Joint Crediting Mechanism Approved Methodology KH_AM004 "Reducing deforestation and forest degradation through forest conservation in Cambodia"

A. Title of the methodology

Reducing deforestation and forest degradation through forest conservation in Cambodia, version 1.0

B. Terms and definitions

Terms	Definitions
Cambodia's official forest reference level (National FRL)	Cambodia's official forest reference level (National FRL) is defined as the most recent and available forest reference level submitted to the UNFCCC secretariat by Cambodia and completed technical assessment by the UNFCCC's assessment team.
Cambodia's official forest map	A land use and land cover map, endorsed as an official map, named Forest Cover, by the Government of Cambodia. The generation of additional landcover data are expected every 2 years, e.g., Forest Cover 2018 and Forest Cover 2020.
Forest classes	Classes of forests adopted in the establishment of Cambodia's official forest reference level.
Transition probability	A probability that a forest class will be changed to another forest class, or be converted, to non-forest, based on the historical pace of transition. Transition probability is between 0 to 1.

C. Summary of the methodology

Items	Summary
Project activities	The project activities include forest conservation activities such as forest management and community livelihood development, including

(emission reduction measures)	agricultural improvement, eco-tourism development, marketing of non-timber forest products and formation/strengthening of community groups that lead to the reduction of emissions from deforestation and degradation.
Establishment of project reference level	Two options have been identified to establish the project reference level, using data from Cambodia's official forest reference level (National FRL): (1) applying the National FRL transition probabilities from forest to non-forest classes only, to the project area, (e.g., transitions *between* different forest classes are not included); and (2) applying all the National FRL transition probabilities among classes that would result in emissions to the project area. Note that Option (1) accounts for emissions from only deforestation, while Option (2) accounts for emissions from forest degradation in form of transitions from one forest class to another, in addition to those from deforestation. Option 2 is similar to the method used in the Cambodia's National FRL submission in 2017, except that the National FRL includes removals as well; this methodology targets *only* emissions.
Calculation of project net emissions	Project net emissions are estimated based on the result of monitoring of forest to non-forest classes (Option 1) and monitoring of forest to non-forest or another forest class (Option 2) within the project area, multiplied by the emission factors (including both above and below ground biomass) plus any displaced emissions within the displacement belt and GHG emissions due to the project activities inside the project area and the activity area in line with Joint Crediting Mechanism Guidelines for Developing Proposed Methodology for Reducing Emissions from Deforestation and Forest Degradation, and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries (REDD-plus), (methodology guidelines). Displaced emissions are calculated as increases of emissions in the displacement belt compared to the reference emissions. Use of fuel and fertilizers, for the implementation of the project activities, are included as GHG emissions sources, and will be monitored and accounted as project emissions.
Monitoring parameters and methods	- Area converted from forest to non-forest (Option 1) or forest to another forest class (Option 2) in the project area - Area converted from forest to non-forest (Option 1) or forest to another forest class (Option 2) in the displacement belt - Quantity of fuel consumed in vehicle and/or equipment - Number of vehicle and/or equipment - Total travel distance of vehicle and/or total use hours of equipment - Average specific energy consumption of vehicle and/or equipment - Mass of synthetic fertilizer applied - Mass of organic fertilizer applied and made from materials sourced from outside of the project area and the activity area - Harvested annual dry matter yield of N-fixing crop per unit area, introduced by the project - Total annual area harvested of N-fixing crop introduced by the project - Ratio of above-ground residues to harvested yield for N-fixing crop - Ratio of below-ground residues to harvested yield for N-fixing crop - Mass of calcic limestone, dolomite and urea fertilizer applied

	- Nitrogen content of synthetic and organic fertilizer applied - Nitrogen content of above-ground and below-ground residues for N-fixing crop - Fraction of total area under N-fixing crop that is renewed annually
Calculation of project emission reductions to be credited	A default discount factor of 20%, as defined in the methodology guidelines, is applied to project emissions reductions to account for the risk of reversal.

D. Eligibility criteria

This methodology is applicable to projects that satisfy all of the following criteria.

Criterion 1	The project is to reduce deforestation and forest degradation through project activities including forest management and community livelihood development.
Criterion 2	Cambodia's official forest reference (emission) level has been submitted to UNFCCC, completed technical assessment by UNFCCC, and is publicly available.
Criterion 3	Cambodia's official forest map for the project start year or less than or equal to two years old is available for the project participant.
Criterion 4	Project activities do not include activities which lead to GHG emissions within the project area and the project activity area, except for the use of fuel or fertilizer including N-fixing crops.

E. Geographical Boundaries

Essential

Geographical boundary	Requirements
Project area	No requirements in addition to those described in paragraphs 17 to 22 of the methodology guidelines ver01.0 (JCM_KH_GL_PM_REDD+_ver01.0)
Reference area	The land area of Cambodia is used to keep consistency with National FRL.

Optional boundaries

Geographical boundary	Required (Y/N/TBD)	Additional requirements
Activity area	Y	No requirements in addition to those described in paragraph 17 and 21 of the methodology guidelines ver01.0.

Displacement belt	Y	Displacement belt is the forest which is located outside of the project area, where deforestation and forest degradation could occur due to the displacement of project activities, such as small-scale logging, agricultural encroachment, and collection of non-timber forest products. The displacement belt is delineated on the basis of information on the impact of project activities which are obtained from local experts and other sources. If other REDD+ projects exist within the belt, project areas of these projects are excluded from the displacement belt. If development plans, including Economic Land Concessions (ELCs), exist within the belt, those areas are also excluded because forest clearance is likely planned inside these areas regardless the project activities.

TBD: to be decided by the project participant

F. Carbon pools and GHG sources

The net emission sources to be considered include all the following Carbon pools and GHG sources.

Project reference level			
Carbon pools and GHG sources		Included (Y/N)	Explanation
Carbon pools	Above ground biomass	Y	This pool is expected to contribute significantly to emissions and emission reductions and is therefore included.
	Below ground biomass	Y	This pool is expected to contribute significantly to emissions and emission reductions and is therefore included.
	Dead wood	N	It is expected that this pool would have decreased in the absence of the project and, therefore, it is conservatively excluded.
	Litter	N	It is expected that this pool would have decreased in the absence of the project and, therefore, it is conservatively excluded.
	Soil organic carbon	N	It is expected that this pool would have decreased in the absence of the project and, therefore, it is conservatively excluded.
GHG sources			
Project net emissions			

Carbon pools and GHG sources		Included (Y/N)	Explanation
Carbon pools	Above ground biomass	Y	This pool is expected to contribute significantly to emissions and emission reductions and is therefore included.
	Below ground biomass	Y	This pool is expected to contribute significantly to emissions and emission reductions and is therefore included.
	Dead wood	N	It is expected that this pool would have decreased in the absence of the project and, therefore, it is conservatively excluded.
	Litter	N	It is expected that this pool would have decreased in the absence of the project and, therefore, it is conservatively excluded.
	Soil organic carbon	N	It is expected that this pool would have decreased in the absence of the project, and therefore, it is conservatively excluded.
GHG sources	CO_2 emissions from combustion of fossil fuels		This GHG source is estimated if the project activities which include combustion of fossil fuels are implemented.
	N_2O and CO_2 emissions from fertilizer application		This GHG source is estimated if the project activities include fertilizer application.

G. Establishment of project reference level

G.1. Establishment of project reference level

Approach for estimating project reference level	In order to maximize consistency, the project reference level is established by applying emission factors and transition probabilities from the national forest reference level (National FRL).

Reference area and reference period are the same as the National FRL, and therefore the reference area is the total of Cambodia’s land area. The reference period is the same as the reference period submitted in the National FRL to the UNFCCC. In the National FRL submitted in 2017; the reference period was 2006 to 2014.

Calculation of transition probability is done by applying one of two options provided in this methodology: (1) Option 1: using the National FRL transition probabilities from forest to non-forest classes only (i.e., transitions *between* different forest classes are not included); or (2) Option 2: using all the National FRL transition probabilities among classes that would result in

GHG emissions. The option selected should also be used for calculation of project net emissions in section H and for determining data and parameters fixed *ex ante* in section J. The option is selected in coordination with Government of Cambodia and project participants.

Yearly reference emission at the project reference level is calculated by applying the transition probabilities to areas of forests at the previous year and multiplying by emission factors.

To ensure the conservativeness of the calculation of the project emission reductions, dead wood, litter and soil organic carbon pools, of which carbon stocks would have decreased in the absence of the project, were excluded.

G.2. Calculation of project reference level

The project reference level in year *y* during the monitoring period is calculated as follows:

$$RL_y = \Delta CS_{ref\,y} * 44/12 \quad \text{Equation 1}$$

Where:

RL_y	Project reference level in year *y*; tCO_2
$\Delta CS_{ref\,y}$	Projected carbon stock change in the project area in year *y*; tC
44/12	Conversion factor of molecular weight of carbon to CO_2; dimensionless

$\Delta CS_{ref\,y}$ is calculated by applying either Option 1 or Option 2 selected in coordination with government of Cambodia and project participants.

Option 1: Use the National FRL transition probabilities from forest to non-forest classes only

Carbon stock change in the project area in year *y* is calculated as follows:

$$\Delta CS_{ref\,y} = \sum_i (A_{i\,y-1} * P_i * EF_i) \quad \text{Equation 2}$$

Where:

$\Delta CS_{ref\,y}$	Projected carbon stock change in the project area in year *y*; tC
$A_{i\,y-1}$	Area of forest class *i* in the project area in year *y-1*; ha
i	Forest class in the project area; dimensionless
P_i	Annual transition probability from forest class *i* to non-forest within the reference area; dimensionless, 0-1
EF_i	Emission factor applicable for forest class *i*; tC ha^{-1}

Area of forest class *i* is assumed to decrease every year due to deforestation, and therefore calculated as follows:

$A_{i\,y+1} = A_{i\,y} * (1 - P_i)$ Equation 3

Where:

$A_{i\,y+1}$	Area of forest class *i* in the project area in year *y+1*; ha
$A_{i\,y}$	Area of forest class *i* in the project area in year *y*; ha
P_i	Annual transition probability from forest class *i* to non-forest within the reference area; dimensionless, 0-1

Please refer to section J for determination of EF_i, $A_{i\,0}$ (area at the inception of the project) and P_i.

Option 2: Use all the National FRL transition probabilities among classes that would result in GHG emissions.

To estimate the total emissions, the projected carbon stock change in year *y* in the project area is calculated as follows:

$$\Delta CS_{ref\ y} = \sum_i \sum_j cs_{ij\ y} \begin{cases} cs_{ij\ y}, & \text{if } cs_{ij\ y} > 0 \\ 0, & \text{otherwise} \end{cases}$$ Equation 4

Where:

$\Delta CS_{ref\ y}$	Projected carbon stock change in the project area in year *y*; tC
$cs_{ij\ y}$	Projected carbon stock change in the project area from changes of land use category *i* to *j* in year *y*; tC
i, j	Land use category in the project area; dimensionless

The notation $cs_{ij\ y}$ is an element of *i*-by-*j* cross-tabulation matrix MCS_y which is a product of element-wise multiplication (Hadamard product) of *i*-by-*j* matrices of area changes and emission factors.

$$\mathrm{MCS}_y = \mathrm{MCA}_y \cdot \mathrm{MEF}$$ Equation 5

Where:

MCS_y	*i*-by-*j* matrix in which each element is projected carbon stock change in the project area from changes of land use category *i* to *j* in the project area in year *y*, $cs_{ij\ y}$; tC
MCA_y	*i*-by-*j* matrix in which each element is projected area of land converted from land use category *i* to *j* in the project area in year *y*, $ca_{ij\ y}$; ha
MEF	*i*-by-*j* matrix in which each element is emission factor for area of land converted

from land use category i to j, EF_{ij}; tC ha^{-1}

Equation 5 is expressed as below:

$$\begin{bmatrix} cs_{11y} & cs_{12y} & \cdots & cs_{1jy} \\ cs_{21y} & cs_{22y} & \cdots & cs_{2jy} \\ \cdots & \cdots & \cdots & \cdots \\ cs_{i1y} & cs_{i2y} & \cdots & cs_{ijy} \end{bmatrix} = \begin{bmatrix} ca_{11y} & ca_{12y} & \cdots & ca_{1jy} \\ ca_{21y} & ca_{22y} & \cdots & ca_{2jy} \\ \cdots & \cdots & \cdots & \cdots \\ ca_{i1y} & ca_{i2y} & \cdots & ca_{ijy} \end{bmatrix} \cdot \begin{bmatrix} EF_{11} & EF_{12} & \cdots & EF_{1j} \\ EF_{21} & EF_{22} & \cdots & EF_{2j} \\ \cdots & \cdots & \cdots & \cdots \\ EF_{i1} & EF_{i2} & \cdots & EF_{ij} \end{bmatrix}$$

For example, the $cs_{11\,y}$ is calculated as bellow:

$cs_{11\,y} = ca_{11\,y} * EF_{11}$

Projected area of land conversion in year y is calculated as the product between areas of land categories in the project area in year $y\text{-}1$ and annual transition probabilities.

$$MCA_y = MA_{y-1}MP \qquad \text{Equation 6}$$

Where:

MCA_y	i-by-j matrix in which each element is the projected area of land converted from land use category i to j in year y, $ca_{ij\,y}$; ha
MA_{y-1}	i-by-j diagonal matrix whose diagonal elements are areas of land use categories i in the project area in year $y\text{-}1$, $A_{i\,y-1}$; ha
MP	i-by-j matrix in which each element is the annual transition probability from land use category i to j, p_{ij}; dimensionless, 0-1

Equation 6 is expressed as below:

$$\begin{bmatrix} ca_{11y} & ca_{12y} & \cdots & ca_{1jy} \\ ca_{21y} & ca_{22y} & \cdots & ca_{2jy} \\ \cdots & \cdots & \cdots & \cdots \\ ca_{i1y} & ca_{i2y} & \cdots & ca_{ijy} \end{bmatrix} = \begin{bmatrix} A_{1y-1} & 0 & \cdots & 0 \\ 0 & A_{2y-1} & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & \cdots & A_{iy-1} \end{bmatrix} \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1j} \\ p_{21} & p_{22} & \cdots & p_{2j} \\ \cdots & \cdots & \cdots & \cdots \\ p_{i1} & p_{i2} & \cdots & p_{ij} \end{bmatrix}$$

For example, selected elements are calculated as bellow:

$ca_{11y} = A_{1y-1} * p_{11} + 0 * p_{21} + \ldots + 0 * p_{i1}$

$ca_{21y} = 0 * p_{11} + A_{2y-1} * p_{21} + \ldots + 0 * p_{i1}$

$ca_{22y} = 0 * p_{12} + A_{2y-1} * p_{22} + \ldots + 0 * p_{i2}$

$ca_{ijy} = 0 * p_{1j} + 0 * p_{2j} + \ldots + A_{iy-1} * p_{ij}$

Area of each land use category is decreased due to transition to other land categories and increased due to transition from other land use categories. In year $y+1$, the area of a land use category is the sum of the area staying in the same land use category (e.g., ca_{11y}) plus the area that transitioned to that land use category from other land use categories (e.g., $ca_{21\,y}$, $ca_{31\,y}$, and $ca_{i1\,y}$). Area of land use category *j* in year *y+1*, $A_{j\,y+1}$, is calculated as follows:

$$A_{j\,y+1} = \sum_i ca_{ij\,y} \qquad \text{Equation 7}$$

Where:

$A_{j\,y+1}$	Area of land use category *j* in project area in year *y+1*; ha
$ca_{ij\,y}$	Area of land converted from land use category *i* to *j* in the project area in year *y*; ha

Please refer to section J for determination of EF_{ij}, $A_{i\,0}$ and p_{ij}, i.e., *MEF*, MA_0 and *MP*.

H. Calculation of project net emissions

Project net emissions in year *y* during the monitoring period are estimated based on results of monitoring, and calculated as follows:

$$PE_y = \Delta CS_{pj\,y} * 44/12 + E_{fuel\,y} + E_{fertilizer\,y} + DE_y \qquad \text{Equation 8}$$

Where:

PE_y	Project net emissions in year *y*; tCO_2-eq
$\Delta CS_{pj\,y}$	Carbon stock change in the project area in year *y*; tC
$E_{fuel\,y}$	CO_2 emissions from fossil fuel combustion in year *y* due to the project activities; tCO_2
$E_{fertilizer\,y}$	GHG emissions from fertilizer application within the project area and the activity area as a part of the project activities in year *y*; tCO_2-eq
DE_y	Displaced emissions to the displacement belt in year *y*; tCO_2

(1) Carbon stock change in the project area in year *y*, $\Delta CS_{pj\,y}$

The same option applied in the calculation of the project reference level must be used for the project emissions.

<u>Option 1: Use the National FRL transition probabilities from forest to non-forest classes only</u>

Carbon stock change in the project area in year *y* is calculated as follows:

$$\Delta CS_{pj\,y} = \sum_i \Delta CS_{pj\,i\,y} = \sum_i CA_{pj\,i\,y} * EF_i \qquad \text{Equation 9}$$

Where:

$\Delta CS_{pj\ y}$	Carbon stock change in the project area in year *y*; tC
$\Delta CS_{pj\ i\ y}$	Carbon stock change in area converted from forest class *i* to non-forest in the project area in year *y*; tC
$CA_{pj\ i\ y}$	Area converted from forest class *i* to non-forest in the project area in year *y*; ha
EF_i	Emission factor applicable for forest class *i*; tC ha^{-1}

$CA_{pj\ i\ y}$ will be determined using Cambodia's official forest maps provided by the government; calculated as the yearly average, if the monitoring interval is more than one year.

Accuracy assessment: to better account for the uncertainty that may be present in Cambodia's official forest map within the project area, an accuracy assessment will be performed of the project area and displacement belt. The accuracy assessment will be performed on the most recent official forest map and using a combination of the points used by the government of Cambodia and with additional points to ensure representative coverage of all classes within the project area. The results of the accuracy assessment of the project area and the displacement belt will determine the error-adjusted area estimates for each forest class. The accuracy assessment will be performed at the start of the project and each subsequent monitoring period to ensure high quality estimates of emission and reductions. This process is based on the methods included in Olofsson et al. 2014 and is endorsed by the FAO. However, the error adjustment of the areas will not be performed, if the government of Cambodia decides to require the project to use Cambodia's official forest map as it is.

See section J for EF_i.

Option 2: Use all the National FRL transition probabilities among classes that would result in GHG emissions

To estimate the total emissions, the carbon stock change in the project area in year *y* is calculated as follows:

$$\Delta CS_{pj\ y} = \sum_i \sum_j cs_{pj\ ij\ y} \begin{cases} cs_{pj\ ij\ y}, & \text{if } cs_{pj\ ij\ y} > 0 \\ 0, & \text{otherwise} \end{cases} \quad \text{Equation 10}$$

Where:

$\Delta CS_{pj\ y}$	Carbon stock change in the project area in year *y*; tC
$cs_{pj\ ij\ y}$	Carbon stock change in the project area from changes of land use category *i* to *j*

in year y; tC

The notation $cs_{pj\ ij\ y}$ is an element of i-by-j cross-tabulation matrix $MCS_{pj\ y}$ which is a product of element-wise multiplication (Hadamard product) of i-by-j matrices of area changes and emission factors.

$$\mathrm{MCS}_{pj\ y} = \mathrm{MCA}_{pj\ y} \cdot \mathrm{MEF} \qquad \text{Equation 11}$$

Where:

$MCS_{pj\ y}$	i-by-j matrix in which each element is carbon stock change in the project area from changes in land use category i to j in year y, $cs_{pj\ ij\ y}$; tC
$MCA_{pj\ y}$	i-by-j matrix in which each element is the area of land converted from land use category i to j in the project area in year y, $ca_{pj\ ij\ y}$; ha
$ca_{pj\ ij\ y}$	Area of land converted from land use category i to j in the project area in year y; ha
MEF	i-by-j matrix in which each element is emission factor for area of land converted from land use category i to j, EF_{ij}; tC ha^{-1}

$ca_{pj\ ij\ y}$ will be determined using Cambodia's official forest maps provided by the government; calculated as the yearly average, if the monitoring interval is more than one year.

To quantify and account for the uncertainty of Cambodia's official forest map in the project area, an accuracy assessment will be performed as described above.

See section J for EF_{ij}.

(2) Emissions due to the project activities

Based on the requirements of the methodology guidelines ver01.0, emissions resulting from the implementation of the project activities shall be accounted, including fossil fuel combustion and the application of fertilizer (synthetic fertilizer, organic fertilizer, N-fixing crop, liming material and urea fertilizer). If the GHG emissions, due to use of fuel or the application of fertilizers, are estimated to less than five percent of the total net emissions at the time of validation, quantities of such GHG sources do not need to be monitored, and planned quantities can be used for calculation of GHG emissions.

<u>Emissions from fossil fuel combustion</u>

CO_2 emissions from fossil fuel combustion resulting from the implementation of project activities[1] are calculated by applying the following direct method or indirect method, and these can be used interchangeably or simultaneously for different types of vehicle and equipment. E.g., project participant can calculate $E_{fuel\ y}$ by applying the direct method for motorbikes and the in-direct method for trucks.

Direct method

$$E_{fuel\ y} = \sum_f E_{fuel\ f\ y} = \sum_f (FC_{f\ y} * NCV_f * EF_{fuel\ f}) \quad \text{Equation 12}$$

Where:

$E_{fuel\ y}$	CO_2 emissions from fossil fuel combustion in year *y* due to the project activities; tCO_2
$E_{fuel\ f\ y}$	CO_2 emissions from combustion of fossil fuel type *f* in year *y*; tCO_2
$FC_{f\ y}$	Quantity of fuel type *f* consumed in year *y*; kg
NCV_f	Net calorific value of fuel *f*; GJ kg^{-1}
$EF_{fuel\ f}$	CO_2 emission factor of the fuel type *f* combusted; tCO_2 GJ^{-1}
f	fuel types combusted; dimensionless

See section J for NCV_f and $EF_{fuel\ f}$.

Indirect method

$$E_{fuel\ y} = \sum_f \sum_j E_{fuel\ j\ f\ y} = \sum_f \sum_j (NVE_{j\ f\ y} * TDU_{j\ f\ y} * SEC_{j\ f} * NCV_f * EF_{fuel\ f}) \quad \text{Equation 13}$$

Where:

$E_{fuel\ y}$	CO_2 emissions from fossil fuel combustion in year *y* due to the project activities; tCO_2
$E_{fuel\ j\ f\ y}$	CO_2 emissions from fossil fuel combustion in vehicle or equipment type *j* using fuel type *f* in year *y*; tCO_2
$NVE_{j\ f\ y}$	Number of vehicle or equipment type *j* using fuel type *f* in year *y*; unit
$TDU_{j\ f\ y}$	Total travel distance for vehicle type *j* or use hours for equipment type *j* using fuel type *f* in year *y*; km or hour $unit^{-1}$
$SEC_{j\ f}$	Average specific energy consumption of vehicle or equipment type *j* for fuel type *f*; kg km^{-1} or $hour^{-1}$
NCV_f	Net calorific value of fuel *f*; GJ kg^{-1}
$EF_{fuel\ f}$	CO_2 emission factor of the fuel type *f* combusted; tCO_2 GJ^{-1}

[1] A/R methodological tool “Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities” was referenced.

f	fuel types combusted; dimensionless
j	type of vehicle or equipment; dimensionless

For NCV_f, $EF_{fuel\ f}$, and $SEC_{j\ f}$, see section J.

Emissions from fertilizer application

GHG emissions from fertilizer application are calculated as follow:

$$E_{fertilizer\ y} = E_{direct\text{-}N\ y} + E_{indirect\text{-}N\ y} + E_{liming\ y} + E_{urea\ y}$$ Equation 14

Where:

$E_{fertilizer\ y}$	GHG emissions from fertilizer application within the project area and the activity area for implementation of the project activities in year *y*; tCO_2-eq
$E_{direct\text{-}N\ y}$	Direct N_2O emissions as a result of nitrogen application within the project area and the activity area for implementation of the project activities in year *y*; tCO_2-eq
$E_{indirect\text{-}N\ y}$	Indirect N_2O emissions as a result of nitrogen application within the project area and the activity area for implementation of the project activities in year *y*; tCO_2-eq
$E_{liming\ y}$	CO_2 emissions as a result of adding liming materials within the project area and the activity area for implementation of the project activities in year *y*; tCO_2
$E_{urea\ y}$	CO_2 emissions as a result of urea fertilization application within the project area and the activity area for implementation of the project activities in year *y*; tCO_2

Direct N_2O emissions as a result of nitrogen application for the implementation of the project activities are calculated as follow[2]:

$$E_{direct-N\ y} = \sum_c [\left(F_{SN\ c\ y} + F_{ON\ c\ y} + F_{CR\ c\ y}\right) * EF_{direct-N\ c}] * 44/28 * GWP_{N2O}$$

Equation 15

Where:

$E_{direct\text{-}N\ y}$	Direct N_2O emissions as a result of nitrogen application within the project area and the activity area for implementation of the project activities in year *y*; tCO_2-eq
$F_{SN\ c\ y}$	Mass of nitrogen in synthetic fertilizer applied for implementation of the project activities in cropland type *c* in the project area and the activity area in year *y*; tN

[2] This is based on A/R Methodology tool “Estimation of direct nitrous oxide emission from nitrogen fertilization” and 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

$F_{ON\ c\ y}$	Mass of nitrogen in organic fertilizer made from materials sourced from outside of the project area and the activity area and applied for implementation of the project activities in cropland type *c* in the project area and the activity area in year *y*; tN
$F_{CR\ c\ y}$	Mass of nitrogen in crop residues (above-ground and below-ground) in N-fixing crops, introduced for implementation of the project activities in cropland type *c* in the project area and the activity area and returned to soils, in year *y*; tN
$EF_{direct\text{-}N\ c}$	Emission factor for N_2O emissions from nitrogen inputs in cropland type *c*; t N_2O-N tN-input^{-1}
44/28	Ratio of molecular weight of N_2O and N; dimensionless
GWP_{N2O}	Global Warming Potential for N_2O; tCO_2 (t N_2O)$^{-1}$
c	Types of croplands: upland cropland and flooded cropland such as rice paddy; dimensionless

See section J for $EF_{direct\text{-}N\ c}$ and GWP_{N2O}.

$$F_{SN\ c\ y} = M_{SN\ c\ y} * NC_{SN\ c} \quad \text{Equation 16}$$

$$F_{ON\ c\ y} = M_{ON\ c\ y} * NC_{ON\ c} \quad \text{Equation 17}$$

Where:

$F_{SN\ c\ y}$	Mass of nitrogen in synthetic fertilizer applied for implementation of the project activities in cropland type *c* in the project area and the activity area in year *y*, tN
$F_{ON\ c\ y}$	Mass of nitrogen in organic fertilizer made from materials sourced from outside of the project area and the activity area and applied for implementation of the project activities in cropland type *c* in the project area and the activity area in year *y*, tN
$M_{SN\ c\ y}$	Mass of synthetic fertilizer applied for implementation of the project activities in cropland type *c* in the project area and the activity area in year *y*, t
$M_{ON\ c\ y}$	Mass of organic fertilizer made from materials sourced from outside of the project area and the activity area and applied for implementation of the project activities in cropland type *c* in the project area and the activity area in year *y*, t
$NC_{SN\ c}$	Nitrogen content of synthetic fertilizer applied in cropland type *c*; tN (t fertilizer)$^{-1}$
$NC_{ON\ c}$	Nitrogen content of organic fertilizer applied in cropland type *c*; tN (t fertilizer)$^{-1}$

Data from producers of synthetic fertilizer and published data are used for $NC_{SN\ c}$ $NC_{ON\ c}$, respectively. If multiple types of synthetic or organic fertilizers are used, choose the highest data as a conservative estimation. Note that organic fertilizer which is made from organic materials sourced from inside the project area and the activity area are NOT accounted because the emissions from those organic materials occur in the areas regardless the implementation of the project activities.

$$F_{CR\,c\,y} = \sum_T \left[Crop_{c\,T\,y} * Area_{c\,T\,y} * Frac_{Renew\,T} * (R_{AG\,T} * N_{AG\,T} + R_{BG\,T} * N_{BG\,T}) \right]$$

Equation 18

Where:

$F_{CR\,c\,y}$	Mass of nitrogen in crop residues (above-ground and below-ground) in N-fixing crops, introduced for implementation of the project activities in cropland type *c* in the project area and the activity area and returned to soils, in year *y*; tN
$Crop_{c\,T\,y}$	Harvested annual dry matter yield for N-fixing crop *T* per unit area, introduced for implementation of the project activities in cropland type *c* in the project area and the activity area in year *y*; t d.m. ha^{-1}
$Area_{c\,T\,y}$	Total annual area harvested of N-fixing crop *T*, introduced for implementation of the project activities in cropland type *c* in the project area and the activity area in year *y*; ha
$Frac_{Renew\,T}$	Fraction of total area under N-fixing crop *T* that is renewed annually; dimensionless, 0-1
$R_{AG\,T}$	Ratio of above-ground residues to harvested yield for N-fixing crop *T*; t d.m. $(t\ d.m.)^{-1}$
$N_{AG\,T}$	N content of above-ground residues for N-fixing crop *T*; t N $(t\ d.m.)^{-1}$
$R_{BG\,T}$	Ratio of below-ground residues to harvested yield for N-fixing crop *T*; t d.m. $(t\ d.m.)^{-1}$
$N_{BG\,T}$	N content of below-ground residues for N-fixing crop *T*; t N $(t\ d.m.)^{-1}$
T	Types of N-fixing crops; dimensionless

Where cropland is renewed on average every X years, $Frac_{renew}$ = 1/X. For annual crops $Frac_{renew}$ = 1.

Indirect N_2O emissions as a result of nitrogen application for implementation of the project activities are calculated as follow:

$$E_{indirect-N,y} = \left[\left(F_{SN\,y} * Frac_{SN} + F_{ON\,y} * Frac_{ON} \right) * EF_{indirect-N} + \left(F_{SN\,y} + F_{ON\,y} + F_{CR\,y} \right) * Frac_{leach} * EF_{leach-N} \right] * {}^{44}/_{28} * GWP_{N2O}$$

Equation 19

Where:

$E_{indirect\text{-}N\ y}$	Indirect N_2O emissions as a result of nitrogen application within the project area and the activity area for implementation of the project activities in year *y*; tCO_2-eq
$F_{SN\ y}$	Mass of nitrogen in synthetic fertilizer applied for implementation of the project activities in the project area and the activity area in year *y*; tN
$F_{ON\ y}$	Mass of nitrogen in organic fertilizer made from materials sourced from outside the project area and the activity area and applied for implementation of the project activities in the project area and the activity area in year *y*; tN
$F_{CR\ y}$	Mass of nitrogen in crop residues (above-ground and below-ground) in N-fixing crops, introduced for implementation of the project activities in the project area and the activity area and returned to soils, in year *y*; tN
$Frac_{SN}$	Fraction that volatilized as NH_3 and NO_X for synthetic fertilizers; dimensionless, 0-1
$Frac_{ON}$	Fraction that volatilized as NH_3 and NO_X for organic fertilizers; dimensionless, 0-1
$EF_{indirect\text{-}N}$	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces; t N_2O-N (t NH_3-N and NO_X-N volatilized)$^{-1}$
$Frac_{leach}$	Fraction of N that is lost through leaching and runoff; dimensionless, 0-1
$EF_{leach\text{-}N}$	Emission factor for N_2O emissions from N leaching and runoff; t N_2O-N (t N leaching and runoff)$^{-1}$
44/28	Ratio of molecular weight of N_2O and N; dimensionless
GWP_{N2O}	Global Warming Potential for N_2O; tCO_2 (t N_2O)$^{-1}$

See Section J for $Frac_{SN}$, $Frac_{ON}$, $Frac_{leach}$, $EF_{indirect\text{-}N}$, $EF_{leach\text{-}N}$ and GWP_{N2O}.

$$F_{SN\ y} = \sum_c F_{SN\ c\ y} \quad \text{Equation 20}$$

$$F_{ON\ y} = \sum_c F_{ON\ c\ y} \quad \text{Equation 21}$$

$$F_{CR\ y} = \sum_c F_{CR\ c\ y} \quad \text{Equation 22}$$

Where:

$F_{SN\ y}$	Mass of nitrogen in synthetic fertilizer applied for implementation of the project activities in the project area and the activity area in year *y*; tN
$F_{ON\ y}$	Mass of nitrogen in organic fertilizer made from materials sourced from outside the project area and the activity area and applied for implementation of the project activities in the project area and the activity area in year *y*; tN
$F_{CR\ y}$	Mass of nitrogen in crop residues (above-ground and below-ground) in N-fixing

	crops, introduced for implementation of the project activities in the project area and the activity area and returned to soils, in year *y*; tN
$F_{SN\ c\ y}$	Mass of nitrogen in synthetic fertilizer applied for implementation of the project activities in cropland type *c* in the project area and the activity area in year *y*; tN
$F_{ON\ c\ y}$	Mass of nitrogen in organic fertilizer made from materials sourced from outside the project area and the activity area and applied for implementation of the project activities in cropland type *c* in the project area and the activity area in year *y*; tN
$F_{CR\ c\ y}$	Mass of nitrogen in crop residues (above-ground and below-ground) in N-fixing crops, introduced for implementation of the project activities in cropland type *c* in the project area and the activity area and returned to soils, in year *y*; tN

Use $F_{SN\ c\ y}$, $F_{ON\ c\ y}$ and $F_{CR\ c\ y}$ calculated in Equations 16, 17 and 18.

CO_2 emissions as a result of adding liming materials for implementation of the project activities are calculated as follow:

$$E_{liming\ y} = \left(M_{limestone\ y} * EF_{limestone} + M_{dolomite\ y} * EF_{dolomite}\right) * {}^{44}/_{12}$$ Equation 23

Where:

$E_{liming\ y}$	CO_2 emissions as a result of adding liming materials within the project area and the activity area during implementation of the project activities in year *y*; tCO_2
$M_{limestone\ y}$	Mass of calcic limestone ($CaCO_3$) applied for implementation of the project activities in the project area and the activity area in year *y*; t
$EF_{limestone}$	Emission factor for limestone; t C (t limestone)$^{-1}$
$M_{dolomite\ y}$	Mass of dolomite ($CaMg(CO_3)_2$) applied for implementation of the project activities in the project area and the activity area in year *y*; t
$EF_{dolomite}$	Emission factor for dolomite; t C (t dolomite)$^{-1}$
44/12	Ratio of molecular weight of CO_2 and C; dimensionless

See Section J for $EF_{limestone}$ and $EF_{dolomite}$.

CO_2 emissions as a result of urea fertilization application for implementation of the project activities are calculated as follow:

$$E_{urea\ y} = M_{urea\ y} * EF_{urea} * {}^{44}/_{12}$$ Equation 24

Where:

$E_{urea\ y}$	CO_2 emissions as a result of application of urea within the project area and the

	activity area for implementation of the project activities in year *y*; tCO_2
$M_{urea\ y}$	Mass of urea fertilizer applied for implementation of the project activities in the project area and the activity area in year *y*; t
EF_{urea}	Emission factor for urea; t C/t urea
44/12	Ratio of molecular weight of CO_2 and C; dimensionless

See Section J for EF_{urea}.

(3) Displaced emissions

In this methodology, displacement is assessed through monitoring of the displacement belt. The displacement belt captures the displacement of baseline activities due to the project activities, or interventions, in the project area.

Although a detailed analysis of the local drivers of deforestation and degradation is not anticipated, the local context will be captured through inputs from local and national experts including authorities. Displaced emissions are calculated as increases of emissions compared to reference emissions from the displacement belt which is separately calculated from reference emissions for the project reference level.

Displaced emissions are calculated as follows:

$$DE_y = \begin{cases} DP_y - DR_y, & \text{if } DP_y - DR_y > 0 \\ 0, & \text{otherwise} \end{cases}$$ Equation 25

Where:

DE_y	Displaced emissions to the displacement belt in year *y*; tCO_2
DR_y	Reference emissions from the displacement belt in year *y*; tCO_2
DP_y	Project emissions from the displacement belt in year *y*; tCO_2

DR_y and DP_y are calculated as follows:

$DR_y = \Delta CS_{d\ y} * 44/12$ Equation 26

Where:

DR_y	Reference emissions from the displacement belt in year *y*; tCO_2
$\Delta CS_{d\ y}$	Projected carbon stock change in the displacement belt in year *y*; tC
44/12	Conversion factor of molecular weight of carbon to CO_2; dimensionless

$DP_y = \Delta CS_{d\ pj\ y} * 44/12$ Equation 27

Where:

DP_y	Project emissions from the displacement belt in year *y*; tCO_2
$\Delta CS_{d\ pj\ y}$	Actual carbon stock change in the displacement belt in year *y*; tC
44/12	Conversion factor of molecular weight of carbon to CO_2; dimensionless

Projected and actual carbon stock changes in the displacement belt area, i.e., $\Delta CS_{d\ y}$ and $\Delta CS_{d\ pj\ y}$, are calculated by applying the option used in Section G.2 Calculation of project reference level.

Option 1: Use the National FRL transition probabilities from forest to non-forest classes only

Projected carbon stock change in the displacement belt in year *y* is calculated as follows:

$$\Delta CS_{d\ y} = \sum_i A_{d\ i\ y-1} * P_{d\ i} * EF_i$$ Equation 28

Where:

$\Delta CS_{d\ y}$	Projected carbon stock change in the displacement belt in year *y*; tC
$A_{d\ i\ y}$	Area of forest class *i* in the displacement belt in year *y*; ha
$P_{d\ i}$	Annual transition probability from forest class *i* to non-forest within the displacement belt; dimensionless, 0-1
EF_i	Emission factor applicable for forest class *i*; tC ha^{-1}

Area of forest class *i* is assumed to decrease every year due to deforestation, and therefore calculated as follows:

$$A_{d\ i\ y+1} = A_{d\ i\ y} * (1 - P_{d\ i})$$ Equation 29

Where:

$A_{d\ i\ y}$	Area of forest class *i* in the displacement belt in year *y*; ha
$P_{d\ i}$	Annual transition probability from forest class *i* to non-forest within the displacement belt; dimensionless, 0-1

Please refer section J for $A_{d\ i\ 0}$ and $P_{d\ i}$.

Actual carbon stock change in the displacement belt in year *y* is calculated as follows:

$$\Delta CS_{d\ pj\ y} = \sum CA_{d\ pj\ i\ y} * EF_i$$ Equation 30

Where:

$\Delta CS_{d\ pj\ y}$	Actual carbon stock change in the displacement belt in year *y*; tC
$CA_{d\ pj\ i\ y}$	Area converted from forest class *i* to non-forest in the displacement belt in year *y*; ha
EF_i	Emission factor applicable for land use category *i*; tC ha^{-1}

$CA_{d\ pj\ i\ y}$ will be determined using Cambodia's official forest maps provided by the government; calculated as yearly average, if the monitoring interval is more than one year. Where evidence can be collected that deforestation in the displacement belt is not attributable to the project, the detected deforestation is not considered as displacement and therefore is excluded from $CA_{d\ pj\ i\ y}$.

To quantify and account for the uncertainty of Cambodia's official forest map in the project area, an accuracy assessment will be performed as described in Section H calculation of project net emission, sub-section (1) carbon stock change in the project area.

See section J for EF_i.

Option 2: Use all transition probabilities resulting in emissions in the National FRL

Projected carbon stock change in the displacement belt in year *y* is calculated as follows:
To estimate the total emissions, the projected carbon stock change in year *y* in the displacement belt is calculated as follows:

$$\Delta CS_{d\ y} = \sum_i \sum_j cs_{d\ ij\ y} \begin{cases} cs_{d\ ij\ y}, & \text{if } cs_{d\ ij\ y} > 0 \\ 0, & \text{otherwise} \end{cases} \quad \text{Equation 31}$$

Where:

$\Delta CS_{d\ y}$	Projected carbon stock change in the displacement belt in year *y*; tC
$cs_{d\ ij\ y}$	Projected carbon stock change in the displacement belt from changes of land use category *i* to *j* in year *y*; tC

The notation $cs_{d\ ij}$ is an element of *i*-by-*j* cross-tabulation matrix $MCS_{d\ y}$ which is a product of element-wise multiplication (Hadamard product) of *i*-by-*j* matrices of area changes and emission factors.

$$\mathrm{MCS}_{d\ y} = \mathrm{MCA}_{d\ y} \cdot \mathrm{MEF} \quad \text{Equation 32}$$

Where:

$MCS_{d\ y}$	*i*-by-*j* matrix in which each element is projected carbon stock change in the displacement belt from changes of land use category *i* to *j* in year *y*, $cs_{d\ ij\ y}$; tC

$MCA_{d\ y}$	*i*-by-*j* matrix in which each element is projected area of land converted from land use category *i* to *j* in the displacement belt in year *y*, $ca_{d\ ij\ y}$; ha
MEF	*i*-by-*j* matrix in which each element is the emission factor for area of land converted from land use category *i* to *j*, EF_{ij}; tC ha^{-1}

Projected area of land conversion in year *y* is calculated as the product between areas of land categories in the displacement belt in year *y* and annual transition probability.

$$\mathrm{MCA}_{\mathrm{d\ y}} = \mathrm{MA}_{\mathrm{d\ y-1}}\mathrm{MP}_{d} \quad \text{Equation 33}$$

Where:

$MCA_{d\ y}$	*i*-by-*j* matrix in which each element is the projected area of land converted from land use category *i* to *j* in the displacement belt in year *y*, $ca_{d\ ij\ y}$; ha
$MA_{d\ y\text{-}1}$	*i*-by-*j* diagonal matrix whose diagonal elements are areas of land use categories in the displacement belt in year *y-1*, $A_{d\ i\ y\text{-}1}$; ha
MP_d	*i*-by-*j* matrix in which each element is the annual transition probability from land use category *i* to *j* in the displacement belt, $p_{d\ ij}$; dimensionless, 0-1

Similar to Equation 7, area of land use category *j* in year *y+1*, $A_{d\ j\ y+1}$, is calculated as follows:

$$A_{d\ j\ y+1} = \sum_i ca_{d\ i j\ y} \quad \text{Equation 34}$$

Where:

$A_{d\ j\ y+1}$	Area of land use category *j* in the displacement belt in year *y+1*; ha
$ca_{d\ ij\ y}$	Area of land converted from land use category *i* to *j* in the displacement belt in year *y*; ha

Please refer section J for determination of EF_{ij}, $A_{d\ i\ 0}$ and $p_{d\ ij}$, i.e., *MEF*, $MA_{d\ 0}$ and MP_d.

<u>Actual carbon stock change</u> in the displacement belt in year *y* is calculated as follows:
To estimate the total emissions, the carbon stock change in the displacement belt in year *y* is calculated as follows:

$$\Delta CS_{d\ pj\ y} = \sum_i \sum_j cs_{d\ pj\ ij\ y} \begin{cases} cs_{d\ pj\ ij\ y}, & \text{if } cs_{d\ pj\ ij\ y} > 0 \\ 0, & \text{otherwise} \end{cases} \quad \text{Equation 35}$$

Where:

$\Delta CS_{d\ pj\ y}$	Actual carbon stock change in the displacement belt in year *y*; tC
$cs_{d\ pj\ ij\ y}$	Carbon stock change in the displacement belt from changes of land use category *i* to *j* in year *y*; tC

The notation $cs_{d\ pj\ ij}$ is an element of the *i*-by-*j* cross-tabulation matrix $MCS_{d\ pj\ y}$ which is a product of element-wise multiplication (Hadamard product) of *i*-by-*j* matrices of area changes and emission factors.

$$\mathrm{MCS}_{d\,pj\,y} = \mathrm{MCA}_{d\,pj\,y} \cdot \mathrm{MEF} \qquad \text{Equation 36}$$

Where:

$MCS_{d\ pj\ y}$	*i*-by-*j* matrix in which each element is carbon stock change in the displacement belt from changes of land use category *i* to *j* in year *y*, $cs_{d\ pj\ ij\ y}$; tC
$MCA_{d\ pj\ y}$	*i*-by-*j* matrix in which each element is area of land converted from land use category *i* to *j* in the displacement belt in year *y*, $ca_{d\ pj\ ij\ y}$; ha
$ca_{d\ pj\ ij\ y}$	Area of land converted from land use category *i* to *j* in the displacement belt in year *y*; ha
MEF	*i*-by-*j* matrix in which each element is emission factor for area of land converted from land use category *i* to *j*, EF_{ij}; tC ha^{-1}

$ca_{d\ pj\ ij\ y}$ will be determined by using Cambodia's official forest maps provided by the government, will be calculated as yearly average, if the monitoring interval is more than one year. Where evidence can be collected that deforestation in the displacement belt is not attributable to the project, the detected deforestation is not considered as displacement and therefore is excluded from $MCA_{d\ pj\ y}$.

To quantify and account for the uncertainty of Cambodia's official forest map in the project area, an accuracy assessment will be performed as described in Section H calculation of project net emission, sub-section (1) carbon stock change in the project area.

See section J for EF_{ij}.

I. Calculation of project emission reductions to be credited

Project emission reductions in year y are calculated as the difference between the project reference level and the project net emissions.

$$ER_y = RL_y - PE_y \qquad \text{Equation 37}$$

Where:

ER_y	Project emissions reductions in year *y*; tCO_2-eq

RL_y	Project reference level in year *y*; tCO_2
PE_y	Project net emissions in year *y*; tCO_2-eq

$ER_{credt\ y} = ER_y * (1\text{-}DF)$ Equation 38

Where:

$ER_{credit\ y,}$	Project emissions reductions available to be credited in year *y*; tCO_2-eq
ER_y	Project emissions reductions in year *y*; tCO_2-eq
DF	Discount factor, default as 0.2

A discount factor is applied as a measure for risk of reversals.

Project emissions reductions available to be credited for a monitoring period are calculated as follows:

$$ER_{credit\ p} = \sum_i ER_{credit\ y}$$ Equation 39

Where:

$ER_{credit\ p}$	Project emissions reductions available to be credited for a monitoring period *p*; tCO_2-eq
$ER_{credit\ y,}$	Project emissions reductions available to be credited in year *y*; tCO_2-eq

J. Data and parameters fixed *ex ante*

The lists of the source of each data and parameter fixed *ex ante* and the source of each of default values selected in this methodology are available at the end of this section.
The same option applied in the calculation of project reference level must be used.

(1) Emission factors for land conversions
Emission factors are calculated by applying carbon stock data used in National FRL, or other official report by Cambodian government.

Table 1 shows carbon stock data used in the National FRL submitted in 2017. As new official data becomes available, emission factors can be updated in coordination with government of Cambodia.

Table 1 Above ground and below ground biomass data used in the National FRL submitted in

2017

Forest/Non-Forest	Land use category	Abbreviation	Above-ground, $tCha^{-1}$	Below-ground, $tCha^{-1}$	Total biomass, $tCha^{-1}$
Forest	Evergreen forest	E	76.61	14.69	91.30
	Semi-evergreen forest	SE	114.21	20.9	135.11
	Pine forest	P	47	9.54	56.54
	Deciduous forest	D	39.95	8.26	48.21
	Bamboo	B	0	0	0
	Mangrove	M	70.5	13.65	84.15
	Rear Mangrove	MR	77.55	14.85	92.40
	Flooded forest	FF	32.9	6.96	39.86
	Forest regrowth	FR	35.25	7.4	42.65
	Tree plantation	TP	47	9.54	56.54
	Pine plantation	PP	47	9.54	56.54
Non-forest	Non-forest	NF	0	0	0

Although Cambodia defined tree plantation (TP) and pine plantation (PP) as forest, emissions and removals in areas converted from the other forest categories to these two categories were excluded from the National FRL submitted in 2017 in consideration of safeguards, while those in areas converted from TP and PP to the other land use categories are included. The project participant uses the latest National FRL, and apply zero as EF for the conversion categories which are excluded from calculation in the National FRL.

<u>Option 1: Use the National FRL transition probabilities from forest to non-forest classes only</u>
EF_i is an emission factor for area of land converted from land use category *i*, which is forest, to non-forest.

$$EF_i = \sum_k C_{ik} \quad \text{Equation 40}$$

Where:

EF_i	Emission factor applicable for forest class *i*; $tC\ ha^{-1}$
C_{ik}	Carbon stock in carbon pool *k* in forest class *i* per unit area; $tC\ ha^{-1}$
k	Carbon pools included in establishment of National FRL; dimensionless

Above ground and below ground are the carbon pools included in the establishment of the National FRL submitted in 2017. Table 2 shows the calculated EF_i based on the National FRL submitted in 2017.

Table 2 Emission factors, EF_i, for Option 1 based on the National FRL submitted in 2017

Forest class, *i*	Abbreviation	EF_i, tC ha^{-1}
Evergreen forest	E	91.30
Semi-evergreen forest	SE	135.11
Pine forest	P	56.54
Deciduous forest	D	48.21
Bamboo	B	0
Mangrove	M	84.15
Rear Mangrove	MR	92.40
Flooded forest	FF	39.86
Forest regrowth	FR	42.65
Tree plantation	TP	56.54
Pine plantation	PP	56.54
Non-forest	NF	0

Option 2: Use all the National FRL transition probabilities among classes that would result in emissions

EF_{ij} is an emission factor for area of land converted from land use category *i* to *j*.

$$EF_{ij} = \sum_k C_{ik} - \sum_k C_{jk} \quad \text{Equation 41}$$

Where:

EF_{ij} Emission factor for area of land converted from land use category *i* to *j*; tC ha^{-1}

C_{ik} Carbon stock in carbon pool *k* in land use category *i* per unit area; tC ha^{-1}

k Carbon pools included in establishment of National FRL; dimensionless

Table 3 Emission factors, EF_{ij}, for Option 2 based on the National FRL submitted in 2017

		Land use category *j*											
		E	SE	P	D	B	M	MR	FF	FR	TP	PP	NF
i	E	0.00	NA	34.76	43.09	91.30	7.15	NA	51.44	48.65	NA	NA	91.30
	SE	43.81	0.00	78.57	86.90	135.11	50.96	42.71	95.25	92.46	NA	NA	135.11
	P	NA	NA	0.00	8.33	56.54	NA	NA	16.68	13.89	NA	NA	56.54
	D	NA	NA	NA	0.00	48.21	NA	NA	8.35	5.56	NA	NA	48.21
	B	NA	NA	NA	NA	0.00	NA	NA	NA	NA	NA	NA	0.00
	M	NA	NA	27.61	35.94	84.15	0.00	NA	44.29	41.50	NA	NA	84.15

	MR	1.10	NA	35.86	44.19	92.40	8.25	0.00	52.54	49.75	NA	NA	92.40
	FF	NA	NA	NA	NA	39.86	NA	NA	0.00	NA	NA	NA	39.86
	FR	NA	NA	NA	NA	42.65	NA	NA	2.79	0.00	NA	NA	42.65
	TP	NA	NA	0.00	8.33	56.54	NA	NA	16.68	13.89	0.00	0.00	56.54
	PP	NA	NA	0.00	8.33	56.54	NA	NA	16.68	13.89	0.00	0.00	56.54
	NF	NA	NA	NA	NA	0.00	NA	NA	NA	NA	NA	NA	0.00

Note that when a land use category with a higher carbon stock is converted to a lower carbon stock, e.g., conversion from evergreen forest to non-forest, the EF_{ij} is positive. Removals are not included in this methodology, and therefore emission factors for conversions from a land use category with lower carbon stock to higher carbon stock are not available in Table 3. As previously described, emissions and removals in areas converted from the other forest categories to tree plantation (TP) or pine plantation (PP) were excluded in the establishment of the National FRL submitted in 2017, and therefore *EFs* of those transitions as well as transitions resulting in removals are also not available in Table 3.

(2) Area of land use category *i* at the inception of the project

This method applies to both options, Option 1 and 2, and to the following parameters:

$A_{i\,0}$ — Area of forest class *i* or land use category *i* in the project area at the inception of the project; ha

$A_{d\,i\,0}$ — Area of forest class *i* or land use category *i* in the displacement belt at the inception of the project; ha

The most recent version of Cambodia's official forest map (≤ 2 years) provided by Cambodian government used to determine the area of land use category *i* in the project area and in the displacement belt at the project start date. Once $A_{i\,0}$ and $A_{d\,i\,0}$ are determined in the project design document, these areas, determined at the project start date, will not be updated.

To quantify and account for the uncertainty of Cambodia's official forest map in the project area, an accuracy assessment will be performed as described in Section H calculation of project net emission, sub-section (1) carbon stock change in the project area.

(3) Annual transition probability in the reference area

Option 1: Use the National FRL transition probabilities from forest to non-forest classes only

Annual deforestation rate for each forest type existing inside the project area, P_i, is calculated by applying area, $A_{ref\,i}$, and area change, $CA_{ref\,i}$, from the National FRL and nationally endorsed data sets, and is used in Equation 2. Table 4 shows P_i calculated based on the National FRL submitted in 2017.

$$P_i = CA_{ref\,i} / (A_{ref\,i} * T_{ref}) \qquad \text{Equation 42}$$

Where:

P_i Annual transition probability from forest class *i* to non-forest within the reference area; dimensionless, 0-1

$CA_{ref\ i}$ Area converted into non-forest from forest class *i* during the reference period, e.g., 2006-2014 in the National FRL submitted in 2017, in reference area; ha

$A_{ref\ i}$ Area of forest class *i* in the reference area at the first year, e.g., 2006 in the National FRL submitted in 2017, of the reference period; ha

T_{ref} Number of years, e.g., eight in the National FRL submitted in 2017, in the reference period; year

Table 4 P_i calculated based on the data used in the National FRL submitted in 2017

Forest class	Abbreviation	P_i, dimensionless
Evergreen forest	E	0.0249
Semi-evergreen forest	SE	0.0309
Pine forest	P	0.0000
Deciduous forest	D	0.0345
Bamboo	B	0.0141
Mangrove	M	0.0100
Rear Mangrove	MR	0.0417
Flooded forest	FF	0.0506
Forest regrowth	FR	0.0972
Tree plantation	TP	0.1169
Pine plantation	PP	0.000

<u>Option 2: Use all the National FRL transition probabilities among classes that would result in GHG emissions</u>

Annual transition probability from land use category *i* to *j* is obtained in the form of a transition probability matrix, MP, using the forest area change matrix reported in National FRL and nationally endorsed data sets. It is important to note that the annual transition probability cannot be obtained by simply dividing transition probability in multiple years by number of the years, because transition probability in multiple years, *c* years, is *c*-th power of annual transition probability. It is recommended to use a method provided in a peer reviewed scientific paper for calculation of the annual transition probability, such as Takada et al. 2010[3]. Calculated MP is

[3] Takada T, Miyamoto A and Hasegawa SF (2010) Derivation of a yearly transition probability matrix for land-use dynamics and its applications. Landscape Ecol 25:561-572

used in Equation 6.

Obtain an area-based *i*-by-*j* transition matrix for each of time interval from the National FRL. In the National FRL submitted in 2017, Forest Area Change Matrices between 2006 and 2010 and between 2010 and 2014 area are available in Annex I Emission/Removal Calculation Tables. Annual transition probabilities derived using the matrices in the National FRL submitted in 2017 are available in Table 6 below.

Transition probability in an observation interval *t* is calculated as follows:

$prob_{ij\ t} = CA_{ref\ ij\ t}/A_{ref\ i\ t}$ Equation 43

Where:

$prob_{ij\ t}$	Transition probability from land use category *i* to *j* during an observation time interval *t*; dimensionless, 0-1
$CA_{ref\ ij\ t}$	Area converted from land use category *i* to *j* during an observation time interval *t* within the reference area; ha
$A_{ref\ i\ t}$	Area of land use category *i* at the first year of an observation time interval *t* within reference area; ha

The notion $prob_{ij\ t}$ is an element of *i*-by-*j* cross-tabulation matrix $MP_{multi\ t}$, and $MP_{multi\ t}$ is the T_{multi}-*th* power of annual transition matrix MP_t.

$MP_{multi\ t} = MP_t^{T_{multi}}$ Equation 44

Where:

$MP_{multi\ t}$	*i*-by-*j* matrix in which each element is the transition probability from land use category *i* to *j* during an observation time interval *t*, $prob_{ij\ t}$; dimensionless, 0-1
MP_t	*i*-by-*j* matrix in which each element is the annual transition probability from land use category *i* to *j* during an observation time interval *t*, $p_{ij\ t}$; dimensionless, 0-1
T_{multi}	number of years of observation interval; year

Table 5 shows the transition probability matrix, $MP_{multi\ 2006\text{-}2010}$, in which each element $prob_{ij\ 2006\text{-}2010}$ is the transition probability from *i* to *j* in 4 years between 2006 and 2010 in the cross-tabulation based on the National FRL submitted in 2017. Note that the diagonal elements represent the probabilities of land being in the same category.

Table 5 Cross-tabulation matrix of 4-year, 2006-2010, transition probability based on the National FRL submitted in 2017

	2010											
2006		E	SE	P	D	B	M	MR	FF	FR	TP	PP	NF
	E	0.960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.039
	Se	0.000	0.952	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.045
	P	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	D	0.000	0.000	0.000	0.971	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029
	B	0.000	0.000	0.000	0.000	0.992	0.000	0.000	0.000	0.000	0.000	0.000	0.008
	M	0.004	0.002	0.000	0.000	0.000	0.968	0.001	0.000	0.000	0.000	0.000	0.025
	MR	0.000	0.003	0.000	0.000	0.000	0.003	0.962	0.000	0.002	0.000	0.000	0.030
	FF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.790	0.001	0.000	0.000	0.209
	FR	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.881	0.001	0.000	0.116
	TP	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.004	0.184	0.000	0.811
	PP												
	NF	0.002	0.001	0.000	0.003	0.000	0.000	0.000	0.007	0.007	0.001	0.000	0.979

Obtain the annual transition probability matrix, MP_t, in which each element $p_{ij\ t}$ is the annual transition probability during an observation time interval *t*, by using $MP_{multi\ t}$ and a method provided in a peer reviewed scientific paper for calculation of annual transition probability such as Takada et al. 2010. The obtained MP_t should be validated by applying Equation 44.

If multiple MP_ts from more than one observation time interval are derived, calculate average annual transition probability as follows:

$$p_{ij} = \sum_t p_{ij\ t} / N_{int} \quad \text{Equation 45}$$

Where:

p_{ij} Annual transition probability from land use category *i* to *j* within the reference area; dimensionless, 0-1

$p_{ij\ t}$ Annual transition probability from land use category *i* to *j*during an observation time interval *t*; dimensionless, 0-1

N_{int} Number of observation intervals reported in National FRL; interval

Table 6 shows the annual transition probability matrix, MP, in which each element p_{ij} is annual transition probability from *i* to *j* based on observations during intervals of 2006-2010 and 2010-2014 presented in the National FRL submitted in 2017.

Table 6 Annual transition probability matrix based on observations during intervals of 2006-2010 and 2010-2014 presented in the National FRL submitted in 2017

	y+1											
y		E	SE	P	D	B	M	MR	FF	FR	TP	PP	NF
	E	0.971	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.027
	SE	0.000	0.963	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.035
	P	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

D	0.000	0.000	0.000	0.960	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.040
B	0.000	0.000	0.000	0.000	0.985	0.000	0.000	0.000	0.001	0.000	0.000	0.015
M	0.001	0.000	0.000	0.000	0.000	0.988	0.001	0.000	0.000	0.000	0.000	0.010
MR	0.000	0.000	0.000	0.000	0.000	0.003	0.944	0.000	0.005	0.001	0.000	0.048
FF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.940	0.001	0.000	0.000	0.060
FR	0.004	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.875	0.002	0.000	0.117
TP	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	-0.001	0.003	0.780	0.000	0.219
PP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
NF	0.001	0.001	0.000	0.003	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.990

(4) Annual transition probability in the displacement belt

The same method as (3), Annual transition probability in the reference area, is applied for the displacement belt instead of the reference area.

(5) Parameters for calculating emissions due to the project activities

Fossil fuel combustion

Default net caloric value and net calorific based emission factors are available in the 2006 IPCC Guidelines, and those of selected fuels types are listed in the table for "the source of each data and parameter fixed *ex ante*".

Reference figures such as manufacturer specifications can be used for $SEC_{j\,f}$. If no specific energy consumption data are available, fuel consumption and distance and/or hours are recorded before the initial verification to calculate $SEC_{j\,f}$. Those figures can be used for the entire project period.

Fertilizer application

Data and parameter fixed *ex ante* and default values for calculating N_2O and CO_2 emissions are shown in the tables for "the source of each data and parameter fixed *ex ante*" and "the source of each of default values selected in this methodology" below.

The source of each data and parameter fixed *ex ante* is listed as below.

Parameter	Description of data	Source
$A_{i\,0}$	Area of forest class *i* or land use category *i* in the project area at the inception of the project; ha	Cambodia's official forest map
P_i	Option (1) Annual transition probability from forest class *i* to non-forest within the reference area; dimensionless, 0-1	Cambodia's official forest reference level (National FRL)
p_{ij}	Option (2) Annual transition probability from land use category *i* to *j* within the reference area; dimensionless, 0-1	Cambodia's official forest reference level (National FRL)
EF_i	Option (1) Emission factor applicable for forest	Cambodia's official

	class *i*; tC ha^{-1}	forest reference level (National FRL)
EF_{ij}	Option (2) Emission factor for area of land converted from land use category *i* to *j*; tC ha^{-1}	Cambodia's official forest reference level (National FRL)
$A_{d\ i\ 0}$	Area of forest class *i* in the displacement belt at the inception of the project; ha	Cambodia's official forest map
$P_{d\ i}$	Option (1) Annual transition probability from forest class *i* to non-forest within the displacement belt; dimensionless, 0-1	Cambodia's official forest maps
$p_{d\ ij}$	Option (2) Annual transition probability from land use category *i* to *j* within the displacement belt; dimensionless, 0-1	Cambodia's official forest maps
NCV_f	Net calorific value of fuel *f*; GJ kg^{-1} – Gas/Diesel oil: 43.0 TJ Gg^{-1} – Motor Gasoline: 44.3 TJ Gg^{-1} – Crude Oil: 42.3 TJ Gg^{-1}	Table 1.2 of Ch. 1 Vol. 2 of 2006 IPCC Guidelines
$EF_{fuel\ f}$	CO_2 emission factor of the fuel type *f* combusted; t CO_2 GJ^{-1} – Gas/Diesel Oil: 74,100 kg CO_2 TJ^{-1} – Motor Gasoline: 69,300 kg CO_2 TJ^{-1} – Crude Oil: 73,300 kg TJ^{-1}	Table 3.2.1 of Ch. 3 and Table 2.5 of Ch.2, Vol. 2 of 2006 IPCC Guidelines Tables 2.5 and 3.2.1

The source of each of default values selected in this methodology is listed as below.

Parameter	Description of data	Source
$EF_{direct\text{-}N\ c}$	Emission factor for N_2O emissions from N inputs in cropland type *c*; tN_2O-N (tN-input)$^{-1}$ – Cropland in general: 0.01 tN_2O-N (tN-input)$^{-1}$ – Rice paddy (flooded rice field): 0.003 tN_2O-N (tN-input)$^{-1}$	Table 11.1 of Ch. 11 Vol. 4 of 2006 IPCC Guidelines
$EF_{indirect\text{-}N}$	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces; tN_2O-N (t NH_3-N and NO_X-N volatilized)$^{-1}$ – 0.010 t N_2O-N (t NH_3-N and NO_X-N volatilized)$^{-1}$	Table 11.3 of Ch. 11 Vol. 4 of 2006 IPCC Guidelines
$EF_{leach\text{-}N}$	Emission factor for N_2O emissions from N leaching	Table 11.3 of Ch. 11

	and runoff; tN_2O-N (t leaching and runoff)$^{-1}$ – 0.0075 tN_2O-N (t N leaching and runoff)$^{-1}$	Vol. 4 of 2006 IPCC Guidelines
$EF_{limestone}$	Emission factor for limestone; tC (t limestone)$^{-1}$ – 0.12 tC (t limestone)$^{-1}$	Section 11.3.1 of Ch. 11 Vol. 4 of 2006 IPCC Guidelines
$EF_{dolomite}$	Emission factor for dolomite; tC (t dolomite)$^{-1}$ – 0.13 tC (t dolomite)$^{-1}$	Section 11.3.1 of Ch. 11 Vol. 4 of 2006 IPCC Guidelines
EF_{urea}	Emission factor for urea; tC (t urea)$^{-1}$ – 0.20 tC (t urea)$^{-1}$	Section 11.4.1 of Ch. 11 Vol. 4 of 2006 IPCC Guidelines
GWP_{N2O}	Global Warming Potential for N_2O; tCO_2 $(tN_2O)^{-1}$ – GWP_{100} for N_2O: 298 tCO_2 $(tN_2O)^{-1}$	Table 2.14 in Ch.2 of Working Group I contribution to the IPCC Forth Assessment Report
$Frac_{SN}$	Fraction that volatilized as NH_3 and NO_X for synthetic fertilizers; dimensionless, 0-1 – 0.10	Table 11.3 of Ch. 11 Vol. 4 of 2006 IPCC Guidelines
$Frac_{ON}$	Fraction that volatilized as NH_3 and NO_X for organic fertilizers; dimensionless, 0-1 – 0.20	Table 11.3 of Ch. 11 Vol. 4 of 2006 IPCC Guidelines
$Frac_{leach}$	Fraction of N that area lost through leaching and runoff; dimensionless, 0-1 – 0.30	Table 11.3 of Ch. 11 Vol. 4 of 2006 IPCC Guidelines

History of the document

Version	Date	Contents revised
01.0	21 February 2020	JC5, Annex 5 Initial approval.