XLM-AGRICULTURAL CROP TOOLKIT

User Manual

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Ministry of Social Security, National Solidarity, and Environment and Sustainable Development
(Environment and Sustainable Development Division)
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XL-Mitigation Agricultural Crop Toolkit

About this manual

This manual, *XL-Mitigation Agricultural Crop User Reference*, forms part of a family of toolkits to compute and plot a number of other variables including GHG emissions for Agricultural Crop sector. The user reference has been written from an application developer's perspective. A fundamental conceptual and operational knowledge of Excel is assumed.

Disclaimer

Data used has been obtained from reliable sources. The Ministry of Social Security, National Solidarity, and Environment and Sustainable Development (Environment and Sustainable Development Division) assumes no responsibility for errors and omissions in the data provided. Users are, however, kindly asked to report any errors or deficiencies in this product to the Ministry. The choices of calculation made in this tool are derived from TNC Report (2016).

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XLM-Agricultural Crop Toolkit

1.0 Introduction

This document refers to the agricultural crop sector.

The mitigation for this sector was assessed in the Third National Communications (TNC) Report (2016) for a Business-as-Usual (BAU) and 3 other scenarios, after a screening exercise to select the most feasible options. Thus, referring to the Strategic Plan 2016 – 2020 of the Ministry of Agro-Industry and Food Security (2016), the first scenario, after the BAU, considered that there will be a decreasing sugarcane field burning, the second considered the reduction in the use of chemical fertilizers and the third looked into bio-farming.

The XLM-Agricultural Crop Toolkit performs basic calculations that take into account the area of sugarcane and the use of fertilizers and manures resulting in emissions of nitrogen from soil. The trend for agricultural area and soil fertilization until 2050 was worked out following assumptions used by TNC (2016). Users of the XLM-Agricultural Crop Toolkit can adjust the scenarios by choosing appropriate parameters/assumptions to suit their needs of the mitigation analysis.

2.0 Overview of the Agricultural Crop sector

The Agriculture sector share 4% of the total GDP.

Agricultural land, which occupy around 36% of the land area of RoM in 2010, is constantly decreasing over the years, mainly due to a decrease in the area under sugar cane (the dominant crop occupying some 92% of the arable land) for economic reasons and due to the expansion of settlements and other infrastructures. The remaining arable land is used for food crops (general vegetables and ornamentals), fruits, tea and livestock production. General vegetables and food crops include major crops such as potato, onion, carrot, crucifers, tomatoes and creepers, as well as many other species regularly cultivated by farmers. This sector is dominated by small scale farmers that cultivate between 0.5-2.0 ha of land using mainly a mixed cropping system. Food crops is also cultivated on rotational lands of sugar cane.

FACTS (Source: Statistics Mauritius):

Sugar cane & Food Crops (2016) **[Harvested area (ha), Production (tonnes)]**	**Others**: (2015)
Sugar Cane: (51477, 386277 (sugar)) Potato: (789, 16854) Tomato: (730, 10136) Onion: (278, 6388) Mixed vegetables and food crops: (1068, 13409) Greens: (259, 2706) Creepers: (2266, 25623) Pineapple: (417, 9707) Banana: (491, 8172) Tea (green leaves): (622, 7301) Paddy (rice): (161, 352)	Irrigated land area (ha): 16,600 Consumption of Fertilizers (tonnes): 22,857

3.0 GHG Emissions for the Crop sector

Agriculture is affected by climate change but is also one of the major global emitter of greenhouse gases (GHG) in the atmosphere.

The Crop sector is particularly important as it also accounts soil emissions. Nitrous Oxide and Methane are the main GHG emitted from agriculture, from the use of organic and nitrogenous mineral fertilizers and from livestock digestion processes respectively. Synthetic fertilizers are extensively used in the production of sugar cane and food crops. In addition compost and manure from the livestock sector and scum are also used as organic fertilizers in sugar cane and food crop production.

Biomass burning of agricultural residues releases Greenhouse Gases into the atmosphere such as CH4 and N2O. These gases are formed from carbon and nitrogen in the plant material during the combustion process. As per the 2006 IPCC Guidelines, the CO2 emissions from burning of agricultural residues are not included in the inventory total since it is assumed that an equivalent amount of CO2 was removed by the growing crop.

For the period 2000 to 2013, Figure 3.1 shows the trend of emissions as well as the sink for the whole AFOLU sector.

Agricultural practices in Mauritius from both crop and livestock sector emitted 127,000 tonnes CO2eq in 2013 (TNC report, 2016). Direct N2O emission from managed soil produces the highest amount of emission of 66.22 Gg CO2e for this sector (76%) followed by indirect N2O emission from managed soil (20.69 Gg CO2e). Emissions from agricultural crop burning and soil are relatively smaller than the carbon sequestrations. Soil emissions are higher than other emissions but are decreasing, most probably due to the reduction of sugarcane lands.

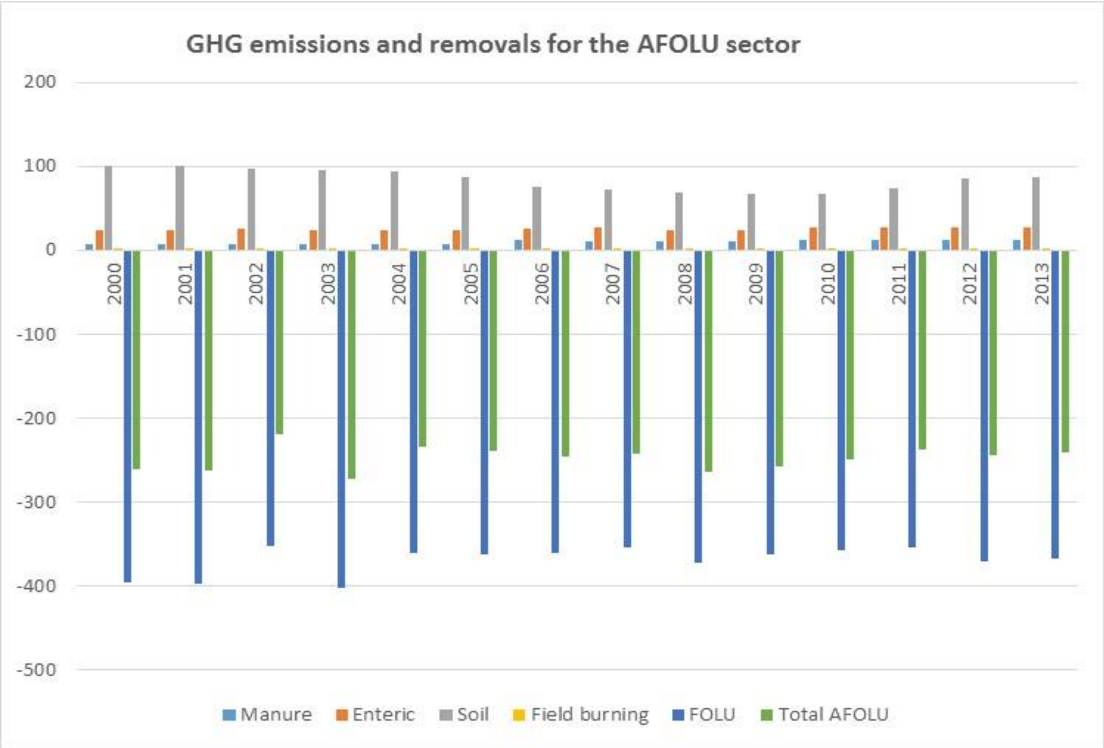

Figure 3.1: Trend of emissions for AFOLU Sector, including Crop sector (Source: TNC, 2016)

4.0. Mitigation Actions proposed under TNC for the Crop sector

4.1 Mitigation Scenarios and Assumptions

Relative to the BAU scenario, three other scenarios were developed in TNC (2016). The assumptions adopted by TNC for mitigations actions for the Crop sector are summarized in Table 4.1.

Table 4.1: Mitigation scenarios for the Crop sector (TNC 2016)

Mitigation scenario		Assumptions
BAU	Business-As-Usual	
SC1	Decreasing sugar cane field burning	Decrease from its present level of 10% of total area cultivated to 8% between 2020 and 2030; 7% in 2035; 6% in 2040; and to 5% in 2050.
SC2	Reduction in the use of N-containing chemical fertilizers	It is assumed that the reduction starts in 2016 at a meagre 1% of the baseline value in 2015, and decreases by 1% absolute per year until 2020. After 2020, the annual decrease is an absolute 2% to reach 25% in 2030. Thereafter, the decrease is 5% every 5 years.
SC3	Bio-farming scenario	Since it is unlikely that the use of chemical fertilizers will be reduced without any substitution, this scenario has been developed for investigating the co-use of compost produced from MSW in food crop cultivation. This scenario also includes the increase in manure applied to soil with increasing livestock heads to enhance food security under the policy option.

The parameters used for the different scenarios appear in section 5.1.

4.2 TNC Targets under different scenarios

Three mitigation scenarios have net emission reductions relative to BAU scenario in brackets as shown in Table 4.2. SC2 provides the largest emission (non-cumulative) reductions; this scenario, shown by the curve in dark red in Figure 4.1, accounts for direct N2O emissions only. The bio-farming scenario (SC3) (lighter blue curve in Figure 4.1) increases emissions relative to SC2 due to the release of N2O from the compost; the curve shows the combined effect of reduced use of chemical fertilizers and use of compost, including the calculation of both direct and indirect N2O generation.

Table 4.2 GHG Emission reductions in from Crop sector

Scenarios	2020	2030	2040	2050
BAU	109	110	111	112
SC1: Decreasing field burning from its present level of 10% of total area cultivated to 8% between 2020 and 2024, and to 5% after 2025	109 (0.4)	109 (0.4)	110 (0.8)	111 (0.8)
SC2: Reduction in the use of chemical fertilizers only (climate smart agriculture). 1% of the baseline value in 2015, and decreases by 1% absolute per year until 2020. After 2020, the annual decrease is an absolute 2% to reach 75% in 2030.	107 (2.7)	98 (13.4)	94 (18.8)	91 (24.1)
SC3: Bio-farming (decreased use of fertilizers + uptake of compost in crop production)	108 (1.4)	101 (8.8)	101 (10.2)	102 (10.0)
SC4: Cumulative reductions	108 (1.8)	101 (9.2)	100 (11)	101 (10.8)

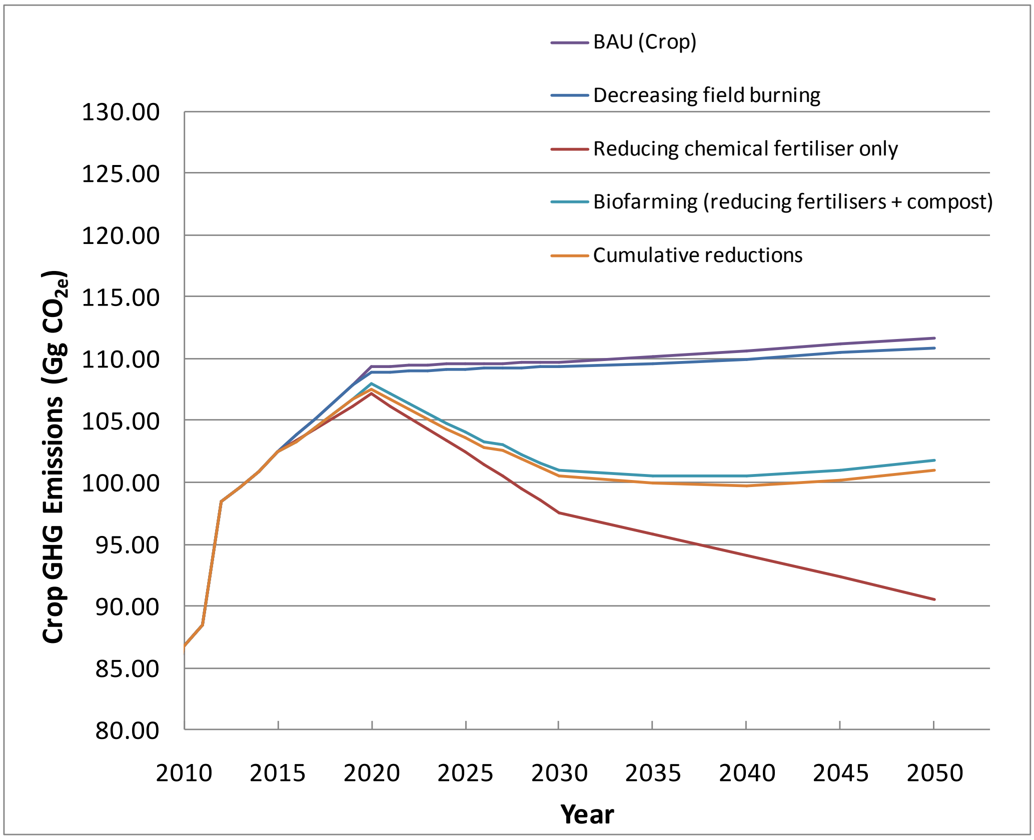

Figure 4.1: GHG emissions scenarios for the Crop sector (source: TNC, 2016)

5.0 XLM Toolkit – Agricultural Crop

The structure, methodology, and components/modules of the XLM Toolkits has been described in the main User Manual.

5.1 Crop Sector Parameters

Table 5.1 presents the major parameters used for the Crop sector. The column USER can be updated but the TNC column is just for comparison purposes.

Table 5.1: List of Parameters for the emissions calculations for Crop sector

PARAMETERS			TNC	USER
Constants (controlled biomass burning - sugar cane fields)				
Parameter	Symbol	Unit	Value	Value
Mass of fuel available for burning	MB	t/ha	6.5	6.5
Combustion factor	Cf	dml	1	1
Emission factor	Gef	gGHG/(kg dm burnt)	2.7	2.7
Global warming potential	GWP	tCO2e/tCH4	25	25
Fraction of available area burnt, 2006-2015	Fb	dml	0.1	10%
Emission factor	EF	kgN2O-N/Kg N input	0.01	0.01
Conversion factor	Cf	kgN2O/kgN2O-N	1.571428571	1.571428571
Emission factor, cattle,poultry, pigs	EF	kgN2O-N/Kg N input	0.02	0.02
Emission factor, sheep & other	EF	kgN2O-N/Kg N input	0.01	0.01
Global warming potential	GWP	kgCO2e/kgN2O	298	298
fraction of synthetic fertiliser that volatilises	Frac(GASF)	(kg NH3-N+Nox-N)/kg N	0.1	0.1
fraction of organic or dung that volatilises	Frac(GASM)	(kg NH3-N+Nox-N)/kg N	0.2	0.2
fraction N leached	Frac(LEACH)	kgN/Kg of N additions	0.3	0.3
Conversion factor	Cf	kgN2O/kgN2O-N	1.571428571	1.571428571
Global Warming Potential	GWP(N2O)	(kg N2O)/(kg N2O-N)	298	298
Emission factor leached	EF-5	Kg N2O-N/kg N leached	0.0075	0.0075
Emission factor volatilised	EF-4	(kg N2O-N)/kg(NH3-N+Nox-N)	0.01	0.01
COMPOST				
Organic waste to compost			0.5	0.5
Nitrogen content in compost			0.0175	1.75%

5.2 Crop Sector Assumptions

The assumptions used here are essentially the areas which may or may not change depending on national circumstances (Table 5.2). These assumptions are further divided according to the type of emissions being considered, such as whether it is for field burning, soil emissions from application of fertilizers and manures or leaching, etc.

Table: 5.2: List of Assumptions for the Crop sector

1	Area available for sugar cane (ha)
2	Percentage of sugar cane burnt (%)
3	Percentage Increase in chemical fertilizers (%)
4	Percentage of chemical fertilizer loadings (%)
5	Organic waste split of MSW amongst food, garden and paper (%)
6	Components of MSW (Gg)
7	Quantity of material composted (%)

The basic assumptions are in fact those taken in the TNC (2016) and which can be updated if required, for any of the land areas and fertilizer uses, as appropriate.

5.3 Graphic Analysis and Reporting

Graphic analysis in the 'Query' worksheet provides the following choices for the type of plots:

Sector	Type of Plot	Plot numbers
Agriculture Crop	All	1-64;
	Crop Burn	1-4; 32-38;
	BAU: N2O emissions from Managed Soils	5-31;
	Scenarios: N2O Emissions from Managed Soils	39-64;
	GHG Emission Reductions	37,44,52,62;
	GHG Emissions	4,14,21,22,30,31,36,38, 43,45,53,61,63,64;
	Total GHG Emissions (TNC)	31,38,45,63,64;

The complete set of figures useful to the User is listed in Table 5.3. The far right column denotes the general topic or item for which the plots can be generated for graphical analysis. The leftmost column denotes the number of plots that can be identified and generated.

Table 5.3: Crop sector Plots

1	BAU: Area of sugar cane available (ha)			
2	BAU: Area of sugar cane burnt (ha)			
3	BAU: GHG Emissions from burnt sugar cane (tCH4)			
4	BAU: GHG Emissions from burnt sugar cane (GgCO2e)			
5	BAU: Nitrogen from Chemical Fertilizers (kgN/yr)	N2O emissions from managed soils - 1/3	Dir N2O Man Soil	N2O emissions from Managed Soils
6	BAU: Nitrogen from Crop Residues (kgN/yr)			
7	BAU: Nitrogen from Manure (kgN/yr)			
8	BAU: N2O Emissions from Chemical Fertilizers (t/yr)			
9	BAU: N2O Emissions from Crop Residues (t/yr)			
10	BAU: N2O Emissions from Manure (t/yr)			
11	BAU: CO2e Emissions from Chemical Fertilizer (Gg/yr)			
12	BAU: CO2e Emissions from Crop Residues (Gg/yr)			
13	BAU: CO2e Emissions from Manure (Gg/yr)			
14	BAU: Total CO2e Emissions from Chemical Fertilizers, Crop Residues and Manure (Gg/yr)			
15	BAU: Nitrogen from (Cattle, Poultry, Pigs) (kgN/yr)	N2O emissions from urine and dung inputs to grazed soils - 3/3		
16	BAU: Nitrogen from (Sheep & Other sources) (kgN/yr)			
17	BAU: N2O Emissions from (Cattle, Poultry, Pigs) (t/yr)			
18	BAU: N2O Emissions from (Sheep & Other sources) (t/yr)			
19	BAU: CO2e Emissions from (Cattle, Poultry, Pigs) (Gg/yr)			
20	BAU: CO2e Emissions from (Sheep & Other sources) (Gg/yr)			
21	BAU: Total CO2e Emissions animal sources (Gg/yr)			
22	BAU: Total CO2e Emissions from Direct sources (Gg/yr)	Total		
23	BAU: Nitrogen from Indirect Fertilizers (kg N/yr)	Managed soil	Ind N2O Man Soil	
24	BAU: Nitrogen from Indirect Crop Residues (kg N/yr)			
25	BAU: Nitrogen from Indirect Manure (kg N/yr)			
26	BAU: N2O Volatilised from Indirect sources (t/yr)	volatized		
27	BAU: CO2e Volatilised from Indirect sources (Gg/yr)			
28	BAU: N2O leached from Indirect sources (y/yr)	leached		
29	BAU: CO2e leached from Indirect sources (Gg/yr)			
30	BAU: Total CO2e Emissions from Indirect sources (Gg/yr)	Total		
31	**BAU: Total CO2e Emissions from Managed Soils (Gg/yr)**	Total		

32	SC1: Area of sugar cane available (ha)	Reduced Percentage of Crop Burn		
33	SC1: Percentage of sugar cane area burnt (%)			
34	SC1: Area of sugar cane burnt (ha)			
35	SC1: GHG Emissions from burnt sugar cane (tCH4)			
36	SC1: GHG Emissions from burnt sugar cane (Gg CO2e)			
37	SC1: Reduction in GHG Emissions due to Scenario (Gg CO2e)			
38	SC1: GHG Emissions (Nett) due to Reduced Crop Burn Scenario (Gg CO2e)	Total		
39	SC2: (BAU Scenario) CO2e Emissions from Chemical Fertilizers (Gg/yr)	Chemical Fertilizer Loading	Dir N2O Man Soil	N2O emissions from Managed Soils
40	SC2: Nitrogen from Reduction in Chemical Fertilizers (kg N/yr)			
41	SC2: N2O Emissions from Reduction in Chemical Fertilizers (t)			
42	SC2: CO2e Emissions from Reduction in Chemical Fertilizers (Gg)			
43	SC2: GHG Emissions due to Scenario (Gg CO2e)			
44	SC2: Reduction in GHG Emissions due to Scenario (Gg CO2e)			
45	SC2: GHG Emissions (Nett) due to Reduced Fertilizer Use Scenario (Gg CO2e)	Total		
46	SC3: Organic waste composted from Food (Gg)	Biofarming from MSW		
47	SC3: Organic waste composted from Garden (Gg)			
48	SC3: Organic waste composted from Paper (Gg)			
49	SC3: Total Organic waste from MSW (Gg)			
50	SC3: Total Compost from MSW (Gg)			
51	SC3: Total Nitrogen in Compost from MSW (kg)			
52	SC3: Change in GHG Emissions due to Scenario (Gg CO2e)			
53	SC3: GHG Emissions (Nett) due to Biofarming Scenario (Gg CO2e)	Total		
54	SC3: Nitrogen from Reduction of Fertilizers (KgN/yr)	managed soil	Ind N2O Man Soil	
55	SC3: Nitrogen from Crop Residues (kgN/yr)			
56	SC3 :Nitrogen from Manure incl Biofarming sources (kg N/yr)			
57	SC3: N2O Volatilised from Indirect sources (t/yr)	volatized		
58	SC3: CO2e Volatilised from Indirect sources (Gg/yr)			
59	SC3: N2O leached from Indirect sources (y/yr)	Leached		
60	SC3: CO2e leached from Indirect sources (Gg/yr)			
61	SC3: Total CO2e Emissions from Indirect sources (Gg/yr)	Total		
62	SC3: Reduction in GHG Emissions due to Scenario (Gg CO2e)			
63	SC3: Total CO2e Emissions with Biofarming (Reduced Fertilizers + Compost)	Total		
64	SC4: GHG Emissions under Biofarming and Crop Burn Reduction	Cumulative		

6.0 References

- **TNC (2016).** Third National Communication: Report to the United Nations Framework Convention on Climate Change. Republic of Mauritius, Port Louis.
- **IPCC (2006).** Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.
- Statistic Mauritius, Digest of Agricultural statistics, 2010.
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- Statistic Mauritius, 2014 Census of Agriculture.
- Crop Bulletin of Chamber of Agriculture.

7.0 Appendices

A: List of Acronyms and Abbreviations

Toolkit		Others	
BAU	Business-As-Usual	IPCC	International Panel of Climate Change
GUI	Graphics User Interface	TNC	Third National Communications
UD1	User-defined Scenario – Case 1	GHG	Greenhouse Gas
UD2	User-defined Scenario – Case 2	GWP	Global Warming Potential
SC*i*	Scenario *i*		
XLMT	Excel Mitigation Toolkit		

B: Useful Links

Click on the links below for access.

IPCC 2006

General AFOLU

TNC

Stats digest of agriculture

Others

C: Governing Equations (IPCC, 2006)

DIRECT N_2O EMISSIONS FROM MANAGED SOILS (TIER 1)

$$N_2O_{Direct}\text{–}N = N_2O\text{–}N_{N\,inputs} + N_2O\text{–}N_{OS} + N_2O\text{–}N_{PRP}$$

Where:

$$N_2O\text{–}N_{N\,inputs} = \begin{bmatrix} \left[\left(F_{SN} + F_{ON} + F_{CR} + F_{SOM}\right) \bullet EF_1\right] + \\ \left[\left(F_{SN} + F_{ON} + F_{CR} + F_{SOM}\right)_{FR} \bullet EF_{1FR}\right] \end{bmatrix}$$

$$N_2O\text{–}N_{OS} = \begin{bmatrix} \left(F_{OS,CG,Temp} \bullet EF_{2CG,Temp}\right) + \left(F_{OS,CG,Trop} \bullet EF_{2CG,Trop}\right) + \\ \left(F_{OS,F,Temp,NR} \bullet EF_{2F,Temp,NR}\right) + \left(F_{OS,F,Temp,NP} \bullet EF_{2F,Temp,NP}\right) + \\ \left(F_{OS,F,Trop} \bullet EF_{2F,Trop}\right) \end{bmatrix}$$

$$N_2O\text{–}N_{PRP} = \left[\left(F_{PRP,CPP} \bullet EF_{3PRP,CPP}\right) + \left(F_{PRP,SO} \bullet EF_{3PRP,SO}\right)\right]$$

Where

N_2O_{Direct}–N = annual direct N_2O–N emissions produced from managed soils, kg N_2O–N yr^{-1}

N_2O–$N_{N\ inputs}$ = annual direct N_2O–N emissions from N inputs to managed soils, kg N_2O–N yr^{-1}

N_2O–N_{OS} = annual direct N_2O–N emissions from managed organic soils, kg N_2O–N yr^{-1}

N_2O–N_{PRP} = annual direct N_2O–N emissions from urine and dung inputs to grazed soils, kg N_2O–N yr^{-1}

F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N yr^{-1}

F_{ON} = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (Note: If including sewage sludge, cross-check with Waste sector to ensure there is no double counting of N_2O emissions from the N in sewage sludge), kg N yr^{-1}

F_{CR} = annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N yr^{-1}

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N yr^{-1}

F_{OS} = annual area of managed/drained organic soils, ha (Note: the subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)

F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1} (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

EF_1 = emission factor for N_2O emissions from N inputs, kg N_2O–N (kg N input)$^{-1}$(Table 11.1)

EF_{1FR} = emission factor for N_2O emissions from N inputs to flooded rice, kg N_2O–N (kg N input)$^{-1}$ (Table 11.1)

EF_2 = emission factor for N_2O emissions from drained/managed organic soils, kg N_2O–N ha^{-1} yr^{-1}; (Table 11.1) (Note: the subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)

EF_{3PRP} = emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg N_2O–N (kg N input)$^{-1}$; (Table 11.1) (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

N FROM ANIMAL MANURE APPLIED TO SOILS (TIER 1)

$$F_{AM} = N_{MMS\ Avb} \bullet \left[1 - \left(Frac_{FEED} + Frac_{FUEL} + Frac_{CNST}\right)\right]$$

Where

F_{AM} = annual amount of animal manure N applied to soils, kg N yr^{-1}

N_{MMS_Avb} = amount of managed manure N available for soil application, feed, fuel or construction, kg N yr^{-1} (see Equation 10.34 in Chapter 10)

$Frac_{FEED}$ = fraction of managed manure used for feed

$Frac_{FUEL}$ = fraction of managed manure used for fuel

$Frac_{CNST}$ = fraction of managed manure used for construction

N FROM CROP RESIDUES AND FORAGE/PASTURE RENEWAL (TIER 1)

$$F_{CR} = \sum_T \left\{ \begin{array}{l} Crop_{(T)} \bullet \left(Area_{(T)} - Area\,burnt_{(T)} \bullet C_f\right) \bullet Frac_{Renew(T)} \bullet \\ \left[R_{AG(T)} \bullet N_{AG(T)} \bullet \left(1 - Frac_{Remove(T)}\right) + R_{BG(T)} \bullet N_{BG(T)}\right] \end{array} \right\}$$

Where

F_{CR} = annual amount of N in crop residues (above and below ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually, kg N yr^{-1}

$Crop_{(T)}$ = harvested annual dry matter yield for crop *T*, kg d.m. ha^{-1}

$Area_{(T)}$ = total annual area harvested of crop *T*, ha yr^{-1}

Area burnt $_{(T)}$ = annual area of crop *T* burnt, ha yr^{-1}

C_f = combustion factor (dimensionless) (refer to Chapter 2, Table 2.6)

$Frac_{Renew\ (T)}$ = fraction of total area under crop *T* that is renewed annually. For countries where pastures are renewed on average every X years, $Frac_{Renew}$ = 1/X. For annual crops $Frac_{Renew}$ = 1

$R_{AG(T)}$ = ratio of above-ground residues dry matter ($AG_{DM(T)}$) to harvested yield for crop T ($Crop_{(T)}$), kg d.m. (kg d.m.)$^{-1}$,

= $AG_{DM(T)} \bullet 1000 / Crop_{(T)}$ (calculating $AG_{DM(T)}$ from the information in Table 11.2)

$N_{AG(T)}$ = N content of above-ground residues for crop T, kg N (kg d.m.)$^{-1}$, (Table 11.2)

$Frac_{Remove(T)}$ = fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding and construction, kg N (kg crop-N)$^{-1}$. Survey of experts in country is required to obtain data. If data for $Frac_{Remove}$ are not available, assume no removal.

$R_{BG(T)}$ = ratio of below-ground residues to harvested yield for crop T, kg d.m. (kg d.m.)$^{-1}$. If alternative data are not available, $R_{BG(T)}$ may be calculated by multiplying R_{BG-BIO} in Table 11.2 by the ratio of total above-ground biomass to crop yield (= $[(AG_{DM(T)} \bullet 1000 + Crop_{(T)}) / Crop_{(T)}]$, (also calculating $AG_{DM(T)}$ from the information in Table 11.2).

$N_{BG(T)}$ = N content of below-ground residues for crop T, kg N (kg d.m.)$^{-1}$, (Table 11.2)

T = crop or forage type

DRY-WEIGHT CORRECTION OF REPORTED CROP YIELDS

$$Crop_{(T)} = Yield\ Fresh_{(T)} \bullet DRY$$

Where

$Crop_{(T)}$ = harvested dry matter yield for crop T, kg d.m. ha^{-1}

$Yield\_Fresh_{(T)}$ = harvested fresh yield for crop T, kg fresh weight ha^{-1}

DRY = dry matter fraction of harvested crop T, kg d.m. (kg fresh weight)$^{-1}$

ALTERNATIVE APPROACH TO ESTIMATE F_{CR} (USING TABLE 11.2)

$$F_{CR} = \sum_T \left\{ \begin{array}{l} AG_{DM(T)} \bullet \left(Area_{(T)} - Area\,burnt_{(T)} \bullet CF\right) \bullet Frac_{Renew(T)} \bullet \\ \left[N_{AG(T)} \bullet \left(1 - Frac_{Remove(T)}\right) + R_{BG-BIO(T)} \bullet N_{BG(T)}\right] \end{array} \right\}$$

Where

F_{CR} = annual amount of N in crop residues (above and below ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually, kg N yr^{-1}