Annex 22. A. OCRI GHG calculation methodology

The calculation methodology of the GHG emission reduction was developed considering different sources of information relating to the OCRI project, assumptions and specific formulas taking into consideration OCRI's components and activities.

Climate additionality of the project:
The emission reductions will not be possible without the support of the GCF as the Government of Benin does not have the capacity to allocate the required funding for the project implementation. The Project activities funded by the GCF will contribute to the reduction of carbon emissions specifically through: (a) the improved CRA practices to enhance agricultural productivity, including the development of small irrigation system, corresponding to emission reduction by 52 587 tCO_2eq over 20 years. Additional reduction in emissions of approximately 29,383 tCO2eq over 20 years is expected from phasing out mineral fertilization.; (b) Strengthening degraded river banks and restoring perennial parkland land with additional trees and SLM/SFM practices, resulting in a direct reduction in emissions of approximately 1 469 260 tCO_2 equivalent (tCO_2eq) over 20 years (per year which corresponds to 73 463 tCO_2eq per year); and (c) improving the management of degraded forest over an area of 9 000 ha, which is subject to severe anthropic pressure, contributing to a reduction emission by 232 518 tCO_2 eq over 20 years. In addition, the land use change related to the construction of dam will emit 115 tCO_2 eq while the irrigation system with trickle will contribution to the emission by 623 tCO_2 eq. Overall, the project is expected to create a carbon sequestration result of 1 783 633 tCO_2eq over 20 years compared to baseline.

Tree planting activities will directly contribute to reduce Benin's GHG emission, thereby supporting the achievement of INDC's goal. The restoration of degraded riverbanks and fields with agroforestry systems (Activity 1.1.2) will contribute to deepening the existing carbon sinks through the plantation of fruit trees and the increase in the density of parkland. This activity contributes to sequester 1 469 260 tCO2eq over 20 years. In addition, the overall improved management on 9 000 ha of degraded forest supported by the project sequesters 232 518 tCO2eq.

A. Scope of the carbon accounting considering OCRI's components

Project Component	**Scope of carbon accounting**		
Component 1. Low carbon climate resilient crop production enhanced and Ecosystem services restored in the Upper and Middle Ouéme			
Output 1.1: Waterworks and tree plantation to protect river banks and secure water access	**Carbon removal**	**Avoided emissions**	**Emissions**
Activity 1.1.1. Build water harvesting and retention infrastructures			

1. Construction of micro-dams, dykes, cisterns and boreholes	N/A	N/A	Some emissions created in construction as a result of land use change from existing annual fallow land
2. 2,000 ha of small irrigated plots with improved Climate Resilient Agriculture (CRA) practices		Emissions avoided as a result of reduced tillage, better residue management practices and no burned residue on improved annual cropland with irrigation	Some emissions from the use of trickle/ high efficiency drip irrigation systems
Activity 1.1.2. Strengthen degraded river banks and restore land with tree			
1. Trees planted to restore vegetation coverage (reforestation) along degraded river banks and fields	Emissions sequestered from enhancing existing tropical moist deciduous forest, improving vegetation coverage and soil quality near river banks by planting trees	N/A	N/A
Output 1.2. 24,250 farmers capacitated to implement CRA, agro-forestry and sustainable land management	**Carbon removal**	**Avoided emissions**	**Emissions**
Activity 1.2.3 Implement CRA, including agroforestry, to enhance agricultural productivity under climate change			
1. Using sustainable land management (SLM) / sustainable forest management (SFM) on river banks: increasing tree cover and organic matter and green manure	Emissions sequestered from additional tree planting to enhance tree cover through agroforestry practices	Emissions avoided from no tillage practices	N/A

2. Using SLM/ SFM on river banks: with higher increase in tree cover and organic matter	Emissions sequestered from additional tree planting to enhance tree cover through agroforestry practices	Emissions avoided from no tillage practices	N/A
3. Using SLM/ SFM on river banks: improving residue management	N/A	Emissions avoided from discontinuation of biomass burning and no tillage practices	N/A
4. Creating orchards on degraded river bank land	Emissions sequestered from additional tree planting	Emissions avoided from no tillage practices	N/A

B. Calculation formula for carbon accounting

Based on areas indicated for conversion in table B and also considering vegetation characteristics and details indicated in other parts, the GHG balance in CO2-eq is calculated for the biomass and soil pool and emissions from fire consistently with the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) specifically Volume 4 (Agriculture, Forestry and Other Land Use), Chapter 2 (Generic Methodologies Applicable to Multiple Land Use Categories)

$$GHGBalance = \Delta C_G + \Delta C_{soil} + L_{fire}$$

For the biomass pool, we used Equation 2.9

$$\Delta C_G = \sum_k A_k \times G_{TOTAL} \times CF$$

ΔCG = annual increase in biomass carbon stocks, given vegetation type and climatic zone ($tC.yr^{-1}$)

A_k = area of land converted following the index k (ha)

GTOTAL= mean annual biomass growth ($tDM.ha^{-1}.yr^{-1}$)

CF = carbon fraction of dry matter ($tC.tDM^{-1}$)

For the soil pool, we used Equation 2.25

$$\Delta C_{soil} = \frac{(SOC_0 - SOC_{0-T})}{D}$$

SOC_0 = soil organic carbon stock in the last year of the project, tC

$SOC_{(0-T)}$ = soil organic carbon stock at the beginning of the project, tC

SOC0 and SOC(0-T) are calculated using the SOC equation in the box where the reference carbon stocks and stock change factors are assigned according to the land-use and management activities and corresponding areas at each of the points in time (time = 0 and time = 0-T)

T = number of years of the project (yr)

D = Time dependence of stock change factors which is the default time period for transition between equilibrium SOC values (yr). Default 20 yr

c = represents the climate zones, s the soil types, and i the set of management systems that are present in a country.

SOC_{REF} = the reference carbon stock, $tC.ha^{-1}$ (default values)

FLU = stock change factor for land-use systems or sub-system for a particular land-use, dimensionless

FMG = stock change factor for management regime, dimensionless

FI = stock change factor for input of organic matter, dimensionless

A = land area of the stratum being estimated (ha).

For the emission from fire, we used Equation 2.27

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

L_{fire} = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH4, N2O.

A = area burnt (ha)

M_B = mass of fuel available for combustion ($t.ha^{-1}$)

C_f = combustion factor, dimensionless (default values)

G_{ef} = emission factor, g.kg^{-1} dry matter burnt (default values)

Project Component	Calculation formula for carbon accounting	
Component 1. Low carbon climate resilient crop production enhanced and Ecosystem services restored in the Upper and Middle Ouéme		
Output 1.1: Waterworks and tree plantation to protect river banks and secure water access	**Carbon removal**	**Avoided emissions**
Activity 1.1.1. Build water harvesting and retention infrastructures		
1. Construction of micro-dams, dykes, cisterns and boreholes	N/A	N/A
2. 2000 ha of small irrigated plots		Emissions avoided as a result of reduced tillage, better residue management practices and no burned residue on area relating to improved annual cropland with irrigation
Activity 1.1.2. Strengthen degraded river banks and restore land with tree	**Carbon removal**	**Avoided emissions**
1. Trees planted to restore vegetation coverage (reforestation) along degraded river banks and fields	Carbon sequestered from enhancing existing tropical moist deciduous forest area, improving vegetation coverage and soil quality near river banks by planting trees	N/A

Output 1.2. 24,250 farmers capacitated to implement CRA, agro-forestry and sustainable land management ***Activity 1.2.3 Implement CRA, including agroforestry, to enhance agricultural productivity under climate change***	**Carbon removal**	**Avoided emissions**
1. Using sustainable land management (SLM) / sustainable forest management (SFM) on river banks: increasing tree cover and organic matter and green manure	Emissions sequestered from area undergoing additional tree planting to enhance tree cover through agroforestry practices	Emissions avoided from no tillage practices implemented on existing perennial parkland area
2. Using SLM/ SFM on river banks: with higher increase in tree cover and organic matter	Emissions sequestered from area undergoing additional tree planting to enhance tree cover through agroforestry practices	Emissions avoided from no tillage practices and high tree density outweigh the emission to the increase input use for perennial parkland area.
3. Using SLM/ SFM on river banks: improving residue management	N/A	Emissions avoided from discontinuation of biomass burning and no tillage practices on perennial crop area
4. Creating orchards on degraded river bank land	Emissions sequestered from area undergoing additional tree planting and implementation of perennial fallow agroforestry system	Emissions avoided from no tillage practices on perennial cropland

C. Assumptions for estimating emissions removal and avoided

C.1 General Assumptions

Parameters	Value	Source	Note
Implementation phase	6 years	Assumption	Based on project implementation period

Capitalization phase	14 years	Assumption	Based on project timeline total of 20 years
Duration of accounting	20 years	Assumption	
Total project area	95,001 ha	GIS estimate	1 ha of micro dam construction 2,000 ha of CRA improved annual cropland 9,000 ha of reduced forest degradation 8,400 ha improved residue management on degraded river bank (perennial crop) 4,000 ha of orchard agroforestry 20,000 of SLM/SFM 51,600 of SLM/SFM with higher tree cover and organic matter
Area of annual fallow land converted to construct micro dams (Land-use change)	1 ha	Assumption	
Area of existing rain-fed annual cropland improved to CRA annual cropland with no residue burning, reduced tillage and high carbon input (Annual systems remaining as annual systems)	2,000 ha	Assumption	
Perennial systems remaining perennial: Area of degraded river banks (not burned) without project; agroforestry system: parkland with reduced/some tillage	67,200 ha	Assumption	
Perennial systems remaining perennial: Area of degraded river banks (burned) without project;	16,800 ha	Assumption	

agroforestry system: parkland with reduced/some tillage			
Perennial systems remaining perennial: Area of degraded river banks (not burned) with project; agroforestry system: parkland with reduced/some tillage	0 ha	Assumption	
Perennial systems remaining perennial: Area of degraded river banks (burned) with- project; agroforestry system: parkland with reduced/some tillage	0 ha	Assumption	
Perennial systems remaining perennial: Area of improved river banks through use of SLM/SFM practices without project	0 ha	Assumption	
Perennial systems remaining perennial: Area of river bank with improved SLM/SFM practices: no tillage, increase in tree cover and organic matter with project; agroforestry system: parkland	51,400 ha	Assumption	
Perennial systems remaining perennial: Area of improved river bank with SLM/SFM practices: no tillage, higher increase in tree cover and organic matter with project; agroforestry system: parkland	20,000 ha	Assumption	
Perennial systems remaining perennial: Area of improved river bank with orchard agroforestry on perennial fallow land with project; no tillage and medium carbon input	4,200 ha	Assumption	
Perennial systems remaining perennial: Area of improved river bank with SLM/SFM practices and no burning of residues; agroforestry system: parkland, no tillage	8,400 ha	Assumption	
Forest degradation and management: Existing moderately degraded tropical moist deciduous forest improved to low forest degradation level with the project	9,000 ha	Assumption	Without the project 40% of the biomass will lost (moderately degraded). With the project will lead to low forest

			degradation (20% of the biomass lost)
Area with improved irrigation systems; trickle/ precision drip irrigation system	2,000 ha	Assumption	This is the same area of land on which improved CRA annual cropland takes place
Above-ground growth rate for parkland agroforestry system	0.59 tC/ha/year	Default values in EX-ACT model	IPCC, 2006 National GHG inventory guidelines
Below-ground growth rate for parkland agroforestry system	0.21 tC/ha/year	Default values in EX-ACT model	IPCC, 2006 National GHG inventory guidelines
Rate of soil carbon sequestration	38 tC/ha/year	Default values in EX-ACT model	IPCC, 2006 National GHG inventory guidelines
Above-ground growth rate for perennial fallow agroforestry system	5.30 tC/ha/year	Default values in EX-ACT model	IPCC, 2006 National GHG inventory guidelines
Below-ground growth rate for perennial fallow agroforestry system	1.27 tC/ha/year	Default values in EX-ACT model	IPCC, 2006 National GHG inventory guidelines
Above-ground growth rate for tropical moist deciduous forest	1.3tC/ha/year	Tier2	Ghana's National Forest reference level 2001-2015
below-ground growth rate for tropical moist deciduous forest	0.3 tC/ha/year	Tier 2	Calculation based on BGB-AGB ratio of 0.23

C.2 Emission factors for estimating avoided emissions

Component 1. Low carbon climate resilient crop production enhanced and Ecosystem	Avoided emissions - without project	Avoided emissions - with project situation	Source

services restored in the Upper and Middle Ouéme			
Output 1.1: Waterworks and tree plantation to protect river banks and secure water access			IPCC, 2019 National GHG inventory guidelines
Activity 1.1.1. Build water harvesting and retention infrastructures	***N/A***		
1. 2,000 ha of small irrigated plots	N/A	No tillage: 1.04 Avoiding residue burning: 1.11	
Output 1.2. 24,250 farmers capacitated to implement CRA, agro-forestry and sustainable land management			
Activity 1.2.3 Implement CRA, including agroforestry, to enhance agricultural productivity under climate change			IPCC, 2019 National GHG inventory guidelines
1. Using sustainable land management (SLM) / sustainable forest management (SFM) on river banks: increasing tree cover and organic matter and green manure	N/A	Tillage factor: 1.10	IPCC, 2019 National GHG inventory guidelines
2. Using SLM/ SFM on river banks: with higher increase in tree cover and organic matter	N/A	Tillage factor: 1.10	IPCC, 2019 National GHG inventory guidelines
3. Using SLM/ SFM on river banks: improving residue management	N/A	Tillage factor: 1.10	IPCC, 2019 National GHG inventory guidelines
4. Creating orchards on degraded river bank land	N/A	Tillage factor: 1.10	IPCC, 2019 National GHG inventory guidelines

5. Avoiding residue burning of existing degraded river banks (perennial parkland)	N/A	Avoided residue burning: 10	IPCC, 2019 National GHG inventory guidelines

D. Emission factors for estimating carbon removal

	Without project situation	With project situation	Source
	tCO_2/ha/yr	tCO_2/ha/yr	
Component 1. Low carbon climate resilient crop production enhanced and Ecosystem services restored in the Upper and Middle Ouéme			
Output 1.1: Waterworks and tree plantation to protect river banks and secure water access			
Activity 1.1.1. Build water harvesting and retention infrastructures			
2,000 ha of small irrigated plots with improved CRA practices	Soil carbon: 6.96	Soil carbon: 6.96	IPCC, 2019
Activity 1.1.2. Strengthen degraded river banks and restore land with tree			
Trees planted to restore vegetation coverage (reforestation) along degraded river banks and fields	Soil carbon : 6.96 Above ground biomass: 20.38 Below ground biomass: 4.73 40% loss of biomass	Soil carbon: 6.96 Above ground biomass: 20.38 Below ground biomass: 4.73 20 % loss of biomass	IPCC, 2019
Output 1.2. 24,250 farmers capacitated to implement CRA, agro-forestry and sustainable land management	**Without project situation**	**With project situation**	
Activity 1.2.3 Implement CRA, including agroforestry, to enhance agricultural productivity under climate change	**tCO_2/ha/yr**	**tCO_2/ha/yr**	
Using sustainable land management (SLM) / sustainable forest management (SFM) on river banks: increasing tree cover and organic matter	Soil carbon: 6.96 Above ground biomass: 2.16 Below ground biomass: 0.77	Soil carbon: 6.96 Above ground biomass: 2.16 Below ground biomass: 0.77	IPCC, 2019

Using SLM/ SFM on river banks: with higher increase in tree cover and organic matter and green manure	Soil carbon: 6.96 Above ground biomass: 2.16 Below ground biomass: 0.77	Soil carbon: 6.96 Above ground biomass: 2.16 Below ground biomass: 0.77	IPCC, 2019
Using SLM/ SFM on river banks: improving residue management	Soil carbon: 6.96 Above ground biomass: 2.16 Below ground biomass: 0.77	Soil carbon: 6.96 Above ground biomass: 2.16 Below ground biomass: 0.77	IPCC, 2019
Creating orchards on degraded river bank land	Soil carbon: 6.96 Above ground biomass: 2.16 Below ground biomass: 0.77	Soil carbon: 6.96 Above ground biomass: 19.43 Below ground biomass: 4.65	IPCC, 2019

E. Summary: Aggregated calculation methodology

Component	Current situation	Area (ha)/#	Without project	With project	Quantification/ Assumptions	Reference
Component 1. Low carbon climate resilient crop production enhanced and Ecosystem services restored in the Upper and Middle Ouéme	Degraded land on river banks	95,000 ha	Continued degradation of existing forests and soil within the area and use of unsustainable residue burning practices	Improved climate resilient annual cropland, enhanced forests and soils with higher tree coverage, improved perennial agroforestry systems on degraded land with no residue burning, no tillage and use of SLM/SFM practices	a) Calculations were done considering a scenario without and with the project b) Improvement of existing agriculture practices to CRA and SLM/SFM, enhancement of existing forest land and reduction in forest degradation, and establishment of agroforestry systems on degraded river banks generate direct and indirect GHG impact	a) IPCC 2019 Guidelines for National Greenhouse Gas Inventories (IPCC, 2019)
				Construction of micro dams on river bank and	**Main assumptions:** a) Direct impact around the project intervention area due	

				implementation of irrigation systems on annual cropland	to carbon removal from increasing forest biomass as a result of new agroforestry systems established and sustainable forest management. b) Indirect impact around the project area due to avoided emissions resulting from sustainable agricultural practices (no tillage, no residue burning) c) Some emissions are created from the construction of micro-dams and implementation of irrigation systems with the project d) Carbon removal and avoided GHG emissions are estimated based on IPCC 2006 Guidelines for National Greenhouse Gas Inventories (IPCC, 2006)	

Ex-Act Module 2.3 Other Land-Use Changes

It is assumed that 1 ha of existing annual fallow land will be converted to construct micro dams during the project, and will create emissions of 115 tCO_2eq.

Ex-Act module 3.1.2. Annual cropping systems remaining annual cropping systems

It is assumed that existing rain fed annual crops of 2,000 ha will be improved to implement CRA practices (no burning of residues) and trickle/drip irrigation system within the project, corresponding to an overall carbon removal of 52,587 tCO_2eq.

Ex-Act module 3.2.2. Perennial systems remaining perennial systems

It is assumed that with the project, 67,200 ha of degraded parkland river banks (no residue burning) and 16,800 ha of degraded parkland river banks (with residue burning) will be improved with SLM/SFM practices on 51,400 ha (using tree cover and organic input increase), 20,000 ha (using higher tree coverage and input increase), 4,200 ha (creation of orchards) and 8,400 ha (with improved residue management and no burning). All the improved land involve no tillage practices. The implementation of these activities results in an overall sequestration of 1,469,260 tCO_2eq.

Ex-Act module 5.1. Forest degradation and management

It is assumed that degradation level of existing 9,000 ha of tropical moist deciduous forest area currently has a moderate level of degradation and will move to a low level of forest degradation with the implementation of enhanced tree coverage and reforestation practices through the project. Carbon sequestration will be 232,518 tCO_2eq with the project.

Ex-Act module 7.1. Inputs

It is assumed that 2,000 ha of existing rain-fed annual crop land will undergo the implementation of trickle/drip irrigation systems. This will result in the emission of 623 tCO_2eq with the project. Additional reduction in emissions of approximately 29,383 tCO2eq over 20 years is expected from phasing out mineral fertilization.