ANNEX 1

MAPPING TABLES

Contents

Annex 1 Relating the *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: U – Update, NG – New Guidance, NR – No Refinement, R – Removed

CHAPTER 1 INTRODUCTION

Refinements in this chapter reflect the new guidance and updates that are made in other chapters of this volume.

Sections

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Introduction	U	1.1	1.1
Overview of greenhouse gas emissions and removals in the AFOLU sector	U	1.2	1.2
Science background	U	1.2.1	1.2.1
Carbon pool definitions and non-CO_2 gases	U	1.2.1	1.2.1
Overview of inventory preparation for the AFOLU sector	U	1.3	1.3
Land-use and management categories	U	1.3.1	1.3.1
Tier definitions for methods in AFOLU	U	1.3.2	1.3.2
Identification of *key categories*	NR	1.3.3	1.3.3
Steps in preparing inventory estimates	U	1.3.4	1.3.4
Organisation of Volume 4 in the *2019 Refinement to the 2006 IPCC Guidelines*	U	1.4	1.4
Historical background on the IPCC greenhouse gas inventory guidance for AFOLU sector	NR	1A	1A

Tables

Table Title	Type of Refinement	2006 IPCC Guidelines Table Number	2019 Refinement Table Number
Definitions of carbon pools used in AFOLU for each land-use category	U	1.1	1.1
Land-use categories, carbon pools and non-CO_2 gases to be estimated under Tier 1, their relevance to AFOLU sections, and the reference to *Revised 1996 IPCC Guidelines*	U	1.2	1.2

Figures

- No refinement

Boxes

Box Title	Type of Refinement	2006 IPCC Guidelines Box Number	2019 Refinement Box Number
Framework of tier structure for AFOLU methods	U	1.1	1.1

CHAPTER 2 GENERIC METHODS

This section has several refinements including a) guidance on application of allometric model and biomass density maps for estimation of biomass C; b) refinements on the guidance to estimate changes in dead organic matter and updates to the factors; c) refinements to the description of methods and factors to estimate soil C stock change in mineral soils, and the addition of a Tier 2 method to estimate the C stock changes from biochar amendments; d) expanded guidance on application of Tier 3 methods; and e) methods for estimating the influence of inter-annual variability on greenhouse gas emissions. There was limited refinement to the methods for estimating non-CO_2 greenhouse gas emissions from biomass burning.

Sections

- Section 2.3.1 provides definitions and new guidance to inventory compilers on the use of allometric models to estimate volume, biomass and carbon stocks in land uses containing vegetation at Tier 2 and 3 levels, including a decision tree to select the appropriated one. The section also provides guidance on how to use of biomass density maps for the estimation of carbon emissions at Tier 2 and Tier 3 levels.

- Section 2.3.2 provides updates on methods and factors for estimating changes in C for dead organic matter.

- Section 2.3.3 provides refinements for estimation of soil C stock changes in mineral soils including more guidance about application of Tier 2 and 3 methods. For Tier 3, several examples are provided that describe methods that have been applied for reporting soil C stock changes by countries. Guidance is provided on using mass-equivalency methods and assessing the impact of soil erosion and deposition. Updates have been made to the default reference C stocks for estimating C stock changes in mineral soils. New guidance is provided to estimate the change in soil C stocks with biochar amendments to soils in grassland and cropland. Biochar C has been intensively studied over the past decade and the recent research has provided a scientific basis for developing a Tier 2 method. Tier 3 methods may also be developed to estimate impacts of biochar amendments on soil C stocks in forest land, settlements, wetlands and other land.

- Section 2.4 is refined to provide a method for estimating mass of fuel in croplands that is consistent with the method for estimating soil N_2O emissions from crop residues (i.e., mass of residues). Ensuring consistency among sources is considered a *good practice* and is the primary reason that the method for estimating mass of fuel has been refined.

- Section 2.5 is revised to expand the guidance on how to parameterize and evaluate Tier 3 models, the integration of data to models, and means to increase its transparency. Case studies have been included to demonstrate how different countries have developed and worked with Tier 3 methods.

- Section 2.6 is 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 disturbances.

- An annex is provided to describe the data that have been used to estimate default reference C stocks for the mineral soil method. An annex is also provided describing the underlying scientific basis for developing Tier 2 and 3 methods to estimate soil C stock change from biochar C amendments to soils.

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Introduction	NR	2.1	2.1
Inventory Framework	U	2.2	2.2
Overview of carbon stock change estimation	NR	2.2.1	2.2.1
Overview of non-CO_2 emission estimation	NR	2.2.2	2.2.2
Conversion of C stock changes to CO_2 emissions	NR	2.2.3	2.2.3
Generic methods for CO_2 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

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Change in dead organic matter	NR	2.3.2	2.3.2
Land remaining in a land-use category	U	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	2.3.3.1	2.3.3.1
Non-CO_2 emissions	U	2.4	2.4
Additional generic guidance for tier 3 methods	U	2.5	2.5
Measurement-based tier 3 inventories	U	2.5.1	2.5.1
Model-based tier 3 inventories	U	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
Optional approach for reporting of emissions and removals from Natural Disturbances	NG	_	2.6.3
Reporting the contribution of natural disturbances and anthropogenic effects to the emissions and removals for managed lands	NG	-	2.6.4
Default Mineral Soil Reference C Stocks	NG	-	2A.1
Additional Information for the Estimation of Soil Carbon Stock Change from Biochar Amendments to Mineral Soils Using Tier 2 and 3 Methods	NG	-	2A.2

Equations

- Equation 2.25A has been added as part of the Tier 2 method guidance. This equation is used to estimate the annual change in soil C stock in mineral soils that are amended with biochar in grassland and cropland.

Equation Title	Type of Refinement	2006 IPCC Guidelines Equation Number	2019 Refinement Equation Number
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_2 emissions to the atmosphere	NR	2.6	2.6

Equation Title	Type of Refinement	2006 IPCC Guidelines Equation Number	2019 Refinement Equation Number
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
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	NR	2.24	2.24
Annual change in organic carbon stocks in mineral soils	NR	2.25	2.25
Annual change in biochar carbon stock in mineral soils receiving biochar additions	NG	-	2.25a
Annual carbon loss from drained organic soils (CO_2)	NR	2.26	2.26
Estimation of greenhouse gas emissions from fire	NR	2.27	2.27
Estimation of Soil Organic Carbon Stocks	NG	-	2A.1.1

Tables

- Table 2.2 includes updates to the default values for litter and deadwood C stocks.

- Table 2.3 has been updated with new reference carbon stocks from Batjes (2011). For a subset of soils types and/or climate regions, new values are not provided in the analysis by Batjes (2011) so values from previous IPCC guidance documents are retained. Updated 95per cent confidence interval limits expressed as a percentage of the mean organic carbon stock are also provided. Where the number of samples used to calculate the mean and confidence limits are known it included in the updated to table to provide an indication of the level of data informing the new factors.

- Tables 2.4 and 2.6 provide updates for estimating mass of fuel associated with non-CO_2 emissions from agricultural residues burning.

- Table 2.6A includes examples of documentation that may be provided by compilers to increase the transparency of Tier 3 models that are used for inventories.

- Table 2.6B provides examples of documentation that may be provided to increase the transparency of model-based Tier 3 inventories.

- Table 2.6C indicates whether or not different estimation methods are able to distinguish between the impact of the individual drivers on the interannual variability of reported annual emission and removal estimates from managed land.

Table Title	Type of Refinement	2006 IPCC 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 (SOC_{REF}) for mineral soils (tonnes C ha^{-1} in 0-30 cm depth)	U	2.3	2.3
Fuel (dead organic matter plus live biomass) biomass consumption values (tonnes dry matter 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
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
General guidance on whether or not the estimation method is able to distinguish between the impact of the individual drivers below on the interannual variability of reported annual emission and removal estimates	NG	-	2.6c

Figures

- Figure 2.4 includes a minor update by inserting the word "method" at the end of the first diamond in the decision tree.

- Figure 2.6A summarizes the main factors that cause anthropogenic (i.e., direct and indirect human) effects and natural effects on greenhouse gas emissions and removals, and their occurrences in managed and unmanaged lands.

- Figure 2.6B is part of BOX.2I, and provides an example of the disaggregation of wildfire emissions in Australia into 'natural disturbance' emissions and removals and the emissions and removals from fires due to human activity.

- Figure 2.6C is part of BOX. 2J, and provides an example of the disaggregation of Canada's FL-FL emissions and removals into those occurring on lands dominated by natural disturbance impacts and those occurring in the remaining managed forest.

- Figure 2.6D and 2.6E are part of BOX. 2K, and provide an example of methodological approach based on the European legislation to estimate the contribution of natural disturbances to the emissions and removals reported for managed lands.

- Figure 2.7 from the *2006 IPCC guidelines* has been moved to Volume I, and expanded with additional guidance for all sectors.

Figure Title	Type of Refinement	2006 IPCC 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
Conceptual illustration of how various anthropogenic (direct and indirect) and natural factors affect land-related GHG emissions and removals in managed and unmanaged lands	NG	-	2.6a
Example of the disaggregation of wildfire emissions in Australia into natural 'natural disturbance' emissions and removals and the emissions and removals from fires due to human activity.	NG	-	2.6b
Example of the disaggregation of Canada's FL-FL emissions and removals into those occurring on lands dominated by natural disturbance impacts and those occurring in the remaining managed forest.	NG	-	2.6c
Time series of managed forest land total GHG net emission (anthropogenic + natural disturbance (ND) and area burnt.	NG	-	2.6d
Time series of managed forest land GHG net emissions and removals (Gg CO_2e)	NG	-	2.6e

Boxes

- Box 2.0A provides information on how consistency and comparability could be maintained when applying IPCC guidelines for AFOLU projects and activities.

- Box 2.0B provides information about definitions of allometric equations.

- Box 2.0C discusses emerging LIDAR technology for application in biomass C inventories.

- Box 2.0D discusses remote sensing technology for application in biomass C inventories.

- Box 2.0E provides an example for how biomass density maps are used to estimate biomass C stock change in the Brazilian Amazon.

- Boxes 2.2A and 2.2E provides information about using equivalent mass methods in soil C inventories.

- Box 2.2B provides background on emissions associated with biochar production and application.

- Box 2.2C provides discussion about methods to address the impact of soil erosion and deposition on soil C stocks.

- Box 2.2D provides several examples of Tier 3 methods that have been used by governments to report soil C stock changes.

- Box 2.2F presents an example of model calibration, evaluation and improvement through data assimilation (Canada's Carbon Budget Model).

- Box 2.2G presents examples (Finland and Canada) of model evaluation and improvement.

- Box 2.2H presents examples (Canada and USA) of quantification of uncertainties in Tier 3 modelling approaches.

- Box 2.2I provides an example of methodological approach developed by Australia to estimate the contribution of natural disturbances to the emissions and removals reported for managed lands

- Box 2.2J provides an example of methodological approach developed by Canada to estimate the contribution of natural disturbances to the emissions and removals reported for managed lands

- Box 2.2K provides an example of methodological approach based on European legislation to estimate the contribution of natural disturbances to the emissions and removals reported for managed lands

- Box 2.2L provides an example of a table format that could be used for voluntary disaggregation of emissions and removals reported for managed lands into anthropogenic and natural disturbance component.

Box Title	Type of Refinement	2006 IPCC 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
Remote Sensing Technologies	NG	-	2.0d
Using a biomass map for GHG estimation: an example from the Brazilian Amazon	NG	-	2.0e
Alternative Formulations of Equation 2.25 for Approach 1 Activity Versus Approach 2 or 3 Activity Data with Transition Matrices	U	2.1	2.1
Comparison between use of approach 1 aggregate statistics and approach 2 or 3 activity data with transition matrices	U	2.2	2.2
Using equivalent mass methods to derive mineral soil stock change factors	NG		2.2a
GHG emission sources with biochar production	NG	-	2.2b
Representing the impact of soil erosion and deposition on soil carbon stock changes	NG		2.2c
Examples of Tier 3 mineral soil C stock change methods	U	-	2.2d
Consideration of equivalent mass methods within Tier 3 modelling approaches	NG	-	2.2e
An example of model calibration, evaluation and improvement through data assimilation	U	-	2.2f
Examples of model evaluation and improvement	U	-	2.2g
Examples of quantification of model uncertainty	U	-	2.2h
Australian approach to estimating interannual variability due to natural disturbances	NG	-	2.2i
Canada's approach to estimating interannual variability from natural disturbances	NG	-	2.2j
Approach to estimating interannual variability from natural disturbances based on the EU legislation	NG	-	2.2k
Example of the table format that could be used for voluntary disaggregation of total estimated fluxes on Managed Lands into anthropogenic and natural Disturbance components	NG		2.2l

CHAPTER 3 CONSISTENT REPRESENTATION OF LANDS

In this chapter updates (U) and new guidance (NG) were introduced to provide a sound scientific basis for representing land area, land-use change and related emissions and removals in the AFOLU sector. It treats specifically how to combine different data sources and types of information (with a special focus on Remoting Sensing (RS) data and products), the coherence between national land-use classification systems and IPCC land-use categories, uncertainty and accuracy of activity data, and the specificities of RS data.

Sections

- While No Refinement was mandated, an elaboration is introduced in Section 3.1 to outline the main steps necessary to achieve consistent representation of lands at the national level for inventory purposes. The steps are detailed in following sections.

- In Section 3.2 elaborations were introduced to further explain the terms "land-use" and "land cover"; the consistency of national definitions with the IPCC land-use categories; the total area (managed and unmanaged) consistency through the reporting period and to provide further guidance on assigning IPCC land-use and land-use change categories.

- In Section 3.3. the 2006 text has been reviewed and refined to elaborate 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.

- 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 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

- 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*).

- An additional Annex (3A.6) was introduced (as part of the elaboration made in section 3.3.3) to provide an example of a process for allocating lands to IPCC land-use classes using Approach 3 wall-to-wall methods

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Introduction	U	3.1	3.1
Land use categories	U	3.2	3.2
Representing land areas	U	3.3	3.3
Three approaches	U	3.3.1	3.3.1
Data for land representation	U	3.3.2	3.3.2
Methods for land-use and land-use change estimation	NG	-	3.3.3
Combining multiple data sources	NG	-	3.3.4
Derivation of IPCC land-use categories from land cover information	NG	-	3.3.5
Stratification of land-use data	U,NG	3.3.2.1	3.3.6
Preparing are data for emissions and removals	NR	3.3.2.2	3.3.7
Matching land areas with factors for estimating greenhouse gas emissions and removals	NR	3.4	3.4

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Use of different approaches and methodological tiers when estimating emissions and removals due to land-use change	NG	-	3.4.1
Uncertainties associated with the Approaches	U	3.5	3.5
Examples of international land cover dataset	U	3A.1	3A.1
Development of land-use databases	U	3A.2	3A.2
Sampling	NR	3A.3	3A.3
Overview of potential methods for developing Approach 3 datasets	NR	3A.4	3A.4
Default climate and soil classifications	U	3A.5	3A.5
Example process for allocating lands to IPCC land-use classes using Approach 3 wall-to-wall methods	NG	---	3A.6

Equations

- No refinement

Tables

- A new Table 3.6A is provided with some examples of different data inputs and methods to derive IPCCC land-use classes and the resulting approach.

- A new Table 3.6B is provided with examples of auxiliary data and possible assumptions that can help to determine and stratify land-use.

- Table 3.A.1.1. was updated with examples of global land cover datasets in 2017

Table Title	Type of Refinement	2006 IPCC Guidelines Table Number	2019 Refinement Table Number
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 different data inputs and methods to derive IPCC land-use classes and the resulting approaches (1,2 or 3)	NG	-	3.6a
Examples of auxiliary data and possible assumptions that can help to determine and stratify land-use	NG	-	3.6b
Summary of uncertainties under Approaches 1 to 3	NR	3.7	3.7
Examples of international land cover dataset	U	3.A.1.1	3.A.1.1
Example of area estimation via proportions	NR	3.A.3.1	3.A.3.1

Figures

- The default climate classification provided in Figure 3A.5.1 has been updated using the classification scheme shown in Figure 3A.5.2 based on the gridded Climate Research Unit (CRU) Time Series (TS) monthly climate data for the period from 1985 to 2015.

- A new Figure 3A.6.1 was introduced representing a decision tree for allocating lands to the IPCC land-use categories when using Approach 3 wall-to-wall methods (i.e., where every land unit is assumed to have information on land cover over time). This method may also be applicable for some sample-based methods.

Figure Title	Type of Refinement	2006 IPCC Guidelines Figure Number	2019 Refinement Figure Number
Decision tree for preparation of land-use area data	NR	3.1	3.1
Principle of sampling	NR	3.A.3.1	3.A.3.1
Simple random layout of plots (left) and systematic layout (right)	NR	3.A.3.2	3.A.3.2
Use of different configurations of permanent and temporary sampling units for estimating changes	NR	3.A.3.3	3.A.3.3
Overview of Approach 3: Direct and repeated assessments of land use from full spatial coverage	NR	3.A.4.1	3.A.4.1
Delineation of major climate zones, updated from the *2006 IPCC Guidelines*	U	3.A.5.1	3.A.5.1
Classification scheme for default climate regions. The classification is based on elevation, mean annual temperature (MAT), mean annual precipitation (MAP), mean annual precipitation to potential evapotransporation ratio (MAP:PET), and frost occurrence	NR	3.A.5.2	3.A.5.2
Classification scheme for mineral soil types based on USDA taxonomy	NR	3.A.5.3	3.A.5.3
Classification scheme for mineral soil types based on World Reference Base for Soil Resources (WRB) classification	NR	3.A.5.4	3.A.5.4
Decision tree for classifying land-use and land-use change through time in Approach 3	NG	-	3.A.6.1

Boxes

- Box 3.1A provides examples of auxiliary data required when land cover change information is used, to allocate land cover change to the underlying cause of disturbance and to assign lands to the IPCC land-use categories through time.

Box Title	Type of Refinement	2006 IPCC Guidelines Box Number	2019 Refinement Box Number
Examples of assigning IPCC land-use and land-use change categories	NG	-	3.1A

CHAPTER 4 FOREST LANDS

Refinements in this chapter include updates to default factors for biomass, additional guidance on application of methods to estimate soil C stock changes and time series consistency. There are no refinements to the guidance on dead organic matter or non-CO_2 greenhouse gas emissions from biomass burning.

Sections

- Section 4.2.3 is updated with current understanding of soil C changes deeper in the soil profile abased on a review of the scientific literature. The level of stratification is also clarified for different tiers.

- Section 4.2.3.1 is refined with discussion on the limited scientific basis for quantification of effects of forest management. This is reason that default stock change factors are not provided in this chapter for management impacts on soil C stocks.

- Section 4.2.3.2 provides new guidance on developing Tier 2 stock change factors for forest land in Box 4.3A. Discussion is provided about soil depth for Tier 2 methods. Application of mass-equivalency methods is clarified in accordance with updates in Chapter 2.

- Section 4.2.3.3 provides guidance for Tier 2 activity data with regard to forest land management.

- Section 4.2.3.5 is refined with new guidance on uncertainty assessments for Tier 3.

- Section 4.3.3.2 includes refinements with additional guidance on developing Tier 2 reference C stocks in accordance with Chapter 2, and mass equivalency is discussed.

- Section 4.3.3.3 has new discussion about the implications of the type of activity data for land-use change, consistent with Chapter 2.

- Section 4.4.2 further guidance on time series consistency is provided on how to ensure methodological consistency in the case of the Forest Land category for gap filling and extrapolation.

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Introduction	NR	4.1	4.1
Forest Land Remaining Forest Land	NR	4.2	4.2
Biomass	NR	4.2.1	4.2.1
Choice of method	NR	4.2.1.1	4.2.1.1
Choice of emission factors	NR	4.2.1.2	4.2.1.2
Choice of activity data	NR	4.2.1.3	4.2.1.3
Calculations steps for Tier 1	NR	4.2.1.4	4.2.1.4
Uncertainty assessment	NR	4.2.1.5	4.2.1.5
Dead organic matter	NR	4.2.2	4.2.2
Choice of method	NR	4.2.2.1	4.2.2.1
Choice of emission/removal factors	NR	4.2.2.2	4.2.2.2
Choice of activity data	NR	4.2.2.3	4.2.2.3
Calculations steps for Tier 1	NR	4.2.2.4	4.2.2.4
Uncertainty assessment	NR	4.2.2.5	4.2.2.5
Soil carbon	U	4.2.3	4.2.3
Choice of method	U	4.2.3.1	4.2.3.1
Choice of stock change and emission factors	U	4.2.3.2	4.2.3.2
Choice of activity data	U	4.2.3.3	4.2.3.3
Calculations steps for Tier 1	NR	4.2.3.4	4.2.3.4

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Uncertainty assessment	U	4.2.3.5	4.2.3.5
Non-CO_2 greenhouse gas emissions from biomass burning	NR	4.2.4	4.2.4
Choice of method	NR	4.2.4.1	4.2.4.1
Choice of emission factors	NR	4.2.4.2	4.2.4.2
Choice of activity data	NR	4.2.4.3	4.2.4.3
Uncertainty assessment	NR	4.2.4.4	4.2.4.4
Land Converted to Forest Land	NR	4.3	4.3
Biomass	NR	4.3.1	4.3.1
Choice of method	NR	4.3.1.1	4.3.1.1
Choice of emission factors	NR	4.3.1.2	4.3.1.2
Choice of activity data	NR	4.3.1.3	4.3.1.3
Calculations steps for Tier 1	NR	4.3.1.4	4.3.1.4
Uncertainty assessment	NR	4.3.1.5	4.3.1.5
Dead organic matter	NR	4.3.2	4.3.2
Choice of method	NR	4.3.2.1	4.3.2.1
Choice of emission/removal factors	NR	4.3.2.2	4.3.2.2
Choice of activity data	NR	4.3.2.3	4.3.2.3
Calculations steps for Tier 1	NR	4.3.2.4	4.3.2.4
Uncertainty assessment	NR	4.3.2.5	4.3.2.5
Soil carbon	U	4.3.3	4.3.3
Choice of methods	NR	4.3.3.1	4.3.3.1
Choice of stock change and emission factors	U	4.3.3.2	4.3.3.2
Choice of activity data	U	4.3.3.3	4.3.3.3
Calculations steps for Tier 1	NR	4.3.3.4	4.3.3.4
Uncertainty assessment	NR	4.3.3.5	4.3.3.5
Non-CO_2 greenhouse gas emissions from biomass burning	NR	4.3.4	4.3.4
Completeness, time series, QA/QC, and reporting	NR	4.4	4.4
Completeness	NR	4.4.1	4.4.1
Developing a consistent time series	U	4.4.2	4.4.2
Quality assurance and quality control	NR	4.4.3	4.4.3
Reporting and documentation	NR	4.4.4	4.4.4
Tables	U	4.5	4.5
Glossary for Forest Land	NR	4A-1	4A-1

Equations

- No refinement.

Tables

- Table 4.4 has updated values for ratio of below-ground biomass to above-ground biomass.

- Table 4.7 has updated values for above-ground biomass in natural forests.

- Table 4.8 has updated values for above-ground biomass in forest plantations.

- Table 4.9 has updated values for above-ground net biomass growth in natural forests.

- Table 4.10 has updated values for above-ground net biomass growth in tropical and sub-tropical plantation forests.

- Table 4.11 has updated values for reported mean annual increment (growth rate of merchantable volume) for some plantation forest species, and replace former Table 4.11A and 4.11B from the *2006 IPCC Guidelines*.

- Table 4.12 has updated values from tables 7.7-4-10.

Table Title	Type of Refinement	2006 IPCC 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
Ratio of below-ground biomass to above-ground biomass (R)	U	4.4	4.4
Default biomass conversion and expansion factors (BCEF), tonnes biomass (m^3 of wood volume)$^{-1}$	NR	4.5	4.5
Emission factors for drained organic soils in managed forests	NR	4.6	4.6
Above-ground biomass in natural forests	U	4.7	4.7
Above-ground biomass in forest plantations	U	4.8	4.8
Above-ground net biomass growth in natural forests	U	4.9	4.9
Above-ground net biomass growth in tropical and sub-tropical plantation forests	U	4.10	4.10
Reported Mean Annual Increment (growth rate of merchantable volume) values for some plantation forest species [m3 ha-1 yr-1]	U	4.11a, 4.11b	4.11
Tier 1 estimated biomass values from Tables 4.7–4.11	U	4.12	4.12
Basic wood density (D) of tropical tree species	NR	4.13	4.13
Basic wood density (D) of selected temperate and boreal tree taxa	NR	4.14	4.14

Figures

- No refinement.

Boxes

- Box 4.3a provides guidance for developing Tier 2 stock change factors for soil C.

- Box 4.3b provides example of how compilers may address forest data gaps.

Box Title	Type of Refinement	2006 IPCC Guidelines Box Number	2019 Refinement Box Number
Levels of detail	NR	4.1	4.1
Biomass conversion and expansion factors for assessing biomass and carbon in forests	NR	4.2	4.2
Examples of *good practice* approach in identification of lands converted to Forest Land	NR	4.3	4.3
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

CHAPTER 5 CROPLANDS

Refinements in this chapter are associated with biomass and soil C sections, in addition to the rice cultivation section of the guidance. There are no refinements to the guidance for dead organic matter or non-CO_2 greenhouse gas emissions from biomass burning.

The biomass C section refined guidance for Tier 1 methodologies for Croplands remaining Croplands by clarifying how to use default factors for perennial crops above-ground woody biomass growth rate; and biomass losses from removal, fuelwood and disturbance. The section also provides updated default factors, additional examples of perennial cropland subcategories, and guidance on activity data required for carbon gain estimation. There is also guidance on how to calculate ΔC_G for Land converted to Cropland, and updated carbon stocks default factors for present stocks after a year of conversion and updated the references to Chapter 4 and 6 for carbon stocks removed by the conversion.

Refinements in the soil C sections is associated with updates to default factors, additional guidance on developing Tier 2 stock change factors, new Tier 2 steady state method that can be used to estimate country-specific stock change factors, and guidance for estimating the impact of biochar C amendments on C stocks in mineral soils. There has been new research on land use change and tillage management since the *2006 IPCC Guidelines* was published that informed the derivation of new stock change factors. The updated factors are based on a new literature review and analysis for land use factors including long-term cultivation, paddy rice cultivation, and perennial woody crops, in addition to tillage management factors. See Annex 5A.1 for methods that have been used to develop the new factors. The Tier 2 steady-state method provides an alternative method for compilers to develop country-specific stock change factors. The activity data requirements of this method are different and from the default method and may provide an opportunity for some countries to conduct an inventory of soil C stock changes in mineral soils of croplands that is not feasible with the default method due to the activity data requirements. Biochar C has been intensively studied over the past decade and provided the basis for development of a Tier 2 method.

Refinements to estimation of CH_4 emissions from rice cultivation include updates on the following: (i) baseline emission factor (EFc) at a global scale (with new default values at regional scale); (ii) scaling factors for water regimes before and during the cultivation periods; and (iii) default conversion factors for different types of organic amendments. A new table on default cultivation periods, at global and regional scales, is provided, and a new section showing an example of how to implement the Tier 1 method. Also included is a new box on *good practice guidance* for developing EFc.

Sections

- Section 5.2.1 provides refinements associated with updated factors for coefficients for above and below ground biomass and above-ground for harvest cycles in agroforestry systems, and biomass accumulation rates for perennial cropland monocultures to estimate biomass, and further refinement to the Tier 1 methods description based on the updated default factors. The guidance on activity data has also been updated.

- Section 5.2.3 has new stock change factors based on a review of the land use and tillage studies. An annex has been updated with details about how the default stock change factors have been estimated. There is also a new steady-state method that has been added as an alternative approach for developing country-specific stock change factors. The updates include parameters are provided for the new steady-state method, and an annex describing the parameterisation method. This section has new guidance on a Tier 2 method to estimate the impact of biochar C amendments on soils in croplands. Guidance is also provided on the activity data requirements for biochar C and steady-state methods.

- Section 5.3.1 includes clarification on how to estimate biomass resulting from the Land conversion to croplands using Tier 1 methodologies. The section also updates the references to the updated tables in the chapter 5 and updated tables contained in other chapters (4 and 6) to find the appropriated default factors for carbon stocks present after the conversion and the carbon stocks removed by the conversion. In addition, provides further guidance on how to deal with conversion of Forest Lands to Croplands for Tier 2 methodologies.

- Section 5.5 with guidance on rice cultivation has been updated by revising the equation to estimate the "Adjusted Daily Emission Factor". Two equations are provided to estimate this factor: the first equation is applicable to Tier 1, while the second equation is for Tier 2. Description of the Tier 2 method has been updated as appropriate. Examples are listed with references for countries that have used Tier 3 methods for reporting CH_4 emissions from rice cultivation. Updates to emission and scaling factors include default cultivation periods, and a new water regime for the scaling factor, SFp (before cultivation period) has been added and the scope of its application is further refined, particularly with regard to methane emissions that occur before the cultivation period and after harvest. For Tier 2 factors, a reference has been added to Box 5.1A about how to develop a baseline emission factor for rice cultivation. A new Annex 5A.2 is included to

fully describe the background for developing the default emission factors and scaling factors for methane emission from paddy field. A new Section 5.5.4 has been added to provide an example of how to calculate methane emission from rice using the Tier 1 method. The section on Uncertainty Assessment has been updated with information on the conditions that influence methane emission and scaling factors, and how uncertainty can be reduced.

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Introduction	NR	5.1	5.1
Cropland Remaining Cropland	NR	5.2	5.2
Biomass	U	5.2.1	5.2.1
Choice of methods	U	5.2.1.1	5.2.2.1
Choice of emission factors	U	5.2.1.2	5.2.1.2
Choice of activity data	U	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	U	5.2.3.1	5.2.3.1
Choice of stock change and emission factors	U	5.2.3.2	5.2.3.2
Choice of activity data	U	5.2.3.3	5.2.3.3
Calculations steps for Tier 1	U	5.2.3.4	5.2.3.4
Uncertainty assessment	NR	5.2.3.5	5.2.3.5
Non-CO_2 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	U	5.3	5.3
Biomass	U	5.3.1	5.3.1
Choice of methods	U	5.3.1.1	5.3.1.1
Choice of emission factors	U	5.3.1.2	5.3.1.2
Choice of activity data	U	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

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
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	U	5.3.3.1	5.3.3.1
Choice of stock change and emission factors	U	5.3.3.2	5.3.3.2
Choice of activity data	U	5.3.3.3	5.3.3.3
Calculations steps for Tier 1	U	5.3.3.4	5.3.3.4
Uncertainty assessment	NR	5.3.3.5	5.3.3.5
Non-CO$_2$ 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	U	5.5.1	5.5.1
Choice of emission factors	U	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	U	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	5A.1	5A.1
Estimation of Default Emission Factors and Scaling Factors for CH$_4$ Emission from Rice Cultivation	NG	-	5A.2
Parameterisation of the Tier 2 – Steady State Method for Mineral Soils	NG	-	5A.3

Equations

- Equations 5.0A to 5.0H are added to estimate country-specific C stock change factors for mineral soils based on the steady state method. These questions include methods for estimating the C input from cropland litter and organic matter to soils.

- Equations 5.2 and 5.2A are provided for estimating "Adjusted Daily Emission Factor" for Tier 1 and 2 methods.

- Equations 5A.2.1 and 5A.2.2 are added in Annex 5A.2.2 to show the relationship of methane flux with controlling factors; and (ii) to improve the transparency on how the default emission factor have been derived for continuously flooded rice fields.

Equation Title	Type of Refinement	2006 IPCC Guidelines Equation Number	2019 Refinement Equation Number
Annual change in soil C stock for mineral soils using the Steady State Method	NG	-	5.0a
Active Sub-Pool Soil C Stock for Mineral Soils using the Steady-State Method	NG	-	5.0b
Slow Sub-Pool Soil C Stock for Mineral Soils using the Steady-State Method	NG	-	5.0c
Passive Sub-Pool Soil C Stock for Mineral Soils using the Steady-State Method	NG	-	5.0d
Temperature Effect on Decomposition for Mineral Soils using the Steady-State Method	NG	-	5.0e
Water Effect on Decomposition for Mineral Soils using the Steady-State Method	NG	-	5.0f
C Input to the Active Soil C Sub-Pool for Mineral Soils using the Steady-State Method	NG	-	5.0g
Cropland C input to Soil for Steady-State Method	NG	-	5.0h
CH_4 emissions from rice cultivation	NR	5.1	5.1
Adjusted daily emission factor (Tier 1)	U	5.2	5.2
Adjusted daily emission factor (Tier 2)	NG	5.2a	5.2a
Adjusted CH_4 emission scaling factors for organic amendments	NR	5.3	5.3
Effect of controlling variables on CH_4 flux from rice fields	NG	-	5A.2.1
Default emission factor for continuously flooded Rice Fields	NG	-	5A.2.2

Tables

- Tables 5.1, 5.2 and 5.3 have updated default biomass parameters of biomass stocks and growth rates.

- Table 5.4 has been updated with more information about the classification of agroforestry systems.

- Tables 5.8 and Table 5.9 include updated factors for biomass estimation, and more complete information on how to use B_{Before} to be consistent with assumptions in other chapters.

- Table 5.5 has updated stock changes factors for land use change and tillage management factors for the Tier 1 method to estimate soil C stock changes in mineral soils.

- Table 5.5B and 5.5C provide lignin and nitrogen content values for crops and organic amendments (i.e., manure), which is needed for the Tier 2 steady-state method for mineral soils.

- Table 5.11 provides baseline emission factor (assuming no flooding for less than 180 days prior to rice cultivation, and continuously flooded during rice cultivation without organic amendments);

- Table 5.12 provides updated scaling factors for water regimes during the cultivation period relative to continuously flooded fields

- Table 5.13 provides updated scaling factors for water regimes before the cultivation period

- Table 5.14 provides updated factors on conversion factor for different types of organic amendment

- Tables 5.14A, 5.14B and 5.14C provide an example calculation of methane emissions from rice cultivation.

Table Title	Type of Refinement	2006 IPCC 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	5.1
Default coefficients for above- and below-ground biomass in agroforestry systems containing perennial species	U	5.2	5.3
Default maximum and time-averaged mean above-ground biomass and above ground biomass accumulation rate for perennial cropland monocultures (tonnes ha^{-1})	U	5.3	5.3
Examples of Classification of agroforestry system	U	5.4	5.4
Relative stock change factors (F_{LU}, F_{MG}, and F_I) (over 20 years) for different management activities on cropland	U	5.5	5.5
Globally calibrated model parameters to be used to estimate soil C stock Changes for Mineral Soils with the Tier 2 Steady-State Method	NG	-	5.5a
Default values for Nitrogen and Lignin Contents in Crops for Steady-State C Model	NG	-	5.5b
Default values for carbon to nitrogen ratios, nitrogen, and lignin contents in livestock manure for the steady-state method	NG	-	5.5c
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 (F_{LU}, F_{MG}, F_I) for land-use conversions to Cropland	NR	5.10	5.10
Default CH_4 baseline emission factor assuming no flooding for less than 180 days prior to rice cultivation, and continuously flooded during rice cultivation without organic amendments	U	5.11	5.11
Default Cultivation Period of Rice	NG	-	5.11a
Default CH_4 emission scaling factors for water regimes during the cultivation period relative to continuously flooded fields	U	5.12	5.12
Default CH_4 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
Description of the selected variables that control CH_4 emissions from rice fields	NG	-	5A.2-1
Studies that were used to evaluate the model sensitivities and parameterise the Tier 2 steady state method for mineral soils	NG	-	5A.3-1
Sensitivity of Model Parameters, Parameter Values and minimum and maximum values for the Tier 2 steady state method for mineral soils	NG	-	5A.3-2
Covariance Matrix for the Tier2 Steady state method for mineral soils	NG	-	5A.3-3

Figures

- No refinement.

Boxes

- Boxes 5.1A and 5.1B provide discussion about the basis for the Tier 2 steady-state method and a description of the method.

- Table 5.2A provides guidance for developing Tier 2 emission factors associated with rice cultivation.

- Box 5.2 is updated by adding new references for research findings on the effects of water management and organic amendment on methane emissions from rice cultivation.

- Box 5.2A is added to describe in detail *good practice guidance* for developing baseline emission factor (EFc) for methane emissions from rice cultivation.

Box Title	Type of Refinement	2006 IPCC Guidelines Box Number	2019 Refinement Box Number
Relevant carbon pools for cropland	NR	5.1	5.1
Understanding the basis for the Tier 2 steady- state method	NG	-	5.1a
Description of the Tier 2 steady-state method for estimating mineral soil organic carbon stock changes	NG	-	5.1b
Conditions influencing CH_4 emissions from rice cultivation	NR	5.2	5.2
Good Practice Guidance for Developing Baseline Emission Factor)EFC(for Methane Emission from Rice Cultivation	NG	-	5.2a

CHAPTER 6 GRASSLANDS

Refinements in this chapter are all associated with the soil C section of the guidance. The refinements include a new classification scheme for grazing management systems, updates to the guidance for Tier 2 methods in the soil section, and guidance for estimating the impact of biochar C amendments on C stocks in mineral soils. The refinement to the grazing management system is associated with introducing a management system with high intensity grazing to replace moderately degraded systems. Classifying high intensity grazing is more objective and can be determined from local grassland production in many countries. In addition, more studies are available to estimate the impact of high intensity grazing compared to moderately degraded systems. Biochar C has been intensively studied over the past decade and provided the basis for development of a Tier 2 method for grasslands.

There are no refinements to the guidance on biomass, dead organic matter, or non-CO_2 greenhouse gas emissions from biomass burning.

Sections

- Sections 6.2.3 and 6.3.3 with new guidance for estimating changes in soil C for mineral soils. The updates include a revision to the classification for management systems and new management factors. There is also new guidance on a Tier 2 method to estimate the impact of biochar C amendments on soils in grassland.

Section Title	Type of Refinement	2006 IPCC 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	U	6.2.3.1	6.2.3.1
Choice of stock change and emission factors	U	6.2.3.2	6.2.3.2
Choice of activity data	U	6.2.3.3	6.2.3.3
Calculations steps for Tier 1	U	6.2.3.4	6.2.3.4
Uncertainty assessment	NR	6.2.3.5	6.2.3.5
Non-CO_2 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

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
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	U	6.3.3.1	6.3.3.1
Choice of stock change and emission factors	U	6.3.3.2	6.3.3.2
Choice of activity data	U	6.3.3.3	6.3.3.3
Calculations steps for Tier 1	U	6.3.3.4	6.3.3.4
Uncertainty assessment	NR	6.3.3.5	6.3.3.5
Non-CO_2 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	6A.1	6A.1

Equations

- No refinement.

Tables

- Table 6.2 includes a new factor for estimating the impact of high intensity grazing on soil C stocks. High intensity grazing systems (or cutting and removal of vegetation) results in shifts in vegetation composition and possibly productivity but is not severely degraded. High intensity grazing replaces moderately degraded management systems in the classification scheme from the *2006 IPCC Guidelines*.

Table Title	Type of Refinement	2006 IPCC 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	6.1	6.1
Relative stock change factors for grassland management	U	6.2	6.2
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

Figures

- Figure 6.1 has been updated with a revised classification scheme for grassland/grazing systems to include heavy intensity grazing systems (or cutting and removal of vegetation), which leads to shifts in vegetation composition and possibly productivity, but is not severely degraded.

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

CHAPTER 7 WETLANDS

Refinements to this Chapter are development of Flooded Lands section on CO_2 and CH_4 emissions and removals from *Flooded Land Remaining Flooding Land* and *Land Converted to Flooded Land*. The methods developed are consistent with the managed land proxy, and include an optional approach to develop indicative estimates of the anthropogenic component of total CO_2 and non-CO_2 emissions from flooded lands. Methods and emission factors are presented for Reservoirs and Other constructed waterbodies.

There are no refinements to the sections on peatlands.

Sections

- Section 7.3 has been refined with new guidance for estimating greenhouse gas emissions from Flooded Land Remaining Flooding Land and Land Converted to Flooded Land.

- Section 7.6, Future Methodological Development has been removed from the guidance because the methods have been developed in the *2013 IPCC Wetlands Supplement* and in this refinement.

Section Title	Type of Refinement	2006 IPCC 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_2 emissions from Peatlands Remaining Peatlands	NR	7.2.1.1	7.2.1.1
Non-CO_2 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_2 emissions on lands being converted for peat extraction	NR	7.2.2.1	7.2.2.1
Non-CO_2 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_2 emissions from Land Remaining Flooded Land	NG	-	7.3.1.1
Non-CO_2 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_2 emissions from Land Converted to Flooded Land	NG	7.3.2.1	7.3.2.1
Non-CO_2 emissions from Land Converted to Flooded Land	NG	7.3.2.2	7.3.2.2
Approach to provide indicative estimates of the anthropogenic component of total CO_2 and non-CO_2 emissions (optional)	NG	-	7.3.3
Uncertainty Assessment	U	7.3.2.3	7.3.4
Completeness, Time series consistency, and QA/QC	NR	7.4	7.5
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	-	7.1

Equations

- Equations 7.10 to 7.18 provide new guidance for *Flooded Land Remaining Flooded Land,* for *Land Converted to Flooded Land*, and Other Constructed Waterbodies. The latter category has added agriculture ponds, aquaculture ponds, canals, ditches and drainage channels where they are not covered in the *2013 Wetland Supplement.*

- 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_2 emissions from Flooded Lands.

Equation Title	Type of Refinement	2006 IPCC Guidelines Equation Number	2019 Refinement Equation Number
CO_2 emissions from wetlands	NR	7.1	7.1
CO_2 emissions in peatlands during peat extraction	NR	7.2	7.2
CO_2 –C emissions from managed peatlands (Tier 1)	NR	7.3	7.3
On-site soil CO_2–C emissions from managed peatlands (Tier 1)	NR	7.4	7.4
Off-site CO_2–C emissions from managed peatlands (Tier 1)	NR	7.5	7.5
On-site CO_2–C emissions from managed peatlands (Tiers 2 and 3)	NR	7.6	7.6
N_2O emissions from peatlands during peat extraction	NR	7.7	7.7
CO_2 –C emissions in peatland being drained for peat extraction	NR	7.8	7.8
CO_2 –C emissions from soils in peatland being drained for peat extraction	NR	7.9	7.9
Annual change in carbon stocks in living biomass on land converted to permanently Flooded Land	R	7.10	-
Annual total CH_4 emissions for Reservoirs >20 Years old from *Flooded Land Remaining Flooded Land*	NG	-	7.10
Equation used to scale CH_4 emission factors for the influence of eutrophication using measured values of chlorophyll a (Modified from Deemer et al (2016)	NG	-	7.11
Annual CH_4 emission from Other Constructed Waterbodies	NG	-	7.12
Annual on-site CO_2-C emissions/removals from Land Converted to Flooded Land	NG	-	7.13
Annual CO_2-C emissions/removals from *Land Converted to Flooded Land* including soil carbon stocks	NG	-	7.14
Annual CH_4 emissions for Reservoirs ≤ 20 years old for *Land Converted to Flooded Land*	NG	-	7.15
Indicative estimate of the anthropogenic component of total annual CH_4 emissions in *Flooded Land Remaining Flooded Land*	NG	-	7.16
Indicative estimate of the anthropogenic component of total annual CO_2 emissions in *land converted to flooded land*	NG		7.17
Indicative estimates of the anthropogenic component of total annual CH_4 emissions in *Land Converted to Flooded Land*	NG	-	7.18
CH_4 diffusive emission (mg C m^{-2} d^{-1})	NG	-	7A.1
CH_4 bubbling emission (mg C m^{-2} d^{-1})	NG	-	7A.2
CO_2 diffusive emission (mg C m^{-2} d^{-1})	NG	-	7A.3
Emission factors for *Land converted to Flooded Land*	NG	-	7A.4
Emission factors for *Flooded Land remaining Flooded Land*	NG	-	7A.5

Tables

- Tables 7.1 and 7.3 are refined based on the new guidance regarding flooded lands.

- Tables 7.7 to 7.15 provide new guidance with the factors and associated information to estimate CO_2 and CH_4 emissions from flooded land.

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

Table Title	Type of Refinement	2006 IPCC 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_2–C and associated uncertainty for lands managed for peat extraction, by climate zone	NR	7.4	7.4
Conversion factors for CO_2–C for volume and weight production data	NR	7.5	7.5
Default emission factors for N_2O emissions from managed peatlands	NR	7.6	7.6
Types of Flooded Land, their human uses and greenhouse gas emissions considered in this chapter	NG	-	7.7
Ramsar classes of human-made wetlands, IPCC terminology used and methodological guidance provided	NG	-	7.8
CH_4 emission factors for reservoirs older than 20 years (> 20 years) – *Flooded Land Remaining Flooded Land*	NG	-	7.9
Ratio of total downstream flux of CH_4 (kg CH_4 ha^{-1} yr^{-1}) to the flux of CH_4 from a reservoir's surface to the atmosphere (kg CH_4 ha^{-1} yr^{-1}) – Rd	NG	-	7.10
Relationships between Trophic Index (TI), surface concentrations of chlorophyll-a (Chl-a), total phosphorus (TP), total nitrogen (TN), Secchi depth (SD), Trophic Class[1] and Trophic State Adjustment Factor (α_i)	NG	-	7.11
CH_4 emission factors for Other Constructed Waterbodies (freshwater ponds, saline ponds, canals, drainage channels and ditches)	NG	-	7.12
CO_2-C emission factors for reservoirs ≤ 20 years old – *Land converted to Flooded Land*	NG	-	7.13
Scaling factor value M_j [y^{-1}] for equation 7.14, Annual on-site CO_2-C emissions/removals from *Land Converted to Flooded Land*.	NG	-	7.14
CH_4 emission factors for reservoirs ≤ 20 years old – *Land converted to Flooded Land*	NG	-	7.15
Number of reservoirs in the grand database in each IPCC climate zone.	NG	-	7A.1
Aggregated climate zones based on differences in CH_4 emissions between categories	NG	-	7A.2
Data sources used for modelling CH_4 emissions from reservoirs within different climate zones.	NG	-	7A.3
Reservoirs and citations for measured R_d values	NG	-	7A.4

Figures

- Figures 7.2 and 7.3 provide decision trees to guide compilers through the classification of waterbodies and through methodological choices for flooded land.

- Figures A1 to A6 elaborate on the development of the emission factors provided in the guidance.

Figure Title	Type of Refinement	2006 IPCC Guidelines Figure Number	2019 Refinement Figure Number
Decision tree to estimate CO_2–C and N_2O emissions from Peatlands Remaining Peatlands	NR	7.1	7.1
Decision tree for types of Flooded Land.	NG	-	7.2
Decision tree for choice of Tier level to estimate emissions of CO_2 and CH_4 from waterbodies	NG	-	7.3
Methane related transport within and from waterbodies, exemplified with a reservoir with an anoxic hypolimnion. For explanations of numbered processes, see text	NG	-	7A.1
Location of the reservoirs in the GranD database and shadowgram of their latitudinal distribution.	NG	-	7A.2
Box plots of model estimates (empty) and Field measurements (filled) of CH_4 emissions (note logarithmic scale) in aggregated IPCC climate zones.	NG	-	7A.3
Comparison of measure CH_4 emissions with estimates based on the Emission Factors (EFs, Tables 7.10 and 7.18) of Tier 1 methodology.	NG	-	7A.4
Measured downstream (DN) CH_4 emissions compared to model estimates. The left and right panels model downstream emissions using the median and mean Rd values collected from the literature, respectively.	NG	-	7A.5
Relationship between CO_2 surge estimates from the newly flooded lands using the decay curve approach and the flooded soil organic carbon stock approach.	NG	-	7A.6

Boxes

- Box 7.1 provides information about sedimentation and burial of carbon in reservoirs.

- Box 7.2 provides information about emissions that are driven by wastewater that occur in reservoirs.

- Box A7.1 describes the basis for developing indicative estimates of the anthropogenic component of total emissions from flooded land.

Box Title	Type of Refinement	2006 IPCC Guidelines Box Number	2019 Refinement Box Number
Additional information on sedimentation and carbon burial in reservoirs	NG	-	7.1
Additional information on emissions arising from wastewater within reservoirs	NG	-	7.2
Approach for developing indicative estimates of the anthropogenic component of total emissions from flooded land	NG	-	7A.1

CHAPTER 8 SETTLEMENTS

Refinements in this chapter are associated to the biomass estimations sections. Default values on crown cover area and annual carbon accumulation per tree for Settlements remaining Settlements are updated. Guidance on how to use the default values while using the three tier methodologies is also refined, including on how to develop country specific values for Tier 3. Based on the update of table 8.4 on defaults for biomass carbon stocks removed in the land conversion to Settlements, refined guidance for tier 2 and Tier 3 on the selection of default emission factors is provided. In addition, steps on data collection for Tier 2 and 3 m3thodologies is clarified.

There are no refinements to the guidance for dead organic matter or soil C.

Sections

- Section 8.2.1.2 includes updated default values in Table 8.1 and Table 8.2 and includes explanations about how to apply the default values while estimating biomass using the Tier 2 methodologies. Also includes refined guidance for Tier 3 methodologies on developing country specific biomass increment factors.

- Section 8.3 includes a short introduction on Land converted to Settlements.

- Section 8.3.1.1 provides guidance clarifying how to apply terms of B_{Before}, B_{After}, ΔC_G and ΔC_L for Equation 2.15 and 2.16.

- Section 8.3.1.2 provides new guidance based on updates to Table 8.4 for Tier 2 and Tier 3 methodologies by clarifying how to select and use of emission factors.

- Section 8.3.1.3 updates the guidance on the steps for data acquisition for Tier 2 and 3.

- Section 8.5 sentences that where found not relevant any more had been deleted.

Section Title	Type of Refinement	2006 IPCC 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	8.2.1.2	8.2.1.2
Choice of activity data	NR	8.2.1.3	8.2.1.3
Uncertainty assessment	NR	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
Land converted to Settlements	U	8.3	8.3
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	U	8.3.1.3	8.3.1.3
Uncertainty assessment	NR	8.3.1.4	8.3.1.4

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
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

Equations

- No refinement.

Tables

- Tables 8.1 and 8.2 are updated with new default values from literature review.

- Table 8.4 is updated to provide more information on how to use B_{Before}.

Table Title	Type of Refinement	2006 IPCC 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

Figures

- No refinement.

CHAPTER 9 OTHER LANDS

- No refinement.

CHAPTER 10 EMISSIONS FROM LIVESTOCK AND MANURE MANAGEMENT

Improvements to this Chapter were made to: i.) Update outdated emission factors and emission factors that could be improved through new knowledge; ii.) Improve the treatment of the relationship between productivity and emissions, focusing in particular on the ability to differentiate between commercial/industrial production systems and local/subsistence systems and; iii.) Improving the consistency of methods among emission sources, to facilitate the use of consistent activity data and livestock characterizations among sources and assure that the calculation and transfers of parameters among enteric fermentation, volatile solid and manure methane estimates, and nitrogen excretion, transfers and losses are consistent throughout the Chapter and with Chapter 11, Managed soils.

Sections

- **Section 10.2** Livestock population and feed characterisation. The Tier 1 method was updated by integrating an advanced Tier 1a. This method is to be applied in cases where agricultural production systems may be transitioning from low productivity local subsistence systems to higher productivity systems or may simply have dual agricultural systems. In these cases, inventory compilers may wish to use the Tier 1a approach in which they are able to better track the transitions and changes in the productivity of their agricultural systems and related emissions over time.

- Various updates were made to text: i) Where references or information provided were dated; ii) To provide suggestions for sources of activity data and parameters sources; iii) Crude protein and neutral detergent fibre were added to the parameters to be collected for animal categories for the implementation of Tier 2 methods.

- The Tier 2 method was updated through the addition of parameters for a Tier 2 characterization of goat production, resulting in modifications to many Tables and Figures.

- The Simplified Tier 2 approach was updated to be consistent with methods in the most recent National Research Council publications and replace the Dairy cattle equations with a more recent method.

- **Section 10.3** Methane emissions from enteric fermentation. The Tier 1 Emission Factors for Cattle, Buffalo, Sheep and Goats were updated based on an extensive review of the literature and global production systems. Emission factors for low and high productivity systems (Tier 1a EFs) for regions that have dual production systems for cattle, sheep and goats were developed (the terms high and low productivity systems were substituted for developed and developing countries used in the *2006 IPCC guidelines*). Emission Factors for minor animal categories were reviewed and updated where information was available. Guidance was provided to implement the Tier 1a approach.

- The discussion and guidance to implement methane conversion rates (Y_m) was updated. The values presented for methane conversion rates were expanded to be consistent with different levels of productivity for Dairy cows and to take into account differing diets used in other cattle production systems. Methane yields were included to simplify the implementation of the simplified Tier 2 approach.

- **Section 10.4** Methane emissions from manure management. The approach to implement Tier 1 emission estimates was changed from a per head basis (kg CH_4 head^{-1}) to a per volatile solid (g CH_4 kg VS^{-1}) basis to be consistent with the Tier 1 approach for nitrous oxide emissions. A Tier 1 approach for calculating volatile solids was introduced with values derived using consistent data for enteric fermentation and nitrogen excretion. Emission Factors were presented for high and low productivity systems based on the *2006 IPCC guideline* parameters and updated MCFs developed for the Tier 2 method. Per head emission factors for minor livestock were reviewed and updated where new information was available.

- In the Tier 2 method, the MCFs developed for major livestock categories were changed from being derived based on an annual temperature basis to being derived from monthly temperatures in climate zones and considering manure storage duration. A simple model was developed for the calculation of MCFs based on monthly temperature profiles and storage duration (presented in Annex A.3 and available for download). New anaerobic digestion MCFs were developed for different qualities of digesters and considering the storage of digestate.

- **Section 10.5** N$_2$O emissions from manure management. *Direct Emissions:* Nitrogen excretion values were updated using data consistent with the derivation of enteric fermentation EFs and volatile solid EFs. Emission Factors for direct emissions were reviewed and updated where possible. A Tier 2 method was introduced for N excretion for swine and poultry.

- *Indirect Emissions:* Improved guidance was provided to calculate losses and transfers of N to managed soils (Consistency of nitrogen flows, Section 10.5.6). A detailed Table consistent with other manure management system tables for manure N loss was introduced. A Tier 1 leaching factor was introduced to account for loss

from manure management storage and changes were made to the approach to calculate total N loss, to assure that all N is accounted for in the Tier 1 and Tier 2 methodology.

- **Annex 10A** – All data used in calculating Tier 1 parameters, enteric fermentation, volatile solids and nitrogen excretion were compiled in Annexes 10A.1 and 10A.2 in Tables 10A.1 to 10A.4. Default values for animal weights and manure management systems were compiled in Tables 10A.5 to 10A.9. An explanation of the simple model that is presented for calculating MCFs considering monthly temperature profiles and manure storage durations in Annex 10A.3. A series of equations is presented in Annex 10A.4 to calculate MCFs from anaerobic digesters. A clear description of the equations required in the calculation of nitrogen movement through the agricultural system is presented in Annex 10A.4

- **Annex 10B** – Brief explanations are provided that provide an overview or justification of how new parameters were selected or developed for the Chapter.

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Introduction	NR	10.1	10.1
Livestock population and feed characterisation	U	10.2	10.2
Steps to define categories and subcategories of livestock	NR	10.2.1	10.2.1
Choice of method	U	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	10.3	10.3
Choice of method	U	10.3.1	10.3.1
Choice of emission factors	U	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	10.4	10.4
Choice of method	U	10.4.1	10.4.1
Choice of emission factors	U	10.4.2	10.4.2
Choice of activity data	U	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_2O emissions from manure management	U	10.5	10.5
Choice of method	NR	10.5.1	10.5.1
Choice of emission factors	U	10.5.2	10.5.2
Choice of activity data	NR	10.5.3	10.5.3
Coordination with reporting for N_2O emissions from managed soils	U	10.5.4	10.5.4
Uncertainty assessment	NR	10.5.5	10.5.5
Completeness, time series, quality assurance/quality control and reporting	U	10.5.6	10.5.6
Use of worksheets	NR	10.5.7	10.5.7

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Data underlying methane default emission factors for Enteric Fermentation, Volatile solids, Nitrogen excretion and retention fractions for Cattle and Buffalo	NG	10A.1	10A.1
Additional data and information for the calculation of methane and nitrous oxide from Manure Management	NG	10A.2	10A.2
MCF spreadsheet example for the calculation of a country or region specific MCFs	NG	-	10A.3
Calculations of Methane Conversion Factors (MCFs) factors for biogas systems	NG		10A.4
Equations relating all direct and indirect N_2O emissions from manure along all stages in agricultural production for livestock.	NG	-	10A.5
Additional data and information for the calculation of N_2O from manure management of other animal	NG	-	10A.6
Data and explanatory text for development of new parameters in the *2019 refinement*.	NG		10B
Raw data used to compile Annex A.1 enteric fermentation Tier 1 emission factors, volatile solids and nitrogen excretion for cattle and buffalo			10B.1
Estimation of default emission factor(s) for goat tier 2 parameters	NG		10B.2
Feed intake estimates using a simplified Tier 2 method	NG		10B.3
Estimation cattle/buffalo ch4 conversion factors (Y_m)	NG		10B.4
Description and discussion of proposed changes to MCF calculations for liquid/slurry.	NG		10B.5
Revision of methane from dung deposited onto pasture range and paddocks (Table 10.17)	NG		10B.6
Estimation of default emission factors for MCF, CH_4 values, EF for direct N_2O emissions, NH_3, NO_3 leaching and N_2 emissions from solid storage and composting systems	NG		10B.7

Equations

- Equation 10.1 was updated to assure consistency in symbols throughout the chapter.

- All equations for calculating net energy were updated by adding parameters required to carry out Tier 2 emission factor development for goats.

- Tier 1 Equations in Sections 10.3, 10.4 and 10.5 were updated to introduce a subscript "p" that represents the productivity level, that can be introduced to the calculation to carry out an advanced Tier 1 (i.e. Tier 1a).

- Equations for calculating the simplified Tier 2 were updated based on the most recent National Research Council publications.

- A Tier 2 equation was added to calculate methane emissions using the parameters dry matter intake and methane yield. (Equation 10.21A)

- A Tier 1 equation was introduced to calculate volatile solids based on animal weights. (Equation 10.21A).

- Tier 2 equations were added to calculate nitrogen excretion from swine and poultry and to clarify the Tier 2 calculation of N excretion from other animals. (Equations 10.31A and 10.32A – Equations 10.33A-33E).

- The equations to calculate N loss were updated Equation 10.34-10.34C to include codigestates and improve N loss estimates.

- Annex equations 10A.1 to 10A.9 were introduced to calculate emission from anaerobic digestion.

- Annex equations 10A.10 to 10A.27 were introduced to detail transfers and losses of N from N excretion to application to managed soils in Chapter 11.

Equation Title	Type of Refinement	2006 IPCC Guidelines Equation Number	2019 Refinement Equation Number
Annual average population	U	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)	U	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)	U	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)	U	10.9	10.9
Net energy for lactation for sheep and goats (milk production unknown	U	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)	U	10.12	10.12
Net energy for pregnancy (for cattle/buffalo and sheep and goats)	U	10.13	10.13
Ratio of net energy available in a diet for maintenance to digestible energy	NR	10.14	10.14
Ratio of net energy available for growth in a diet to digestible energy consumed	NR	10.15	10.15
Gross energy for cattle/buffalo, sheep and goats	U	10.16	10.16
Estimation of dry matter intake for calves	U		10.17
Estimation of dry matter intake for growing cattle	U	10.17	10.18
Estimation of dry matter intake for steers and bulls Estimation of dry matter intake for heifers	U	-	10.18a
Estimation of dry matter intake for mature beef cattle	U	10.18a	-
Estimation of dry matter intake for lactating dairy cows	U	10.18b	10.18b
Enteric fermentation emissions from a livestock category (Tier 1)	U	10.19	10.19
Total emissions from livestock enteric fermentation	U	10.20	10.20
Methane emission factors for enteric fermentation from a livestock category	NR	10.21	10.21
Methane emission factors for enteric fermentation from a livestock category	NG	-	10.21a
CH_4 Emissions from manure management（Tier 1）	U	10.22	10.22
Annual Volatile Solid excretion rates	NG	-	10.22a
CH_4 Emission Factor from manure management	U	10.23	10.23
Volatile solid excretion rates	U	10.24	10.24
Direct N_2O emissions from manure management	U	10.25	10.25
N losses due to volatilisation from manure management	U	10.26	10.26
N losses due to leaching from manure management systems	U	10.28	10.27

Equation Title	Type of Refinement	2006 IPCC Guidelines Equation Number	2019 Refinement Equation Number
Indirect N_2O emissions due to volatilisation from manure management	NR	10.27	10.28
Indirect N_2O emissions due to leaching from manure management	NR	10.29	10.29
Annual N excretion rates	U	10.30	10.30
Annual N excretion rates Option 1 (tier 2)	NR	10.31	10.31
Annual N excretion rates Option 2 (tier 2)	NG		10.31a
N intake rates for cattle	NR	10.32	10.32
N intake rates for swine and poultry	NG	-	10.32a
N retention rates for cattle (N retained rates for cattle *in 2006*)	NR	10.33	10.33
Annual N excretion rates for breeding sows	NG	-	10.33a
N Retained in weaned piglets	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
Fraction of total animal manure N lost in manure management systems for animal type t	NG	-	10.34a
Estimation of $Frac_{N2ms}$	NG	-	10.34c
Calculation of MCF for biogas digesters	NG		10A.1
Calculation of relative amount of potential off gas related to B_0	NG		10A.2
Calculation of relative amount of residual gas related to B_0	NG		10A.3
Calculation of relative amount of residual gas related to CH_4 production	NG		10A.4
Digester's methane balance	NG		10A.5
Calculation of methane leakage rate of digester	NG		10A.6
Calculation of methane conversion factor	NG		10A.7
Calculation of methane conversion factor of residues	NG		10A.8
Calculation of methane conversion factor for the combination "prestorage + digester + digestate storage"	NG		10A.9
Total N_2O emissions for animal type t	NG		10A.10
Total N_2O emissions from manure management for animal type t	NG		10A.11 10A.12
Total, direct and indirect N_2O emissions from the application of manure to managed soils for animal type t	NG		10A.13 10A.14
Total amount of animal manure N applied to soils other than by grazing animals for animal type t	NG		10A.15
Fraction of total animal manure N lost in manure management systems for animal type t	NG		10A.16

Equation Title	Type of Refinement	2006 IPCC Guidelines Equation Number	2019 Refinement Equation Number
Fraction of animal manure N available for application to managed soils, applied to managed soils for animal type t	NG		10A.17
Total, direct and indirect n$_2$o emissions from N in urine and dung deposited by grazing animals on pasture, range and paddock (tier 1) for animal type t	NG		10A.18 10A.19
Relationship between average annual nitrogen flows associated with an individual animal [kg N animal^{-1} yr^{-1}] and the annual nitrogen flow for the animal population of livestock category/species t in a country [kg N yr^{-1}]	NG		10A.20
Total manure-N excreted	NG		10A.21
Nitrogen excretion calculated either using a default fraction of retention (tier 1) or directly from retention data	NG		10A.22 10A.23
Total manure-n in manure management and storage systems	NG		10A.24
Manure-n managed in system s	NG		10A.25
Manure-n deposited by grazing animals, with x=cpp,so	NG		10A.26
N in bedding material added to managed manure	NG		10A.27

Tables

- In **Section 10.2**, 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 and clarify elements that were raised during the Guidance review process.

- In the simplified Tier 2 methodology a new Table 10.8A was added for mature cattle DMI estimates.

- In **Section 10.3**, Tables 10.10 and 10.11 Tier 1 emission factors were updated and Tier 1a emission factors were developed. The methane conversion rate (Y_m) Table 10.12 was expanded to integrate Yms for different productivity levels and feeding systems and Sheep and Goat Yms were updated (Table 10.13).

- In **Section 10.4**, Table 10.14 was developed with emission factors based on volatile solids replacing two Tables with Emission factors expressed on a per head basis. Table 13A was added to calculate Tier 1 volatile solids. Table 16 moved the maximum methane potentials (B_0) which were previously in the Annex in the main text of the Chapter.

- The Table 10.17 was updated with MCFs based on climate zones and manure storage durations.

- In **Section 10.5**, N excretion (Table 10.19) values and N retention (Table 10.20) values were updated and some N$_2$O emission Factors (Table 10.21) were updated. N loss factors (Table 10.22) were presented in a consistent manner with all other manure management systems and default leaching factors were added. Finally, a Table was added for use in the estimation of denitrification (Table 10.23).

- In the **Annexes** all information for the calculation of Tier 1 Enteric Fermentation emission factors, volatile solids and nitrogen excretion for cattle and buffalo were presented in a series of four Tables. All default information required to carry out Tier 1 emission estimates for manure management are presented in Tables 10A.5 to 10A.9. Tables 10A.10 through 10A.18 provide supporting material for the development of the revisions to guidance presented in this refinement.

Table Title	Type of Refinement	2006 IPCC Guidelines Table Number	2019 Refinement Table Number
Representative livestock categories	U	10.1	10.1
Representative feed digestibility for various livestock categories	U	10.2	10.2
Summary of the equations used to estimate daily gross energy intake for cattle, buffalo and sheep and goats	U	10.3	10.3
Coefficients for calculating net energy for maintenance (NE_m)	U	10.4	10.4
Activity coefficients corresponding to animal's feeding situation	U	10.5	10.5
Constants for use in calculating NE_g for sheep and goats	U	10.6	10.6
Constants for use in calculating NE_p in equation 10.13	U	10.7	10.7
DMI required by mature non-dairy cows based on forage quality	NG		10.8
Coefficients for calculating net energy for maintenance (NE_m)	U	10.4	10.4
Activity coefficients corresponding to animal's feeding situation	U	10.5	10.5
Constants for use in calculating NE_g for sheep and goats	U	10.6	10.6
Constants for use in calculating NE_p in equation 10.13	U	10.7	10.7
DMI required by mature non-dairy cows based on forage quality	NG		10.8
Examples of NE_{mf} content of typical diets fed to cattle for estimation of dry matter intake in equations 10.17 and 10.18	U	10.8	10.8a
Suggested emissions inventory methods for enteric fermentation	U	10.9	10.9
Enteric fermentation emission factors for tier 1 method1 (kg CH_4 head^{-1} yr^{-1})	U	10.10	10.10
Tier 1 and Tier 1a enteric fermentation emission factors for cattle and buffalo	U	10.11	10.11
Cattle/Buffalo methane conversion factors (Y_m)	U	10.12	10.12
Sheep and goats CH_4 conversion factors (Y_m)	U	10.13	10.13
Default values for volatile solid excretion rate (kg VS (1000 kg animal mass^{-1}) day^{-1})	NG	-	10.13a
Methane Emission Factors by animal category, manure management system and climate zone	U		10.14
Manure management methane emission factors by temperature for Cattle, Swine and Buffalo,	R	10.14	-
Manure management methane emission factors by temperature for Sheep, Goats, Camels Horses, Mules and Asses and Poultry	R	10.15	-
Manure management methane emission factors for deer, reindeer, rabbits, and fur-bearing animals	U	10.16	10.15

Table Title	Type of Refinement	2006 IPCC Guidelines Table Number	2019 Refinement Table Number
Default values for maximum methane potentials (B_0) (m^3 CH_4 kg^{-1} VS)	U	10A.4, 10A.5, 10A.6, 10A.7, 10A.8, 10A.9	10.16
Methane Conversion Factors for manure management systems	U	10.17	10.17
Definitions of manure management systems	U	10.18	10.18
Default values for nitrogen excretion rate (kg N (1000 kg animal mass)$^{-1}$ day^{-1})	U	10.19	10.19
Default values for the fraction of nitrogen in feed intake of livestock that is retained by the different livestock species/categories (fraction n-intake retained by the animal)	U	10.20	10.20
Calculation of N retention in breeding swine from different production systems.	NG	-	10.20a
Default values for N_{gain} by growth stage	NG	-	10.20b
Default Emission Factors for direct N_2O emissions from manure management	U	10.21	10.21
Default values for nitrogen loss due to volatilisation of NH_3 and NO_x and leaching of nitrogen from manure management	U	10.22	10.22
Default values for total nitrogen loss from manure management	R	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 (Tier 1)	R	10A.1	
Data for estimating Tier 1 and Tier 1A Enteric Fermentation CH_4 Emission Factors, Volatile solid excretion and N excretion rates, and N retention fraction rates for Dairy Cattle	NG		10A.1
Data for estimating Tier 1 enteric fermentation CH_4 emission factors for Other Cattle in Table 10.11	R	10A.2	
Data for estimating Tier 1 Enteric Fermentation CH_4 Emission Factors, Volatile Solid and Nitrogen excretion rates and N retention fraction for Other cattle	NG		10A.2
Data for estimating Tier 1A Enteric Fermentation CH_4 Emission Factors, Volatile Solid and Nitrogen excretion rates and N retention fraction for Other cattle	NG		10A.3
Data for estimating Tier 1 enteric fermentation CH_4 emission factors for Buffalo	R	10A.3	
Data for estimating Tier 1 Enteric Fermentation CH_4 Emission Factors, Volatile solid and Nitrogen excretion rates, and N retention fraction rates for Buffalo	NG		10A.4
Manure management methane emission factor derivation for Dairy Cows	R	10A.4	
Manure management methane emission factor derivation for Other Cattle	R	10A.5	

Table Title	Type of Refinement	2006 IPCC Guidelines Table Number	2019 Refinement Table Number
Manure management methane emission factor derivation for Other Cattle	R	10A.5	
Manure management methane emission factor derivation for Buffalo	R	10A.6	
Manure management methane emission factor derivation for Market Swine	R	10A.7	
Manure management methane emission factor derivation for Breeding Swine	R	10A.8	
Manure management methane emission factor derivation for Other Animals	R	10A.9	
Default values for Live weights for animal categories (kg)	NG		10A.5
Animal waste management system (AWMS) regional averages for Cattle and Buffalo	NG		10A.6
Animal waste management system (AWMS) regional averages for Swine	NG		10A.7
Animal waste management system (AWMS) regional averages for Sheep and Goats	NG		10A.8
Animal waste management system (AWMS) regional averages for Poultry and Other Animals	NG		10A.9
Comparison of manure storage type definitions used by the IPCC and by the EMEP/EEA air pollutant emission inventory guidebook 2016	NG		10A.10
Methane conversion factor (MCF_{DG}) including biogas digester and storage	NG		10A.11
Summary statistics from Niu et al. (2018) database	NG		10A.12
Threshold calculation based on NDF correction	NG		10A.13
Summary of Data compiled for the compilation of Y_m values for cattle and buffalo	NG		10A.14
Mean, median, maximum, minimum and quartile 1 and 3 (Q1 and Q3) values for a selection feed diet composition, feed intake, body weight and milk productivity	NG		10A.15
Mean, median, maximum, minimum and quartile 1 and 3 (Q1 and Q3) values for CH_4 production results preferred as a proportion of gross energy intake (CH_4 conversion factor: Ym), day^{-1}, kg DM $intake^{-1}$, kg of milk $produced^{-1}$ and kg of body $weight^{-1}$	NG		10A.16
From IPCC 2006 Table of MCF values for Liquid/Slurry (Table 10.17), updates to MCFs calculated for each retention time and climate. (selected IPCC Climate regions shown)	U	10.17	10A.17 10A.18
Source of Methane from PRP excretion data	NG		10A.19
Methane conversion factor (MCF) and methane emission factors (per kg faecal dry matter (FDM)) and volatile solids (VS) for cattle and sheep	NG		10A.20

Figures

- Modification of Decision tree for inclusion of Tier 1a concept.

- All Annex Figures are provided as supporting material for the development of the revisions to guidance presented in this refinement.

Figure Title	Type of Refinement	2006 IPCC Guidelines Figure Number	2019 Refinement Figure Number
Decision tree for livestock population characterisation	NR	10.1	10.1
Decision Tree for CH4 Emissions from Enteric Fermentation	U	10.2	10.2
Decision tree for CH4 emissions from Manure Management	U	10.3	10.3
Decision tree for N2O emissions from Manure Management (Note 1)	U	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)	NG		10A.1
Colour code for cells in the example spreadsheet.	NG		10A.1
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.	NG		10A.2
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).	NG		10A.3
Model inputs and outputs over a three year period.	NG		10A.4
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.	NG		10A.5
Monthly patterns in Year 3: manure temperature, VS available, VS emptied, and methane production.	NG		10A.6
Summary of Year 3 VS and methane production, and calculation of MCF. Top panel shows results, bottom panel shows equations.	NG		10A.7
Annual enteric methane output per animal expressed in mass in relation to daily dry matter (DM) intake.	NG		10A.8
Daily enteric methane output per animal expressed in energy in relation to daily gross energy (GE) intake.	NG		10A.9
Annual enteric methane output per animal expressed in mass in relation to daily dry matter (DM) intake	NG		10A.10
Daily enteric methane output per animal expressed in energy in relation to daily gross energy (GE) intake	NG		10A.11
Daily N excretion output per animal expressed in relation to animal weight	NG		10A.12
Daily N excretion output per animal expressed in relation to daily N intake	NG		10A.13
Comparison between ranges of CH4-C emissions observed in collected studies in Pardo et al. (2015) (new) with estimations for the same studies according to IPCC (2006) methodology. Figure adapted from Pardo et al. (2015)	NG		10A.14
Effect on cumulative NH3-N emissions of different solid storage and composting methods compared with conventional solid storage. Figure adapted from Pardo et al. (2015)	NG		10A.15

CHAPTER 11 N₂O EMISSIONS FROM MANAGED SOILS AND CO₂ EMISSIONS FROM LIME AND UREA APPLICATIONS

Refinements in Chapter 11 include updates of the emission factors EF_1, EF_{1FR} and EF_{3PRP} (Table 11.1) and EF_4, EF_5, $Frac_{GASF}$ $Frac_{GASM}$ and $Frac_{LEACH-(H)}$ (Table 11.3). Updated aggregated values were computed for all of these factors drawing on a much larger number of measurements than were available for the *2006 IPCC Guidelines*. Furthermore, disaggregated EF_1, $EF_{3PRP, CPP}$ and EF_4 values for wet and dry climates are provided, with a distinction between synthetic and other fertilisers in wet climate for the EF_1. In addition, the EF_{1FR} is disaggregated by flooding / drainage regime. Finally, different $Frac_{GASF}$ values are provided according to chemical composition of fertiliser categories. Data and methods used for these updates are provided in Annexes 11A.2 – 9.

Refinements also include an update of the equation for calculating the annual amount of N in crop residues returned to soils annually (F_{CR}) (Equation 11.6). Default values to be used in this Equation are available in the new Table 11.1A. Notwithstanding, the alternative to estimate the above-ground crop residue ($AG_{DM(T)}$) with data in Table 11.2 remains available in the guidance.

Sections

- Slight rewording was done in section 11.2.

- Section 11.2.1.1 has an update to footnote 1 and guidance for locating EF_2 values in the Wetland supplement. Information is also provided for Tier 2 approaches such as factors specific to mitigation options (e.g. application of nitrification inhibitors) or exponential response of N₂O emissions to N application. Complementary guidance for Tier 3 approach (e.g. N-flow principle) is also added.

- Section 11.2.1.2 is updated according to updated EF values of TABLE 11.1.

- Section 11.2.1.3 is updated with a link to FAOSTAT throughout the section. Substantial changes are brought to subsection *Crop residue N, including N-fixing crops and forage/ pasture renewal, returned to soils* otherwise most of the text is unchanged. In subsection *Crop residue N, including N-fixing crops and forage/ pasture renewal, returned to soils (F_{CR})*, text is added to eliminate the possibility of double-counting by cross-checking with Chapters 10 (Livestock and manure management) and 5 (Cropland). Equation 11.6 is updated and Equation 11.7A has been removed. The existing text is also slightly edited following the review process. A new Table (Table 11.1A) is added that is used to produce default values from Table 11.2 in the *2006 IPCC Guidelines* and introduces new default values to be used in updated Equation 11.6. Table 11.2 is updated, default values remain unchanged but $AG_{DM(T)}$ has been changed to be in conformity with equation 11.6 and several variables are moved to new Table 11.1A.

- Section 11.2.2 has minor edits.

- Section 11.2.2.1 information is updated for Tier 2 approaches such as factors specific to mitigation options (e.g. application of nitrification inhibitors). Complementary guidance for Tier 3 approach (e.g. N-flow principle) was also added.

- Section 11.2.2.2 is edited to reflect the updates for the emission factor $Frac_{LEACH-(H)}$.

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Introduction	NR	11.1	11.1
N₂O emissions from managed soils	U	11.2	11.2
Direct N₂O 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	U	11.2.1.3	11.2.1.3
Uncertainty assessment	NR	11.2.1.4	11.2.1.4
Indirect N₂O 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

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
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_2 Emissions from Liming	NR	11.3	11.3
CO_2 Emissions from Urea Fertilization	NR	11.4	11.4
References for crop residue data in Table 11.2	NR	11A.1	11A.1
Estimation of Default Emission Factor(s) for EF_1	NG	-	11A.2
Estimation of Default Emission Factor(s) for EF_{1FR}	NG	-	11A.3
Estimation of Default Emission Factor(s) for EF_{3PRP}	NG	-	11A.4
Estimation of Default Emission Factor(s) for EF_4	NG	-	11A.5
Estimation of Default Emission Factor(s) for EF_5	NG	-	11A.6
Estimation of Default Emission Factor(s) for $Frac_{GASF}$	NG	-	11A.7
Estimation of Default Emission Factor(s) for $Frac_{GASM}$	NG	-	11A.8
Estimation of Default Emission Factor(s) for $Frac_{LEACH-(H)}$	NG	-	11A.9

Equations

- Equation 11.6 is updated to be consistent with revisions for estimating residue N.

- Equation 11.7A is removed, but the option to estimate $AG_{DM(T)}$ with data in Table 11.2 remains available in the guidance.

Equation Title	Type of Refinement	2006 IPCC Guidelines Equation Number	2019 Refinement Equation Number
Direct N_2O emissions from managed soils (Tier 1)	NR	11.1	11.1
Direct N_2O 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
Alternative approach to estimate F_{CR}	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_2O from atmospheric deposition of N volatilised from managed soils (Tier 1)	NR	11.9	11.9
N_2O from N leaching/runoff from managed soils in regions where leaching/runoff occurs (Tier 1)	NR	11.10	11.10
N_2O from atmospheric deposition of N volatilised from managed soils (Tier 2)	NR	11.11	11.11

Tables

- Table 11.1 contains updated EF_1, EF_{1FR} and EF_{3PRP}. Methods, data and references used for determining updated values and their uncertainties are in the annexes 11A.2, 11A.3, 11A.4.

- Table 11.1A is 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 (F_{CR}).* The Table reproduces default values from Table 11.2 in the *2006 IPCC Guidelines* for columns 'Dry matter fraction of harvested product (DRY)', 'N content of above-ground residues (N_{AG})', 'Ratio of below-ground residues to above-ground biomass ($R_{BG\text{-}BIO}$)', and 'N content of below-ground residues (N_{BG})'. It also introduces new default values for $R_{AG(T)}$, ratio of above-ground residues dry matter ($R_{AG(T)}$) to harvested yield for crop T, to be used in updated version of Equation 11.6.

- Table 11.2 is updated. The title "Default factors for estimation of N added to soils from crop residues" is changed to "Alternative method and data for estimating above-ground residue $AG_{DM(T)}$". The units of $AG_{DM(T)}$ are changed from Mg ha^{-1} to kg. d.m. ha^{-1}; in alignment with the unit in Equation 11.6. Default values for slope, intercept, errors remain unchanged. Former columns 'Dry matter fraction of harvested product (DRY)', 'N content of above-ground residues (N_{AG})', 'Ratio of below-ground residues to above-ground biomass ($R_{BG\text{-}BIO}$)', and 'N content of below-ground residues (N_{BG})' are moved to new Table 11.1A.

- Table 11.3 contains updated EF_4, EF_5, Frac$_{GASF}$ Frac$_{GASM}$ and Frac$_{LEACH\text{-}(H)}$. Methods, data, references and methods used for determining updated values are in the annexes11A.5, 11A.6, 11A.7, 11A.8, 11A.9.

Table Title	Type of Refinement	2006 IPCC Guidelines Table Number	2019 Refinement Table Number
Default emission factors to estimate direct N_2O emissions from managed soils	U	11.1	11.1
Default values for N $_{AG(T)}$, N $_{BG(T)}$, R $_{AG(T)}$, RS $_{(T)}$ and DRY to be used in Equations 11.6 and 11.7	NG	-	11.1a
Alternative method and data for estimating above-ground residue ($AG_{DM(T)}$)	U	11.2	11.2
Default emission, volatilisation and leaching factors for indirect soil N_2O emissions	U	11.3	11.3

Figures

- No refinement.

CHAPTER 12 HARVESTED WOOD PRODUCTS

The guidance in chapter 12 maintains the existing approaches covered in the *2006 IPCC Guidelines*. The refinement takes account of new relevant scientific information, including relevant methodological information and parameters contained in *KP Supplement* (e.g. carbon conversion factors). Some cross references are made to the earlier guidance where needed, for example in cases where it may be helpful to show consistency with the earlier guidance. The new structure of this chapter aims to clarify the relationships between new information and the *2006 IPCC Guidelines* and to allow for inclusion and updating of new parameters where appropriate. The description of the application of methodologies is clarified based on the updated parameters. Section 12.2 clarifies some existing terms, definitions and concepts. Section 12.3 provides guidance on available HWP approaches, describing and clarifying the options for defining a conceptual framework and system boundary for estimating emissions and removals arising from HWP.

The subsequent guidance in this chapter is structured to consider three distinct subject areas relevant to harvested wood biomass: i) wood products in use (i.e. wood utilised as a material); ii) wood biomass used for energy purposes and iii) wood biomass in solid waste disposal sites (SWDS). Section 12.4 gives detailed guidance on wood products in use, specifically providing *good practice guidance* on the choice of method for wood products in use. This includes improved methodological guidance for estimating CO_2 emissions and removals arising from HWP following different approaches. This section also includes refined guidance for calculating the initial carbon stock in the HWP pool in use as well as parameters such as HWP carbon conversion factors. Section 12.5 addresses wood biomass used for energy purposes. Section 12.6 provides clarification of the treatment of "wood biomass in SWDS".

It should also be noted that the HWP Worksheet accompanying the *2006 IPCC Guidelines* (HWP calculator) cannot be used in conjunction with this updated guidance. 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.

Sections

- 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.

- Section 12.2 updates (clarifies) the description of some existing terms, definitions and concepts.

- 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.

- 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.

- Section 12.5 updates the discussion to clarify where CO_2 and non-CO_2 emissions from harvested wood used for energy purposes are reported, in particular where CO_2 emissions are reported when HWP are used in the Energy sector and imports and exports are involved.

- Section 12.6 provides clarification of the treatment of "wood biomass in SWDS" in this guidance.

- Section 12.7 updates discussion of uncertainty assessment allowing for updated description of application of technical parameters for Tiers 1 to 3.

- Section 12.8 updates the discussion of QA/QC allowing for updated description of application of technical parameters.

- Annex 12.A.1 updated technical description of HWP approaches is provided in the annex.

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Preamble to Introduction	U	12 (before 12.1)	12.1
Introduction	U	12.1	12.1, 12.2, 12.5
Methodological issues	U	12.2	12.3, 12.4.1
Choice of method	U	12.2.1	12.4.1
Tier 1	U	12.2.1.1	12.4.2
Tier 2: Using country data	U	12.2.1.2	12.4.3
Tier 3: Country-specific methods	U	12.2.1.3	12.4.4
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_2	U	12.2.1.5	12.4,.2
Choice of emission factors	U	12.2.2	12.4.2.2, 12.4.3.2 & 12.4.4.1
Choice of activity data	U	12.2.3	12.4.2.1, 12.4.3.1 & 12.4.4.1
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	12.A.1	12.3, 12. A.1

Equations

- Previous Equation 12.1: Equation 12.2 in the updated *2019 Refinement* is effectively the same as Equation 12.1 but involves updated treatment of C (1900) (see Section 12.4.2 of *2019 Refinement* in particular discussion of Equation 12.4/Box 12.1).

- Previous Equation 12.2: Updated principally through Equations 12.3 & 12.6 in *2019 Refinement*, allowing for updated consideration of activity data and updated technical parameters.

- Previous Equation 12.3: Updated principally through Equations 12.3, 12.7, 12.8, 12.9 & 12.10 in *2019 Refinement*, allowing for updated consideration of activity data and updated technical parameters.

- Previous 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 *2019 Refinement*).

- Previous Equation 12.5: Updated principally through Equations 12.2 & 12.3 in *2019 Refinement*, 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 *2019 Refinement*).

- Previous Equation 12.6: Updated principally through Equation 12.4 in *2019 Refinement*, allowing for updated guidance in Section 12.4.2 in particular discussion accompanying Equation 12.4/Box 12.1.

- Previous Equations 12.A.1 to 12.A.6: Updated principally through Equation 12.1 in *2019 Refinement*, 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 *2019 Refinement*). Updated equations (12.5 and 12.11) are provided to maintain the 'atmospheric flow' approach.

Equation Title	Type of Refinement	2006 IPCC 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 & 12.10
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 & 12.11
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

Tables

- Previous Table 12.1 table no longer required due to updated guidance included in Section 12.4 of *2019 Refinement*.

- Previous Table 12.2 updated (inclusion of updated technical parameters) in Table 12.3 of *2019 Refinement*.

- Previous Table 12.3 table no longer required due to updated guidance (see Section 12.4.2 in *2019 Refinement* in particular discussion of Equation 12.4/Box 12.1).

- Previous Table 12.4 updated (inclusion of updated technical parameters) in Tables 12.1 and 12.2 of *2019 Refinement*.

- Previous Table 12.5 table no longer required due to updated guidance (see Section 12.4.1.1 in *2019 Refinement*).

- Previous Table 12.6 table no longer required due to updated guidance included in Section 12.7 of *2019 Refinement*, which includes an indication of overall uncertainties. Previous Tables 12.7 & A12.1 table no longer required due to adoption of CRF table as agreed in Decision 24/CP.19, Annex II.

Figures

- Previous Figure 12.1 updated decision tree in Figure 12.1 allowing for improved understanding of available activity data.

- Previous Figure 12.A.1 updated system boundary diagrams in Figures 12.A.1 & 12.A.2 clarifying linkages to relevant updated guidance on activity data and reporting according to Decision 24/CP.19 Annex II (see Section 12.A.2.1 in Annex 12.A of *2019 Refinement*).

- Previous Figure 12.A.2 updated system boundary diagrams in Figures 12.A.5 & 12.A.6 clarifying linkages to relevant updated guidance on activity data and reporting according Decision 24/CP.19 Annex II (see Section 12.A.3 in Annex 12.A of *2019 Refinement*).

- Previous Figure 12.A.3 updated system boundary diagrams in Figures 12.A.3 & 12.A.4 clarifying linkages to relevant updated guidance on activity data and reporting according Decision 24/CP.19 Annex II (see Section 12.A.2.2 in Annex 12.A of *2019 Refinement*).

Figure Title	Type of Refinement	2006 IPCC 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 & 12.A.2
System boundary of the atmospheric flow approach	U	12.A.2	12.A.5 & 12.A.6
System boundary of the production approach	U	12.A.3	12.A.3 & 12.A.4

Boxes

None.