

# **ANNEX 1**

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## **MAPPING TABLES**

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## Annex 1 Relating 2019 Refinement to the 2006 IPCC Guidelines

This annex provides a road map for relating sections, equations, tables, figures and boxes in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Type of Refinement: E – Elaboration, U – Update, NG – New Guidance, NR- No Refinement, R - Removed.

### CHAPTER 1, INTRODUCTION

No Refinement to Chapter 1

### CHAPTER 2, GENERIC METHODS

#### Sections

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Introduction	NR	2.1	2.1
Inventory Framework	E	2.2	2.2
Overview of carbon stock change estimation	NR	2.2.1	2.2.1
Overview of non-CO <sub>2</sub> emission estimation	NR	2.2.2	2.2.2
Conversion of C stock changes to CO <sub>2</sub> emissions	NR	2.2.3	2.2.3
Generic methods for CO <sub>2</sub> emissions and removals	NR	2.3	2.3
Change in biomass carbon stocks (above-ground biomass and below-ground biomass)	NR	2.3.1	2.3.1
Land remaining in a land-use category	NR	2.3.1.1	2.3.1.1
Land converted to a new land-use category	NR	2.3.1.2	2.3.1.2
Additional generic guidance for tier 2 methods	NG	-	2.3.1.3
Change in dead organic matter	NR	2.3.2	2.3.2
Land remaining in a land-use category	E	2.3.2.1	2.3.2.1
Land converted to a new land-use category	U	2.3.2.2	2.3.2.2
Change in carbon stocks in soils	NR	2.3.3	2.3.3
Soil organic C estimation methods (Land remaining in a Land-use category and land conversion to a new land use)	U, NG, E	2.3.3.1	2.3.3.1
Non-CO <sub>2</sub> emissions	U	2.4	2.4

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Additional generic guidance for tier 3 methods	E	2.5	2.5
Measurement-based tier 3 inventories	E	2.5.1	2.5.1
Model-based tier 3 inventories	E	2.5.2	2.5.2
Inter-annual variability	NG	-	2.6
Definitional issues	NG	-	2.6.1
Direct and indirect human effects, and natural effects	NG	-	2.6.1.1
Natural disturbances	NG	-	2.6.1.2
Relationship between different methodological approaches and the representation of emissions and removals from inter-annual variability	NG	-	2.6.2
Methodological approaches to estimating the contribution of ND to the emissions and removals reported for managed land	NG	—	2.6.3
Reporting the contribution of natural disturbances to the emissions and removals for managed lands	NG	-	2.6.4
Default Mineral Soil Reference C Stocks	NG	-	Annex 2A.1
Supporting Material for the Estimation of Soil Carbon Stock Change from Biochar Amendments to Mineral Soils	NG	-	Annex 2A.2
Parameterisation of Three-Pool Steady-State C Model for Mineral Soils: Tier 2 Method	NG	-	Annex 2A.3

Discussion:

A paragraph was inserted to define why a term for biochar application to soil was added to equation 2.24.

A section was added describing the biochar method.

A sentence was added to indicate where information pertaining to soil sampling strategies could be found in chapter 2 of volume 1 and two general references on soil sampling and analysis were inserted. This was completed in response to a request in the internal review.

A section has been inserted to describe the new Tier 2 three-pool steady-state carbon model for mineral soils.

A section providing a step-by-step procedure for implementing the three-pool steady-state soil carbon model for mineral soils was added.

Section 2.5 was revised to expand on guidance on how to parameterize and evaluate Tier 3 models, the integration of data to models, and means to increase transparency. Include case studies demonstrating how parties have developed and worked with Tier 3 methods including models have been included.

A new section (2.6) was added to provide an option that may be used to disaggregate Managed Land Proxy (MLP) emissions and removals into those that are considered to result from human effects and those that are considered to result from natural effects.

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**Equations**

<b>Equation Title</b>	<b>Type of Refinement</b>	<b>2006 Guidelines Equation Number</b>	<b>2019 Refinement Equation Number</b>
Annual carbon stock changes for the entire AFOLU Sector estimated as the sum of changes in all land-use categories	NR	2.1	2.1
Annual carbon stock changes for a land-use category as a sum of changes in each stratum within the category	NR	2.2	2.2
Annual carbon stock changes for a stratum of a land-use category as a sum of changes in all pools	NR	2.3	2.3
Annual carbon stock change in a given pool as a function of gains and losses (Gain-Loss Method)	NR	2.4	2.4
Carbon stock change in a given pool as an annual average difference between estimates at two points in time (Stock-Difference Method)	NR	2.5	2.5
Non-CO <sub>2</sub> emissions to the atmosphere	NR	2.6	2.6
Annual change in carbon stocks in biomass in land remaining in a particular land-use category (Gain-Loss Method)	NR	2.7	2.7
Annual change in carbon stocks in biomass in land remaining in the same land-use category (Stock-Difference Method)	NR	2.8	2.8
Annual increase in biomass carbon stocks due to biomass increment in land remaining in same category	NR	2.9	2.9
Average annual increment in biomass	NR	2.10	2.10
Annual decrease in carbon stocks due to biomass losses in land remaining in same category	NR	2.11	2.11
Annual carbon loss in biomass of wood removals	NR	2.12	2.12
Annual carbon loss in biomass of fuelwood removal.	NR	2.13	2.13

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Annual carbon losses in biomass due to disturbances	NR	2.14	2.14
Annual change in biomass carbon stocks on land converted to other land-use category (Tier 2)	NR	2.15	2.15
Initial change in biomass carbon stocks on land converted to another land category	NR	2.16	2.16
Annual change in carbon stocks in dead organic matter	NR	2.17	2.17
Annual change in carbon stocks in dead wood or litter (Gain-Loss Method)	NR	2.18	2.18
Annual change in carbon stocks in dead wood or litter (Stock-Difference Method)	NR	2.19	2.19
Annual carbon in biomass transferred to dead organic matter	NR	2.20	2.20
Annual biomass carbon loss due to mortality	NR	2.21	2.21
Annual carbon transfer to slash	NR	2.22	2.22
Annual change in carbon stocks in dead wood and litter due to land conversion	NR	2.23	2.23
Annual change in carbon stocks in soils	U	2.24	2.24
Annual change in organic carbon stocks in mineral soils	NR	2.25	2.25
Annual carbon loss from drained organic soils (CO <sub>2</sub> )	NR	2.26	2.26
Annual change in biochar carbon stock in mineral soils receiving biochar additions	NG	-	2.26A
Annual SOC stock change for mineral soils using three-pool steady-state C model	NG	-	2.26B
Active Pool SOC Stock for Three-Pool Steady-State C Model	NG	-	2.26C
Slow Pool SOC Stock for Three-Pool Steady-State C Model	NG	-	2.26D
Passive Pool SOC Stock for Three-Pool Steady-State C Model	NG	-	2.26E

Temperature Impact on Decomposition for Three-Pool Steady-State C Model	NG	-	2.26F
Water Effect on Decomposition for Three-Pool Steady-State C Model	NG	-	2.26G
C input to the Active SOC Pool for Three-Pool Steady-State C Model	NG	-	2.26H
Estimation of greenhouse gas emissions from fire	NR	2.27	2.27

Discussion:

Equation 2.24. A term representing the change in soil carbon stocks due to biochar application was added.

Equation 2.26A was added to calculate the annual change in biochar carbon stock in mineral soil receiving biochar additions.

A series of equations (2.26B– 2.26H) were added for the calculations required in the new Tier 2 three-pool steady-state soil carbon model.

## Tables

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Example of a simple matrix (Tier 2) for the impacts of disturbances on carbon pools	NR	2.1	2.1
Tier 1 default values for litter and dead wood carbon stocks	U	2.2	2.2
Default reference (under native vegetation) soil organic C stocks ( $\text{SOC}_{\text{REF}}$ ) for mineral soils (tonnes C $\text{ha}^{-1}$ in 0-30 cm depth)	U	2.3	2.3
Default values for organic carbon content factor of biochar by production type ( $F_{C_p}$ ).	NG	-	2.3A
Default values for $F_{\text{perm}_p}$ (fraction of biochar C remaining after 1000 years)	NG	-	2.3B
Model parameters used to estimate steady state soil organic carbon pools (slow, active, and passive)	NG	-	2.3C
Fuel (dead organic matter plus live biomass) biomass consumption values (tonnes dry matter $\text{ha}^{-1}$ ) for fires in a range of vegetation types.	U	2.4	2.4
Emission factors for various types of burning	NR	2.5	2.5

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Combustion factor values (proportion of prefire fuel biomass consumed) for fires in a range of vegetation types	U	2.6	2.6
Examples of documentation to assemble in support of transparent reporting of Tier 3 measurement-based inventories	NG	-	2.6A
Examples of documentation to assemble in support of transparent reporting of Tier 3 model-based inventories	NG	-	2.6B
Does the estimation method distinguish between the impact of the drivers below on the inter-annual variability of reported annual emission and removal estimates.	NG	-	2.6C
Parameterization of Three-Pool Steady-State C Model for Mineral Soils: Tier 2 Method	NG	-	2A.3-1
Sensitivity of model parameters in the three-pool steady state model for mineral soils.	NG	-	2A.3-2
Covariance matrix for the three pool steady state model for mineral soils.	NG	-	2A.3-3

## Discussion

Table 2.3. Reference soil organic carbon stocks were updated using data presented in Batjes (2011). Where data was lacking, values from previous IPCC guidance documents were inserted. A new series of footnotes have been provided. Updated 95% confidence interval limits expressed as a percentage of the mean organic carbon stock were provided. Where the number of samples used to calculate the mean and confidence limits was known it was added to provide an indication of the level of data support for the values in the table.

Tables 2.3A and 2.3B provide the parameters for estimating the change in soil C with biochar amendments.

Table 2.3C: The default values for a series of parameters required for the calculations that make up the Tier 2 three-pool steady-state soil carbon model are presented in this table.

Tables 2.4 and 2.6 provides updated information for estimating non-CO<sub>2</sub> emissions from agricultural residues burning.

Table 2.6C provides explanation on how the choice of estimation method and data affects the extent to which the interannual variability of different drivers is reflected in reported estimates

Tables 2.7 and 2.8 were added to provide a summary of how estimation method affects emissions and an example of a table format for voluntary disaggregation of reported fluxes, respectively.



71 **Figures**

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Generalized carbon cycle of terrestrial AFOLU ecosystems showing the flows of carbon into and out of the system as well as between the five C pools within the system	NR	2.1	2.1
Generic decision tree for identification of appropriate tier to estimate changes in carbon stocks in biomass in a land-use category	NR	2.2	2.2
Generic decision tree for identification of appropriate allometric models to estimate biomass or carbon stocks in organic matter	NG	-	2.2A
Generic decision tree for identification of appropriate tier to estimate changes in carbon stocks in dead organic matter for a land-use category	NR	2.3	2.3
Generic decision tree for identification of appropriate tier to estimate changes in carbon stocks in mineral soils by land-use category	U	2.4	2.4
Generic decision tree for identification of appropriate tier to estimate changes in carbon stocks in organic soils by land-use category	NR	2.5	2.5
Generic decision tree for identification of appropriate tier to estimate greenhouse gas emissions from fire in a land-use category	NR	2.6	2.6
Steps to develop a Tier 3 model-based inventory estimation system	R	2.7	-
Conceptual illustration of how various anthropogenic (direct and indirect) and natural factors simultaneously affect land-related GHG emissions and removals	NG	-	2.7A
Example of the disaggregation of fire emissions in Australia into natural 'background' emissions and fires due to human activity.	NG	-	2.7B

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Example of the separation of Canada's FL-FL emissions and removals into those due to predominantly anthropogenic causes and those due to predominantly natural disturbances. Note the low IAV in the anthropogenic fluxes and the high IAV in the natural disturbance fluxes (exceeding 250 Mt CO <sub>2</sub> e/yr).	NG	-	2.7C
Time series of managed forest land total GHG net emission (anthropogenic + natural disturbance (ND) and area burnt.	NG	-	2.7D
Iterative process to calculate the background level and margin (i.e. 95% CI) used to identify years in which area burned exceeded the mean plus two standard deviations	NG	-	2.7E

Discussion:

Figure 2.4: The text “method” was added to the end of the first diamond. A second diamond was added to indicate the inclusion of the addition three-pool steady-state Tier 2 modelling approach for soil carbon stock change.

Figure 2.7A: Summarizes the main factors that cause anthropogenic (i.e., direct and indirect human) effects and natural effects and their occurrences in managed and unmanaged lands.

Figure 2.7B: Is part of BOX.2J that provide an example of methodological approach developed by Australia to estimate the contribution of natural disturbances to the emissions and removals reported for managed lands

Figure 2.7C: Is part of BOX. 2K that provide an example of methodological approach developed by Canada to estimate the contribution of natural disturbances to the emissions and removals reported for managed lands

Figure 2.7D and 2.7E: Are part of BOX. 2L that provide an example of methodological approach developed by a European country to estimate the contribution of natural disturbances to the emissions and removals reported for managed lands (that applied variations of the method approved for the Kyoto Protocol's second commitment period)

## Boxes

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
Consistency between AFOLU projects or activities and IPCC inventory guidelines	NG	-	2.0A
Allometric Definitions	NG	-	2.0B
New Technology: Terrestrial LIDAR	NG	-	2.0C
Using a biomass map for GHG estimation: an example from the Brazilian Amazon	NG	-	2.0D
Alternative Formulations of Equation 2.25 for Approach 1 Activity Versus	E	2.1	2.1

Approach 2 or 3 Activity Data with Transition Matrices			
Comparison between use of approach 1 aggregate statistics and approach 2 or 3 activity data with transition matrices	U	2.2	2.2
GHG emission sources with biochar production	NG	-	2.2A
Using equivalent mass methods to derive mineral soil stock change factors	NG		2.2B
Description of the Tier 2 three-pool steady-state soil carbon model for estimating mineral soil organic carbon stock changes	NG	-	2.2C
Representing the impact of soil erosion and deposition on soil carbon stock changes	NG		2.2D
Examples of Tier 3 mineral soil C stock change methods	E	-	2.2E
Model calibration through data assimilation	E	-	2.2F
Model evaluation and improvement	E	-	2.2G
Quantification of model uncertainty	E	-	2.2H
List of examples of natural disturbances (from the IPCC 2013 KP Supplement)	NG	-	2.2I
Australian approach to managing interannual variability due to natural disturbances	NG	-	2.2J
Canada's approach to managing interannual variability from natural disturbances	NG	-	2.2K
Methodology based on the 2013 IPCC KP Supplement	NG	-	2.2L
Example of a reporting table that shows the first and second order approximations of the anthropogenic emissions and removals on managed lands.	NG	-	2.2M

87 Discussion:

88 Box 2.2F present an example of model calibration through data assimilation.

89 Box 2.2G present examples of model evaluation and improvement.

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- 90 Box 2.2H provide information for the purposes and for the presentation of examples of quantification of  
91 uncertainties in Tier 3 modelling approaches.
- 92 Box 2.2J provide an example of methodological approach developed by Australia to estimate the contribution of  
93 natural disturbances to the emissions and removals reported for managed lands
- 94 Box 2.2K provide an example of methodological approach developed by Canada to estimate the contribution of  
95 natural disturbances to the emissions and removals reported for managed lands
- 96 Box 2.2L provide an example of methodological approach developed by a European country to estimate the  
97 contribution of natural disturbances to the emissions and removals reported for managed lands (that applied  
98 variations of the method approved for the Kyoto Protocol's second commitment period)
- 99 Box 2.4 provides an elaboration with a definition for a parcel.
- 100 Box 2.5: The assumption made on when the land use change occurred was added to help compilers derive that  
101 values presented in the approach 1 and approach 2 examples. Mistakes found in the values presented for approach  
102 1 and approach 2 were corrected.
- 103 Box 2.6 provides an explanation of greenhouse gas emissions from biochar production.
- 104 Box 2.7: This box was added to describe the Tier 2 three-pool steady-state soil carbon model for estimating  
105 mineral soil organic carbon stock changes.
- 106 Box 2.8 provides examples of the Tier 3 methods that compilers have developed and used for reporting soil C  
107 stock changes.
- 108

**CHAPTER 3, CONSISTENT REPRESENTATION OF LANDS****Sections**

<b>Section Title</b>	<b>Type of Refinement</b>	<b>2006 Guidelines Section Number</b>	<b>2019 Refinement Section Number</b>
Introduction	NR	3.1	3.1
Land use categories	E	3.2	3.2
Representing land areas	E	3.3	3.3
Three approaches	E	3.3.1	3.3.1
Using the data	E, U	3.3.2	3.3.2
Matching land areas with factors for estimating greenhouse gas emissions and removals	NG	3.4	3.4
Uncertainties associated with the Approaches	E	3.5	3.5
Examples of international land cover dataset	U	Annex 3A.1	Annex 3A.1
Development of land-use databases	E,U	Annex 3A.2	Annex 3A.2
Sampling	NR	Annex 3A.3	Annex 3A.3
Overview of potential methods for developing Approach 3 datasets	NR	Annex 3A.4	Annex 3A.3
Default climate and soil classifications	U	Annex 3A.5	Annex 3A.5

Discussion:

While No Refinement was mandated, an elaboration (E) is introduced on the clarification of the managed land proxy. In addition, there is a placeholder to further revise the text pending on the outcome of the refinement proposed for interannual variability (IAV) in Chapter 2.

In Section 3.3, the 2006 text has been reviewed and refined to expand guidance on how to integrate different data types and sources for the consistent representation of lands, in order to improve transparency, consistency and accuracy of land-use, land-use change and related GHG emissions and removals estimates. The refinement includes new guidance on how to combine the data, how to derive IPCC land-use categories (including land-use classification and stratification processes) and tracking and distinguishing land-use changes. Case study examples have been incorporated demonstrating how parties have combined and worked with different types of data and sources of information in order to classify land-use and attribute land-use conversions. Annex 3.A.1 has been updated with new land-use datasets and 3.A.2 have also been refined, including the elaboration and actualization of the existing text (e.g. RS data preprocessing and classification methods) and new guidance on time series consistency in data processing.

Section 3.4 provide new guidance on how to use, combine and integrate different approaches and tiers to derive consistent emissions and removals estimated from land-use change. A special reference is made to the use of biomass maps.

Even though “No Refinement” was mandated in Section 3.5 authors have decided to include the proposed refinement on Activity Data uncertainty (as requested) in this section. The elaborated text in this Section is to be read in conjunction with Vol. 1\_Ch 3 Uncertainties.

Annex 3.A.1 has been updated with new land-use datasets

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Annex 3.A.2 have been refined, including the elaboration and updating of the existing text (e.g. RS data preprocessing and classification methods) and new guidance on time series consistency in data processing).

In Annex 3.A.5 only Figure 3.A.5.1 have being updated (Delineation of major climate zones, updated from the 2006 IPCC Guidelines).

**Equations**

No refinement

**Tables**

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Elements to be considered for classifying areas under land-use and land-use change categories. examples on how to address them (to be used in conjunction with a land-use hierarchy)	E	---	3.1A
Example stratifications with supporting data for Tier 1 emissions estimation methods	NR	3.1	3.1
Example of Approach 1: Available land use data with complete national coverage	NR	3.2	3.2
Illustrative example of stratification of data for Approach 1	NR	3.3	3.3
Illustrative example of tabulating all land-use conversion for Approach 2 including nationally defined Strata	NR	3.4	3.4
Illustrative example of Approach 2 data in a land-use conversion matrix with category stratification	NR	3.5	3.5
Simplified land-use conversion matrix for Approach 2 example	NR	3.6	3.6
Examples of approach 1, 2 and 3 methods using different data inputs and processes	E	-	3.6A
Example of data combination for the attribution of land-use conversions between year X and year Y	E	-	3.6B
Examples of auxiliary data and possible assumptions that can help to determine and stratify land-use	E	-	3.6C
Summary of uncertainties under Approaches 1 to 3	NR	3.7	3.7

Examples of international land cover dataset	U	3A.1.1	3A.1.1
Example of area estimation via proportions	NR	3A.3.1	3A.3.1

Discussion

Additional tables were included as part of the elaboration on existent guidance

## **Figures**

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Decision tree for preparation of land-use area data	NR	3.1	3.1
Decision tree for classifying land-use and land-use change through time in Approach 3	E	-	3.2
Example of potential multiple counting of land using Approach 2 methods where multiple changes occur on a single unit of land	E	-	3.3
Delineation of major climate zones, updated from the 2006 IPCC Guidelines	U	3.A.5.1	3.A.5.1

Discussion:

Additional figures were included as part of the elaboration on existent guidance

## **Boxes**

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
Combining incomplete spatially-explicit data and auxiliary information for land-use change attribution (Argentina)	E	-	3.1

Discussion:

Case study example have been incorporated demonstrating how countries have combined and worked with different types of data and sources of information in order to classify land use and attribute land-use conversions.

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**CHAPTER 4, FOREST LANDS****Sections (Additions for Soil C)**

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Soil carbon	NR	4.2.3	4.2.3
Choice of method	E	4.2.3.1	4.2.3.1
Choice of stock change and emission factors	E	4.2.3.2	4.2.3.2
Choice of activity data	E	4.2.3.3	4.2.3.3
Calculation steps for Tier 1	NR	4.2.3.4	4.2.3.4
Uncertainty assessment	E	4.2.3.5	4.2.3.5
Soil carbon	NR	4.3.3	4.3.3
Choice of method	E	4.3.3.1	4.3.3.1
Choice of stock change and emission factors	E	4.3.3.2	4.3.3.2
Choice of activity data	NR	4.3.3.3	4.3.3.3
Calculation steps for Tier 1	NR	4.3.3.4	4.3.3.4
Uncertainty assessment	NR	4.3.3.5	4.3.3.5
Times series consistency	E	4.4.2	4.4.2

Discussion for Sections (soil):

4.2.3.1: References to elaboration on Tier 3 methodologies in Chapter 2 were added, as well as references to the new box 4.3a giving information to support development of Tier 2 stock change methods for forest land.

4.2.3.2: Question of soil depth for Tier 2 was clarified as a reply to comments. Text on mass-equivalency was clarified in accordance with elaboration in Chapter 2 and a reference to Chapter 2 was added.

4.2.3.5: Elaboration of uncertainty assessment for Tier 3.

4.3.3.2: Text on Tier 2 reference C stock was clarified as a reply to comments and elaborated in accordance with Chapter 2.

4.3.3.3: Text on implications of the type of land-use activity data was clarified as a reply to comments and a reference to Chapter 2 was added.

**Tables - Biomass**

Ratio of below-ground biomass to above-ground biomass (R)	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Climate domains (FAO, 2001), climate regions (Chapter 3), and ecological zones (FAO 2001)	NR	4.1	4.1
Forest and land cover classes	NR	4.2	4.2
Carbon fraction of aboveground forest biomass	NR	4.3	4.3



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Ratio of below-ground biomass to above-ground biomass (R)	E	4.4	4.4
Default biomass conversion and expansion factors (BCEF), tonnes biomass (m <sup>3</sup> of wood volume) <sup>-1</sup>	U	4.5	4.5
	NR	4.6	4.6
Above-ground biomass in natural forests	E	4.7	4.7
Above-ground biomass in plantation forest	E	4.8	4.8
Above-ground net biomass growth in natural forests	E	4.9	4.9
Above-ground net biomass growth in plantation forests	E	4.10	4.10
Reported Mean Annual Increment (growth rate of merchantable volume) values for some plantation forest species [m <sup>3</sup> ha <sup>-1</sup> yr <sup>-1</sup> ]	E	4.11A, 4.11B	4.11
Tier 1 estimated biomass values from Tables 4.7–4.11 (except Table 4.11B) (values are approximate; use only for Tier 1)	U	4.12	4.12

### Equations

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Equations	NR	All	-

### Figures

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Figures	NR	All	-

### Boxes

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
Developing Tier 2 stock change factors for forest lands	NG	-	4.3A
Example of resolving forest data gaps through extrapolation based on functional relationships	NG	-	4.3B

Discussion:

Added guidance for developing Tier 2 stock change factors for soil C.

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**CHAPTER 5, CROPLANDS****Sections**

<b>Section Title</b>	<b>Type of Refinement</b>	<b>2006 Guidelines Section Number</b>	<b>2019 Refinement Section Number</b>
Introduction	NR	5.1	5.1
Cropland Remaining Cropland	NR	5.2	5.2
Biomass	E, U	5.2.1	5.2.1
Choice of methods	E, U	5.2.1.1	5.2.2.1
Choice of emission factors	E, U	5.2.1.2	5.2.1.2
Choice of activity data	E	5.2.1.3	5.2.1.3
Calculations steps for Tier 1 and Tier 2	NR	5.2.1.4	5.2.1.4
Uncertainty assessment	NR	5.2.1.5	5.2.1.5
Dead organic matter	NR	5.2.2	5.2.2
Choice of methods	NR	5.2.2.1	5.2.2.1
Choice of emission/removal factors	NR	5.2.2.2	5.2.2.2
Choice of activity data	NR	5.2.2.3	5.2.2.3
Calculations steps for Tier 1 and Tier 2	NR	5.2.2.4	5.2.2.4
Uncertainty assessment	NR	5.2.2.5	5.2.2.5
Soil carbon	NR	5.2.3	5.2.3
Choice of methods	E, U, NG	5.2.3.1	5.2.3.1
Choice of stock change and emission factors	E, U, NG	5.2.3.2	5.2.3.2
Choice of activity data	E, U, NG	5.2.3.3	5.2.3.3
Calculations steps for Tier 1	U, NG	5.2.3.4	5.2.3.4
Uncertainty assessment	NR	5.2.3.5	5.2.3.5
Non-CO2 greenhouse gas emissions from biomass burning	NR	5.2.4	5.2.4
Choice of methods	NR	5.2.4.1	5.2.4.1
Choice of emission factors	NR	5.2.4.2	5.2.4.2
Choice of activity data	NR	5.2.4.3	5.2.4.3
Uncertainty assessment	NR	5.2.4.4	5.2.4.4
Land Converted to Cropland	E	5.3	5.3
Biomass	E	5.3.1	5.3.1

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Choice of methods	E	5.3.1.1	5.3.1.1
Choice of emission factors	E, U	5.3.1.2	5.3.1.2
Choice of activity data	E	5.3.1.3	5.3.1.3
Calculations steps for Tier 1 and Tier 2	NR	5.3.1.4	5.3.1.4
Uncertainty assessment	NR	5.3.1.5	5.3.1.5
Dead organic matter	NR	5.3.2	5.3.2
Choice of methods	NR	5.3.2.1	5.3.2.1
Choice of emission/removal factors	NR	5.3.2.2	5.3.2.2
Choice of activity data	NR	5.3.2.3	5.3.2.3
Calculations steps for Tier 1 and Tier 2	NR	5.3.2.4	5.3.2.4
Uncertainty assessment	NR	5.3.2.5	5.3.2.5
Soil carbon	NR	5.3.3	5.3.3
Choice of methods	E, NG	5.3.3.1	5.3.3.1
Choice of stock change and emission factors	E, NG	5.3.3.2	5.3.3.2
Choice of activity data	E, NG	5.3.3.3	5.3.3.3
Calculations steps for Tier 1	U, NG	5.3.3.4	5.3.3.4
Uncertainty assessment	NR	5.3.3.5	5.3.3.5
Non-CO2 greenhouse gas emissions from biomass burning	NR	5.3.4	5.3.4
Choice of methods	NR	5.3.4.1	5.3.4.1
Choice of emission factors	NR	5.3.4.2	5.3.4.2
Choice of activity data	NR	5.3.4.3	5.3.4.3
Uncertainty assessment	NR	5.3.4.4	5.3.4.4
Completeness, time series, QA/QC, and reporting	NR	5.4	5.4
Completeness	NR	5.4.1	5.4.1
Developing a consistent time series	NR	5.4.2	5.4.2
Quality assurance and quality control	NR	5.4.3	5.4.3
Reporting and documentation	NR	5.4.4	5.4.4
Methane emissions from rice cultivation	NR	5.5	5.5
Choice of methods	E	5.5.1	5.5.1

Choice of emission factors	U, NG	5.5.2	5.5.2
Choice of activity data	NR	5.5.3	5.5.3
Example calculation for Tier 1	NG	-	5.5.4
Uncertainty assessment	NR	5.5.4	5.5.5
Completeness, time series, QA/QC, and reporting	NR	5.5.5	5.5.6
Estimation of default stock change factors for mineral soil C emissions/removals for cropland	U	Annex 5A.1	Annex 5A.1
Estimation of Default Emission Factors and Scaling Factors for CH <sub>4</sub> Emission from Rice Cultivation	NG	-	Annex 5A.2

Discussion:

The biomass C section refined guidance by clarifying how to use default factors, and also provides updated factors. This section also provides additional examples of perennial cropland subcategories. This section also provides elaboration on activity data required for carbon gain estimation.

This biomass C section refined guidance by elaborating on how to calculate  $\Delta$ CG for Land converted to Cropland

Updates in the soil C sections are mostly associated with new stock changes factors based on a new literature review and analysis.

New guidance in the soil C sections is associated with the Tier 2, three-pool steady-state carbon model for mineral soils and biochar amendments to mineral soils.

The rice cultivation section updates the 2006 Guidelines for the: (i) baseline emission factor for continuously flooded rice fields without organic amendments (EF<sub>c</sub>); (ii) scaling factor to account for the differences in water regimes during the cultivation period (SF<sub>w</sub>); (iii) scaling factors to account for the differences in water regimes in the pre-season -before the cultivation period (SF<sub>p</sub>); and (iv) scaling factors to account for the organic amendments applied (SF<sub>o</sub>).

This rice cultivation section includes good practice guidance for developing a baseline emission factor. An example of how to apply the Tier 1 method for estimating methane emission from rice cultivation is also added. The revised guidelines also maintain the separate calculation of N<sub>2</sub>O emission from rice cultivation (as one form of managed soil) which is dealt with in Chapter 11.

## Equations

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Cropland Litter Carbon Input for Three-Pool Steady-State C Model	NG	-	5.0A
CH <sub>4</sub> emissions from rice cultivation	NR	5.1	5.1
Adjusted daily emission factor	NR	5.2	5.2
Adjusted CH <sub>4</sub> emission scaling factors for organic amendments	NR	5.3	5.3

Discussion:

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Equation added to estimate the cropland litter C input for the three pool steady-state C model in the soil C section.  
More information on the model is provided in Chapter 2.

**Tables**

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Default coefficients for above-ground biomass and harvest/maturity cycles in agroforestry systems containing perennial species	U	5.1, 5.2, 5.3	5.1
Examples of Classification of agroforestry system	U	5.4	5.2
Default coefficients for above- and below-ground biomass in agroforestry systems containing perennial species	U	5.2, 5.3	5.3
Default maximum and time-averaged mean above-ground biomass and above ground biomass accumulation rate for Perennial cropland monocultures (tonnes ha <sup>-1</sup> )	U	5.1	5.4
Relative stock change factors (FLU, FMG, and FI) (over 20 years) for different management activities on cropland	U	5.5	5.5
Default values for Nitrogen and Lignin Contents in Crops for Three-Pool Steady-State C Model	NG	-	5.5A
Annual emission factors (EF) for cultivated organic soils	NR	5.6	5.6
Example of a simple disturbance matrix (Tier 2) for the impacts of land conversion activities on carbon pools	NR	5.7	5.7
Default biomass carbon stocks removed due to land conversion to cropland	U	5.8	5.8
Default biomass carbon stocks present on Land Converted to Cropland in the year following conversion	U	5.9	5.9
Soil stock change factors (FLU, FMG, FI) for land-use conversions to Cropland	NR	5.10	5.10
Default CH <sub>4</sub> baseline emission factor assuming no flooding for less than 180 days prior to rice cultivation, and continuously flooded during rice	U	5.11	5.11

cultivation without organic amendments			
Default CH <sub>4</sub> emission scaling factors for water regimes during the cultivation period relative to continuously flooded fields	U	5.12	5.12
Default CH <sub>4</sub> emission scaling factors for water regimes before the cultivation period	U	5.13	5.13
Default conversion factor for different types of organic amendment	U	5.14	5.14
Calculation for total harvested area	NG	-	5.14A
Calculation for adjusted daily emission factor	NG	-	5.14B
Calculation for total methane emission from Rice Cultivation	NG	-	5.14C

## Discussion

Biomass C tables include updated default biomass parameters of biomass stocks and growth rates in Table 5.1, Table 5.2 and Table 5.3, as well as the explanation of how to use the updated values. Updated default parameters are also provided in Table 5.8 and Table 5.9, with explanation about how to use the updated tables. Table 5.8 is updated to provide more complete information on how to use BBefore to be consistent with assumptions in other chapters. Table 5.9 is updated with default values consistent with Tables 5.1 to 5.3 in Cropland Remaining Cropland.

Updated stock changes factors in soil C sections are based on a new literature review and analysis.

New table in soil C section provided lignin and nitrogen content values for cropland, which is needed for the Tier 2, three-pool steady-state carbon model for mineral soils.

Emission and scaling factors for methane emissions from rice cultivation are updated based on a new literature review and analysis and an example calculation is given in Table 5.14A, 5.14B and 5.14C.

## Figures

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Classification scheme for cropland systems	NR	5.1	5.1
Decision tree for CH <sub>4</sub> emissions from rice production	NR	5.2	5.2

## Boxes

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
Relevant carbon pools for cropland	NR	5.1	5.1

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Conditions influencing CH <sub>4</sub> emissions from rice cultivation	NR	5.2	5.2
Good Practice Guidance for Developing Baseline Emission Factor (EF <sub>C</sub> ) for Methane Emission from Rice Cultivation	NG	-	5.2A

Discussion:

Added guidance for developing Tier 2 emission factors is provided in Table 5.2A.



223 **CHAPTER 6, GRASSLANDS**224 **Sections**

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Introduction	NR	6.1	6.1
Grassland Remaining Grassland	NR	6.2	6.2
Biomass	NR	6.2.1	6.2.1
Choice of methods	NR	6.2.1.1	6.2.1.1
Choice of emission factors	NR	6.2.1.2	6.2.1.2
Choice of activity data	NR	6.2.1.3	6.2.1.3
Calculations steps for Tier 1 and Tier 2	NR	6.2.1.4	6.2.1.4
Uncertainty assessment	NR	6.2.1.5	6.2.1.5
Dead organic matter	NR	6.2.2	6.2.2
Choice of methods	NR	6.2.2.1	6.2.2.1
Choice of emission/removal factors	NR	6.2.2.2	6.2.2.2
Choice of activity data	NR	6.2.2.3	6.2.2.3
Calculations steps for Tier 1 and Tier 2	NR	6.2.2.4	6.2.2.4
Uncertainty assessment	NR	6.2.2.5	6.2.2.5
Soil carbon	NR	6.2.3	6.2.3
Choice of methods	E, U, NG	6.2.3.1	6.2.3.1
Choice of stock change and emission factors	E, U, NG	6.2.3.2	6.2.3.2
Choice of activity data	E, U, NG	6.2.3.3	6.2.3.3
Calculations steps for Tier 1	U, NG	6.2.3.4	6.2.3.4
Uncertainty assessment	NR	6.2.3.5	6.2.3.5
Non-CO2 greenhouse gas emissions from biomass burning	NR	6.2.4	6.2.4
Choice of methods	NR	6.2.4.1	6.2.4.1
Choice of emission factors	NR	6.2.4.2	6.2.4.2
Choice of activity data	NR	6.2.4.3	6.2.4.3
Uncertainty assessment	NR	6.2.4.4	6.2.4.4
Land Converted to Grassland	NR	6.3	6.3
Biomass	NR	6.3.1	6.3.1
Choice of methods	NR	6.3.1.1	6.3.1.1
Choice of emission factors	NR	6.3.1.2	6.3.1.2
Choice of activity data	NR	6.3.1.3	6.3.1.3
Calculations steps for Tier 1 and Tier 2	NR	6.3.1.4	6.3.1.4
Uncertainty assessment	NR	6.3.1.5	6.3.1.5
Dead organic matter	NR	6.3.2	6.3.2
Choice of methods	NR	6.3.2.1	6.3.2.1
Choice of emission/removal factors	NR	6.3.2.2	6.3.2.2
Choice of activity data	NR	6.3.2.3	6.3.2.3
Calculations steps for Tier 1 and Tier 2	NR	6.3.2.4	6.3.2.4
Uncertainty assessment	NR	6.3.2.5	6.3.2.5
Soil carbon	NR	6.3.3	6.3.3
Choice of methods	E, NG	6.3.3.1	6.3.3.1

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Choice of stock change and emission factors	E, NG	6.3.3.2	6.3.3.2
Choice of activity data	E, NG	6.3.3.3	6.3.3.3
Calculations steps for Tier 1	U, NG	6.3.3.4	6.3.3.4
Uncertainty assessment	NR	6.3.3.5	6.3.3.5
Non-CO <sub>2</sub> greenhouse gas emissions from biomass burning	NR	6.3.4	6.3.4
Choice of methods	NR	6.3.4.1	6.3.4.1
Choice of emission factors	NR	6.3.4.2	6.3.4.2
Choice of activity data	NR	6.3.4.3	6.3.4.3
Uncertainty assessment	NR	6.3.4.4	6.3.4.4
Completeness, time series, QA/QC, and reporting	NR	6.4	6.4
Completeness	NR	6.4.1	6.4.1
Developing a consistent time series	NR	6.4.2	6.4.2
Quality assurance and quality control	NR	6.4.3	6.4.3
Reporting and documentation	NR	6.4.4	6.4.4
Estimation of default stock change factors for mineral soil C emissions/removals for grassland	U	Annex 6A.1	Annex 6A.1

Discussion:

Updates in the soil C sections are mostly associated with new stock changes factors based on a new literature review and analysis.

New guidance in the soil C sections is associated with the Tier 2 three-pool steady-state carbon model for mineral soils, and biochar amendments to mineral soils.

### Equations

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Grassland Litter Carbon Input for Three-Pool Steady-State C Model	NG	-	6.1

Discussion:

New equation added in this section to estimate grassland litter C input for three-pool steady-state carbon model for mineral soils.

### Tables

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Default expansion factors of the ratio of below-ground biomass to aboveground biomass (R) for the major grassland ecosystems of the world	NR <sup>1</sup>	6.1	6.1
Relative stock change factors for grassland management	U	6.2	6.2
Default values for Nitrogen and Lignin Contents in Crops for Three-Pool Steady-State C Model	NG	-	6.2A
Annual emission factors (EF) for drained grassland organic soils	NR	6.3	6.3

Default biomass stocks present on grassland, after conversion from other land use	NR	6.4	6.4
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237 Discussion

238 Updated stock changes factors in soil C sections are based on a new literature review and analysis.

239 New table in soil C section provided lignin and nitrogen content values for grassland, which is needed for the Tier  
240 2, three-pool steady-state carbon model for mineral soils

241

## 242 **Figures**

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Classification scheme for grassland/grazing systems	NR	6.1	6.1

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**CHAPTER 7, FLOODED LANDS****Sections**

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Introduction	NR	7.1	7.1
Managed Peatlands	NR	7.2	7.2
Peatlands Remaining Peatlands	NR	7.2.1	7.2.1
CO <sub>2</sub> emissions from Peatlands Remaining Peatlands	NR	7.2.1.1	7.2.1.1
Non-CO <sub>2</sub> emissions from Peatlands Remaining Peatlands	NR	7.2.1.2	7.2.1.2
Uncertainty assessment	NR	7.2.1.3	7.2.1.3
Land Being Converted for Peat Extraction	NR	7.2.2	7.2.2
CO <sub>2</sub> emissions on lands being converted for peat extraction	NR	7.2.2.1	7.2.2.1
Non-CO <sub>2</sub> emissions from lands being converted to managed peatlands	NR	7.2.2.2	7.2.2.2
Uncertainty assessment	NR	7.2.2.3	7.2.2.3
Flooded Land	NG	7.3	7.3
Flooded Land Remaining Flooded Land	NG	7.3.1	7.3.1
CO <sub>2</sub> emissions from Land Remaining Flooded Land	NG	-	7.3.1.1
Non-CO <sub>2</sub> emissions from Flooded Land remaining Flooded Land	NG	-	7.3.1.2
Land Converted to Flooded Land	NG	7.3.2	7.3.2
CO <sub>2</sub> emissions from Land Converted to Flooded Land	NG	7.3.2.1	7.3.2.1
Non-CO <sub>2</sub> emissions from Land Converted to Flooded Land	NG	7.3.2.2	7.3.2.2
Uncertainty assessment	E	7.3.2.3	7.2.3.3
Completeness, Time series consistency, and QA/QC	NR	7.4	7.4
Completeness	NR	7.4.1	7.5.1
Developing a consistent time series	NR	7.4.2	7.5.2
Quality Assurance and Quality Control (QA/QC)	NR	7.4.3	7.5.3
Reporting and Documentation	NR	7.4.4	7.5.4
Future methodological development	R	7.5	-
Estimation of Default Emission Factor(s) for greenhouse gas emissions from flooded lands	NG	-	Annex 7.1

Discussion:

Most of the refinements in this chapter are associated with new guidance for Flooded Lands.

A new section, Section 7.4, has been included to provide guidance for the Tier 2 three-pool steady-state carbon model for mineral soils

Section 7.5, Future Methodological Development was removed from the guidance because the methods have been developed in the 2013 IPCC Wetlands Supplement and in this refinement.

254 **Equations**

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
CO <sub>2</sub> emissions from wetlands	NR	7.1	7.1
CO <sub>2</sub> emissions in peatlands during peat extraction	NR	7.2	7.2
CO <sub>2</sub> –C emissions from managed peatlands (Tier 1)	NR	7.3	7.3
On-site soil CO <sub>2</sub> –C emissions from managed peatlands (Tier 1)	NR	7.4	7.4
Off-site CO <sub>2</sub> –C emissions from managed peatlands (Tier 1)	NR	7.5	7.5
On-site CO <sub>2</sub> –C emissions from managed peatlands (Tiers 2 and 3)	NR	7.6	7.6
N <sub>2</sub> O emissions from peatlands during peat extraction	NR	7.7	7.7
CO <sub>2</sub> –C emissions in peatland being drained for peat extraction	NR	7.8	7.8
CO <sub>2</sub> –C emissions from soils in peatland being drained for peat extraction	NR	7.9	7.9
Annual CH <sub>4</sub> emissions for Reservoirs >20 years old (Flooded Land Remaining Flooded Land)	NG	-	7.10
Equation used to scale CH <sub>4</sub> emission factors for the influence of eutrophication using measured values of chlorophyll a	NG	-	7.11
Annual CH <sub>4</sub> emission from Other Constructed Water Bodies	NG	-	7.12
Annual on-site CO <sub>2</sub> -C emissions/removals from newly flooded land	NG	-	7.13
Annual change in carbon stocks in living biomass on land converted to permanently Flooded Land	R	7.10	-
Annual CH <sub>4</sub> emissions for Reservoirs < 20 year old (Land Converted to Flooded Land)	NG	-	7.14
G-res CH <sub>4</sub> diffusive emission (mg C m <sup>-2</sup> d <sup>-1</sup> )	NG	-	A1

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G-res CH <sub>4</sub> bubbling emission (mg C m <sup>-2</sup> d <sup>-1</sup> )	NG	-	A2
G-res CO <sub>2</sub> diffusive emission (mg C m <sup>-2</sup> d <sup>-1</sup> )	NG	-	A3
Derivation of emission factor for Land converted to Flooded Land	NG	-	A4
Derivation of emission factor for Flooded Land remaining Flooded Land	NG	-	A5

Discussion:

Converted to Flooded Land, and Other Constructed Water Bodies. The latter category has added agriculture ponds, aquaculture ponds, canals, and drainage channels and brings ditches from the Wetland Supplement.

Reservoirs are divided into two classes: < 20 years old and > 20 years old.

Annual change in carbon stocks in living biomass on land converted to permanently Flooded Land has been removed due to changes in the methods associated with estimating the CO<sub>2</sub> emissions from Flooded Lands.

## Tables

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Sections addressing major greenhouse gas emissions from managed wetlands	U	7.1	7.1
Guidance on emissions from wetlands managed for other uses	NR	7.2	7.2
Ramsar classes of human-made wetlands	U	7.3	7.3
Emission factors for CO <sub>2</sub> -C and associated uncertainty for lands managed for peat extraction, by climate zone	NR	7.4	7.4
Conversion factors for CO <sub>2</sub> -C for volume and weight production data	NR	7.5	7.5
Default emission factors for N <sub>2</sub> O emissions from managed peatlands	NR	7.6	7.6
Types of flooded land, their human uses and greenhouse gases considered	NG	-	7.7
Ramsar classes of human-made wetlands, IPCC terminology used and methodological guidance provided	NG	-	7.8
CH <sub>4</sub> emission factors for reservoirs older than 20 years (> 20 years) – Flooded Land Remaining Flooded Land	NG	-	7.9
Ratio of total downstream flux of methane (kg CH <sub>4</sub> ha <sup>-1</sup> yr <sup>-1</sup> ) to the flux of methane from a reservoir's surface to the atmosphere (kg CH <sub>4</sub> ha <sup>-1</sup> yr <sup>-1</sup> )	NG	-	7.10
Relationships between Trophic Index (TI), surface concentrations of chlorophyll-a (Chl-a), and total phosphorus (TP), and, Secchi depth (SD,	NG	-	7.11

metres), and Trophic Class (after Carlson 1977) and Trophic State Adjustment Factor ( $\frac{1}{T}$ )			
CH <sub>4</sub> emission factors for Other Constructed Water Bodies	NG	-	7.12
Scaling factor value for equation 7.13, Annual on-site CO <sub>2</sub> -C emissions/removals from newly flooded land. $M_j$ = scaling factor [ $y^{-1}$ ]	NG		7.13
CH <sub>4</sub> emission factors for reservoirs < 20 years old – Land converted to Flooded Land	NG	-	7.14
Number of reservoirs with greenhouse gas emission estimates derived from G-res in each IPCC climate zone.	E	-	A1
Aggregated climate zones based on differences in CH <sub>4</sub> emissions between categories	E	-	A2
Data sources used for modelling CH <sub>4</sub> emissions from reservoirs within different climate zones.	E	-	A3
Reservoirs and citations for measured $R_d$ values	E	-	A4

263 Discussion

264 New tables are added associated with the guidance for Flooded Lands.

265 Tables A1-A4 elaborate on the development of the emission factors provided in the guidance.

266

## 267 **Figures**

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Decision tree to estimate CO <sub>2</sub> -C and N <sub>2</sub> O emissions from Peatlands Remaining Peatlands	NR	7.1	7.1
Decision tree for factoring out emissions from Unmanaged Land converted to Flooded Land.	NG	-	7.2
Methane related transport within and from waterbodies, exemplified with a reservoir with an anoxic hypolimnion.	E	-	A1
Location of the reservoirs in the Grand database and shadowgram of their latitudinal distribution.	E	-	A2
Box plots of model estimates (empty) and Field measurements (filled) of CH <sub>4</sub> emissions (note logarithmic scale) in aggregated IPCC climate zones.	E	-	A3
Comparison of measure CH <sub>4</sub> emissions with estimates based on the Emission Factors (EFs, Tables 7.9 and 7.14) of Tier 1 methodology.	E	-	A4

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Relationship between CO <sub>2</sub> surge estimates from the newly flooded lands using the decay curve approach and the flooded soil organic carbon stock approach.	E	-	A5
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- 268 Discussion:
- 269 Figure 7.2 is included to assist compilers with factoring out emissions associated with Flooded Lands prior to
- 270 flooding.
- 271 Figures A1-A4 elaborate on the development of the emission factors provided in the guidance.
- 272



**CHAPTER 8, SETTLEMENTS****Sections**

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Introduction	NR	8.1	8.1
Biomass	NR	8.2.1	8.2.1
Choice of method	NR	8.2.1.1	8.2.1.1
Choice of emission/removal factors	U, E	8.2.1.2	8.2.1.2
Choice of activity data	NR	8.2.1.3	8.2.1.3
Uncertainty assessment	E	8.2.1.4	8.2.1.4
Dead Organic Matter	NR	8.2.2	8.2.2
Choice of method	NR	8.2.2.1	8.2.2.1
Choice of emission/removal factors	NR	8.2.2.2	8.2.2.2
Choice of activity data	NR	8.2.2.3	8.2.2.3
Uncertainty assessment	NR	8.2.2.4	8.2.2.4
Soil Carbon	NR	8.2.3	8.2.3
Choice of method	NR	8.2.3.1	8.2.3.1
Choice of stock change and emission factors	NR	8.2.3.2	8.2.3.2
Choice of activity data	NR	8.2.3.3	8.2.3.3
Uncertainty assessment	NR	8.2.3.4	8.2.3.4
Choice of method	U	8.3.1.1	8.3.1.1
Choice of emission/removal factors	U	8.3.1.2	8.3.1.2
Choice of activity data	E	8.3.1.3	8.3.1.3
Uncertainty assessment	NR	8.3.1.4	8.3.1.4
Dead organic matter	NR	8.3.2	8.3.2
Choice of method	NR	8.3.2.1	8.3.2.1
Choice of emission/removal factors	NR	8.3.2.2	8.3.2.2
Choice of activity data	NR	8.3.2.3	8.3.2.3
Uncertainty assessment	NR	8.3.2.4	8.3.2.4
Soil carbon	NR	8.3.3	8.3.3
Choice of method	NR	8.3.3.1	8.3.3.1
Choice of stock change and emission factor	NR	8.3.3.2	8.3.3.2
Choice of activity data	NR	8.3.3.3	8.3.3.3
Uncertainty assessment	NR	8.3.3.4	8.3.3.4
Completeness, time series consistency, QA/QC and reporting	NR	8.4	8.4
Basis for future methodological development	U	8.5	8.5

Discussion:

- (i) Section 8.2.1.2 includes refinement of guidance to update default values in Table 8.1 and Table 8.2 and includes elaborate explanations on how to apply the default values.
- (ii) In section 8.2.1.4, new information may be added after updating Tables 8.1 and 8.2
- (iii) A section, providing step-by-step procedures for implementing the three-pool steady-state soil carbon model for mineral soils, was added.
- (iv) Section 8.3.1.1 provides guidance by clarifying how to apply terms of BBefore, BAfter,  $\Delta CG$  and  $\Delta CL$  for Equation 2.15 and 2.16 in each Tier.

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- (v) In section 8.3.1.2, new guidance, based on an updated Table 8.4 and explanations on Tier 2 and Tier 3 were included. The guidance on Tier 2 and Tier 3 are enhanced to clarify choice and use of emission/removal factors under higher tiers.
- (vi) In section 8.3.1.3, new guidance was elaborated by adding a few sentences explaining data acquisition for Tier 2 and 3.
- (vii) In section 8.5, details of the basis for future methodological development which were no longer relevant were deleted

**Equations**

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Annual carbon change in live biomass pools in Settlements Remaining Settlements	NR	8.1	8.1
Annual biomass increment based on total crown cover area	NR	8.2	8.2
Annual biomass growth based on number of individual woody plants in broad classes	NR	8.3	8.3

**Tables**

Table title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Tier 2A default crown cover area-based growth rates (CRW) for urban tree crown cover by region	U	8.1	8.1
Tier 2B default average annual carbon accumulation per tree in urban trees by species classes	U	8.2	8.2
Default activity data by potential natural vegetation (PNV) type for percent tree cover	NR	8.3	8.3
Default biomass carbon stocks removed due to Land conversion to settlements	U	8.4	8.4

## Discussion

- Updated tables 8.1 and 8.2 include new default values
- Uncertainty ranges for carbon stock in biomass before conversion are updated.
- Updated Table 8.4 provides more information on how to use  $B_{\text{Bef}}$

**299 CHAPTER 9, OTHER LANDS**

300 No Refinement to Chapter 9.

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302 **CHAPTER 10, LIVESTOCK AND MANURE MANAGEMENT**303 **Sections**

<b>Section Title</b>	<b>Type of Refinement</b>	<b>2006 Guidelines Section Number</b>	<b>2019 Refinement Section Number</b>
<b>Introduction</b>	NR	10.1	10.1
Livestock population and feed characterisation	U/E	10.2	10.2
Steps to define categories and subcategories of livestock	NR	10.2.1	10.2.1
Choice of method	U/E	10.2.2	10.2.2
Uncertainty assessment	NR	10.2.3	10.2.3
Characterisation for livestock without species: specific emission estimation methods	NR	10.2.4	10.2.4
Methane emissions from enteric fermentation	U/E	10.3	10.3
Choice of method	U/E	10.3.1	10.3.1
Choice of emission factors	U/E	10.3.2	10.3.2
Choice of activity data	NR	10.3.3	10.3.3
Uncertainty assessment	NR	10.3.4	10.3.4
Completeness, time series, quality assurance/ quality control and reporting	NR	10.3.5	10.3.5
Methane emissions from manure management	U/E	10.4	10.4
Choice of method	U/E	10.4.1	10.4.1
Choice of emission factors	U/E	10.4.2	10.4.2
Choice of activity data	E	10.4.3	10.4.3
Uncertainty assessment	NR	10.4.4	10.4.4
Completeness, time series, quality assurance / quality control and reporting	NR	10.4.5	10.4.5
N <sub>2</sub> O emissions from manure management	U/E	10.5	10.5
Choice of method	NR	10.5.1	10.5.1
Choice of emission factors	U/E	10.5.2	10.5.2
Choice of activity data	NR	10.5.3	10.5.3

Coordination with reporting for n2o emissions from managed soils	U/E	10.5.4	10.5.4
Uncertainty assessment	NR	10.5.5	10.5.5
Completeness, time series, quality assurance/quality control and reporting	E	10.5.6	10.5.6
Use of worksheets	NR	10.5.7	10.5.7
Data underlying methane default emission factors for enteric fermentation	U/E	Annex 10A.1	Annex 10A.1
Additional data and information for the calculation of methane from manure management	U/E	Annex 10A.2	Annex 10A.2
MCF spreadsheet example for the calculation of a country or regions specific mcf	NG	-	Annex 10A.3
Equations relating all direct and indirect n2o emissions from manure along all stages in agricultural production for livestock.	NG	-	Annex 10A.4
Additional data and information for the calculation of n2o from manure management of other animal	NG	-	Annex 10A.5
Data and explanatory text for development of new parameters in the 2019 refinement.	NG		Annex 10B.1
Estimation of default emission factor(s) for goat tier 2 parameters	NG		Annex 10B.2
Feed intake estimates using a simplified tier 2 method	NG		Annex 10B.3
Estimation cattle/buffalo ch4 conversion factors (ym)	NG		Annex 10B.4
Description and discussion of proposed changes to mcf calculations for liquid/slurry.	NG		Annex 10B.5
Revision of methane from dung deposited onto pasture range and paddocks (table 10.17)	NG		Annex 10B.6
Estimation of default emission factors for mcf ch4 values, ef for direct n2o emissions, nh3, no3 leaching and n2 emissions from solid storage and composting systems	NG		Annex 10B.7

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## Discussion:

10.2.2: Choice of Method. The Tier 1 method was elaborated upon through the development of an additional livestock characterization was added in order to improve guidance for countries in which there are large differences in the types of production systems, either because their agricultural sectors are transitioning from a local food production system model to a more commercial model, or simply that distinct low production food systems exist in parallel to high production agricultural systems. In these cases, countries have an intermediary option to customize their emission estimates between the traditional Tier 1 method and the more data intensive Tier 2 methods. Production systems were defined for different animal categories.

Various updates were made to certain sections of text, where references were dated and the symbol used for digestibility was modified from DE to DC to avoid confusion with digestible energy. Digestibility is the fraction of digestible energy to gross energy and the use of this symbol can cause confusion who are used to seeing DE as digestible energy and not digestibility.

The Tier 2 method was elaborated upon through the addition of parameters for a Tier 2 characterisation of goat production resulting in modifications to many Tables and Figures.

The Simplified Tier 2 approach was elaborated to include dairy cattle specific equations and more up to date equations for the non-dairy sector.

In Section 10.3.1 elaboration to text were integrated to maintain consistency with elaborations carried out in Section 10.2.2. In Section 10.3.2.

**Equations**

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Annual average population	NR	10.1	10.1
Coefficient for calculating net energy for maintenance	NR	10.2	10.2
Net energy for maintenance	NR	10.3	10.3
Net energy for activity (for cattle and buffalo)	NR	10.4	10.4
Net energy for activity (for sheep and goats)	E	10.5	10.5
Net energy for growth (for cattle and buffalo)	NR	10.6	10.6
Net energy for growth (for sheep and goats)	E	10.7	10.7
Net energy for lactation (for beef cattle, dairy cattle and buffalo)	NR	10.8	10.8
Net energy for lactation for sheep and goats (milk production known)	E	10.9	10.9
Net energy for lactation for sheep and goats (milk production unknown)	E	10.10	10.10
Net energy for work (for cattle and buffalo)	NR	10.11	10.11
Net energy to produce wool (for sheep and goats)	E	10.12	10.12

NET ENERGY FOR PREGNANCY (FOR CATTLE/BUFFALO AND SHEEP <b>AND GOATS</b> )	E	10.13	10.13
Ratio of net energy available in a diet for maintenance to digestible energy	E	10.14	10.14
Ratio of net energy available for growth in a diet to digestible energy consumed	E	10.15	10.15
Gross energy for cattle/buffalo, sheep and goats	E	10.16	10.16
Estimation of dry matter intake for calves	E		10.17
Estimation of dry matter intake for growing cattle	E	10.17	10.18A
Estimation of dry matter intake for steers and bulls	NG	-	10.18B
Estimation of dry matter intake for heifers	NG		10.118B
Estimation of dry matter intake for mature beef cattle	E	10.18a	-
ESTIMATION OF DRY MATTER INTAKE FOR LACTATING DAIRY COWS	E	10.18b	10.18C
Enteric fermentation emissions from a livestock category(Tier 1A)	E	10.19	10.19A
Enteric fermentation emissions from a livestock category(Tier 1B)	NG	-	10.19B
Total emissions from livestock enteric fermentation	NR	10.20	10.20
Methane emission factors for enteric fermentation from a livestock category	NR	10.21	10.21A
Methane emission factors for enteric fermentation from a livestock category	NG	-	10.21B
Ch <sub>4</sub> emissions from manure management ( for Tier 1a)	U	10.22	10.22A
Ch <sub>4</sub> emissions from manure management ( for Tier 1B)	U	10.22	10.22B
Ch <sub>4</sub> emissions from manure management (tier 2)	NG	-	10.22XX
Annual vs excretion rates	NG	-	10.22C
Annual vs excretion rates (tier 1b)	NG	-	10.22D
Ch <sub>4</sub> emission factor from manure management	U	10.23	10.23
Volatile solid excretion rates	E	10.24	10.24A

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Calculation of mcf for biogas digesters	NG	-	10.24B
Calculation of relative amount of potential off gas related to Bo	NG	-	10.24C
Calculation of relative amount of potential off gas related to Bo	NG	-	10.24D
Calculation of relative amount of potential off gas related to ch4 production	NG		10.24E
Calculation of methane leakage rate of digester	NG	-	10.24F
Calculation of methane conversion factor	NG	-	10.24G
Calculation of methane conversion factor in gastight storage	NG	-	10.24H
Direct n2o emissions from manure management	E	10.25	10.25A
N losses due to volatilisation from manure management	E	10.26	10.26A
N losses due to leaching from manure management	NG	-	10.26B
Indirect n2o emissions due to volatilisation of n from manure management	NR	10.27	10.27
N losses due to leaching from manure management systems	NR	10.28	10.28
Indirect n2o emissions due to leaching from manure management	NR	10.29	10.29
Annual n excretion rates	E	10.30	10.30
Annual n excretion rates (tier 2)	NR	10.31	10.31
N intake rates for cattle	NR	10.32	10.32A
N intake rates for swine and poultry	NG	-	10.32B
N retained rates for cattle	NR	10.33	10.33A
Annual n excretion rates for breeding sows	NG	-	10.33B
N retention rates for growing pigs	NG	-	10.33C
N excretion rates for layer type hens	NG	-	10.33D
Annual n excretion rates for pullets or broilers	NG	-	10.33E



Managed manure n available for application to managed soils, feed, fuel or construction uses	U	10.34	10.34
<b>FRACTION OF TOTAL ANIMAL MANURE N LOST IN MANURE MANAGEMENT SYSTEMS FOR ANIMAL TYPE T</b>	NG	-	10.34B
Estimation of $\text{frac}_{n2ms}$	NG	-	10.34C
Total $n_2o$ emissions for animal type t			A.4-1
Total $n_2o$ emissions from manure management for animal type t			A.4-2 A.4-3
Total, direct and indirect $n_2o$ emissions from the application of manure to managed soils for animal type t			A.4-4 A.4-5 A.4-6
Total amount of animal manure n applied to soils other than by grazing animals for animal type t			A.4-7
Fraction of total animal manure n lost in manure management systems for animal type t			A.4-8
Fraction of animal manure n available for application to managed soils, applied to managed soils for animal type t			A.4-9
Total, direct and indirect $n_2o$ emissions from n in urine and dung deposited by grazing animals on pasture, range and paddock (tier 1) for animal type t			A.4-10 A.4-11 A.4-12
Relationship between average annual nitrogen flows associated with an individual animal [ $\text{kg n animal}^{-1} \text{ yr}^{-1}$ ] and the annual nitrogen flow for the animal population of livestock category/species t in a country [ $\text{kg n yr}^{-1}$ ]			A.4-13
Total manure-n excreted			A.4-14
Nitrogen excretion calculated either using a default fraction of retention (tier 1) or directly from retention data			A.4-15 A.4-16
Total manure-n in manure management and storage systems			A.4-17
Manure-n managed in system s			A.4-18
Manure-n deposited by grazing animals, with $x=\text{cpp,so}$			A.4-19

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N in bedding material added to managed manure			A.4-20
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Discussion:

Discussion: All equations for calculating net energy were modified by adding parameters required to carry out Tier 2 emission factor development for goats. The equations used in the calculation of gross energy were not modified with the exception of the nomenclature used for digestibility, changing from DE to DC, for reasons explained above.

Equations required to carry out Tier 1b calculations were added.

Equations for calculating the simplified Tier 2 were updated and elaborated upon. Finally, an equation was added to calculate an emission factor directly from dry matter intake estimates (DMI).

### Tables

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
<b>REPRESENTATIVE LIVESTOCK CATEGORIES<sup>1,2</sup></b>	E	10.1	10.1
Representative feed digestibility for various livestock categories	U/E	10.2	10.2
Summary of the equations used to estimate daily gross energy intake for cattle, buffalo and sheep and goats	E	10.3	10.3
COEFFICIENTS FOR CALCULATING NET ENERGY FOR MAINTENANCE ( NEM )	U/E	10.4	10.4
ACTIVITY COEFFICIENTS CORRESPONDING TO ANIMAL'S FEEDING SITUATION	U/E	10.5	10.5
CONSTANTS FOR USE IN CALCULATING NE <sub>G</sub> FOR SHEEP AND GOATS	U/E	10.6	10.6
Constants for use in calculating ne <sub>p</sub> in equation 10.13	E	10.7	10.7
DMI REQUIRED BY MATURE NON DAIRY COWS BASED ON FORAGE QUALITY	NG	-	10.8A
Examples of nem <sub>f</sub> content of typical diets fed to cattle for estimation of dry matter intake in equations 10.17 and 10.18a	NR	10.8	10.8B
Suggested emissions inventory methods for enteric fermentation	E	10.9	10.9
Enteric fermentation emission factors for tier 1 method1 (kg ch <sub>4</sub> head <sup>-1</sup> yr <sup>-1</sup> )	U/E	10.10	10.10

Tier 1a enteric fermentation emission factors for cattle and buffalo <sup>1</sup>	U	10.11	10.11A
Enteric fermentation emission factors for cattle <sup>1</sup> (tier 1b)	NG	-	10.11B
<b>CATTLE/BUFFALO METHANE CONVERSION FACTORS (<math>Y_m</math>)</b>	U/E	10.12	10.12
Sheep and goats $CH_4$ conversion factors ( $Y_m$ )	U/E	10.13	10.13
<b>DEFAULT VALUES FOR VOLATILE SOLID EXCRETION RATE (KG VS (1000 KG ANIMAL MASS)<sup>-1</sup> DAY<sup>-1</sup>)</b>	NG	-	10.14A
<b>AVERAGE REGIONAL <math>CH_4</math> EMISSION FACTORS OF CATTLE BY CLIMATE ZONE (G <math>CH_4</math> KG VS<sup>-1</sup>)</b>	U	10.14	10.14B
<b>AVERAGE REGIONAL <math>CH_4</math> EMISSION FACTORS OF SWINE BY CLIMATE ZONE (G <math>CH_4</math> KG VS<sup>-1</sup>)</b>	U	10.14	10.14C
Average regional $CH_4$ emission factors of buffalo by climate zone (g $CH_4$ kg vs <sup>-1</sup> )	U	10.14	10.14D
Average regional $CH_4$ emission factors of poultry by climate zone (g $CH_4$ kg vs <sup>-1</sup> )	NG	10.14	10.14E
Manure management methane emission factors by temperature for sheep, goats, camels, horses, mules and asses (g $CH_4$ kg vs <sup>-1</sup> )	U	10.15	10.15
MANURE MANAGEMENT METHANE EMISSION FACTORS FOR DEER, REINDEER, RABBITS, AND FUR-BEARING ANIMALS	U/E	10.16	10.16A
Default values for $b_0$ (m <sup>3</sup> $CH_4$ kg <sup>-1</sup> vs)	NG	-	10.16B
Methane conversion factors for manure management systems	U	10.17	10.17
<b>DEFINITIONS OF MANURE MANAGEMENT SYSTEMS</b>	U/E	10.18	10.18
DEFAULT VALUES FOR NITROGEN EXCRETION RATE (KG VS (1000 KG ANIMAL MASS) <sup>-1</sup> DAY <sup>-1</sup> )	U	10.19	10.19
DEFAULT VALUES FOR THE FRACTION OF NITROGEN IN FEED INTAKE OF LIVESTOCK THAT IS RETAINED BY THE DIFFERENT LIVESTOCK	NR	10.20	10.20A

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SPECIES/CATEGORIES (FRACTION N-INTAKE RETAINED BY THE ANIMAL)			
Default parameters for calculating breeding swine n retention	NG	-	10.20B
Default values for $n_{\text{gain}}$ by growth stage	NG	-	10.20C
DEFAULT PARAMETERS FOR THE CALCULATION	NG	-	10.20D
Default emission factors for direct $n_2o$ emissions from manure management	U	10.21	11.21
Manure management $n_2o$ emission factors for deer, reindeer, rabbits, and fur-bearing animals ( need to be update )	NG	-	10.21B
<b>DEFAULT VALUES FOR NITROGEN LOSS DUE TO VOLATILISATION OF NH3 AND NOX AND LEACHING OF NITROGEN FROM MANURE MANAGEMENT</b>	U	10.22	10.24
Default values for total nitrogen loss from manure management		10.23	-
Default value for molecular nitrogen ( $n_2$ ) loss from manure management	NG	-	10.23
Data for estimating enteric fermentation emission factors for dairy cattle and nitrogen excretion factor (tier 1a)	U	A.1	A. 1a
Data for estimating enteric fermentation emission factors for dairy cattle and nitrogen excretion factor (tier 1b)	U	A.1	A. 1b
Data for estimating tier 1a enteric fermentation $ch_4$ emission factors for other cattle in table 10.11	U	A.2	A. 2a
Data for estimating tier 1b enteric fermentation $ch_4$ emission factors for other cattle in table 10.11	U	A.2	A. 2b
Data for estimating enteric fermentation emission factors for buffalo and nitrogen excretion factor	U	A.3	A. 3
Information used in the calculation of volatile solids from dairy cattle	NG	-	A.2-1A

Calculations in the development of volatile solid estimates for non dairy cattle	NG	-	A.2-1B
Suggested animal waste management system (awms) breakdowns for different world regions and corresponding production systems for cattle. In the case of cattle, awms do not differ by productivity systems (high or low productivity) for tier 1b calculations.	U	A-4 A-5	A.2-2
Suggested animal waste management system (awms) breakdowns for different world regions and corresponding production systems for buffalo.	U	A-6	A.2-3
Suggested animal waste management system (awms) breakdowns for different world regions and corresponding production systems for swine.	U E	A-7 A-8	A.2-4
Suggested animal waste management system (awms) breakdowns for different world regions and corresponding production systems for sheep.	U E	A-9	A.2-5
Suggested animal waste management system (awms) breakdowns for different world regions and corresponding production systems for goat.	U E	A-9	A.2-6
Suggested animal waste management system (awms) breakdowns for different world regions and corresponding production systems for poultry.	U E	A-9	A.2-7
Manure management methane emission factor derivation for other animals	U	A-9	A.2.8
Assumptions used in the development of default parameters for breeding swine			A.4-1
Manure management nitrous oxide emission factor derivation for other animals			A.5-1
Mean, median, maximum, minimum and quartile 1 and 3 (q1 and q3) values			Table X

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for a selection feed diet composition, feed intake, body weight and milk productivity.			
Mean, median, maximum, minimum and quartile 1 and 3 (q1 and q3) values for ch <sub>4</sub> production results referred as a proportion of gross energy intake (ch <sub>4</sub> conversion factor: ym), per day, per kg dm intake, per kg of milk produced and per kg of body weight			Table X

Discussion:

Table 10.1 added high and low productivity systems and identified the enhanced livestock definitions that would go with them while Table 10.2 was modified to update information in it, such that the values were consistent with production systems in 2019.

Modifications to Tables 10.3 to 10.7 provide additional values required to calculate Tier 2 estimates for goat production.

The simplified Tier 2 methodology was elaborated with new equations and some new parameters were added to Tables. In Section 10.3.2, Tier 1a emission factors were updated and Tier 1b emission factors were developed. The methane conversion rate (Ym) Table was expanded to increase the number of animal categories and improve consistency with feed quality as well as factors to calculate emissions directly from the DMI estimate using the simplified Tier 2 approach.

## Figures

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Decision tree for livestock population characterisation	NR	10.1	10.1
Decision Tree for CH <sub>4</sub> Emissions from Enteric Fermentation	U	10.2	10.2
Decision tree for CH <sub>4</sub> emissions from Manure Management	NR	10.3	10.3
Decision tree for N <sub>2</sub> O emissions from Manure Management (Note 1)	NR	10.5	10.4
Processes leading to the emission of gaseous N species from manure	NG	-	10.5
Mapping of IPCC climate zones. (taken from Volume 4, Chapter 3, Annex 3A.5)			A.2-1
Colour code for cells in the example spreadsheet.			A.3-1
<b>Temperature and manure removal inputs to the model. Top panel: alphanumeric values in each cell. Middle panel: dropdown menu to select “Air” or “Manure”. Bottom panel: all formulae are visible.</b>			Figure 2

<b>Constants and other input parameters for the model are shown in the top panel. Named Cells in column I are shown in column O, and in the Name Manager dialog box (bottom panel). No formulae exist in this part of the spreadsheet.</b>			Figure 3
<b>Model inputs and outputs over a three year period.</b>			Figure 4
<b>Formulae used in the model. To conserve space, only 12 months are shown. Top panel: columns C:G. Middle panel: columns H:L. Bottom panel: sums in rows 64:66 for selected columns.</b>			Figure 5
<b>Monthly patterns in Year 3: manure temperature, VS available, VS emptied, and methane production.</b>			Figure 6
<b>Summary of Year 3 VS and methane production, and calculation of MCF. Top panel shows results, bottom panel shows equations.</b>			Figure 7
Annual enteric methane output per animal expressed in mass in relation to daily dry matter (DM) intake.			Figure 1
Daily enteric methane output per animal expressed in energy in relation to daily gross energy (GE) intake.			Figure 2

347 Discussion:

348 Modification of decision tree for inclusion of Tier 1b concept.

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## CHAPTER 11, N<sub>2</sub>O EMISSIONS FROM MANAGED SOILS AND CO<sub>2</sub> EMISSIONS FROM LIME AND UREA APPLICATIONS

### Sections

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Introduction	NR	11.1	11.1
N <sub>2</sub> O emissions from managed soils	U	11.2	11.2
Direct N <sub>2</sub> O emissions	U	11.2.1	11.2.1
Choice of method	U	11.2.1.1	11.2.1.1
Choice of emission factors	U	11.2.1.2	11.2.1.2
Choice of activity data		11.2.1.3	11.2.1.3
<i>Applied synthetic fertiliser (<math>F_{SN}</math>)</i>	NR		
<i>Applied organic N fertilisers (<math>F_{ON}</math>)</i>	NR		
<i>Urine and dung from grazing animals (<math>F_{PRP}</math>)</i>	NR		
<i>Crop residue N, including N-fixing crops and forage/ pasture renewal, returned to soils, (<math>F_{CR}</math>)</i>	U		
<i>Mineralised N resulting from loss of soil organic C stocks in mineral soils through land-use change or management practices (<math>F_{SOM}</math>)</i>	NR		
<i>Calculation steps for estimating changes in N supply from mineralization</i>	NR		
<i>Area of drained/managed organic soils (<math>F_{OS}</math>)</i>	NR		
Uncertainty assessment	NR	11.2.1.4	11.2.1.4
Indirect N <sub>2</sub> O emissions	U	11.2.2	11.2.2
Choice of method	U	11.2.2.1	11.2.2.1
Choice of emission, volatilisation and leaching factors	U	11.2.2.2	11.2.2.2
Choice of activity data	NR	11.2.2.3	11.2.2.3
Uncertainty assessment	NR	11.2.2.4	11.2.2.4
Completeness, Time series, QA/QC	NR	11.2.3	11.2.3
CO <sub>2</sub> Emissions from Liming	NR	11.3	11.3
CO <sub>2</sub> Emissions from Urea Fertilization	NR	11.4	11.4



References for crop residue data in Table 11.2	NR	Annex 11A.1	Annex 11A.1
Estimation of Default Emission Factor(s) for EF <sub>1</sub>	NG	-	Annex 11A.2
Estimation of Default Emission Factor(s) for EF <sub>1FR</sub>	NG	-	Annex 11A.3
Estimation of Default Emission Factor(s) for EF <sub>3PRP</sub>	NG	-	Annex 11A.4
Estimation of Default Emission Factor(s) for EF <sub>4</sub>	NG	-	Annex 11A.5
Estimation of Default Emission Factor(s) for EF <sub>5</sub>	NG	-	Annex 11A.6
Estimation of Default Emission Factor(s) for Frac <sub>GASF</sub>	NG	-	Annex 11A.7
Estimation of Default Emission Factor(s) for Frac <sub>GASM</sub>	NG	-	Annex 11A.8
Estimation of Default Emission Factor(s) for Frac <sub>LEACH-(H)</sub>	NG	-	Annex 11A.9
References	U	-	-

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**Equations**

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Direct N <sub>2</sub> O emissions from managed soils (Tier 1)	NR	11.1	11.1
Direct N <sub>2</sub> O emissions from managed soils (Tier 2)	NR	11.2	11.2
N from organic N additions applied to soils (Tier 1)	NR	11.3	11.3
N from animal manure applied to soils (Tier 1)	NR	11.4	11.4
N in urine and dung deposited by grazing animals on pasture, range and paddock	NR	11.5	11.5
N from crop residues and forage/pasture renewal (Tier 1)	U	11.6	11.6
Dry-weight correction of reported crop yields	NR	11.7	11.7

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Alternative approach to estimate $F_{CR}$ (using Table 11.2)	R	11.7A	-
N mineralised in mineral soils as a result of loss of soil C through change in land use or management (Tiers 1 and 2)	NR	11.8	11.8
N <sub>2</sub> O from atmospheric deposition of N volatilised from managed soils (Tier 1)	NR	11.9	11.9
N <sub>2</sub> O from N leaching/runoff from managed soils in regions where leaching/runoff occurs (Tier 1)	NR	11.10	11.10
N <sub>2</sub> O from atmospheric deposition of N volatilised from managed soils (Tier 2)	NR	11.11	11.11

Discussion:

Equation 11.6 was updated.

Equation 11.7A was removed from the guidance, but the option is available to estimate  $AGR(T)$  with data in Table 11.3.

## Tables

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Default emission factors to estimate direct N <sub>2</sub> O emissions from managed soils	U	11.1	11.1
Default factors for estimation of N added to soils from crop residues	U	11.1a	11.2
Default values for $R_{AG(T)}$ to be used in Equation 11.6	E	11.2	11.2
Default emission, volatilisation and leaching factors for indirect soil N <sub>2</sub> O emissions	U	11.3	11.3

Discussion:

Table 11.1 contains updated  $EF_1$ ,  $EF_{IFR}$  and  $EF_{3PRP}$ . Methods, data and references used for determining updated values and their uncertainties are in the annexes.

Table 11.2 was updated. The title “Default factors for estimation of N added to soils from crop residues” was changed to “Alternative Method for Estimating Above-ground Residue ( $AGR(T)$ )”. The units of  $AGR(T)$  were changed from Mg/ha to kg. d.m. ha<sup>-1</sup>; in alignment with the unit in Equation 11.6. Default values for slope, intercept, errors remained unchanged. Former columns ‘Dry matter fraction of harvested product (DRY)’, ‘N content of above-ground residues (NAG)’, ‘Ratio of below-ground residues to above-ground biomass (RBG-BIO)’, and ‘N content of below-ground residues (NBG)’ were moved to new Table 11.X.

A new Table (Table 11.X) was added to the section 11.2.1.3 Choice of activity data, Crop residue N, including N-fixing crops and forage/ pasture renewal, returned to soils, (FCR). The Table reproduces default values from Table 11.2 in the 2006 guidelines for columns ‘Dry matter fraction of harvested product (DRY)’, ‘N content of above-

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ground residues (NAG)', 'Ratio of below-ground residues to above-ground biomass (RBG-BIO)', and 'N content of below-ground residues (NBG)'. It also introduces new default values for  $R_{AG(T)}$ , ratio of above-ground residues dry matter (AGDM(T)) to harvested yield for crop T, to be used in updated Equation 11.6.

Table 11.3 contains updated EF<sub>5</sub>, Frac<sub>GASF</sub>, Frac<sub>GASM</sub> and Frac<sub>LEACH-(H)</sub>. Methods, data and references used for determining updated values and their uncertainties are in the annexes.

## Figures

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Schematic diagram illustrating the sources and pathways of N that result in direct and indirect N <sub>2</sub> O emissions from soils and waters	NR	11.1	11.1
Decision tree for direct N <sub>2</sub> O emissions from managed soils	NR	11.2	11.2
Decision tree for indirect N <sub>2</sub> O emissions from managed soils	NR	11.3	11.3

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**CHAPTER 12, HARVESTED WOOD PRODUCTS****Sections**

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Preamble to Introduction	U	12 (before 12.1)	12.1
Introduction	U	12.1	12.1
Methodological issues	U	12.2	12.4, 12.5 & 12.6
Choice of method	U	12.2.1	12.5.1
Tier 1	U	12.2.1.1	12.5.2 & 12.6
Tier 2: Using country data	U	12.2.1.2	12.5.3
Tier 3: Country-specific methods	U	12.2.1.3	12.5.4
Estimating carbon release to the atmosphere from the HWP variables	U	12.2.1.4	12.4, 12.5 & 12.6
Estimating carbon released to the atmosphere in the form of CO <sub>2</sub>	U	12.2.1.5	12.4, 12.5 & 12.6
Choice of emission factors	U	12.2.2	12.5.2.2, 12.5.3.2 & 12.5.4.1
Choice of activity data	U	12.2.3	12.5.2.1, 12.5.3.1 & 12.5.4.1
Uncertainty assessment	U	12.3	12.7
Quality assurance/quality control	U	12.4	12.8
Completeness	U	12.5	12.9
Reporting and documentation	NR	12.6	No equivalent section, see note 9
Reporting tables and worksheets	NR	12.7	No equivalent section, see note 9
Some Approaches	U	Annex 12.A.1	12.3

Discussion:

1. Section 12.1: Provides an overview of the HWP chapter in the 2019 Refinement. Updates the explanation of some key concepts relevant to estimation based on updated parameters.
2. Section 12.2: Updates (clarifies) the description of some existing terms, definitions and concepts.
3. Section 12.3: Updates the explanation of the different HWP approaches. Clarifies essential differences between approaches including brief discussion of the implications of selecting HWP approaches relevant to estimation based on updated technical parameters.
4. Section 12.4: Updates methodological guidance for estimating under the approaches, including updated guidance for applying technical parameters for the calculation of initial stock establishment and updated technical parameters including HWP carbon conversion factors. Includes an update of all technical parameters relevant to estimation methods.
5. Section 12.5: Updates the discussion to clarify where CO<sub>2</sub> and non-CO<sub>2</sub> emissions from harvested wood used for energy purposes are reported, in particular where CO<sub>2</sub> emissions are reported when HWP are used in the Energy sector and imports and exports are involved.
6. Section 12.6: Provides clarification of the treatment of “wood biomass in SWDS” in this guidance.
7. Section 12.7: Updates discussion of uncertainty assessment allowing for updated description of application of technical parameters for Tiers 1 to 3.
8. Section 12.8: Updates the discussion of QA/QC allowing for updated description of application of technical parameters.
9. No update on reporting and documentation has been included since the reporting conventions and format are specified in Decision 24/CP.19 Annex II and the associated CRF.
10. Annex 12.A.1: Updated technical description of HWP approaches is provided in the annex.

**Equations**

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Estimation of carbon stock and its annual change in HWP pools of the reporting country	NR	12.1	12.2
Estimation of HWP products placed in use annually from domestic consumption	U	12.2	12.3 & 12.6
Estimation of HWP products produced annually from domestic harvest	U	12.3	12.3, 12.7 & 12.8 & 12.9
Estimation of annual change in carbon in HWP in domestic SWDS where HWP came from harvest	U	12.4	No equivalent equation, see note 4
Estimation of carbon release using HWP variables	U	12.5	12.2 & 12.3
Equation to estimate production, imports or export variables in Table 12.5 for years before 1961	U	12.6	12.4
Emissions from AFOLU by the stock-change approach	U	12.A.1	12.1
Stock-change approach: HWP contribution	U	12.A.2	12.1
Emissions from AFOLU as by the atmospheric flow approach	U	12.A.3	12.5 & 12.10
Atmospheric flow approach: HWP contribution	U	12.A.4	12.1
Emissions from AFOLU by the production approach	U	12.A.5	12.1
Production approach: HWP contribution	U	12.A.6	12.1

## Discussion:

- Equation 12.1: Equation 12.2 in the updated draft 2019 Guidance is effectively the same as Equation 12.1 but involves updated treatment of C (1900) (see Section 12.5.2 of draft 2019 Guidance in particular discussion of Equation 12.4/Box 12.1).
- Equation 12.2: Updated principally through Equations 12.3 & 12.6 in draft 2019 Guidance, allowing for updated consideration of activity data and updated technical parameters.
- Equation 12.3: Updated principally through Equations 12.3, 12.7, 12.8 & 12.9 in draft 2019 Guidance, allowing for updated consideration of activity data and updated technical parameters.
- Equation 12.4: No equation needed due to updated guidance on treatment of wood in SWDS in the context of Decision 24/CP.19 Annex II (see Section 12.6 of draft 2019 Guidance).
- Equation 12.5: Updated principally through Equations 12.2 & 12.3 in draft 2019 Guidance, allowing for updated consideration of activity data and updated technical parameters and treatment of wood in SWDS in the context of Decision 24/CP.19 Annex II (see Section 12.6 of draft 2019 Guidance).
- Equation 12.6: Updated principally through Equation 12.4 in draft 2019 Guidance, allowing for updated guidance in Section 12.5.2 in particular discussion accompanying Equation 12.4/Box 12.1.
- Equations 12.A.1 to 12.A.6: Updated principally through Equation 12.1 in draft 2019 Guidance, allowing for updated consideration of activity data and updated technical parameters and reporting according to Decision 24/CP.19 Annex II (see Section 12.6 of draft 2019 Guidance).

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430 **Tables**

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
HWP variables used to estimate annual HWP contribution to AFOLU CO <sub>2</sub> emissions/removals	U	12.1	No equivalent table, see note 1
Default half-life for “products in use” carbon pools and associated fraction retained each year	U	12.2	12.3
Estimated annual rates of increase for industrial roundwood production (harvest) by world region for the period 1900 to 1961	U	12.3	No equivalent table, see note 3
Default factors to convert from product units to carbon	U	12.4	12.1 & 12.2
UN FAO activity data needed for Tier 1 variables, and default conversion factors	U	12.5	No equivalent table, see note 5
Uncertainty associated with activity data and parameters (emission factors) for the Tier 1 method to estimate the five annual HWP variables	U	12.6	No equivalent table, see note 6
Annual carbon HWP contribution to total AFOLU CO <sub>2</sub> removals and emissions and background information	U	12.7	No equivalent table, see note 7
Summary of how to compute HWP contribution using variables in Table 12.7	U	A12.1	No equivalent table, see note 7

## 431 Discussion

- 432 1. Table 12.1: Table no longer required due to updated guidance included in Section 12.4 of draft 2019
- 433 Guidance.
- 434 2. Table 12.2: Updated (inclusion of updated technical parameters) in Table 12.3 of draft 2019
- 435 Guidance.
- 436 3. Table 12.3: Table no longer required due to updated guidance (see Section 12.4.2 in draft 2019
- 437 Guidance in particular discussion of Equation 12.4/Box 12.1).
- 438 4. Table 12.4: Updated (inclusion of updated technical parameters) in Tables 12.1 and 12.2 of draft
- 439 2019 Guidance.
- 440 5. Table 12.5: Table no longer required due to updated guidance (see Section 12.4.1.1 in draft 2019
- 441 Guidance).
- 442 6. Table 12.6: Table no longer required due to updated guidance included in Section 12.7 of draft 2019
- 443 Guidance, which includes indications of uncertainties where available.
- 444 7. Tables 12.7 & A12.1: Table no longer required due to adoption of CRF table as agreed in Decision
- 445 24/CP.19, Annex II.

**Figures**

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Decision tree for reporting HWP Contribution of zero or selecting a tier	U	12.1	12.1
System boundary of the stock-change approach	U	12.A.1	12.A.1
System boundary of the atmospheric flow approach	U	12.A.2	12.A.3
System boundary of the production approach	U	12.A.3	12.A.2

**Discussion:**

- Figure 12.1: Updated decision tree in Figure 12.1 allowing for improved understanding of available activity data.
- Figure 12.A.1: Updated system boundary diagram in Figure 12.A.1 clarifying linkages to relevant updated guidance on activity data and reporting according to Decision 24/CP.19 Annex II (see Section 12.A.1 in Annex 12.A of draft 2019 Guidance).
- Figure 12.A.2: Updated system boundary diagram in Figure 12.A.3 clarifying linkages to relevant updated guidance on activity data and reporting according Decision 24/CP.19 Annex II (see Section 12.A.2 in Annex 12.A of draft 2019 Guidance).
- Figure 12.A.3: Updated system boundary diagram in Figure 12.A.2 clarifying linkages to relevant updated guidance on activity data and reporting according Decision 24/CP.19 Annex II (see Section 12.A.1 in Annex 12.A of draft 2019 Guidance).

**Boxes**

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
None			