	-189,918	0	0		-35,165	-154,753	11,870	2,374	-9,496
Perennial	0	-9,189,759	-9,189,759	-9,189,759	0		0	0	0	-459,488	-459,488
Rice	0	0	0	0	0		0	0	0	0	0
Grassland & Livestocks											
Grassland	23,997	-3,201	-27,198	0	-3,201		-10,667	-13,330	1,200	-160	-1,360
Livestocks	25,213,792	25,213,792	0				0	0	1,260,690	1,260,690	0
Degradation & Management											
Forest degradation	0	-472,169	-472,169	-419,950	-52,219		0	0	0	-23,608	-23,608
Peat extraction	0	0	0		0		0	0	0	0	0
Drainage organic soil	0	0	0		0		0	0	0	0	0
Rewetting organic soil	0	0	0		0		0	0	0	0	0
Fire organic soil	0	0	0		0			0	0	0	0
Coastal wetlands	0	0	0	0	0		0	0	0	0	0
Inputs & Investments	217,461	207,257	-43,919			-10,204	0	0	10,873	10,363	-510
Fishery & Aquaculture	0	0	0			0	0	0	0	0	0
Total	25,692,648	14,460,218	-11,266,145	-9,464,515	-1,543,797	-10,204	-45,832	-168,083	1,284,632	723,011	-561,621
Per hectare	305.4	171.9	-133.5	-112.6	-18.4	-0.1	-0.5	-2.0			
Per hectare per year	15.3	8.6	-6.7	-5.6	-0.9	0.0	0.0	-0.1	15.3	8.6	-6.7

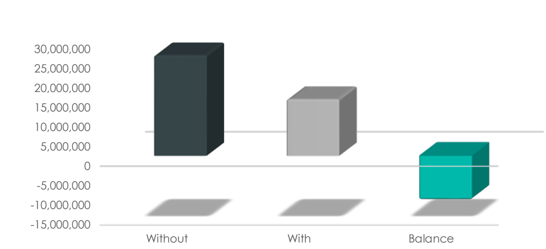
Fluxes per component



Balance per component



Total without and with project and balance



Share of the balance per GHG (plus origin for CO2)

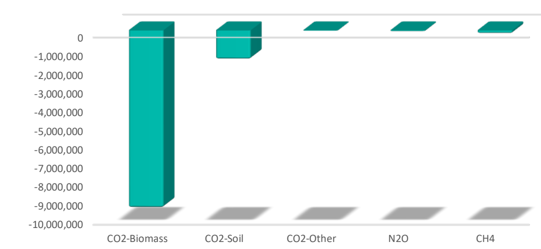
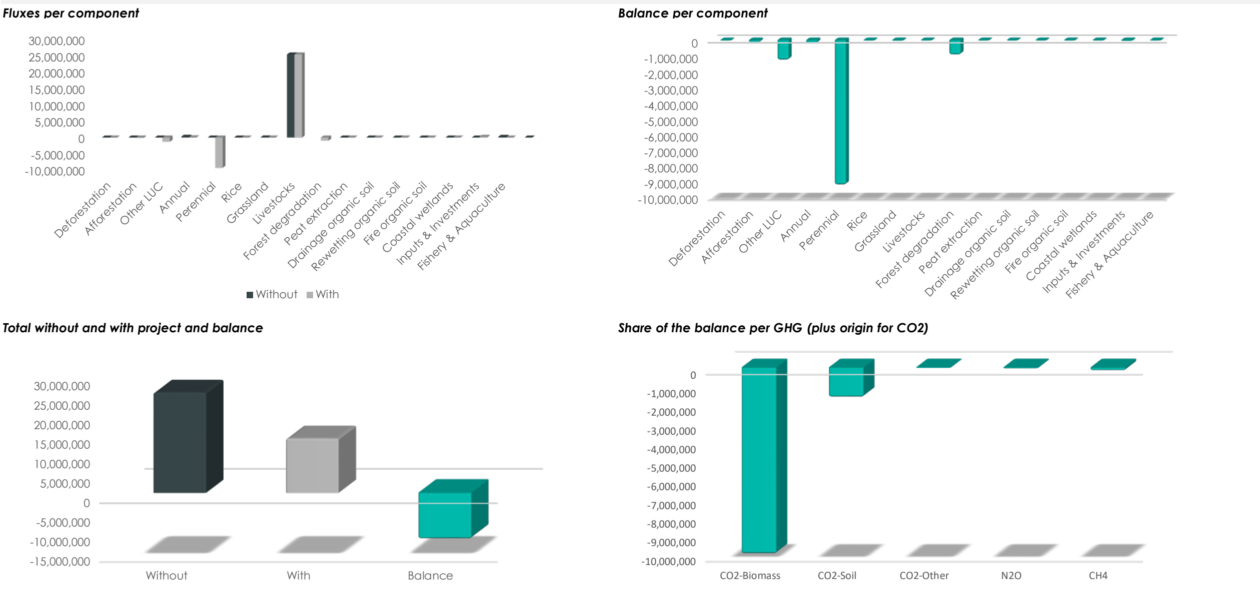


Figure 3. EX-ACT Results for the optimistic project scenario

Project Name	*PCR*	**Climate**	*Tropical (Dry)*
Continent	*South America*	**Dominant Regional Soil Type**	*HAC Soils*
Duration of the Project (Years)	*20*	**Total area (ha)**	*84124*

Components of the project	Gross fluxes (All GHG in tCO2eq; Positive = source / negative = sink) Without	With	Balance	Share per GHG of the Balance (All GHG in tCO2eq) CO_2 Biomass	CO_2 Soil	CO_2 Other	N_2O	CH_4	Result per year Without	With	Balance
Land use changes											
Deforestation	0	0	0	0	0		0	0	0	0	0
Afforestation	0	-128,722	-128,722	-128,722	0		0	0	0	-6,436	-6,436
Other LUC	0	-1,274,118	-1,274,118	209,011	-1,483,129		0	0	0	-63,706	-63,706
Agriculture											
Annual	237,398	47,480	-189,918	0	0		-35,165	-154,753	11,870	2,374	-9,496
Perennial	0	-9,189,759	-9,189,759	-9,189,759	0		0	0	0	-459,488	-459,488
Rice	0	0	0	0	0		0	0	0	0	0
Grassland & Livestocks											
Grassland	23,997	-3,033	-27,029	0	-3,033		-10,667	-13,330	1,200	-152	-1,351
Livestocks	25,213,792	25,213,792	0				0	0	1,260,690	1,260,690	0
Degradation & Management											
Forest degradation	0	-944,338	-944,338	-839,901	-104,438		0	0	0	-47,217	-47,217
Peat extraction	0	0	0		0		0	0	0	0	0
Drainage organic soil	0	0	0		0		0	0	0	0	0
Rewetting organic soil	0	0	0		0		0	0	0	0	0
Fire organic soil	0	0	0		0			0	0	0	0
Coastal wetlands	0	0	0	0	0		0	0	0	0	0
Inputs & Investments	217,461	207,257	-43,919			-10,204	0	0	10,873	10,363	-510
Fishery & Aquaculture	0	0	0			0	0	0	0	0	0
Total	25,692,648	13,928,559	-11,797,804	-9,949,372	-1,590,599	-10,204	-45,832	-168,083	1,284,632	696,428	-588,204
Per hectare	305.4	165.6	-139.8	-118.4	-18.9	-0.1	-0.5	-2.0			
Per hectare per year	15.3	8.3	-7.0	-5.9	-0.9	0.0	0.0	-0.1	15.3	8.3	-7.0



4 Uncertainty assessment

The overall uncertainty is estimated at 47.1 percent and 46.5 percent for the pessimistic and optimistic scenarios, respectively. Such uncertainties are rather common in GHG appraisals for the AFOLU sector as emission processes are very sensitive to environmental conditions (notably the climate and soils) and furthermore hard to model accurately (Gibbons *et al.*, 2006; Rypdal and Winiwarter, 2001). These high emission level uncertainties indicate potential for improvements and, consequently, the need for recalculations including the use of Tier 2 values for carbon stocks in the biomass.

5 Conclusion and recommendations

The total budget spent on Component 1 amounts to USD 76 748 311[7], while the total budget of the PCRP amounts to USD 202 500 000. Considering only the budget spent on the implementation of Component 1[8], the investment amounts to 6.51 to 6.81 USD per tCO_2eq. Considering the total budget of the PCRP, the investment amounts to 17.16 to 17.97 USD per tCO_2eq.

The GHG assessment is based to large extents on refined TIER 1 values (from Cardinael et al., 2018 and IPCC 2006 and 2019). Yet, emission reductions due to the installation of solar panels were not considered in this appraisal. This should be accounted for in a next GHG appraisal of this project.

Under the current financial scenario, BNDES, the States, and the Private sector have a limited capacity to invest in climate change mitigation and adaptation in Northeast Brazil. The targeted final beneficiaries do not have access to finance with formal banks and building resilience to climate change is not considered a first priority in terms of investments for them. Furthermore, a constitutional spending rule introduced in 2016 set a decline of about 0.5 percentage points of GDP annually in federal government expenditure in 2019−24, which could reduce the current public budget available for climate change in the upcoming years. GCF financing is key in making viable and attractive investments in diversified agroforestry systems; mitigation and adaptation benefits of the PCRP could not occur in the absence of GCF financing.

[7] For a detailed description of the budget under Component 1, please refer to Annex 7.2.

[8] All activities impacting the carbon-balance are to be found under Component 1.

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7 Annexes

7.1 Detailed assumptions

Table 3. Detailed assumptions for the optimistic scenario.

	Category	Business as usual scenario	Project scenario	Area in ha
1	LUC	Currently 36 000 ha are exlusively used as Caatinga dry forests (28%), shrubs (47%) and grasslands (24%), see proportionate land cover table (2) in Land cover Caatinga. This area is heavily affected by goat grazing, i.e. severely degraded pasture-, wood- and shrublands (IFAD personnal communication).	Afforestation of shrubs and dry forests on 10% of degraded grasslands. The shrubs and dry forests will be afforested proportionately to their current presence on the 36 000 ha, i.e. 62% shrubs and 38% dry forests (*see proportionate land cover table (2)* in *Land cover Caatinga*).	871
	Grassland		Live fences, pasture rotation and silage will be introduced on the remaining 90% of grasslands to limit goat grazing and improve grasslands. Non-degraded soil carbon stocks (SOC) in the region are about 26.09 tC/ha (SOC value retrieved from Earthmap, FAO 2020). As a straigthfoward approach we considered the percentage difference the different grazing intensity as reported by Schulz et al 2016, see table SOC grassland in land cover Caatinga sheet.	7 836
	Forest management		The introduction of live fences will also reduce the level of biomass lost of shrubs and dry forests with a large degradation level by 10% (to a moderate degradation level).	27 293
2	LUC	Degraded Grasslands	Baja-caatinga pastures with declining productivity will be converted into silvopasture agroforestry systems (defined as " Woody species planted on permanent grasslands, often grazed"), where slash and burn will also cease.	24 062

3	Cropland	Mono-culture crops with residue burning	Mono-culture crops will be converted into Climate Resilient Production Systems with multiple crops (pg.8 of FP). Under the CRPS, following practices will be undertaken: (i) Soil Preparation: Maintenance of dispersed trees, setting up cradles and natural fertilization; (ii) Soil Protection: Soil cover and biomass production with resilient plant varieties, (iii) Water management: capture and storage (both in soil and vegetation), level curves and terraces; (iv) Planting: Stratification, diversification and densification with herbaceous, shrub and tree species maximizing photosynthetic capacity; (v) Management: Active pruning and thinning. (vi) residues are no longer burnt	24 062
4	Livestock	Livestock number is estimated at 3 750 000 goats.	Livestock number is estimated at 3 750 000 goats.	N/A
5	Inputs	No additional inputs	540 biodigestors, 540 eco-efficient stoves and 31 000 Solar pumps (yet those solar pumps were not accounted for as no information was available for the time being). Currently 4 t of compost is applied on agricultural fields and these practices are expected to be continued.	N/A
6	Inputs	Compost estimated at 4 kg per ha on degraded grasslands (under 2) and mono-culture crops (under 3)	Same amount of compost will be applied to the agroforestry systems.	N/A

Table 4. Detailed assumptions for the pessimistic scenario.

	Category	Current	Project scenario	Area in ha
1	LUC	Currently 36 000 ha are exlusively used as Caatinga dry forests (28%), shrubs (47%) and grasslands (24%), see proportionate land cover table (2) in Land cover Caatinga. This area is heavily affected by goat grazing, i.e. severely degraded pasture-, wood- and shrublands (IFAD personnal communication).	Afforestation of shrubs and dry forests on 5% of degraded grasslands. The shrubs and dry forests will be afforested proportionately to their current presence on the 36 000 ha, i.e. 62% shrubs and 38% dry forests (s*ee proportionate land cover table (2)* in *Land cover Caatinga*).	435
	Grassland		Live fences, pasture rotation and silage will be introduced on the remaining 95% of grasslands to limit goat grazing and improve grasslands. Non-degraded soil carbon stocks (SOC) in the region are about 26.09 tC/ha (SOC value retrieved from Earthmap, FAO 2020). As a straigthfoward approach we considered the percentage difference the different grazing intensity as reported by Schulz et al 2016, see table SOC grassland in land cover Caatinga sheet.	8272
	Forest management		The introduction of live fences will also reduce the level of biomass lost of shrubs and dry forests with a large degradation level by 5% (to a moderate degradation level).	27 293
2	LUC	Degraded Grasslands	Baja-caatinga pastures with declining productivity will be converted into Silvopasture agroforestry systems (defined as " Woody species planted on permanent grasslands, often grazed"), where slash and burn will also cease.	24 062
3	Cropland	Mono-culture crops with residue burning	Mono-culture crops will be converted into Climate Resilient Production Systems with multiple crops (pg.8 of FP). Under the CRPS, following practices will be undertaken: (i) Soil Preparation: Maintenance of dispersed trees, setting up cradles and natural fertilization; (ii) Soil Protection: Soil cover and biomass production with resilient plant varieties, (iii) Water management: capture and storage (both in soil and vegetation), level curves and terraces; (iv) Planting: Stratification, diversification and densification with herbaceous, shrub and tree species maximizing photosynthetic capacity; (v) Management: Active pruning and thinning. (vi) residues are no longer burnt	24 062

4	Livestock	Livestock number is estimated at 3 750 000 goats.	Livestock number is estimated at 3 750 000 goats.	N/A
5	Inputs	No additional inputs	540 biodigestors, 540 eco-efficient stoves and 31 000 Solar pumps (yet those solar pumps were not accounted for as no information was available for the time being). Currently 4 t of compost is applied on agricultural fields and these practices are expected to be continued.	N/A
6	Inputs	Compost estimated at 4 kg per ha on degraded grasslands (under 2) and mono-culture crops (under 3)	Same amount of compost will be applied to the agroforestry systems	N/A

7.2 Budget of Component 1

Component	Output	Activity	Total (USD)
Component 1. Climate Resilient Productive Systems (CRPS)	Output 1.1. Increase climate resilience for family farmers and traditional communities while mitigating carbon emissions by applying CRPS	Activity 1.1.1. Selection of Project Areas and development of TRIPs	62 424
		Activity 1.1.2. Implement CRPS in family farms and backyard gardens	62 682 081
		Activity 1.1.3. Implement Collective Resilient Investments	10 600 052
		Activity 1.1.4. Build a Farmers Network and Promote local entrepreneurship for products and services that support family farming	3 133 755
		Total	**76 478 311**

7.3 Additional notes on GHG accounting

In order to account for the GHG reduction benefits of biodigestors and eco-stoves, additional calculations had to be made that are not yet part of the EX-ACT tool. In particular, both biodigestors and eco-stoves will lead to a reduction of annual carbon losses in biomass of fuelwood removal and a reduction of the emissions for the combustion of woody biomass. Biodigestors furthermore reduce manure methane emissions by converting the manure to biogas.

7.3.1 Combustion of woody biomass

The GHG emissions from the combustion of woody biomass is estimated as the following, Equation 1:

$$\mathrm{Emissions}_{\mathrm{Woody\ biomass\ combustion}} = \mathrm{Q} \times \mathrm{D} \times (CF_{CH4} \times EF_{CH4} + CF_{N2O} \times EF_{N2O})$$

where Q is the quantity of wood consumed in tonnes, D is the wood density in oven-dry tonnes per moist m^3 and CF_{CH4} and CF_{N2O} oxide are the combustion factors for CH_4 and N_2O and EF_{CH4} and EF_{N2O} are the emission factors of Methane and Nitrous oxide based on their global warming potential (Hingane, 1991 and IPCC, 2006).

7.3.2 Annual carbon loss in biomass of fuelwood removal

$$\mathrm{L}_{\mathrm{Fuelwood}} = \left[\{\mathrm{FG}_{\mathrm{trees}} \times \mathrm{BCEF}_{R} \times (1 + \mathrm{R})\} + \mathrm{FG}_{\mathrm{part}} \times \mathrm{D}\right] \times \mathrm{CF}$$

where $L_{fuelwood}$ is the annual carbon loss due to fuelwood removals in tonnes C per year, FG_{trees} is the annual volume of fuelwood removal of whole trees in m^3 per year, FG_{part} is the annual volume of fuelwood removal as tree parts, m^3 per year, R is the ratio of below-ground biomass to above-ground biomass, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$; R must be set to zero if assuming no changes of below-ground biomass allocation patterns, CF is the carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$, D is the basic wood density, tonnes d.m. m^{-3}, BCEFR is the biomass conversion and expansion factor for conversion of removals in merchantable volume to biomass removals (including bark), tonnes biomass removal (m^3 of removals)$^{-1}$ and CF is the conversion factor m^3 biomass to t biomass (1.38m^3/t) for fuelwood (IPCC, 2006).

7.3.3 Eco-efficient stoves emission reductions

The emissions reductions due to the installation of eco-stoves, $R_{\text{eco-stove combustion}}$, is estimated from the following equation:

$$\mathrm{R}_{\mathrm{eco-stove\ combustion}} = \mathrm{Emissions}_{\mathrm{Woody\ biomass\ combustion}} - \mathrm{Emissions}_{\mathrm{Woody\ biomass\ combustion\ reductions}} \times \mathrm{N} \times \mathrm{S}$$

Where:

- $\text{Emissions}_{\text{Woody biomass combustion}}$ is the total emissions due to the combustion of woody biomass as defined in 7.3.1;
- $\text{Emissions}_{\text{Woody biomass combustion reductions}}$ is the emission reduction of combustion of woody biomass only for the quantity of households with eco-stoves;
- N is the number of biodigestors, and
- S is the energy saving potential due to the improved energy efficiency of the stoves;

With $\mathrm{R}_{\mathrm{eco-stove\ fuelwood\ removal}}$ estimated as the following:

$$\mathrm{R}_{\mathrm{eco-stove\ fuelwood\ removal}} = \mathrm{L}_{\mathrm{Fuelwood\ removal}} - \mathrm{L}_{\mathrm{Fuelwood\ removal\ reductions}} \times \mathrm{N} \times \mathrm{S}$$

Where:

- $L_{\text{Fuelwood removal}}$ is the total annual carbon loss due to fuelwood removals in tonnes C per year and,
- $L_{\text{Fuelwood removal reductions}}$ is the emission reduction of combustion of woody biomass only for the quantity of households with eco-stoves (IPCC, 2006 and Regueira, 2010).

7.3.4 Total manure emission reductions

$$\mathrm{CH4_{manure}} = EF_{manure} \times \mathrm{GWP} \times \mathrm{N}/1000 - \mathrm{CH4_{manure\ reduction\ biodigestor}}$$

where $CH4_{manure}$ is the methane emission factor by average annual temperature, N is the number of heads and $CH4_{manure\ reduction\ biodigestor}$ is the manure methane emission reductions by the biodigestors (IPCC, 2016 and Santiago, 2013).

$$\mathrm{CH4_{manure\ reduction\ biodigestor}} = D_{CH4} \times EF_{CH4} \times \mathrm{f}_{manure} \times \mathrm{SV} \times \mathrm{T} \times \mathrm{B}$$

where D is the methane density, f_{manure} s the transformation conversion factor defined by the US EPA (2008), SV are the volatile solids per day, T is the time and B is the maximum production capacity depending on the manure type (Winsock, 2008).

7.3.5 Biodigestor emissions

The biodigestor converts the manure in biogas, which is composed mainly of methane. For this analysis, a biodigestor system was subdivided into two main subsystems:

i) an internal chamber which creates an anaerobic fermentation process
ii) an external chamber which creates a semi-aerobic fermentation process

For the external chamber, a methane leakage fraction was assumed. To estimate the GHG emissions of biodigestors, following equations were established:

iii) an internal chamber which creates an anaerobic fermentation process

$$\mathrm{Emissions_{internal\ chamber}} = \mathrm{D_{CH4}} \times \mathrm{EF_{CH4}} \times \mathrm{f_{anaerobic}} \times \mathrm{SV} \times \mathrm{T} \times \mathrm{B} \times \left(\frac{CE_h}{100}\right) \times \left(1 - \frac{ED}{100}\right)$$

where $Emissions_{internal\ chamber}$ are the methane emissions of the internal chamber of the biodigestor, $f_{internal}$ is the transformation conversion factor of biodigestor's internal chamber, CE_h is the collection efficiency relative to the internal membrane and the external supernatant and ED is the Methane Destruction Efficiency of Natural Gas (IPCC, 2006 and Santiago, 2013).

iv) an external chamber which creates a semi-aerobic fermentation process

$$\mathrm{Emissions_{\,external}} = \mathrm{D_{CH4}} \times \mathrm{EF_{CH4}} \times \mathrm{f_{semi-aerobic}} \times \mathrm{SV} \times \mathrm{T} \times \mathrm{B} \times (1 - CE_h)$$

where $Emissions_{external}$ are the methane emissions of the internal chamber of the biodigestor and $f_{semi\text{-}aerobic}$ is the transformation conversion factor of biodigestor's external chamber.

For more information on the calculations and the references, please refer to the attached EX-ACT calculations.

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

Mainstreaming greenhouse gas accounting into agricultural investments and policies

The 2030 Agenda and Paris Agreement tied the knot between sustainable economic development and a climate-resilient, low greenhouse gas (GHG) emissions future. Moving forward, accounting for potential changes in GHG emissions will be a vital component of any agricultural investment, project, or policy proposal under consideration by any country, institution, or organization. To support the international community's efforts with quantifying changes in GHG emissions, the Food and Agriculture Organization of the United Nations (FAO) developed the EX-Ante Carbon-balance Tool (EX-ACT).

Based on the Intergovernmental Panel on Climate Change (IPCC) methodology, EX-ACT provides its users a consistent way of estimating and tracking the impact of agricultural, forestry, and other land-use (AFOLU) investments and policies on GHG emission levels. EX-ACT is a free, open-source, Excel-based model and is available in all UN languages, as well as Bahasa, Vietnamese, Portuguese and German.

Objectives

- Identify the climate mitigation impact of various investments projects and policies.
- Support countries in accessing funds from international financial institutions and international mechanisms to support projects, programmes and policies.
- Strengthen the capacities of national stakeholders in estimating and monitoring emissions reductions goals from a wide range of projects.
- Support policymakers in integrating climate change mitigation objectives into national policies and international commitments (e.g. nationally determined contributions).
- Provide accurate and transparent estimates of GHGs emissions reductions using country or project-specific data if available.

WEBSITE

www.fao.org/tc/exact

EX- ACT COUNTRY CASE STUDIES

This report is part of a series of briefs, presenting project appraisals for different country case studies using either the EX-ACT Tool, which provides the potential climate change mitigation impacts of investment projects in the Agriculture, Forestry and Land Use (AFOLU) sector, or the EX-ACT MRV Tool, a project monitoring mechanism of the impact of greenhouse gases and adaptation to climate change on the same type of projects portfolio. Each brief provides a short description of the project analyzed, the main results obtained and the related materials (case study document, EX-ACT and EX-ACT MRV sheets). The tested projects treat the following areas: rural activities, agriculture, forestry, watershed and restoration of degraded soils.