ANNEX 13
GHG in the RIOS project
Methodological note on emission factors

Restoration for adaptation to Climate Change (RIOS)

Ex-Act Tool in the RIOS project

The methodology is based on similar assumptions than the co-financed GEF project CONECTA. INECC, is refining the assumptions that will use for Ex-Act models, and if there are modification during project design, they will be reflected in the proposal.

Methodological note on emission factors

The default values used in the Ex-Act tool are consistent with Tier 1 factors from the 2016 report of the Intergovernmental Panel on Climate Change (IPCC). Through a review of the documentation of the Greenhouse Gas Inventory 2018 (NIR) and the Second Biennial Update Report (BUR II) to the United Nations Framework Convention on Climate Change (UNFCCC), some available national emission factors were identified to improve the Tier 2 analysis. The NIR 2018 and BUR II emission factors were obtained from the official INECC website[1]. A detailed review was conducted on the applied methodological aspects, emission/absorption factors and information used in the presentation of NIR 2018 focusing on agriculture, forestry, and other land use issues, chapters 5 [3A], 3 [B] 3 [C6] and annexes D [3] and E [3]. The NIR compiles the reported emissions from the period 1990 to 2015. The BUR reviews the issues of degradation factors, benefits of livestock best practices, and observations concerning emissions counting in locations with multiple initiatives to avoid over counting.

Ex-Act module: 1. Description

As the climate and humidity conditions are similar between basins, it is assumed that the project will have a 20 years' scope, five for implementation, and 15 for follow-up.

a) Ameca-Mascota watershed

The general characteristics for the Ameca-Mascota basin were:

- Continent: North America
- Climate: Tropical
- Humidity regime: Moist
- Dominant soil: HAC soils

b) Jamapa watershed

Within the complete basin of Jamapa, we have a diversity of climatic conditions from boreal to tropical mountains. However, the tropical climate was selected as RIOS main focus area in the targeted sub-basins have this characteristic. Thus, it will determine the types of vegetation in Ex-Act following modules.

The general characteristics selected for the Jamapa basin were:

[1] NIR http://cambioclimatico.gob.mx:8080/xmlui/handle/publicaciones/226
BUR http://cambioclimatico.gob.mx:8080/xmlui/handle/publicaciones/117

- Continent: North America
- Climate: Tropical
- Humidity regime: Moist
- Dominant soil: HAC soils

Ex-Act module: 2. LUC

The vegetation types in the basins are described below to obtain differentiated data by soil type and relate them to the vegetation types included in the Ex-Act.

a) Ameca-Mascota watershed

From the vector data set of the vegetation and land-use series VI (INEGI, 2017), vegetation classes were grouped based on the forest sets available in Ex-Act according to the general characteristics of the Ameca-Mascota basin. The grouping was done in the following way:

Ex-Act forest area	Vegetation and land-use series VI
Forest zone 1	Pine, oak and mixed forests (including secondary vegetation)
Forest zone 2	Savannah and mangrove
Forest zone 3	Dry forests (including secondary vegetation)

The Sierra de Vallejo Río Ameca Natural Protected Area (PA) covers an area of 61,044 hectares within the Ameca-Mascota basin, of which 43 hectares include human settlements. The following table shows the types and areas of natural vegetation at the watershed, sub-basin, and PA levels.

Land use land cover	Ameca-Mascota watershed	PA Sierra de Vallejo – Ameca river	Talpa-Mascota Sub-basin
Cloud forest	695	498	-
Cropland	40491	1091	5703
Dry forest	11253	9170	30
Grassland	6295	2006	2939
Mangrove	136	-	-
Mixed forest	37334	17630	3510
Oak forest	15630	3402	3579
Pine forest	7844	1193	718
Savannah	4213	591	-
Secondary vegetation cloud forest	92	454	-
Secondary vegetation dry forest	4349	11398	367
Secondary vegetation mixed forest	6515	7798	1728
Secondary vegetation oak forest	14436	5322	3693
Secondary vegetation pine forest	1116	448	-
Subtotal	**150399**	**61001**	**22267**

b) Jamapa watershed

The Ex-Act vegetation types and their relationship with the vegetation classes established by INEGI for the Jamapa basin are:

Ex-Act forest area	Vegetation and land-use series VI
Forest zone 1: Tropical rain forest	Fir, pine, pine-oak, oak-pine, high-mountain and cloud forests
Forest zone 2: Tropical moist deciduous forest	Tropical evergreen forests, popal, savannah, coastal dune vegetation, and mangrove

The Jamapa basin has 45,586 hectares of natural vegetation, of which 3,347 hectares are in the Pico de Orizaba natural protected area as type 1 forests. In the rest of the basin, there are 22,705 hectares of type 1 forests and 19,534 hectares of type 2 forests.

Land use land cover	Jamapa watershed	PA Pico de Orizaba - Forest 1	Jamapa basin (excluding PA)	Jamapa basin (excluding PA) Forest zone 1	Jamapa basin (excluding PA) Forest zone 2
High-mountain meadow	1181	1181	0		0
Fir forest	832	169	663	663	
Pine forest	6758	1997	4761	4761	
Oak forest	903		903	903	
Pine-oak forest	4655		4655	4655	
Oak-pine forest	719		719	719	
Cloud forest	11004		11004	11004	
Tropical evergreen forest	1830		1830		1830
Deciduous forest	13529		13529		13529
Popal	201		201		201
Savannah	2268		2268		2268
Coastal dune vegetation	865		865		865
Mangrove	841		841		841
Subtotal	**45586**	**3347**	**42239**	**22705**	**19534**

Module: 2.1 Deforestation

a) Ameca-Mascota watershed

Currently, the Jalisco state government reports an average annual deforestation rate of 1.79% for the 2011-2014 period. It is assumed that, with the implementation of the project, deforestation in the Ameca-Mascota watershed will be reduced by 10% and will increase to an annual rate of 1.61% after 5 years of implementation, and it is expected to be maintained during the 15 years of the project's capitalization. The Sierra de Vallejo-Río Ameca protected natural area is located within the watershed; given that the project seeks to affect productive zones, it is expected to reduce the deforestation rate within the PNA by only 5%.

The watershed has 103,613 ha of natural vegetation, of which 57,904 are within the PNA. Without the implementation of the project, 2,892 ha of forests and jungles would be lost, which would result in the emission of 592,428 tCO2-eq. Meanwhile, with the implementation of the project, emissions of 49,595 tCO2-eq would be avoided during the 20 years of the project.

Emission factors

The emission factors that were used for the calculations are shown in the below table.

Carbon pools	Forest zone 1	Forest zone 2	Forest zone 3	Tier	Source
	Carbon stocks (in tC/ha)	Carbon stocks (in tC/ha)	Carbon stocks (in tC/ha)		
Above-ground	32.9	20.1	11.8	Tier 2	Table 74, in NIR, 2018 for the type of forest Zone1 (FZ1) Bosque de pino, (FZ2) Bosque de encino (FZ3) Selva caducifolia
Below-ground	7.9	5.0	3.2	Tier 2	Table 74, in NIR, 2018 for type of forest Zone1 Selva Perrennifolia (FZ1) and Selva caducifolia (FZ2)
Litter	1.9	1.5	.9	Tier 2	Tabla 79, in NIR, 2018 2018 for the type of forest Zone1 (FZ1) Bosque de pino, (FZ2) Bosque de encino (FZ3) Selva caducifolia
Dead wood	6.2	2.6	3.5	Tier 2	Table 79, in NIR, 2018[2] for the type of forest Zone1 (FZ1) Bosque de pino, (FZ2) Bosque de encino y (FZ3) Selva caducifolia
Soil carbon	43.8	30.2	38.5	Tier 2	Data provided by INECC, these data are reported grouped in Table 80. NIR 2018[3].

[2] Summatoriy of emission factors "muertos en pie, tocones, MLC y MOM· Table 79 NIR 2018.
[3] In Table 80 of the 2018 NIR, soil carbon values are reported that group all forest vegetation types, INECC provided these disaggregated values for the vegetation types used in this section

b) Jamapa watershed

Based on the comparison between INEGI series II and VI, an average deforestation rate of 3.23% per year is estimated. It is assumed that with the implementation of the project, it will be reduced by 10% in the Jamapa watershed, going to a rate of 2.907% per year, once the 5 years of implementation are over, and it is expected to be maintained during the 15 years of project capitalization. The Pico de Orizaba National Park (ANP) is located within the watershed; given that the project seeks to affect productive zones, it is only expected to reduce the deforestation rate within the ANP by 5%.

The watershed has 45,586 ha of natural vegetation, of which 3,347 ha are within Pico de Orizaba National Park. Without the implementation of the project, 1,472 ha of forests and jungles would be lost, which would result in the emission of 284,999 tCO2-eq. The implementation of the project would prevent emissions of 26,415 tCO2-eq during the 20-year duration of the project.

Emission factors

The emission factors that were used for the calculations are shown in the below table.

Carbon pools	**Forest zone 1**	**Forest zone 2**	**Tier**	Source
	Carbon stocks (in tC/ha)	**Carbon stocks (in tC/ha)**		
Above-ground	34.9	11.8	Tier 2	Table 74, in NIR, 2018 for the type of forest Selva Perrennifolia (FZ1) and Selva caducifolia (FZ2)
Below-ground	8.7	3.2	Tier 2	Table 74, in NIR, 2018 for type of forest Selva Perrennifolia (FZ1) and Selva caducifolia (FZ2)
Litter	2.8	0.9	Tier 1	Table 74, in NIR, 2018 for type of forest Selva Perrennifolia (FZ1) and Selva caducifolia (FZ2)
Dead wood	12.3	3.5	Tier 1	Table 79, in NIR, 2018[4] for the type of forest Zone1 (FZ1) Bosque de pino, (FZ2) Bosque de encino y (FZ3) Selva caducifolia
Soil carbon	60.7	33.5	Tier 1	Data provided by INECC, these data are reported grouped in Table 80. NIR 2018[5]

<u>Module: 2.2. Afforestation</u>

[4] These values correspond to the sum of the emission factors for standing dead, stumpage, MLC and MOM from Table 79 of the 2018 NIR.

[5] In Table 80 of the 2018 NIR, soil carbon values are reported that group all forest vegetation types, INECC provided these disaggregated values for the vegetation types used in this section

In order to have a more precise estimate, using adsorption factors according to the region, this estimate was made independently of Ex-Act. The factors used and the values obtained are described at the end of this document (Pag 11).

Module: 2.3. Other land changes

a) Ameca-Mascota watershed

With the intervention of the RIOS project, the extensive cattle-raising meadows will be converted to silvopastoral systems, and the annual crops to agroforestry systems. Considering that 90% of the activities of adaptation of productive practices will focus on silvopastoral systems, while 10% will focus on agroforestry systems. In the sub-basin of the Talpa-Mascota river, it is contemplated that 1,724 hectares will be intervened with the adaptation of practices on slopes with agricultural land use, associated with riparian systems. Of these, 172 will focus on agroecological systems and 1552 on silvopastoral systems, of which 1,242 hectares were degraded land and 310 hectares of grassland.

Emission factors

The emission factors that were used for the calculations are shown in the below table.

Tier 2 values were used for Biomass carbon pools based on national data (NIR 2018) on the cases of silvopastures from degraded lands and agroforestry. The initial value of 1.08tC/ha for degraded lands and 2.1 tC from biomass in agricultural lands were used. In the case of silvopastures from grasslands Ex-Act default values (7.6) were used as national data was not available. The values for final use were those included in Ex-Act tier 1. Those were compared with a recent study from 2018 *Revisiting IPCC Tier 1 coefficients for soil organic and biomass carbon storage in agroforestry systems*[6].

National studies show higher carbon values for soil carbon in silvopasture and agroforestry systems compared with Exact default values. The more conservative values were selected. In the case of belowground carbon pools ex-act default values were used.

Carbon pools	Silvopasture in degraded land	Silvopasture in grassland	Agroforestry	Tier	
	Carbon stocks (in tC/ha)	Carbon stocks (in tC/ha)	Carbon stocks (in tC/ha)		
Biomass	1.1	7.6	2.1	Tier 2	Source NIR, 2018. Identifies 1.08 tC/ha for degraded land-use and y 2.1 tC/ha for irrigated and rainfed crops. Silvopasture in grassland Ex-Act default values.
Soil carbon	21.5	65	31.2	Tier 1	Ex-Act default values
Biomass (1st year)	2.91	2.91	2.43	Tier 1	Ex-Act default values and recent revisions (2018)

[6] ver: https://iopscience.iop.org/article/10.1088/1748-9326/aaeb5f/pdf

Soil carbon (1st year)	65.7	86.5	39.0	Tier 1	Ex-Act default values
Belowground	0.79	0.79	0.57	Tier 1	Ex-Act default values

b) Jamapa watershed

The RIOS project in Jamapa will adapt productive practices in 5,600 hectares: 5,040 hectares of grasslands and 560 hectares of coffee cultivated area. The 5,040 hectares of grasslands (20% of the total) and degraded lands (80% of the total) will be converted through the adaptation of productive practices to silvopasture resulting in -665,560 tCO2 eq removed over a period of 20 years. The remaining 10% of adaptation practices will take place in 560 hectares of annual crops that will be converted to agroforestry systems. As a result, -15,862 tCO2 eq are expected to be removed over a period of 20 years.

Emission factors

The emission factors that were used for the calculations are shown in the below table.

Tier 2 values were used for Biomass carbon pools based on national data (NIR 2018) on the cases of silvopastures from degraded lands and agroforestry. The initial value of 1.08tC/ha for degraded lands and 2.1 tC from biomass in agricultural lands were used. In the case of silvopastures from grasslands Ex-Act default values (7.6) were used as national data was not available. The values for final use were those included in Ex-Act tier 1. Those were compared with a recent study from 2018 *Revisiting IPCC Tier 1 coefficients for soil organic and biomass carbon storage in agroforestry systems*[7].

National studies show higher carbon values for soil carbon in silvopasture and agroforestry systems compared with Ex-Act default values. The more conservative values were selected. In the case of belowground carbon pools Ex-Act default values were used.

Carbon pools	Silvopasture in degraded land	Silvopasture in grassland	Agroforestry	Tier	
	Carbon stocks (in tC/ha)	Carbon stocks (in tC/ha)	Carbon stocks (in tC/ha)		
Biomass	1.1	7.6	2.1	Tier 2	Source NIR, 2018. Identifies 1.08 tC/ha for degraded land-use and y 2.1 tC/ha for irrigated and rainfed crops. Grassland Ex-Act default values.
Soil carbon	21.5	65	31.2	Tier 1	Ex-Act default values
Biomass (1st year)	2.91	2.91	2.43	Tier 1	Ex-Act default values and recent revisions (2018)

[7] ver: https://iopscience.iop.org/article/10.1088/1748-9326/aaeb5f/pdf

Soil carbon (1st year)	65.7	86.5	39.0	Tier 1	Ex-Act default values
Belowground	0.79	0.79	0.57	Tier 1	Ex-Act default values

<u>Ex-Act module: 3. Cropland</u>

Module: 3.2.1 Perennial systems from other land uses

a) ***Ameca-Mascota watershed***

With the project, 1724 hectares of crops and pastures will be transformed into perennial systems.

b) ***Jamapa watershed***

With the project, 5,600 hectares of non-forest areas will be converted to perennial cropping systems. Due to this activity, the total removals are estimated at -1,018,893 tCO2 eq over 20 years.

<u>Ex-Act module: 4 Grassland</u>

With the Project, 85 heads of cattle in the Ameca-Mascota basin and 200 in the Jamapa watershed will be better managed through technical mitigation options. The Ex-Act tool also allows the evaluation of mitigation techniques and practices modeled on Smith et al. (2007)[8]. These are measured through a reduction in enteric fermentation emissions (A), the level of improvements proposed by the project, and non-project intervention.

Region	**Dairy cattle**		
	Best feeding practices	**Specific agents**	**Reproduction management**
	A. Proposed improvements in %.		
With project % of Implementation	50%	5%	100%
No project % Implementation	10%	0%	5%

Due to this activity, the total removals are estimated at -1,493 tCO2.

Emission factors

[8] Smith, P., D. Martino, Z. Cai, D. Gwary, H.H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, R.J. Scholes, O. Sirotenko, M. Howden, T. McAllister, G. Pan, V. Romanenkov, U. Schneider, S. Towprayoon, M. Wattenbach, and J.U. Smith, 2007a: Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society, B., 363. doi:10.1098/rstb.2007.2184

Accurate data were obtained on the key variables: temperature, enteric fermentation emission factors, excreta management, nitrous oxide excreta management at the state level. These variables were changed to "Tier 2" in the Ex-Act tool. The tool uses level 1 method equations from Chapter 10 of the 2016 IPCC report that allows for the incorporation of Tier 2 variables when available.

Region	Heads of cattle	Average temperature (°C)	Average weight of bovine for milk production (kg)	Average milk production (kg/head/year)	Annual bovine secretion for milk production
Ameca-Mascota (Jalisco)	85	20.8	425	916	68
Jamapa (Veracruz)	200	23.6	415	985	67

Region	A = Enteric fermentation kg of CH4/animal/year	B = Excreta handling Methane kg of CH4/head of cattle/year	Nitrogen excretion factor bovine for milk production kg of N(1000 kg of animal mass)/day	C = Excreta handling N2O kg N2 O-N (kg excreted nitrogen)-1	Volatilization % NH3 and NOx liquid handled	Indirect FE N2O kg N2O-N (kg excreted nitrogen)-1
Jalisco	117	78	0.44	0.005	40	0.01
Veracruz	128	85				

<u>Afforestation</u>

There are no national emission factors applicable to Ex-Act afforestation section that reflect the projects intention to transform degraded areas into forest lands. However, there are some emission factors at a national level that can be used (NIR 2018). A manual calculation (see annex: *RIOS Restauracion calculo manual.xlsx*) was carried out. The emission factors from NIR reflect the transformation from degraded forest areas to forest areas that recover their tree density.

a) Ameca-Mascota watershed

The RIOS project seeks to intervene 36 hectares to recover the forest cover of the riparian systems in previously identified strategic sites.

This surface was multiplied by the period and the emission factors for above-ground biomass and below-ground biomass emission factors obtained from Table 70 (NIR 2018), 1.06 tC/ha/year and 0.25 tC/ha/year, respectively. These calculations result in -3,452 tCO2 eq removed over a period of 20 years.

Restoration surface	EF Aboveground (tC/ha/ano	EF Below-ground (tC/ha/ano)	Period (yr)	Above-ground biomass	Below-ground biomass	tC	tCo2
36.00	1.06	0.25	20	764	177	**941.28**	**3452**

b) Jamapa watershed

The RIOS project will restore 366 ha of riparian vegetation of the Jamapa basin. Of these, 329 hectares of degraded tropical moist deciduous forest will be restored. This surface was multiplied by the period and the emission factors for above-ground biomass and below-ground biomass emission factors obtained from Table 70 (NIR 2018) are, 0.55 tC/ha/year and 0.14 tC/ha/year, respectively. These results in -16,601 tCO2 eq removed over a period of 20 years. The remaining 10% of restoration activities, 37 hectares are associated with agroforestry systems in the cloud forest ecosystem. The emission factors for above-ground biomass and below-ground biomass emission factors obtained from Table 70 (NIR 2018) are, 1.85 tC/ha/year and 0.44 tC/ha/year, respectively. As a result, -6,205 tCO2 eq are expected to be removed over a period of 20 years.

Restoration surface	EF Aboveground (tC/ha/year	EF Below-ground (tC/ha/year)	Period (yr)	Above-ground biomass	Below-ground biomass	tC	tCo2
37.00	1.85	0.44	20	1366	326	**1692**	**6205**
329.00	0.55	0.14	20	3590	937	**4527**	**16601**

Conclusion

The total sequestered carbon through the RIOS project is estimated to be 2.39 $MtCO_2eq$. The following table details the contribution of each Ex-Act module previously described and the contribution of each basin, 0.59 $MtCO_2eq$ in total for the Ameca-Mascota basin and 1.8 $MtCO_2eq$ for the Jamapa watershed.

Components of the project	Ameca			Jamapa			OVERALL RIOS PROJECT		
	Gross fluxes			Gross fluxes			Gross fluxes		
	Without	With	Balance	Without	With	Balance	Without	With	Balance
	All GHG in tCO2eq			All GHG in tCO2eq			All GHG in tCO2eq		
	Positive=source/negative=sk			Positive=source/negative=sk			Positive=source/negative=sk		
Land use change									
Deforestation	592,428	542,833	-49,595	284,999	258,584	-26,415	877,427	801,417	-76,010
*Afforestation**		-3,452	-3,452		-22,806	-22,806		-26,258	-26,258
other LUC		-209,868	-209,868		-681,422	-681,422		-891,290	-891,290
Cropland									

Perennial		-328,896	-328,896		1,068,290	-1,068,290		-1,397,186	1,397,186
Grassland & Livestocks									
Livestocks	11,669	11,089	-580	29,882	28,390	-1,493	41,551	39,479	-2,073
Total	604,097	11,706	-592,391	314,881	1,485,544	-1,800,426	918,978	-1,473,838	2,392,817
	*** The afforestation values were obtained manually as explained previously in Pag.11.**								

Ex-act estimates the carbon balance at 20 years; however, the implementation of the project is for five years. During the first year of the project, it is expected that there will be a reduction in emissions from deforestation of 5% due to the inter-institutional coordination that will be promoted through the dissemination of the project in the regions, this percentage will continue to increase as the project develops. Regarding CO_2 capture linked to subprojects, such as afforestation, other changes in land use, cropland, and grassland, in the first year, no progress is expected in the carbon balance. During this first year, the project is disseminated, calls for subproject proposal are made and selected. The reduction of emissions for these activities is expected from the second year once the subprojects are implemented. In the third and fourth years, it is expected that the subprojects will be consolidated, and the network of beneficiaries will be strengthened, which has a direct impact on the reduction of emissions in the last two years of project implementation.

	% OF EMISSION REDUCTION THROUGHOUT THE PROJECT IMPLEMENTATION				
Components of the project	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Land use changes					
Deforestation	5%	15%	20%	30%	30%
Afforestation	0%	10%	20%	35%	35%
Other LUC	0%	10%	20%	35%	35%
Cropland					
Perennial	0%	10%	20%	35%	35%
Grassland & Livestocks					
Livestocks	0%	10%	20%	35%	35%
Total					

	Balance	**Balance**	**PROJECT LIFETIME PROJECTION (t Co2/eq)**				
Components of the project	***20 year***	**5-year Project lifetime**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Land use changes	**(tCO2eq)**	**(tCO2eq)**					
Deforestation	-76,010	-19,003	-950.1	-2,850	-3,801	-5,701	-5,701
Afforestation	-26,258	-6,565	0	-656	-1,313	-2,298	-2,298

Another LUC	-891,290	-222,823	0	-22,282	-44,565	-77,988	-77,988
Cropland	0	0					
Perennial	-1,397,186	-349,297	0	-34,930	-69,859	-122,254	-122,254
Grassland & Livestock	0	0					
livestock	-2,073	-518	0	-52	-104	-181	-181
Total	-2,392,817	-598,204	-950	-60,771	-119,641	-208,422	-208,422