XLM-FOLU TOOLKIT

User Manual

AUGUST 1, 2017

Ministry of Social Security, National Solidarity, and Environment and Sustainable Development
(Environment and Sustainable Development Division)
Republic of Mauritius

XL-Mitigation FOLU Toolkits

User Manual

<u>About this manual</u>

This manual, *XL-Mitigation Forestry and Other Land Use (FOLU) User Reference*, forms part of a family of toolkits to compute and plot a number of variables including GHG emissions for FOLU 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-FOLU Toolkit

1. Introduction

This document refers to a user-friendly toolkit developed to mitigate the emissions/removal of Greenhouse Gas (GHG) from the Forestry and Other Land Use (FOLU) sector – also known as Land Use, Land Use Change and Forestry (LULUCF) sector of the Republic of Mauritius.

The mitigation for FOLU sector was assessed in the Third National Communications (TNC) Report (2016) for a Business-as-Usual (BAU) and 2 other scenarios, after a screening exercise to select the most feasible options. Thus, the first scenario, after the BAU, considered that there will be a tree planting campaign pursuant to the Strategic Plan 2016 – 2020 of the Ministry of Agro-Industry and Food Security (2016). The second scenario considers afforestation of abandoned sugarcane lands.

The XLM-FOLU Toolkit performs basic calculations taking the area of forests under different land classes and by types of species, amongst others. The trend for area of forests and other suitable lands and their carbon sequestrations until 2050 was thus worked out following assumptions taken from the TNC. Users of the XLM-FOLU Toolkit can adjust the scenarios by choosing appropriate parameters/assumptions to suit their needs of the mitigation analysis.

2. Overview of the Forestry and Other Land Use (FOLU) sector

The FOLU sector is particularly important as it is the only sector that accounts for carbon sink.

As per the 2006 IPCC Guidelines, Land (Category 3B) is subdivided into 6 land subcategories, namely: Forest Land, Cropland, Grassland, Settlements, Wetlands, and Other Lands. Forests are the major carbon sinks in Mauritius and include both planted and natural forests. These have been classified according to types and ecological zones so as to be used in the IPCC (2006) software.

According to the Forestry Service, the total extent of forest cover in Mauritius, at the end of the year 2016, is estimated at 47,066 hectares, representing about 25% of the total land area (Table 2.1).

There are only two types of forest ownership in Mauritius: public and private; there are more forests on private lands with an estimated extent of around 25,000 hectares as compared to about 22,066 hectares on state lands. Approximately 14,612 hectares of land are covered with planted forests. The remaining are natural forests, most of which are badly degraded. Only around 2% of the land area of Mauritius is considered to be covered with good quality native forests.

The forests of Mauritius also perform other vital functions, the most important of them being soil and water conservation. Where water is scarce, activities like agriculture, tourism or manufacturing are seriously affected. The environmental functions of forests in small island developing states (SIDS) far outweigh their direct economic functions. The roles of forests in reducing soil erosion, enhancing carbon sequestration, conservation of biodiversity & genetic resources, recreation & ecotourism are now widely recognized and valued. Consequently, conservation, protection and development of the remaining forests through sustainable management are priority objectives of the overall national forest policy of Mauritius. In fact, the forests of Mauritius are now managed more for these environmental functions rather than for timber production. Consequently, timber exploitation is gradually being phased out and restricted to salvage operations following cyclones and other natural disasters such as outbreaks of insect attacks, diseases and droughts. In future, emphasis in forest management will be on increasing the size of the forest estate, resource conservation, protection of watersheds, forest ecosystems and biodiversity conservation and replacement of harmful invasive exotic species by native species.

Table 2.1: Classification of forest lands in Mauritius (2016)

I. State-owned Forest Lands		
		Area (hectares)
Forests on State Lands		**21,443**
a	Plantations (mostly *Pinus elliottii*)	11,798
b	(i) Black River Gorges National Park	6,574
	(ii) Bras d'Eau National Park	497
c	Islet National Parks	134
d	(i) Nature Reserves on mainland	200
	(ii) Nature Reserves on islets	599
e	Vallée d'Osterlog Endemic Garden	275
f	Others, including scrublands, native forests, wetlands and marginal lands	1,366
Forests on Pas Géométriques		**623**
a	Plantations (mostly *Casuarina equisetifolia*)	214
b	Leased for grazing	230
c	Others (mostly rocky)	179
	Total State Forest Lands	**22,066**
II. Privately-owned Forest Lands		
a	(i) Mountain Reserves	3,800
	(ii) River Reserves	2,740
b	Private reserves	13
c	Plantations (mostly *Eucalyptus tereticornis*)	2,600
d	Other forest lands, including scrublands and grazing areas	15,847
	Total Private Forest Lands	**25,000**
	Grand Total	**47,066**

3. GHG Emissions from the FOLU sector

For the period 2000 to 2013, Figure 3.1 shows the trend of emissions for the whole of the Agriculture including FOLU (AFOLU) as well as the sink for the FOLU sector. Emissions from AFOLU are relatively smaller than the carbon sequestrations; the latter (for FOLU) is shown by the negative values in the graph, which represents the CO_2 removals (the blue bars). The Total AFOLU (the net emissions/removals) is therefore negative.

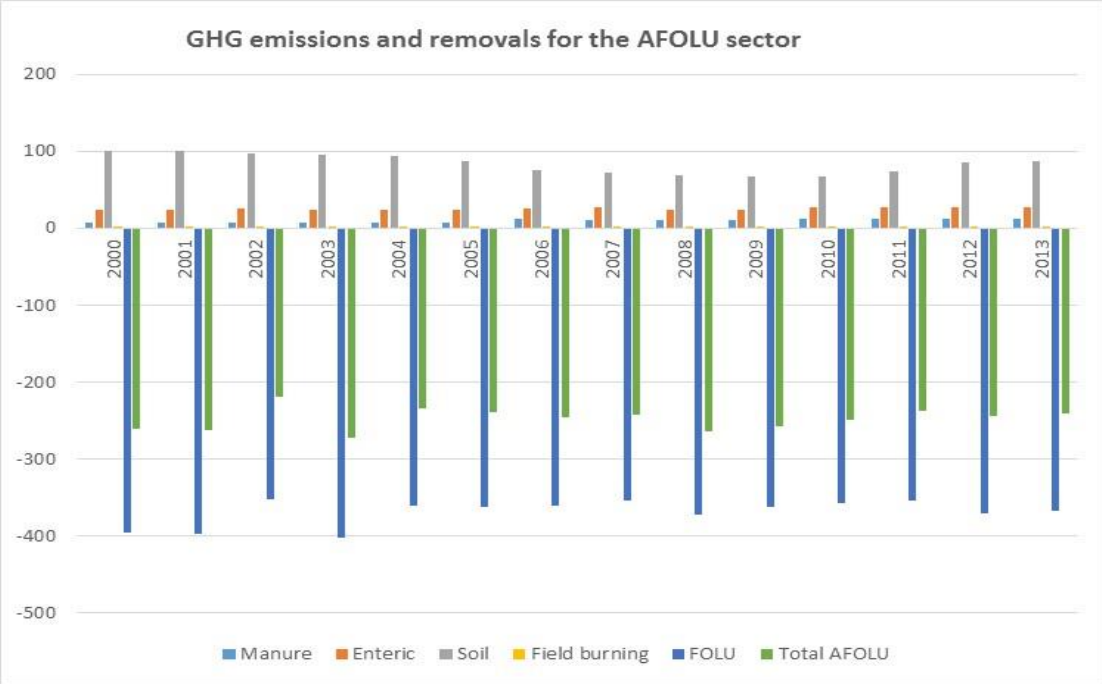

Figure 3.1: Trend of emissions for AFOLU Sector (Source: TNC, 2016)

4. FOLU Mitigation Actions proposed under 2016 TNC

4.1 Mitigation Scenarios and Assumptions

The National Forest Policy 2006, under which the Forest Sector is managed, clearly spells out the mitigation actions to be taken, namely ***"Issue 2: Increasing tree cover to enhance the environment and the carbon sink capacity of the forests"*** through afforestation, reforestation and nationwide tree planting programmes.

Relative to the BAU scenario, two other scenarios were developed by TNC (2016). Scenario 1 (SC1) involves the implementation of Tree Planting as per the Strategic Plan 2016 – 2020 for Food Crop, Livestock and Forestry. Scenario 2 (SC2) concerns the afforestation of abandoned ex-sugar cane lands, between 2021 and 2050.

The assumptions adopted by TNC for mitigation actions for the FOLU sector are summarized in Table 4.1. The assumptions in this table are taken into the calculations and the User of the toolkit only needs to update these in the relevant worksheet(s), if required. This means that worksheets for assumptions already contain the areas for the different tree species and vegetation types that can be updated by the User.

Table 4.1: Mitigation actions proposed by TNC (2016) and assumptions used

Scenario		Assumptions
BAU	Business-As-Usual	BAU assumes that the carbon stock is maintained at its 2014 level based on the observation that the stock of trees has remained unchanged between 2006 and 2014 with the exception of an increase in the area of mangrove forests due to ongoing baseline initiatives (Table 4.2). The loss of carbon stock due to fuelwood removal decreases by ~7.4% and ~6.6% annually for eucalyptus and pine wood >20 years, respectively (Table 4.2)[#]. The disturbed area has been kept constant at the average between 2006 and 2014 (i.e. at 100 ha per annum).
SC1	Tree Planting	Main Assumption: As spelt out earlier, the Strategic Plan 2016 – 2020 of the Ministry of Agro-Industry and Food Security (2016) makes provision for tree planting between 2016 and 2020. In the Tree Planting scenario, the number of trees planted outside forest areas and their distributions in terms of native and exotic trees are captured in Table 4.3. Note: Trees planted in clear-felled forest areas and gaps are merely replacing trees (already accounted in BAU scenario). Hence, these trees are not included in the policy scenario in order to avoid double accounting.
SC2	Afforestation	Main Assumption: Afforesting of abandoned land for GHG sinks between 2021 and 2050. (*The Afforestation scenario, therefore, builds on the Tree Planting scenario that covers only the period 2016 to 2020*). Two cases are proposed: 1) It is assumed that all of the 5 000 ha of land is available in the agro-ecological zone of Dry Lowland (DLL). 2) An Afforestation scenario based on only 1 000 ha of abandoned sugar cane land because of competing land uses. The relative breakdowns between native and exotic species are unchanged – i.e. the only change in Table 4.4 is dividing all parameters by factor 5.

Note [#]. These percentages have already been incorporated into the final areas projected in the TNC and are as such in the worksheets and can be updated by the user.

The parameters used for the different scenarios appear in section 5.2.

BAU Scenario

In Table 4.2, it can be seen that while mangrove areas increase, the wood and fuelwood removals decreases. This entails increased projected carbon sequestrations.

Table 4.2: Selected assumptions used in the FOLU-BAU scenario

		2015	2020	2030	2040	2050
Mangrove forest (ha)		182	187	197	200	213
Wood removal (m^3/yr)	DLL Eucalyptus	528	478	300	200	100
	WUL Pine>20 yr	708	650	550	300	100
Fuelwood removal (m^3/yr)	DLL Eucalyptus	1 769	1 204	557	400	100
	WUL Pine>20 yr	1 587	1 125	565	350	100

Source: Forestry Services, Ministry of Agro-Industry and Food Security

Tree planting Scenario

The tree planting scenario in Table 4.3 have been incorporated into the areas of the different land and forests classes by tree species.

Table 4.3: Parameters for Tree Planting scenario for trees outside forest areas

Parameters	2016	2017	2018	2019	2020
Total area planted (ha)	25	35	40	45	50
Approximate number of trees	30 100	38 500	44 000	49 500	55 000
Ratio of native to exotic plants	1.17	1.25	1.50	1.75	2.00

Source: Forestry Services, Ministry of Agro-Industry and Food Security

Afforestation Scenario

The afforestation of the abandoned sugarcane lands with the different tree species have been reflected in the areas by land and forests classes, as per the TNC calculations. These are presented in the assumption worksheets that can be updated with areas of tree species, without doing any further calculations using the values of Table 4.4. This means that the different areas of native and exotic tree species are already included in the data for this scenario, based on the TNC calculations. The areas of forests and other lands by species have therefore been adjusted in the TNC by the addition of the exotic and native species.

Table 4.4: **Area afforested with native and exotic species in the Afforestation scenario**

Time period	Area planted with native tree species (ha/yr)	Area planted with exotic tree species (ha/yr)		
		Araucaria	Eucalyptus	Tabebuia
2021 - 2025	50	12.5	25	12.5
2026 - 2030	75	18.75	37.5	18.75
2031 - 2035	75	18.75	37.5	18.75
2036 - 2040	100	25	50	25
2041 - 2045	100	25	50	25
2046 - 2050	100	25	50	25

Source: Forestry Services, Ministry of Agro-Industry and Food Security

4.2 TNC Targets under different scenarios

For the FOLU sector, the increase in GHG sequestration relative to BAU scenario for the three scenarios is summarized in both Table 4.5 and Figure 4.1.

Table 4.5: TNC (2016) Estimations of GHG Removals in FOLU sector

Scenario		**TNC TARGETS** *Expected GHG Removals*	**TNC Remarks**
BAU	Business-As-Usual	BAU GHG removals (net) 409.0 GgCO2e in 2020; 412.0 GgCO2e in 2030; 413.74 GgCO2e in 2040; 415.66 GgCO2e in 2050;	
SC1	Tree Planting	Removal over and above BAU: 1.90 GgCO2e in 2020; 2.20 GgCO2e in 2030; 2.44 GgCO2e in 2040; 2.68 GgCO2e in 2050	The net increase in carbon sink arising from SC1 is marginal
SC2	Afforestation (5000 ha)	Removal over and above BAU: 1.90 GgCO2e in 2020; 20.48 GgCO2e in 2030; 46.14 GgCO2e in 2040; 75.8 GgCO2e in 2050.	SC2 produces substantial increase in carbon sequestrations but are unrealistic
SC3	Afforestation (1000 ha)	Removal over and above BAU: 1.90 GgCO2e in 2020; 5.81 GgCO2e in 2030; 10.94 GgCO2e in 2040; 17.1 GgCO2e in 2050.	SC3 projects higher carbon sequestrations than BAU but lower than the 5000 ha afforestation.

The overall projected carbon sequestrations from BAU, SC1 and SC2 are shown in Figure 4.1. It can be seen that while the tree planting has marginal increased in carbon stocks, the afforestation has a far better benefit.

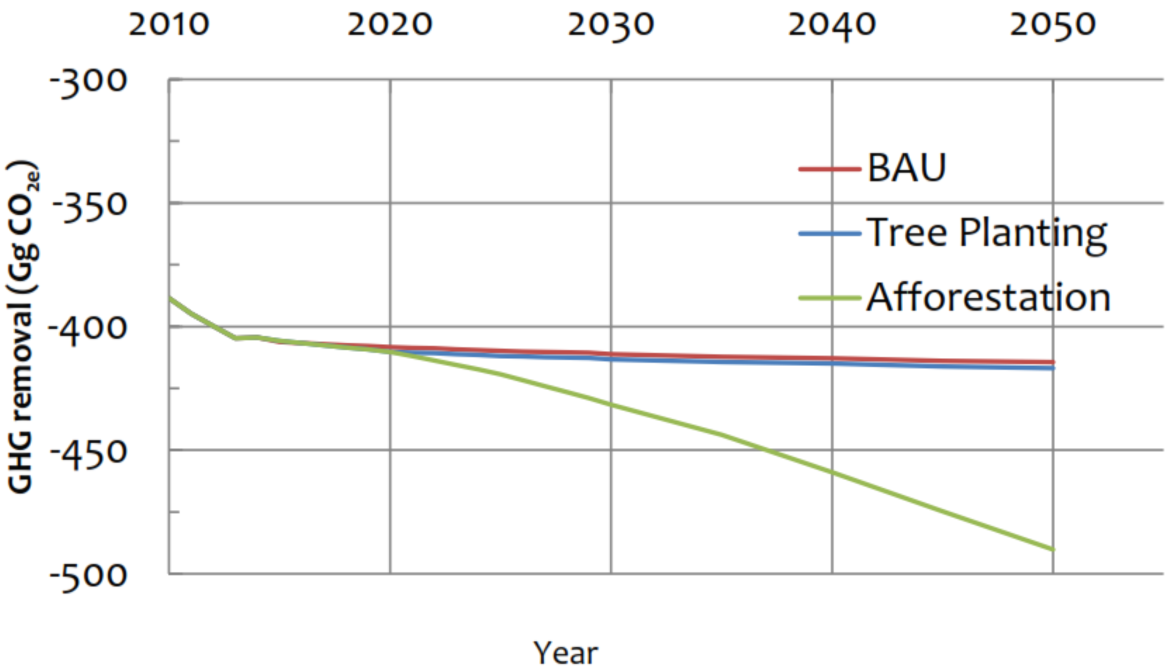

Figure 4.1: Carbon sequestration scenarios in FOLU (2010-2050) (source: TNC, 2016)

5.0 XLM-FOLU Toolkit

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

5.1 FOLU Data

The '*Data*' worksheet essentially contains the areas of the different land classes with their respective tree species. The areas of Dry Lowland (DLL), Moist, and Wet Upland (WUL) forests planted with different exotic species are thus classified for each year. The actual data pertains to year 2000 to 2014 and beyond that, the projections have been made for the TNC studies (2016). These data are used in combination with the parameters in the '*Parameters*' worksheet (emission/removal factors, biomass growth factors, etc.) and the assumptions in the 'Assumptions', to make the calculations for the carbon sequestrations. The projected areas are also used in the calculations for future carbon sequestrations.

The data sources for this sector are typically from the Forestry Service which keeps a record of the forests by types, including tree species.

5.2 FOLU Parameters

Tables 5.1 and 5.2 present the major parameters used for the FOLU sector used in the XLM-FOLU Toolkit; all parameters used appear in the '*Parameters*' worksheet.

Table 5.1: List of Parameters for the carbon stock increase for FOLU sector

Ecological Zone	Category	Species	Climate Region	Ecosystem Type	Soil Type	Age class	G.S (m3/ha)	C fraction	R	BCEF	AGB	AGB growth	SOC	Litter C	Gtotal
								Def	Def	Def	Def	Def	Def	Def	Def
Dry Lowland Forest R < 1000mm	P	Araucari	Tropical Dry	Tropical Dry Forest	LAC	> 20 yr	> 200 *	0.47	0.28	0.61	179	10	35	5.2	12.8
	P	Casuarin			Sandy M.	> 20 yr	81-120	0.47	0.28	0.73	126	10	31	2.1	12.8
	P	Euc.			Sandy M.	> 20 yr	41-80	0.47	0.28	0.89	139	13	31	2.1	16.64
	P	Tabebuia			LAC	> 20 yr	121-200 *	0.47	0.28	0.73	260	10	35	2.1	12.8
	NF	Scrublan			Sandy M.	> 20 yr	21-40	0.47	0.28	2.11	55	1.8	31	2.1	2.304
	P	Mangrov		Tropical Shrubland	Sandy M.	> 20 yr *	21-40	0.47	0.4	2.11	23	10	31	2.1	14
Moist Forest 2000mm>R> 1000mm	P	Araucari	Trop. Moist,Short Dry Season	Trop. Moist deciduous F.	LAC	> 20 yr	> 200 *	0.47	0.24	0.77	190	9	47	5.2	11.16
	P	Casuarin			LAC	> 20 yr	121-200 *	0.47	0.24	1.44	155	9	47	2.1	11.16
	P	Euc.			LAC	> 20 yr	121-200 *	0.47	0.24	1.44	166	9	47	2.1	11.16
	NF	Natural			LAC	> 20 yr	41-60	0.47	0.2	2.28	82	1.3	47	2.1	1.56
	P	Tabebuia			LAC	> 20 yr	121-200 *	0.47	0.2	1.44	280	9	47	2.1	10.8
Wet Upland Forest R > 2000mm	P	Euc.	Tropical Wet	Tropical rainforest	HAC	> 20 yr	121-200 *	0.47	0.37	1.44	277	6	44	2.1	8.22
	P	Cryptom			HAC	> 20 yr	61-80	0.47	0.37	0.89	38	6	44		8.22
	P	Pinus			HAC	< 20 yr	121-200 *	0.47	0.37	0.77	60	6	44	5.2	8.22
	P	Pinus			HAC	> 20 yr	121-200 *	0.47	0.37	0.77	200	4.6	44	5.2	6.302
	P	Araucari			HAC	> 20 yr	> 200 *	0.47	0.37	0.77	202	6	44	5.2	8.22
	NF	Natural			HAC	> 20 yr	61-80	0.47	0.37	1.89	130	3.1	44	2.1	4.247

Table 5.1: List of Parameters for the carbon reductions for FOLU sector

	WOOD REMOVAL		FUELWOOD REMOVAL			DISTURBANCE				
	Type of Forest, m3/yr)			Type of Forest, m3/yr)			Area (ha)	Frac BioLoss	Area (ha)	Frac BioLoss
Year	DLL_Euc	WUL_P>20y		DLL_Euc	WUL_P> 20y		DLL_Euc		DLL_Scrubland	
2006	2055	6419		3280	2778		94	0.25		
2007	1752	5133		3857	3210		154	0.06		
2008	1000	4614		2199	3018		136	0.05		
2009	718	4331		2335	3147		80	0.03	43	0.003
2010	1700	3216		3593	5819		90	0.04	98	0.008
2011	912	3576		2612	3860		96	0.039		
2012	936	2219		2821	2256		98	0.04	56	0.004
2013	656	776		2064	1821	*19.282*	102	0.04	55	0.004
2014	528	708		1911	1700		151	0.06	56	0.004
2015	528	708		1769.34	1587.04	*6.645*	111.22	0.04	56	0.004
2016	528	708	*7.413*	1638.18	1481.59		113.14	0.04	56	0.004
2017	528	708		1516.75	1383.14		108.60	0.04	56	0.004
2018	528	708		1404.32	1291.23		105.55	0.04	56	0.004
2019	528	708		1300.22	1205.44		108.39	0.04	56	0.004
2020	478	650		1203.83	1125.34		110.43	0.04	56	0.004
2021	478	650		1114.60	1050.56		112.04	0.05	56	0.004
2022	478	650		1031.97	980.76		113.60	0.05	56	0.004
2023	478	650		955.48	915.59		114.88	0.04	56	0.004
2024	478	650		884.65	854.75		110.87	0.04	56	0.004
2025	425	600		819.07	797.95		110.83	0.04	56	0.004
2026	425	600		758.36	744.93		110.58	0.04	56	0.004
2027	425	600		702.14	695.43		110.80	0.04	56	0.004
2028	425	600		650.09	649.22		111.38	0.04	56	0.004
2029	425	600		601.90	606.09		111.71	0.04	56	0.004
2030	300	550		557.28	565.81		111.85	0.04	56	0.004
2035	200	400		500	450		100	0.04	56	0.004
2040	200	300		400	350		100	0.04	56	0.004
2045	100	200		200	200		100	0.04	56	0.004
2050	100	100		100	100		100	0.04	56	0.004

It is to be noted that the carbon stock increase parameters (Table 5.1) follows from the fact that during growth, the trees removes carbon from the atmosphere and sequester them in the plant tissues. Several factors are involved in the calculations of the increase in the carbon stock. The carbon stock is finally converted into CO_2 sequestered. On the other hand, the values for the carbon lost or decrease (Table 5.2), changes from year to year, depending on the tree species that are harvested for wood and fuelwood. The other loss occurs from disturbances such as fire or cyclones.

5.3 FOLU Assumptions

The assumptions (in the '*Assumptions'* worksheet) used in the XLM FOLU Toolkit are essentially the forest areas which may or may not change depending on national circumstances such as afforestation, harvests, conservations activities and others (Table 5.3). These assumptions used are derived from TNC (2016). Users can be update these, if required, for any of the land and forest classes, as appropriate. There are a few side-assumptions such as ratios of exotic to native species, or percentage increase of some species, that have been taken on-board in the Toolkit to calculate the areas for the different forest and other land areas. The details of these side-assumptions are not required to be updated in this assumption sheets, but can be used to work out the areas to be projected.

Table 5.3: List of Assumptions for the FOLU sector

1	Dry Lowland Forest area (ha) by tree species and vegetation type* (ha)
2	Moist Forest area by tree species and vegetation types* (ha)
3	Wet Upland Forest area (ha) by tree species and vegetation types* (ha)
4	Mangrove Forest area (ha)

*Tree species and vegetation types: Araucaria, Casuarina, Eucalyptus (white and Red), Tabebuia, Cryptomeria, Pine, Mangrove, Natural, Scrub Land.

5.4 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
FOLU	ALL	1-144;
	Area by type of forests and tree species	1-21; 41-69; 97-117;
	Increase in carbon stock for different Tree Species and Forest Type	22-42; 70-90; 118-138;
	Carbon Sequestration (tC/yr)	47, 95, 143;
	Reduction in carbon	43-46; 91-94; 139-142;
	Carbon Sequestration (GgCO2e/yr) (TNC)	48, 96, 144;

The complete set of figures that the XLM-FOLU Toolkit provides is listed in Table 5.4. In this table, the rightmost column denotes the general topic or item for which the plots can be generated for graphical analysis.

Table 5.4: XLM-FOLU Toolkit Plots

			Plot Numbers			
			BAU	SC1	SC2	
AREA OF FORESTS BY TYPE (ha)	Dry Lowland Forest, ha	Araucaria	1	49	97	
		Casuarina	2	50	98	
		Eucalyptus	3	51	99	
		Tabebuia	4	52	100	
		Scrub Land	5	53	101	
	Moist Forest, ha	Araucaria	6	54	102	
		Casuarina	7	55	103	
		Eucalyptus	8	56	104	
		Natural	9	57	105	
		Tabebuia	10	58	106	
	Wet Upland Forest, ha	Eucalyp Red	11	59	107	
		Cryptomeria	12	60	108	
		Pine<20y	13	61	109	
		Pine>20y	14	62	110	
		Araucaria	15	63	111	
		Natural	16	64	112	
	Mangrove, ha	Forest	17	65	113	
	Wet Upland Forest, ha	Pine<20y	18	66	114	
		Pine>20y	19	67	115	
	Wet Upland Forest, ha	Euc Red<20y	20	68	116	
	Total (ha)		21	69	117	
INCREASE IN CARBON STOCK FOR THE DIFFERENT TREE SPECIES AND FOREST TYPE, tC/yr	Dry Lowland Forest, tC/yr	Araucaria	22	70	118	
		Casuarina	23	71	119	
		Eucalyptus	24	72	120	
		Tabebuia	25	73	121	
		Scrub Land	26	74	122	
	Moist Forest, tC/yr	Araucaria	27	75	123	
		Casuarina	28	76	124	
		Eucalyptus	29	77	125	
		Natural	30	78	126	
		Tabebuia	31	79	127	
	Wet Upland Forest, tC/yr	Eucalyp Red	32	80	128	
		Cryptomeria	33	81	129	
		Pine<20y	34	82	130	
		Pine>20y	35	83	131	
		Araucaria	36	84	132	
		Natural	37	85	133	
	Mangrove, tC/yr	Forest	38	86	134	
	Wet Upland Forest Pine, tC/yr	Pine<20y	39	87	135	No Data
		Pine>20y	40	88	136	No Data
	Wet Upland Forest Euc Red, tC/yr	Euc Red<20	41	89	137	No Data

	Total, tC/yr		42	90	138
Reduction in Carbon, tC/yr	**WOOD REMOVAL, tC/yr**		43	91	139
	FUELWOOD, tC/yr		44	92	140
	DISTURBANCE, tC/yr		45	93	141
	LOSS TOTAL, tC/yr		46	94	142
Carbon sequestration	**NET INCREASE IN C STOCK**	**tC/yr**	47	95	143
		GgCO2e/yr	48	96	144

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.
- Strategic Plan 2016 – 2020 of the Ministry of Agro-Industry and Food Security (2016).

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	FOLU	Forestry and Other Land Use
UD2	User-defined Scenario – Case 2	LULUCF	Land Use, Land Use Change and Forestry
SC*i*	Scenario *i*	AGB	Above-ground Biomass
XLMT	Excel Mitigation Toolkit	BCEF	Biomass Conversion and Expansion Factor
		C	Carbon Fraction
		G.S	Growing Stock
		GWP	Global Warming Potential
		HAC	High Activity Clay
		LAC	Low Activity Clay
		Litter C	Litter Carbon
		R	Root-to-Shoot Ratio
		Sandy M	Sandy Mineral
		SOC	Soil Organic Carbon
		WD	Wood Density (Basic)
		FS	Forestry Service

B: Useful Links

- IPCC 2006 and General
- TNC
- Forestry
- Digest environment and others
- **IPCC Good Practice Guidance for LULUCF**
- **2006 IPCC Guidelines for National Greenhouse Gas Inventories**
- **Global Forest Resources Assessment (FRA) 2015**

C: Glossary

Above-ground Biomass	All living biomass above the soil including stem, stump, branches, bark, seeds and foliage.
Above-ground Biomass Growth	Oven-dry weight of net annual increment of a tree, stand or forest plus oven-dry weight of annual growth of branches, twigs, foliage, top and stump.
Basic Wood Density	Ratio between oven-dry mass and fresh stem-wood volume without bark.
Below-ground Biomass	All biomass of live roots. Fine roots of less than 2 mm diameter are excluded because these often cannot be distinguished empirically from soil organic matter or litter.
Biomass Conversion and Expansion Factor	A multiplication factor that converts merchantable volume of growing stock, merchantable volume of net annual increment, or merchantable volume of wood removal and fuelwood removals to above-ground biomass, above-ground biomass growth, or biomass removals, respectively. Biomass conversion and expansion factors for growing stock (BCEFS), for net annual increment (BCEFI), and for wood-removal and fuelwood-removals (BCEFR) usually differ.
Biomass Expansion Factor	A multiplication factor that expands the dry-weight of growing stock biomass, increment biomass, and biomass of wood-removal or fuelwood-removals to account for non-merchantable or non-commercial biomass components, such as stump, branches, twigs, foliage, and, sometimes, non-commercial trees. Biomass expansion factors usually differ for growing stock (BEFS), net annual increment (BEFI), and wood-removal and fuelwood removals (BEFR).
Carbon Fraction	Tonnes of carbon per tonne of biomass dry matter.
Growing Stock	Volume over bark of all living trees with a diameter of 10 cm at breast height (or above buttress if these are higher). Includes the stem from ground level up to a top diameter of 0 cm, excluding branches.
High Activity Clay	Soils with high activity clay (HAC) minerals are lightly to moderately weathered soils, which are dominated by 2:1 silicate clay minerals (in the World Reference Base for Soil Resources (WRB) classification these include Leptosols, Vertisols, Kastanozems, Chernozems, Phaeozems, Luvisols, Alisols, Albeluvisols, Solonetz, Calcisols, Gypsisols, Umbrisols, Cambisols, Regosols; in USDA classification includes Mollisols, Vertisols, high-base status Alfisols, Aridisols, Inceptisols).
Low Activity Clay	Soils with low activity clay (LAC) minerals are highly weathered soils, dominated by 1:1 clay minerals and amorphous iron and aluminium oxides (in WRB classification these include Acrisols, Lixisols, Nitisols, Ferralsols, Durisols; in USDA classification includes Ultisols, Oxisols, acidic Alfisols).
Litter Carbon	Carbon in all non-living biomass with a diameter less than the minimum diameter for dead wood (e.g. 10 cm), lying dead in various states of decomposition above the mineral or organic soil.
Merchantable Volume	Merchantable volume is the volume overbark of all trees defined using the conditions described for growing stock.
Root-Shoot Ratio	Ratio of Below-ground Biomass to Above-ground biomass
Sandy Mineral	Includes all soils (regardless of taxonomic classification) having > 70% sand and < 8% clay, based on standard textural measurements (in FAO classification, include: Arenosols, sandy Regosols)).
Soil Organic Carbon	Organic carbon in mineral and organic soils (including peat) to a soil depth of 30 cm.

D: Governing Equations

Terms	Description	Units	Data sources	Remarks
Annual change in carbon stocks in biomass $\Delta C_B = \Delta C_G - \Delta C_L$ (I)				
ΔC_B	Annual change in carbon stocks in biomass (the sum of above-ground and below-ground biomass for each land sub-category, considering the total area	tonnes C yr^{-1}		Calculated
ΔC_G	Annual increase in carbon stocks due to biomass growth for each land sub-category, considering the total area	tonnes C yr^{-1}		Calculated
ΔC_L	Annual decrease in carbon stocks due to biomass loss for each land sub-category, considering the total area	tonnes C yr^{-1}		Calculated
Annual Increase in Biomass Carbon Stocks Due To Biomass Increment in Land Remaining in the Same Land-Use Category $\Delta C_G = \sum_{i,j}(A_{i,j} \times G_{TOTAL_{i,j}} \times CF_{i,j})$ (II)				
ΔC_G =	Annual increase in biomass carbon stocks due to biomass growth in land remaining in the same land-use category by vegetation type and climatic zone	tonnes C yr^{-1}		
i =	Ecological zone (i = 1 to n)		IPCC 2006 *Table 4.1*	Local classifications - FS
j =	Climate domain (j = 1 to m)		IPCC 2006 *Table 4.1*	Local classifications - FS
A	Area of land remaining in the same land-use category	ha	Forestry Service	Area (ha) by land class and tree species
G_{TOTAL}	G_{TOTAL}= mean annual biomass growth	tonnes d. m. ha^{-1} yr^{-1}	IPCC 2006	For each species See following equation (III)
CF	Carbon fraction of dry matter	tonne C (tonne $d.m.)^{-1}$	IPCC 2006 *Table 4.3*	
AVERAGE ANNUAL INCREMENT IN BIOMASS Tier 1 $G_{TOTAL} = \Sigma\{G_W \times (1+ R)\}$ (III) Biomass increment data (dry matter) are used directly				
G_{TOTAL}	Average annual biomass growth above and below-ground	tonnes d. m. ha^{-1} yr^{-1}		Calculated
Σ	Summation			Sum
G_W	Average annual above-ground biomass growth for a specific woody vegetation type	tonnes d. m. ha^{-1} yr^{-1}	IPCC 2006 Table 4.10.	
R	Ratio of below-ground biomass to above-ground biomass for a specific vegetation type	tonne d.m. below-ground biomass (tonne d.m. above-ground biomass) $^{-1}$.	IPCC 2006 Table 4.4.	R must be set to zero if assuming no changes of below-ground biomass allocation patterns (Tier 1).

Terms	Description	Units	Data sources	Remarks
Annual Decrease in Carbon Stocks Due To Biomass Losses in Land Remaining In the Same Land-Use Category $\Delta C_L = L_{wood-removals} + L_{fuelwood} + L_{disturbance}$ (IV)				
ΔC_L	Annual decrease in carbon stocks due to biomass loss in land remaining in the same land-use category	tonnes C yr^{--1}		Calculated
$L_{wood-removals}$	Annual carbon loss due to wood removals,	tonnes C yr^{-1}	Forestry Service	Calculated for selected species
$L_{fuelwood}$	Annual biomass carbon loss due to fuelwood removals	tonnes C yr^{-1}	Forestry Service	Calculated for selected species
$L_{disturbance}$	Annual biomass carbon losses due to disturbances	tonnes C yr^{-1}	Forestry Service	Calculated for selected land
ANNUAL CARBON LOSS IN BIOMASS OF WOOD REMOVALS $L_{wood\ -removals} = \{H \bullet BCEF_R \bullet (1+R) \bullet CF\}$ (V)				
$L_{wood-removals}$	Annual carbon loss due to biomass removals	tonnes C yr^{-1}	Calculated	
H	Annual wood removals, roundwood,	$m^3\ yr^{-1}$	Forestry Service	
$BCEF_R$	Biomass conversion and expansion factor for conversion of removals in merchantable volume to total biomass removals (including bark)	tonnes biomass removal (m^3 of removals)$^{-1}$.	IPCC 2006 *Table 4.5*[1]	
R	Ratio of below-ground biomass to above-ground biomass	tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$	IPCC 2006 *Table 4.4*	R must be set to zero if assuming no changes of below-ground biomass allocation patterns (Tier 1).
CF	Carbon fraction of dry matter	tonne C (tonne d.m.)$^{-1}$	IPCC 2006 *Table 4.3*	
ANNUAL CARBON LOSS IN BIOMASS OF FUELWOOD REMOVALS $L_{wood\ -removals} = \{H \bullet BCEF_R \bullet (1+R) \bullet CF\}$ (VI) **SAME AS PREVIOUS FORMULA**				

[1] However, if $BCEF_R$ values are not available and if the biomass expansion factor for wood removals (BEF_R) and basic wood density (D) values are separately estimated, then the following conversion can be used: $BCEF_R = BEF_R \bullet D$ (BEF_R=biomass expansion factor for conversion of removals, D=Basic wood density).

ANNUAL CARBON LOSSES IN BIOMASS DUE TO DISTURBANCES $L_{disturbance} = \{A_{disturbance} \bullet BW \bullet (1+R) \bullet CF \bullet fd\}$ (VII)				
$L_{disturbances}$	Annual other losses of carbon	tonnes C yr^{-1}		Calculated. see note[2]
$A_{disturbance}$ =	Area affected by disturbances	ha yr^{-1}	FS	
BW	Average above-ground biomass of land areas affected by disturbances	tonnes d.m. ha^{-1}	IPCC 2006 (as in TNC)	
R	Ratio of below-ground biomass to above-ground biomass	tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$	IPCC 2006 *Table 4.4.*	R must be set to zero if no changes of below-ground biomass are assumed (Tier 1)
CF	Carbon fraction of dry matter,	tonne C (tonnes d.m.)$^{-1}$	IPCC 2006 *Table 4.3*	
fd	Fraction of biomass lost in disturbance (see note below)	fraction	IPCC2006 (see TNC sheets)	

[2] (Note that this is the amount of biomass that is lost from the total biomass. The partitioning of biomass that is transferred to dead organic matter and biomass that is oxidized and released to the atmosphere is explained in Equations 2.15 and 2.16 of IPCC 2006 GL).