INITIATIVE FOR CLIMATE ACTION TRANSPARENCY PROJECT: SET UP OF SECTORAL MRV SYSTEMS FOR THE AGRICULTURE SECTOR

Fiji Agriculture Rice Cultivation Emissions Guidance Document

4-5th August 2021

Initiative for Climate Action Transparency - ICAT

SET UP OF SECTORAL MRV SYSTEMS FOR THE AGRICULTURE SECTOR

Fiji Agriculture Rice Cultivation Emissions Guidance Document

August 2021

DISCLAIMER

PREPARED UNDER

The Initiative for Climate Action Transparency (ICAT), supported by Austria, Germany, Italy, the Children's Investment Fund Foundation and the ClimateWorks Foundation.

Supported by: Federal Foreign Office on the basis of a decision by the German Bundestag

IKI International Climate Initiative

CIFF CHILDREN'S INVESTMENT FUND FOUNDATION

MINISTERO DELL'AMBIENTE E DELLA SICUREZZA ENERGETICA

Federal Ministry Republic of Austria Climate Action, Environment, Energy, Mobility, Innovation and Technology

climateworks FOUNDATION

Environment and Climate Change Canada

Environnement et Changement climatique Canada

UNOPS

The ICAT project is managed by the United Nations Office for Project Services (UNOPS).

Table of Contents

1. Introduction

The National Greenhouse Gas Inventory (NGGI) is compiled using the 2006 IPCC Guidelines for NGGI that has been divided into 5 volumes. This guidance document for greenhouse gas (GHG) emissions from rice cultivation has been developed with reference to Chapters 5 and 11 of the 2006 IPCC Guidelines for NGGI. Emphasis is placed on key categories[1] for methane (CH_4), nitrous oxide (N_2O) and carbon dioxide emissions from rice cultivation. This Manual provides methodology to help identify, build, and access the minimum set of activity data needed for GHG estimation. Required data is largely drawn from MOA, Fiji; Fiji Bureau of Statistics; Fiji National Agricultural Census and FAOSTAT Statistical Database,2021. Users are provided with step-by-step guidance on how to use this minimum set to build a default, yet complete national GHG emission dataset for agriculture and land use, which follows the default, Tier 1 approach of the Intergovernmental Panel on Climate Change (IPCC) Guidelines on National GHG Inventories. There are three different methodologies[2] that are used to determine the GHG emissions from rice cultivation: Tier 1, Tier 2 and Tier 3. The pros and cons of each methodology is discussed in Table 1.

Table 1: IPCC Inventory Tier Structure

Tier Level	Pros	Cons
Tier 1	• Basic • Require minimum information regarding activity data • Use default values provided in the 2006 IPCC Guidelines for NGGI.	• Does not capture country specific national circumstances • Potentially have large uncertainties
Tier 2	• Use country and region-specific emission factors • Has reduced uncertainty compared to Tier 1.	• Is more complex, thus requires detailed activity data.
Tier 3	• Detailed country specific modelling • Has the ability to test mitigation strategies using simulations. • Potentially low uncertainties.	• Model calibration/ validation may lack diversity. • It is considerably difficult to collect high resolution spatial data.

[1] Prominent and significant source or sink of GHG in a country's NGGI
[2] "Good Practice" is to use advanced methodologies (Tier 2 or Tier 3) for Key Categories (depending on data availability for the specific country)
https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf

Principles for quality of GHG Inventory

It should have followed the below principles:

- **Transparency**: Sufficient information (Can the data be readily documented and shared with the public?)
- **Accuracy**: reduce bias (How close to reality is any of the estimated data being used?)
- **Completeness:** Documentation (Does the data adhere to the methods of the GHG inventory? Can the same methods be used year over year?
- **Consistency**: Between years Does the data adhere to the methods of the GHG inventory? Can the same methods be used year over year?
- **Comparability**: Between countries (allows it to be compared with national GHG inventories for other countries)

The GHG Inventory Compilation Cycle

The GHG Inventory management system helps inventory compilers manage the following seven stages of the GHG inventory compilation cycle.

1. Plan
2. Collect
3. Estimate
4. Write
5. Review
6. Finalize and submit report
7. Archive

Table 2- Sequence for task and schedule of GHG Inventory Preparation

Process	**Relevant Organizations**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec**
1.Preparation	**MOA,Fiji**	→	→										
2 Data request	**MOA,Fiji**			→									
3 Data preparation	**MOA,Fiji and MOE,Fiji**				→								
4 Data Collection	**MOA,Fiji**				→	→							
5 Preparation of draft GHG inventory	**MOA,Fiji**					→	→						
6 Feedback on draft GHG inventory	**Data Providing Organizations**					→	→	→	→				
7 Finalizing GHG inventory	**MOA,Fiji**								→	→			
8 Publishing GHG inventory	**PC**											→	→

Aggregated Sources and Non-CO2 Emission Sources from Land (3C)

The "Aggregated sources and non-CO2 emission sources from Land" (3C) category comprise activities that produce emissions which are not covered under 3A or 3B. The GHG emissions activities under 3C are subdivided into:

- **Biomass Burning (3C.1)**
- **Liming (3C.2)**
- **Urea application (3C.3)**
- **Direct N2O emissions from managed soil (3C.4)**
- **Indirect N2O emissions from managed soil (3C.5)**
- **Rice cultivations (3C.7)**

*There is no biomass burning and lime application in rice cultivation in Fiji.

Data, sources, and methodology

This section provides an overview of the data, data sources and the description of the methodology applied in the inventory.

Data and data sources

The data used in this inventory were obtained from the Ministry of Agriculture and the FAOSTAT. The datasets were in different formats and had varying publishing periods. While some of the datasets were readily available online, those that were not readily available required special requests to the data providers. In cases, where the dataset was completely unavailable at the national, regional and international levels, expert judgement was used. In some cases, the data were available both nationally and internationally, but they were at variance. In such instances, the country-specific dataset was used instead of the one acquired from international sources. Table 3 provides an overview of the data, data source and data providers

Table 3: Overview of the data and data sources in the inventory in Rice Cultivation (Fiji)

Categories	Sub-categories	Data Type	Data Source	Principal Data Providers	Remarks
3.C Aggregated and non-CO2 emissions on land					
3.C3	Urea application	Annual Urea consumption figures	Agric Facts and Figures	Ministry of Agriculture, Koronivia , Economic Planning and Stats department ,Raiwaqa	Data on Urea application from MOA and urea application rate were used to fill missing data for the time series
3.C4	Direct N2O emissions from manage soils	Annual generic NPK consumption	Agric Facts and Figures	Ministry of Agriculture, Koronivia , Economic Planning and Stats department ,Raiwaqa	Data on crop production from FAOSTAT were used to fill missing data for the time series

3.C5	Indirect N2O emissions from manage soils	Annual crop production in tonnes per annum			Data on crop production from FAOSTAT were used to fill missing data for the time series
3.C7	Rice cultivation	Annual rice production areas		Ministry of Agriculture, Koronivia , Economic Planning and Stats department ,Raiwaqa	Data on rice production from FAOSTAT were used to fill missing data for the time series. Expert judgement was used to split the proportions of rice cultivation areas under different production systems (upland rice, valley-bottom rise and rice under irrigation.

2. Methane Emissions from Rice Cultivation

1) Rice Cultivation

Definition: Greenhouse gas (GHG) emissions from rice cultivation consist of methane gas from the anaerobic decomposition of organic matter in paddy fields.
The anaerobic decomposition of organic material such as rice straw in flooded rice fields produce methane (CH4) by methanogenic bacteria. This methane escapes to the atmosphere primarily by transport through the rice plants. From the submerged soils, methane also escapes to the atmosphere through diffusion of dissolved methane and ebullition of gas bubbles. The annual amount of methane emitted from a given area of rice field is a function of the number and duration of crops grown, water regime before and during growing period, and the amount of organic and inorganic soil amendments. Soil type, temperature, and rice cultivar or variety also affect methane emissions.

Rice cultivation, for instance, also emits CH4 depending on where the rice cultivation occurs (ecosystem – upland rice, irrigated rice, and rainfed rice). Most of the CH4 emissions are from rainfed and irrigated rice cultivation based on rice flooding regime. The applicable data for the 3C in Fiji's situation is as follows:

- Quantities of nitrogen fertiliser and urea consumption and mode of application
- Areas of rice cultivations and quantities produced per year.

The main data source for this category was the Agriculture Facts and Figures published by the Ministry of Agriculture and the FAOSTAT.

2.1 Methodology and Quality Information

As methane emissions from rice cultivation is not a significant source and country-specific emission factors were also not available, Fiji has applied the Tier 1 approach. Equations 5.1. and 5.3 in chapter 5.5, volume 4 of IPCC148 were applied to determine the methane emissions from rice production.149 Area and production data were taken over from a review of rice production. It is assumed that 50% of the total area planted is irrigated and the other 50% is rain fed. A total of 90 days cultivation was taken into consideration. Based on the production data, a rice-straw ratio of 1:2 is assumed to calculate the amount of straw produced. The amount of straw absorbed into the soil is determined on the basis of an equal mass basis equal to the dry weight of the straw

2.2 Basic GHG Emissions Calculation

The generic equation to calculate GHG emissions is:

$$\boldsymbol{GHG\ Emissions = Activity\ Data\ \times Emission\ Factors}$$

Where:

Activity Data: magnitude of human activity (number of animals, tonnes of fertiliser applied, area of rice collected each year etc).

Emission Factor: coefficients for the emissions or removals per unit of activity data. (e.g., kg of CH_4 per area of rice). Tier 1, default IPCC emission factors, in g CH4 m-2 yr-1

Normally constant across the time series unless changes in technologies (e.g., change in management practice). For most emission factors, default values are available in the 2006 IPCC Guidelines, and other values are contained in the IPCC Emission Factor Database.

CH4 emissions from rice

Anaerobic decomposition of organic material in flooded rice fields produces methane (CH4), which escapes to the atmosphere primarily by transport through the rice plants.

The annual amount of CH4 emissions from a given area of rice is a function of:

- Cultivation period (days).
- Water regimes (before and during cultivation period).
- Organic amendments applied to the soil.
- Others (soil type, temperature, rice cultivar).

It is important to note that upland rice fields do not produce significant quantities of CH4.

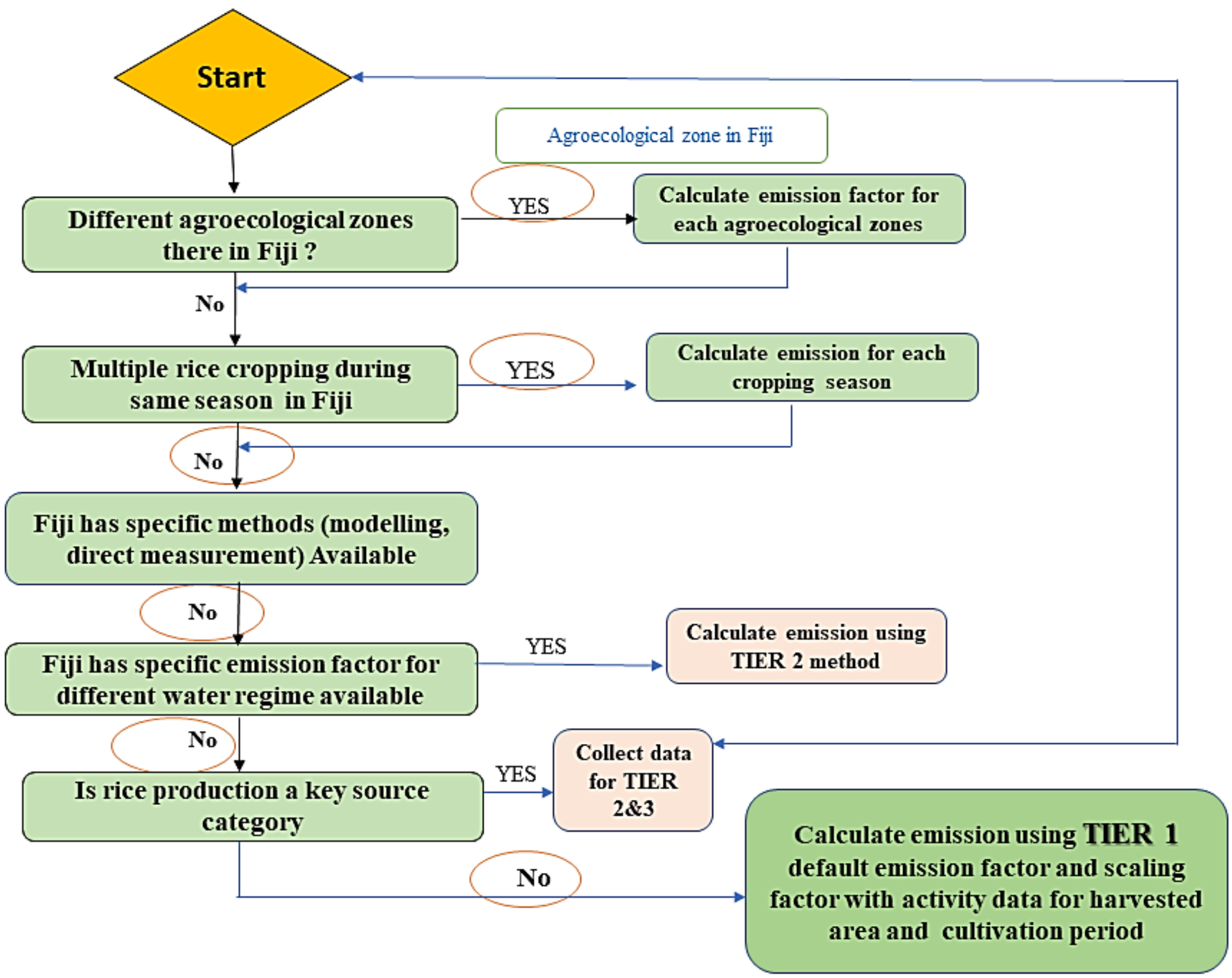


Fig 1. Decision tree for CH4 emission from rice production for Fiji

Note: Pathway indicated in green has been followed for Fiji calculation

CH4 emissions from rice cultivation are given by the basic equation follows Equation 5.1

$$CH_{4\ Rice} = \sum_{i,j,k} \left(EF_{i,j,k} \bullet t_{i,j,k} \bullet A_{i,j,k} \bullet 10^{-6} \right)$$

Where:

CH4 Rice = annual methane emissions from rice cultivation, Gg CH4 yr-1
EFijk = a daily emission factor for i, j, and k conditions, kg CH4 ha-1 day-1
tijk = cultivation period of rice for i, j, and k conditions, day
Aijk = annual harvested area of rice for i, j, and k conditions, ha yr-1
i, j, and k = represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH4 emissions from rice may vary

What do the conditions **i, j,** and **k** represent in equation 5.1?

These variables represent the conditions that influence CH4 emissions from rice cultivation

Variable i - Water Regime	Variable j - Organic Amendment to Soils	Variable k - Other Conditions
Combination of (i) ecosystem type (i.e., irrigated, rainfed, and deep water rice production) and, (ii) flooding pattern (continuously/ intermittently flooded, regular rainfed, drought prone, and deep water).	The impact on CH4 emissions depends on type and amount of the applied material, that can either be of (i) endogenous (straw, green manure, etc.) or (ii) exogenous origin (compost, farmyard manure, etc.)	It is known that other factors, such as soil type, rice cultivar or sulphate containing amendments can significantly influence CH4 emissions

In order to estimate emissions from rice cultivation, use equation 5.1 (2006 GL)and apply the following steps:

- Due to the complexity and variability of rice production management, it is good practice to stratify the total harvested area into sub-units according to the i, j and k conditions, as well as the cultivation period and the emission factor (e.g., harvested areas under different water regimes).
- For each sub-unit, calculate the emissions by multiplying the respective emission factor by the cultivation period (t) and the annual harvested area (A).
- Then, sum the emissions from each sub-unit of harvested area to determine the total annual national emissions in rice cultivation

Calculating the adjusted daily emission factor requires applying equation 5.2 shown below equation 5.1 and 5.2 .

$$CH_{4\ Rice} = \sum_{i,j,k} \left(EF_{i,j,k} \bullet t_{i,j,k} \bullet A_{i,j,k} \bullet 10^{-6} \right)$$

EQUATION 5.2

ADJUSTED DAILY EMISSION FACTOR

$$EF_i = EF_c \bullet SF_w \bullet SF_p \bullet SF_o \bullet SF_{s,r}$$

Where:

EF_i = adjusted daily emission factor for a particular harvested area

EF_c = baseline emission factor for continuously flooded fields without organic amendments

SF_w = scaling factor to account for the differences in water regime during the cultivation period (from Table 5.12)

SF_p = scaling factor to account for the differences in water regime in the pre-season before the cultivation period (from Table 5.13)

SF_o = scaling factor should vary for both type and amount of organic amendment applied (from Equation 5.3 and Table 5.14)

$SF_{s,r}$ = scaling factor for soil type, rice cultivar, etc., if available

EFi is calculated by multiplying a baseline emission factor EFc by various scaling factors (SF). Default values and methods needed to calculate the daily emission factors are provided by the 2006 IPCC Guidelines

CH4 emissions from rice: Components of Equation 5.2 The Baseline emission factor is for continuously flooded fields without organic amendments. The default value for EFc could be found in Table 5.11 shown below.

EF_c

Baseline emission factor

$$EF_i = EF_c \cdot SF_w \cdot SF_p \cdot SF_o \cdot SF_{s,r}$$

TABLE 5.11
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

	Emission factor	Error range
CH_4 emission (kg CH_4 ha^{-1} d^{-1})	1.30	0.80 - 2.20

Source: Yan et al., 2005

This variable is used as a starting point and is then adjusted according to the scaling factors. It applies to areas with no flooded fields for less than 180 days, prior to rice cultivation and continuously flooded during the rice cultivation period without organic amendments.

Scaling factor to account for the differences in water regime during the cultivation period

SF_w

Water during cultivation

$$EF_i = EF_c \cdot SF_w \cdot SF_p \cdot SF_o \cdot SF_{s,r}$$

apply disaggregated scaling factors whenever possible

If Activity data are only available for rice ecosystem types, and not disaggregated for flooding patterns, use aggregated scaling factor.

Ecosystem	Water regime	Aggregated	Disaggregated
Upland		0	0
Irrigated	Flooded		1
	Single drainage	0.78	0.6
	Multiple drainage		0.52
Rainfed	Regular		0.28
	Drought	0.27	0.25
	Deep water		0.31

It is good practice to collect more disaggregated activity data on water regime during the cultivation and apply disaggregated scaling factors whenever possible. When activity data are only available for rice ecosystem types, and not disaggregated for flooding patterns, use aggregated scaling factor. For Inventory (Fiji) due to absence of data on different water regime (continuously flooded, intermediated single aeration , multiple aeration etc.) the aggregated a value for SFw is taken for calculation but once the values for water regime in 2022 will be available disaggregated scaling factors can be taken into account.

Scaling factor to account for the differences in water regime in the pre-season before during the cultivation period.

SF_p

Water before cultivation

$$EF_i = EF_c \cdot SF_w \cdot SF_p \cdot SF_o \cdot SF_{s,r}$$

apply disaggregated scaling factors whenever possible

CH_4 Emissions from Rice – SFp

Water regime	Aggregated	Disaggregated
Non flooded < 180 days		1
Non flooded > 180 days	1.22	0.68
Flooded > 30 days		1.90

It is good practice to collect more disaggregated activity data and apply disaggregated scaling factors whenever possible. For Inventory (Fiji) due to absence of data on different water regime prior to rice cultivation the aggregated a value for SFp is taken for calculation but once the values for water regime in 2022 will be available disaggregated scaling factors can be taken into account.

Scaling factor to account for type and amount of organic amendment applied.

Organic amendments applied to rice cultivation include compost, farmyard manure, green manure and rice straw. Equation 5.3 (2006 GL) below is used to find the value of organic amendments.

SF_o

Organic amendment

$$EF_i = EF_c \cdot SF_w \cdot SF_p \cdot SF_o \cdot SF_{s,r}$$

$$SF_o = \left(1 + \sum_i ROA_i \bullet CFOA_i\right)^{0.59}$$

ROA_i Application rate of organic amendment i, in dry weight for straw and fresh weight for others, tonne ha^{-1}. No default value is provided. National statistics, specific surveys and expert judgement should be used It is good practice to collect data Application rate of organic amendment in dry weight for straw and fresh weight. For Inventory (Fiji) due to absence of data on different application rate of organic amendment in dry weight for straw and fresh weight rice cultivation based on the production data, a rice-straw ratio of 1:2 is assumed to calculate the amount of straw produced. The amount of straw absorbed into the soil is determined on the basis of an equal mass basis equal to the dry weight of the straw taken for calculation but once the values for application rate of organic amendment in 2022 will be available disaggregated scaling factors can be taken into account.

$CFOA_i$ Conversion factor for organic amendment i (in terms of its relative effect with respect to straw applied shortly before cultivation) as shown in

TABLE 5.14
DEFAULT CONVERSION FACTOR FOR DIFFERENT TYPES OF ORGANIC AMENDMENT

Organic amendment	Conversion factor (CFOA)	Error range
Straw incorporated shortly (<30 days) before cultivation[a]	1	0.97 - 1.04
Straw incorporated long (>30 days) before cultivation[a]	0.29	0.20 - 0.40
Compost	0.05	0.01 - 0.08
Farm yard manure	0.14	0.07 - 0.20
Green manure	0.50	0.30 - 0.60

[a] Straw application means that straw is incorporated into the soil, it does not include case that straw just placed on the soil surface, nor that straw was burnt on the field.

Source: Yan *et al*., 2005

Scaling factor to account for soil type, rice cultivar, etc.

$SF_{s,r}$
Other conditions

$$EF_i = EF_c \cdot SF_w \cdot SF_p \cdot SF_o \cdot SF_{s,r}$$

Both experiments and mechanistic knowledge confirm the importance of these factors, but large variations within the available data do not allow to define reasonably accurate default values.

IPCC guidance suggests that country-specific scaling factors should only be used if they are based on well-researched and documented measurement data, and if they are stratified by soil type and rice cultivar, at least.

Activity Data, is primarily based on harvested area statistics and should be available from a national statistics agency, as well as complementary information on cultivation period and agronomic practices.

$$CH_{4\ Rice} = \sum_{i,j,k} (EF_{i,j,k} \bullet t_{i,j,k} \bullet A_{i,j,k} \bullet 10^{-6})$$

- ✓ The activity data should be stratified according to the stratification of the scaling factors (i.e. cropping practices and water regime).
- ✓ Harvested area should, at a minimum, be disaggregated by three baseline water regimes as listed below:
- ✓ Irrigated.
- ✓ Upland
- ✓ Rainfed and Deep Water

If these data are not available in-country, they can be obtained from international data sources: e.g., International Rice Research Institute (IRRI), which include harvest area of rice by ecosystem type for major rice producing counties, a rice crop calendar for each country, and other useful information, and the FAOSTAT. Moreover table 4-11 of the Revised 1996 IPCC Guidelines provides data on harvested area and on ecosystem type by country or region.

Methodological Tier used for CH4 emission from rice cultivation in Fiji
Tier 1 Applies to Fiji and countries in which either CH_4 emissions from rice cultivation are not a key category or country specific emission factors do not exist. The disaggregation of the annual harvest area for at least three baseline water regimes including irrigated, rainfed, and upland. Emissions adjusted by multiplying a baseline default emission factor by scaling factors
Choice of emission factors
Tier 1 A baseline emission factor for no flooded fields for less than 180 days prior to rice cultivation and continuously flooded during the rice cultivation period without organic amendments (EFc).Scaling factors are used to adjust the EFc to account for the various conditions, e.g..: water regime during and before cultivation period and organic amendments
Choice of activity data

Activity data are primarily based on harvested area statistics, available from a national statistics agency as together with information on cultivation period and agronomic practices. The activity data should be broken down by regional differences in rice cropping practices or water regime. National data is preferable but if not available, international datasets e.g., FAOSTAT can be used especially with Tier 1 methods. The use of locally verified areas correlated with available data for emission factors under differing conditions such as climate, agronomic practices, and soil properties is very useful especially for higher tier methods.

In addition to the essential activity data requested above, it is good practice to match data on organic amendments and soil types to the same level of disaggregation as the activity data. It may be necessary to complete a survey of cropping practices to obtain data on the type and amount of organic amendments applied.

The use of locally verified areas would be most valuable when they are correlated with available data for emission factors under differing conditions such as climate, agronomic practices, and soil properties. Therefore, it may be necessary to consult local experts for a survey of agronomic practices relevant to methane emissions (organic amendments, water management, etc.).

Fiji: The rice area and production data were taken over from a review of rice production paper(Bong et al 2017) the data was also taken from MPI and FAOSTAT.

Check list for Agriculture information compilers
Activity Data
✓ **Harvested area of rice ecosystems for each type rice cultivations and quantities produced per year. disaggregated by three baseline water regimes as listed below:** ✓ **Irrigated.** ✓ **Upland** ✓ **Rainfed and Deep Water**
✓ **Cultivation period (number of days) of rice for different ecosystems** ✓ **Irrigated.** ✓ **Upland** ✓ **Rainfed and Deep water**
✓ **water regime during the cultivation period different water regime (continuously flooded, intermediated single aeration, multiple aeration**
✓ **Organic amendments/ crop residues applied – type and amount**
✓ **Type of drainage for each area and ecosystem type**
✓ **Pre-season flooding (time/days)**
✓ **Rice cultivar**
✓ **Fraction of crop residue burnt**
✓ **Soil carbon change (if available)**
✓ **soil type,**

Moreover, the information on activity data that may be required to estimate CH_4 emissions from rice cultivation can be holistically outlined as:

2.3 Applicability to Fiji

In the GHG for Rice cultivation, this category refers to the anaerobic decomposition of organic material in flooded rice fields that produces methane, which escapes to the atmosphere primarily through air-bubbles and by being transported through the rice plants. The amount emitted is a function of the rice species, the number and duration of harvests, the soil type and temperature, the irrigation method, and fertilizer use.

The emission factor (EF) used to determine CH4 emission is the default value which is produced by IPCC. There are several regional (ecosystem) applicable to Fiji under which rice is planted. they are upland, continually flooded and rainfed.

Table: Activity data currently available Fiji

Data		Data used for rice GHG inventory	Sources
Available data	Aggregated data	• Number of crops • Duration of crops grown • Soil type • Air temperature • Rice cultivar • Area • Rice ecosystem type • Fertilizer applied rate	Rice division Ministry of Agriculture, Koronivia
		• Area • Yield	FAOSTAT/MPI,Fiji
		• Climate Data	Fiji Metrological data
Currently not available	Disaggregated data	• Water regimes before the cultivation period • Water regime during the cultivation period' • Organic and inorganic soil amendments • Type of drainage for each area • Soil temperature • flooding pattern before and during the cultivation period • Soil pH • Soil Eh (Redox potential) • *Production data will be available from Fiji Bureau of Statistics from 2022	*Not available in FAOSTAT and National Stats or expert advise

***Data may be available from 2022 -2023 by Rice division of Ministry of Agriculture, Koroniva will record this information.**

2.4 Examples of such calculations and the tables with results using Fiji's Activity Data for Rice Cultivation –Fiji**

1.Worked Example 1 with Fiji datasets * Data Source: Production data Fiji Census 2020

For calculation we use 3C7 Excel spreadsheet 1 and 2 from IPCC. Additional sheet can be inserted for rough calculations as done below.

Area(ha)	2300	Yield(t)	Production	SFw	SFp	CFOA	SFo	Residue	HI	Total Biomass	Cultivation days
Irrigated	0.2	2.5	1150	0.78	1.22	1	2.878122	5	3	7.5	70
Rainfed	0.44	2.5	2530	0.27	1.22	1	1	5	3	7.5	90
Dryland	0.36	4	3312	0	0	0	1	8	3	12	90

The solution is given below .

2.Worked Example 2:

Using the information below for the 4 ecosystems, calculate the CH_4 emissions from rice production.

Ecosystem 1	Ecosystem 2
• Irrigated continuously flooded ecosystem • No flooding pre-season < 180 day • Straw 4 t/ha incorporated 30 days' prior cultivation • 150 days' cultivation period • 500 ha area	• Rainfed deep water ecosystem • No flooding pre-season < 180 day • Straw 4 t/ha incorporated, 30 days' prior cultivation • 120 days' cultivation period • 100 ha area
Ecosystem 3 • Rainfed deep water ecosystem • No flooding pre-season < 180 day • Farm yard manure 2 t/ha incorporated, 30 days prior cultivation • 100 days cultivation period • 50 ha area	**Ecosystem 4** • Irrigated multiple drainage ecosystem • No flooding pre-season < 180 day • Straw 4 t/ha incorporated, 30 days prior cultivation • 150 days cultivation period • 500 ha area

The solution is provided below.

Sector	**Agriculture, Forestry and Other Land Use**										
Category	**Rice Cultivation: Annual CH_4 emission fro*m rice(Example data for Fiji)***										
Category code	**3C7**										
Sheet	**1 of 2**										
Equation	**Eq. 2.2**	**Equation 5.1**		**Equation 5.2**			**Equation 5.3**			**Equation 5.2**	**Equation 5.1**
Rice Ecosystem	Subcategories for reporting year[1]	Annual harvested area	Cultivation period of rice	Baseline emission factor for continuously flooded fields without organic amendments	Scaling factor to account for the differences in water regime during the cultivation period	Scaling factor to account for the differences in water regime in the pre-season before the cultivation period	Application rate of organic amendment in fresh weight	Conversion factor for organic amendment	Scaling factor for both types and amount of organic amendment applied	Adjusted daily emission factor for a particular harvested area	Annual CH_4 emission from Rice Cultivation
		($ha\ yr^{-1}$)	(day)	$kg\ CH_4\ ha^{-1}\ day^{-1}$	(-)	(-)	($tonnes\ ha^{-1}$)	(-)	(-)	($kg\ CH_4\ ha^{-1}\ day^{-1}$)	$Gg\ CH_4\ yr^{-1}$
				Table 5.11	Table 5.12	Table 5.13		Table 5.14	$SF_o = (1+ROA_i * CFOA_i)^{0.59}$	$EF_i = EF_c * SF_w * SF_p * SF_o * SF_{s,r}$	$CH_{4Rice} = A * t * EF_i * 10^{-6}$
		A	**t**	$\mathbf{EF_c}$	$\mathbf{SF_W}$	$\mathbf{SF_p}$	$\mathbf{ROA_i}$	$\mathbf{CFOA_i}$	$\mathbf{SF_o}$	$\mathbf{EF_i}$	$\mathbf{CH_{4Rice}}$
Irrigated		460	70	1.3	0.78	1.22	5	1	2.878	3.56	0.1146
	Sub-total										
Rainfed and deep water		1012	90	1.3	0.27	1.22	5	1	2.878	1.232	0.112
	Sub-total										
Total											**0.23**
[1] Rice ecosystem can be stratified according to water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary.											
Sector	**Agriculture, Forestry and Other Land Use**										
Category	**Rice Cultivation: Annual CH_4 emission fro*m rice***										

Category code	**3C7**										
Sheet	**1 of 2**										
Equation	**Eq. 2.2**	**Equation 5.1**		**Equation 5.2**			**Equation 5.3**			**Equation 5.2**	**Equation 5.1**
Rice Ecosystem	Subcategories for reporting year[1]	Annual harvested area	Cultivation period of rice	Baseline emission factor for continuously flooded fields without organic amendments	Scaling factor to account for the differences in water regime during the cultivation period	Scaling factor to account for the differences in water regime in the pre-season before the cultivation period	Application rate of organic amendment in fresh weight	Conversion factor for organic amendment	Scaling factor for both types and amount of organic amendment applied	Adjusted daily emission factor for a particular harvested area	Annual CH_4 emission from Rice Cultivation
		(ha yr^{-1})	(day)	kg CH_4 ha^{-1} day^{-1}	(-)	(-)	(tonnes ha^{-1})	(-)	(-)	(kg CH_4 ha^{-1} day^{-1})	Gg CH_4 yr^{-1}
				Table 5.11	Table 5.12	Table 5.13		Table 5.14	$SF_o = (1+ROA_i * CFOA_i)^{0.59}$	$EF_i = EF_c * SF_w * SF_p * SF_o * SF_{s,r}$	$CH_{4Rice} = A * t * EF_i * 10^{-6}$
		A	**t**	**EF_c**	**SF_W**	**SF_p**	**ROA_i**	**$CFOA_i$**	**SF_o**	**EF_i**	**CH_{4Rice}**
Irrigated		500	150	1.3	1	1	4	0.29	1.58	2.05	0.15
		500	150	1.3	0.52	1	4	0.29	1.58	1.06	0.08
	Sub-total								3.15	3.11	0.23
Rainfed and deep water		100	120	1.3	0.31	1	4	0.29	1.58	0.63	0.01
		50	100	1.3	0.31	1	2	0.14	1.16	0.47	0.00
	Sub-total								2.73	1.10	0.01
Total											**0.24**
[1] Rice ecosystem can be stratified according to water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary.											

3. Nitrous Oxide Emissions from Rice Cultivation

Nitrous oxide is produced naturally in soils through the processes of nitrification and denitrification.

Nitrification is the aerobic microbial oxidation of ammonium to nitrate, and **denitrification** is the anaerobic microbial reduction of nitrate to nitrogen gas (N_2). Nitrous oxide is a gaseous intermediate in the reaction sequence of denitrification and a by-product of nitrification that leaks from microbial cells into the soil and ultimately into the atmosphere. One of the main controlling factors in this reaction is the availability of inorganic N in the soil. This methodology, therefore, estimates N_2O emissions using human-induced net N additions to soils.

The emissions of N_2O that result from anthropogenic N inputs or N mineralisation occur through both a direct pathway (i.e., directly from the soils to which the N is added/released) and indirect pathways.

Direct emissions of N_2O from managed soils are estimated separately from indirect emissions, though using a common set of activity data. The Tier 1 methodologies do not take into account different land cover, soil type, climatic conditions or management practices (other than specified above). Neither do they take account of any lag time for direct emissions from crop residues N, and allocate these emissions to the year in which the residues are returned to the soil. These factors are not considered for direct or (where appropriate, indirect) emissions because limited data are available to provide appropriate emission factors.

3.1 Direct N2O emissions from managed soils

Nitrous oxide is produced naturally in soils through the processes of nitrification and denitrification.

The emissions of N2O due to anthropogenic N inputs occur through both a direct pathway (i.e. directly from the soils to which the N is added), and through two indirect pathways (i.e. through volatilisation as NH3 and NOx and subsequent redeposition, and through leaching and runoff)

Full sectoral coverage of direct/indirect N2O emissions.

Revised emission factors for nitrous oxide from agricultural soils based on extensive literature review; and Removal of biological nitrogen fixation as a direct source of N2O because of the lack of evidence of significant emissions arising from the fixation process.

Decision tree

Upon considering the various conditions and analysing the country specific data available for Fiji, the decision tree illustrated in Fig. 2 is used to outline the pathway to choosing Tier 1 as the appropriate method to determine N_2O emissions from rice cultivation.

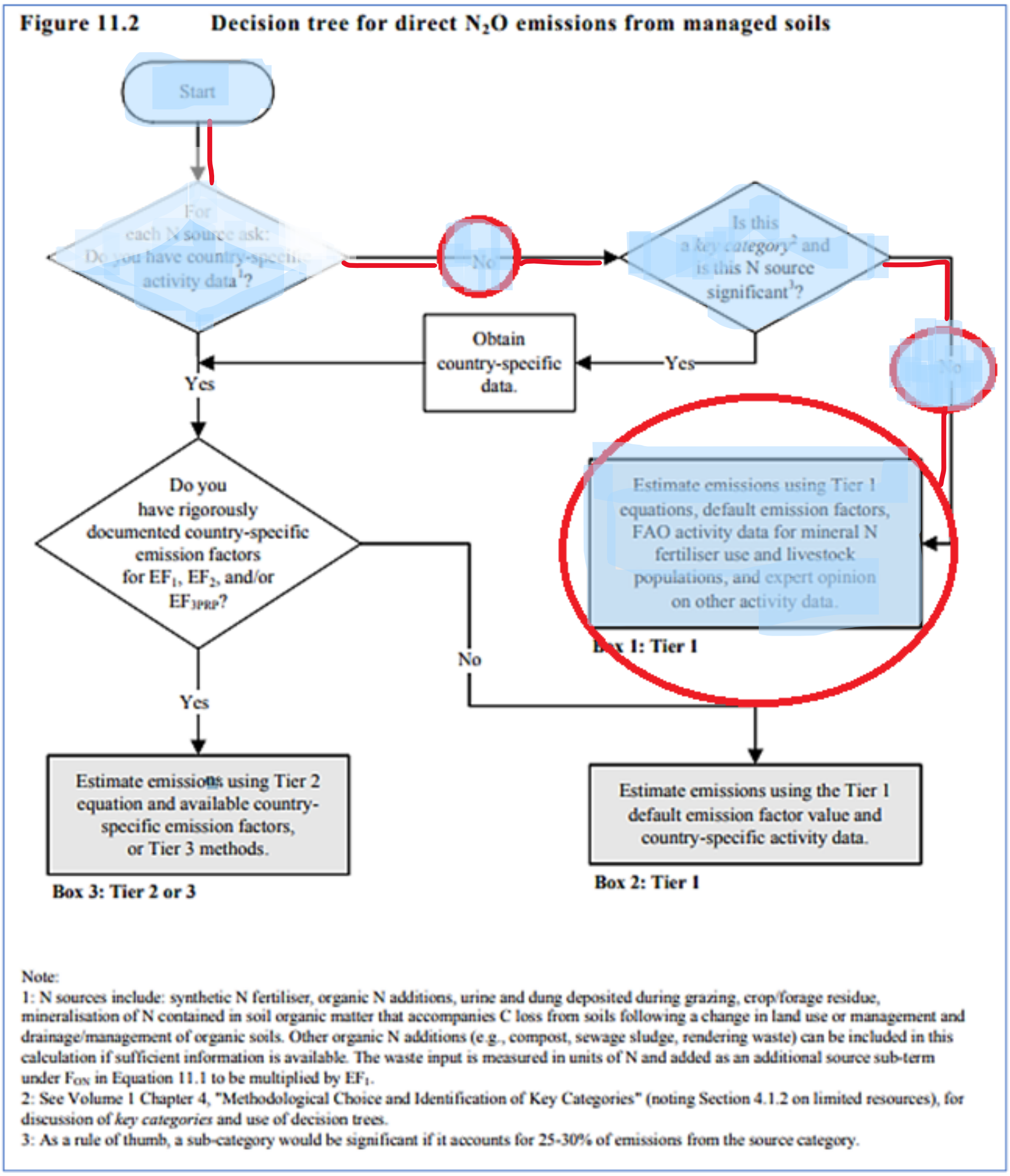


Fig 1 Decision tree for direct N2O emissions from rice cultivation

The pathway in the decision tree for Fiji is shown in blue colour for deciding the use of TIER 1 approach.

3.2 Methodological tiers - Direct N2O emissions from managed soils used in Fiji
Tier 1. -Applies to countries in which either N2O emissions managed soils are not a key category or country-specific emission factors do not exist. -use of IPCC defaults with national statistics or data from international datasets
Choice of emission factors

Three emission factors required:
EF1 represents the amount of N2O emitted from the various nitrogen additions to soils;
EF2 represents the amount of N2O emitted from cultivation of organic soil; and
EF3PRP) estimates the amount of N2O emitted from urine and dung N deposited by grazing animals on pasture, range and paddock.
Country-specific factors should be used as far as possible in order to reflect the specific conditions of a country and the agricultural practices involved with suitable disaggregation
Data from countries with similar conditions or IPCC defaults can be used if national data is unavailable.

Choice of Activity Data
Several types of activity data are required, including:
N inputs from application of synthetic fertilisers (FSN), animal manure (FAM)
mineralisation of crop residues returned to soils (FCR)
soil nitrogen mineralisation due to cultivation of organic soils (FOS)
Urine and dung from grazing animals (FPRP)
The data sources are:
Synthetic fertiliser consumption data (FSN) should be collected from official statistics (e.g. national bureaux of statistics) or International Fertiliser Industry Association (IFIA), FAO.
FAM should be calculated from the manure excreted and managed in MMS
FCR from crop production data (national or FAO) and IPCC default fractions.
The area (in hectares) of organic soils cultivated annually (FOS) can be obtained from official national statistics.
Urine and dung from grazing animals (FPRP) can be calculated from number of livestock, N excretion rates and fractions of manure deposited on pastures.

Direct N2O emissions from managed soils

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

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

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

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

Where:

N2ODirect –N = annual direct N2O–N emissions produced from agricultural soils, kg N2O–N yr-1
N2O–NNinputs = annual direct N2O–N emissions from N inputs to agricultural soils, kg N2O–N yr-1
N2O–NOS = annual direct N2O–N emissions from agricultural organic soils, kg N2O–N yr-1

$N_2O–N_{PRP}$ = annual direct $N_2O–N$ emissions from urine and dung inputs to grazed soils, kg $N_2O–N$ yr-1
F_{SN} = annual amount of synthetic fertiliser N applied to agricultural soils, kg N yr-1
F_{ON} = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to agricultural soils, kg N yr-1
F_{CR} = annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N yr-1
F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N yr-1
F_{OS} = annual area of managed/drained agricultural organic soils, ha (Note: the subscripts CG, Temp, Trop, NR and NP refer to Cropland and Grassland, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)
F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr-1 (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)
EF_1 = emission factor for N_2O emissions from N inputs, kg $N_2O–N$ (kg N input)-1 (Table 11.1)
EF_{1FR} is the emission factor for N_2O emissions from N inputs to flooded rice, kg $N_2O–N$ (kg N input)-1
(Table 11.1) 5
EF_2 = emission factor for N_2O emissions from drained/managed organic soils, kg $N_2O–N$ ha-1 yr-1; (Note: the subscripts CG, Temp, Trop, NR and NP refer to Cropland and Grassland, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)
EF_{3PRP} = emission factor for N_2O emissions from urine and dung N deposited on pasture, range and
paddock by grazing animals, kg $N_2O–N$ (kg N input)-1; (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

3.3 N2O emissions factor from Flooded Cultivated Rice fields in Fiji

Nitrous oxide from flooded rice cultivated fields are different than N_2O emission from other categories. Therefore, if you have flooded cultivated rice fields in Fiji you need to use this formula which includes an emission factor specific to rice wit N inputs computed for flooded rice.

EF_1 = emission factor for N_2O emissions from N inputs, kg $N_2O–N$ (kg N input)-1(Table 11.1)
EF_{1FR} is the emission factor for N_2O emissions from N inputs to flooded rice, kg $N_2O–N$ (kg N input)-1(Table11.1)*
Although there is some evidence that intermittent flooding can increase N_2O emissions, current scientific data indicate that EF1Fr also applies to intermittent flooding situations.
Upland rice should be classified as a traditional crop (EF1).

$$N_2O\text{-}N_{N\,inputs} = (F_{ON} + F_{CR} + F_{SOM} + F_{SN}) \times EF_1 + (F_{ON} + F_{CR} + F_{SOM} + F_{SN})_{FR} \times EF_{1FR}$$

TABLE 11.1
DEFAULT EMISSION FACTORS TO ESTIMATE DIRECT N_2O EMISSIONS FROM MANAGED SOILS

Emission factor	Default value	Uncertainty range
EF_1 for N additions from mineral fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon [kg N_2O–N (kg N)$^{-1}$]	0.01	0.003 - 0.03
EF_{1FR} for flooded rice fields [kg N_2O–N (kg N)$^{-1}$]	0.003	0.000 - 0.006
$EF_{2\,CG,\,Temp}$ for temperate organic crop and grassland soils (kg N_2O–N ha^{-1})	8	2 - 24
$EF_{2\,CG,\,Trop}$ for tropical organic crop and grassland soils (kg N_2O–N ha^{-1})	16	5 - 48
$EF_{2F,\,Temp,\,Org,\,R}$ for temperate and boreal organic nutrient rich forest soils (kg N_2O–N ha^{-1})	0.6	0.16 - 2.4
$EF_{2F,\,Temp,\,Org,\,P}$ for temperate and boreal organic nutrient poor forest soils (kg N_2O–N ha^{-1})	0.1	0.02 - 0.3
$EF_{2F,\,Trop}$ for tropical organic forest soils (kg N_2O–N ha^{-1})	8	0 - 24
$EF_{3PRP,\,CPP}$ for cattle (dairy, non-dairy and buffalo), poultry and pigs [kg N_2O–N (kg N)$^{-1}$]	0.02	0.007 - 0.06
$EF_{3PRP,\,SO}$ for sheep and 'other animals' [kg N_2O–N (kg N)$^{-1}$]	0.01	0.003 - 0.03

Sources:
EF_1: Bouwman et al. 2002a,b; Stehfest & Bouwman, 2006; Novoa & Tejeda, 2006 in press; EF_{1FR}: Akiyama *et al.*, 2005; $EF_{2CG,\,Temp}$, $EF_{2CG,\,Trop}$, $EF_{2F,Trop}$: Klemedtsson *et al.*, 1999, IPCC Good Practice Guidance, 2000; $EF_{2F,\,Temp}$: Alm *et al.*, 1999; Laine *et al.*, 1996; Martikainen *et al.*, 1995; Minkkinen *et al.*, 2002: Regina *et al.*, 1996; Klemedtsson *et al.*, 2002; $EF_{3,\,CPP}$, $EF_{3,\,SO}$: de Klein, 2004.

3.4 N from Crop Residues

EQUATION 11.6
N FROM CROP RESIDUES AND FORAGE/PASTURE RENEWAL (TIER 1)

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

Where:

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

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

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

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

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

$Frac_{Renew\,(T)}$ = fraction of total area under crop T that is renewed annually [15]. For countries where pastures are renewed on average every X years, $Frac_{Renew}$ = 1/X. For annual crops $Frac_{Renew}$ = 1

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

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

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

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

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

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

T = crop or forage type

EQUATION 11.7
3.5 DRY-WEIGHT CORRECTION OF REPORTED CROP YIELDS

EQUATION 11.7
DRY-WEIGHT CORRECTION OF REPORTED CROP YIELDS

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

Where:
Crop(T) = harvested dry matter yield for crop T, kg d.m. ha-1
Yield_Fresh(T) = harvested fresh yield for crop T, kg fresh weight ha-1
DRY = dry matter fraction of harvested crop T, kg d.m. (kg fresh weight)-1
The regression equations in Table 11.2 may also be used to calculate the total above-ground residue dry matter,and the other data in the table then permit the calculation in turn of the N

in the above-ground residues, the below-ground dry matter, and the total N in the below-ground residues. The total N addition, FCR, is the sum of the above-and below-ground N contents. With this approach, FCR is given by Equation 11.7A

EQUATION 11.7A
ALTERNATIVE APPROACH TO ESTIMATE F_{CR} (USING TABLE 11.2)

$$F_{CR} = \sum_{T} \left\{ \begin{array}{l} Frac_{Renew(T)} \bullet \\ \left[\left(Area_{(T)} - Area\,burnt_{(T)} \bullet CF \right) \bullet AG_{DM(T)} \bullet 1000 \bullet N_{AG(T)} \bullet \left(1 - Frac_{Remove(T)} \right) + Area_{(T)} \bullet \left(AG_{DM(T)} \bullet 1000 + Crop_{(T)} \right) \bullet R_{BG-BIO(T)} \bullet N_{BG(T)} \right] \end{array} \right\}$$

It is recommended approach for crop residues.
Convert N2O–N emissions to N2O emissions.
N2O = N2O–N * 44/28.
Where :
Fcr= Residues returned to soil (kg dm ha-1)
Fcr= (Area -Area burnt * Cf) * AGdm* 1000 * Nag * (1-Frre) + (AGdm* 1000 + Yield) * Rbg* Nbg
Yield (kg dm ha-1)
Area (ha)
Area burnt (ha)
Cf (combustion factor) (Table 2.6)
AGdm(Mg/ha) = (Yield / 1000) * Slope + Intercept
Nag –N content of aboveground residues
Frre–fraction of aboveground residues removed
Rbg–ratio of roots to yield
Nbg–N content of roots

3.6 Example Calculation for N from Crop Residues

Fcr= Residues returned to soil (kg dm ha-1) = 18799
Fcr= (Area -Area burnt * Cf) * AGdm* 1000 * Nag * (1-Frre) + (AGdm* 1000 + Yield) * Rbg* Nbg
Yield (kg dm ha-1) = 2000(Yield wmha-1) * 0.89 (DRY) = 1780
Area (ha) = 500
Area burnt (ha) = 0
Cf (combustion factor) (Table 2.6) = 1
AGdm(Mg ha-1) = (Yield dm / 1000) * 0.95 + 2.46 = 4.36 (Table 11.2)
Nag –N content of aboveground residues (Table 11.2) = 0.007
Frre–fraction of aboveground residues removed = 0
Rbg–ratio of roots to yield (Table 11.2) = 0.16
Nbg–N content of roots (Table 11.2) = 0.009

TABLE 11.2
DEFAULT FACTORS FOR ESTIMATION OF N ADDED TO SOILS FROM CROP RESIDUES [a]

Crop	Dry matter fraction of harvested product (DRY)	Above-ground residue dry matter $AG_{DM(T)}$ (Mg/ha): $AG_{DM(T)} = (Crop_{(T)}/1000) * slope_{(T)} + intercept_{(T)}$					N content of above-ground residues (N_{AG})	Ratio of below-ground residues to above-ground biomass (R_{BG-BIO})	N content of below-ground residues (N_{BG})
		Slope	± 2 s.d. as % of mean	Intercept	± 2 s.d. as % of mean	R^2 adj.			
Major crop types									
Grains	0.88	1.09	± 2%	0.88	± 6%	0.65	0.006	0.22 (± 16%)	0.009
Beans & pulses[b]	0.91	1.13	± 19%	0.85	± 56%	0.28	0.008	0.19 (± 45%)	0.008
Tubers[c]	0.22	0.10	± 69%	1.06	± 70%	0.18	0.019	0.20 (± 50%)	0.014
Root crops, other[d]	0.94	1.07	± 19%	1.54	± 41%	0.63	0.016	0.20 (± 50%)	0.014
N-fixing forages	0.90	0.3	± 50% default	0	-	-	0.027	0.40 (± 50%)	0.022
Non-N-fixing forages	0.90	0.3	± 50% default	0	-	-	0.015	0.54 (± 50%)	0.012
Perennial grasses	0.90	0.3	± 50% default	0	-	-	0.015	0.80 (± 50%)[l]	0.012
Grass-clover mixtures	0.90	0.3	± 50% default	0	-	-	0.025	0.80 (± 50%)[l]	0.016[p]
Individual crops									
Maize	0.87	1.03	± 3%	0.61	± 19%	0.76	0.006	0.22 (± 26%)	0.007
Wheat	0.89	1.51	± 3%	0.52	± 17%	0.68	0.006	0.24 (± 32%)	0.009
Winter wheat	0.89	1.61	± 3%	0.40	± 25%	0.67	0.006	0.23 (± 41%)	0.009
Spring wheat	0.89	1.29	± 5%	0.75	± 26%	0.76	0.006	0.28 (± 26%)	0.009
Rice	0.89	0.95	±19%	2.46	± 41%	0.47	0.007	0.16 (± 35%)	NA
Barley	0.89	0.98	± 8%	0.59	± 41%	0.68	0.007	0.22 (± 33%)	0.014
Oats	0.89	0.91	± 5%	0.89	± 8%	0.45	0.007	0.25 (± 120%)	0.008
Millet	0.90	1.43	± 18%	0.14	± 308%	0.50	0.007	NA	NA
Sorghum	0.89	0.88	± 13%	1.33	± 27%	0.36	0.007	NA	0.006
Rye[e]	0.88	1.09	± 50% default	0.88	± 50% default	-	0.005	NA	0.011

TABLE 11.2 (CONTINUED)
DEFAULT FACTORS FOR ESTIMATION OF N ADDED TO SOILS FROM CROP RESIDUES [a]

Crop	Dry matter fraction of harvested product (DRY)	Above-ground residue dry matter $AG_{DM(T)}$ (Mg/ha): $AG_{DM(T)} = (Crop_{(T)}/1000) * slope_{(T)} + intercept_{(T)}$					N content of above-ground residues (N_{AG})	Ratio of below-ground residues to above-ground biomass (R_{BG-BIO})	N content of below-ground residues (N_{BG})
		Slope	± 2 s.d. as % of mean	Intercept	± 2 s.d. as % of mean	R^2 adj.			
Soyabean[f]	0.91	0.93	± 31%	1.35	± 49%	0.16	0.008	0.19 (± 45%)	0.008
Dry bean[g]	0.90	0.36	± 100%	0.68	± 47%	0.15	0.01	NA	0.01
Potato[h]	0.22	0.10	± 69%	1.06	± 70%	0.18	0.019	0.20 (± 50%)[m]	0.014
Peanut (w/pod)[i]	0.94	1.07	± 19%	1.54	± 41%	0.63	0.016	NA	NA
Alfalfa[j]	0.90	0.29[k]	± 31%	0	-	-	0.027	0.40 (± 50%)[n]	0.019
Non-legume hay[j]	0.90	0.18	± 50% default	0	-	-	0.015	0.54 (± 50%)[n]	0.012

[a] Source: Literature review by Stephen A. Williams, Natural Resource Ecology Laboratory, Colorado State University. (Email: stevewi@warnercnr.colostate.edu) for CASMGS (http://www.casmgs.colostate.edu/). A list of the original references is given in Annex 11A.1.

[b] The average above-ground residue:grain ratio from all data used was 2.0 and included data for soya bean, dry bean, lentil, cowpea, black gram, and pea.

[c] Modelled after potatoes.

[d] Modelled after peanuts.

[e] No data for rye. Slope and intercept values are those for all grain. Default s.d.

[f] The average above-ground residue:grain ratio from all data used was 1.9.

[g] Ortega, 1988 (see Annex 11A.1). The average above-ground residue:grain ratio from this single source was 1.6. default s.d. for root:AGB.

[h] The mean value for above-ground residue:tuber ratio in the sources used was 0.27 with a standard error of 0.04.

[i] The mean value for above-ground residue: pod yield in the sources used was 1.80 with a standard error of 0.10.

[j] Single source. Default s.d. for root:AGB.

[k] This is the average above-ground biomass reported as litter or harvest losses. This does not include reported stubble, which averaged 0.165 x Reported Yields. Default s.d.

[l] Estimate of root turnover to above-ground production based on the assumption that in natural grass systems below-ground biomass is approximately equal to twice (one to three times) the above-ground biomass and that root turnover in these systems averages about 40% (30% to 50%) per year. Default s.d.

[m] This is an estimate of non-tuber roots based on the root:shoot values found for other crops. If unmarketable tuber yield is returned to the soil then data are derived from Vangessel and Renner, 1990 (see Annex 11A.1) (unmarketable yield = 0.08 * marketable yield = 0.29 * above-ground biomass) suggest that the total residues returned might then be on the order of 0.49 * above-ground biomass. Default s.d.

[n] This is an estimate of root turnover in perennial systems. Default s.d.

[p] It is assumed here that grass dominates the system by 2 to 1 over legumes.

Example calculation:

Rice	Synthetic fertilizer used	Area(ha)	Crop residue
Managed	70 Kg N in 2 splits Calculated as 70*2=1400 112000	800ha	(500 tonnes) 19000*800/500= 30400
Flooded Rice	1500 ha X 140 Kg N fertilizer =210000	1500	57000

From Table 11.2 most of the information of all crops for N2O is provided and it also have some uncertainty covered in it depicted.

3.6 Worked Example (Direct N2O emission from Residue)

Sector		**Agriculture, Forestry and Other Land Use**							
Category		**Direct N_2O Emissions from Managed Soils**							
Category code		**3C4**							
Sheet		**1 of 2**							
Equation		**Equation 11.1**							
Anthropogenic N input type		Annual amount of N applied		Emission factor for N_2O emissions from N inputs		Annual direct N_2O-N emissions produced from managed soils			
		(kg N yr^{-1})		[kg N2O-N (kg N input)$^{-1}$]		(kg N_2O-N yr^{-1})			
				Table 11.1		N_2O-$N_{N\ inputs}$ = F * EF	G9*44/28	H9*298	I9/1000
		F		**EF**		**N_2O-$N_{N\ inputs}$**	**N2O(kg)**	**CO2e(Kg)**	CO2e(kt)
Anthropogenic N input types to estimate annual direct N_2O-N emissions produced from managed soils	synthetic fertilizers	F_{SN}: N in synthetic fertilizers	112000	EF_1	0.01	1120	1760	524480	524.48
	animal manure, compost, sewage sludge	F_{ON}: N in animal manure, compost, sewage sludge, other							
	crop residues	F_{CR}: N in crop residues	30400		0.01	304	478	142444	142.444

	changes to land use or management	F_{SOM}: N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management							
Anthropogenic N input types to estimate annual direct N_2O-N emissions produced from flooded rice	synthetic fertilizers	F_{SN}: N in synthetic fertilizers	210000	EF_{1FR}	0.003	630	990	262350	
	animal manure, compost, sewage sludge	F_{ON}: N in animal manure, compost, sewage sludge, other							
	crop residues	F_{CR}: N in crop residues	57000		0.003	171	269	71209	
	changes to land use or management	F_{SOM}: N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management							
Total									

3.7 Check list for Agriculture information compilers
Activity Data for Direct N2O emission in Managed soils
✓ **Harvested area and yield of rice ecosystems for each type rice cultivations and quantities produced per year. disaggregated by three baseline water regimes as listed below:** ✓ **Irrigated.** ✓ **Upland** ✓ **Rainfed and Deep Water**
✓ **Nitrogen applied per year and amount of synthetic fertilizers, animal manure, compost, sewage sludge, crop residues changes to land use or management added for different ecosystems per year** ✓ **Irrigated.** ✓ **Upland** ✓ **Rainfed and Deep water**

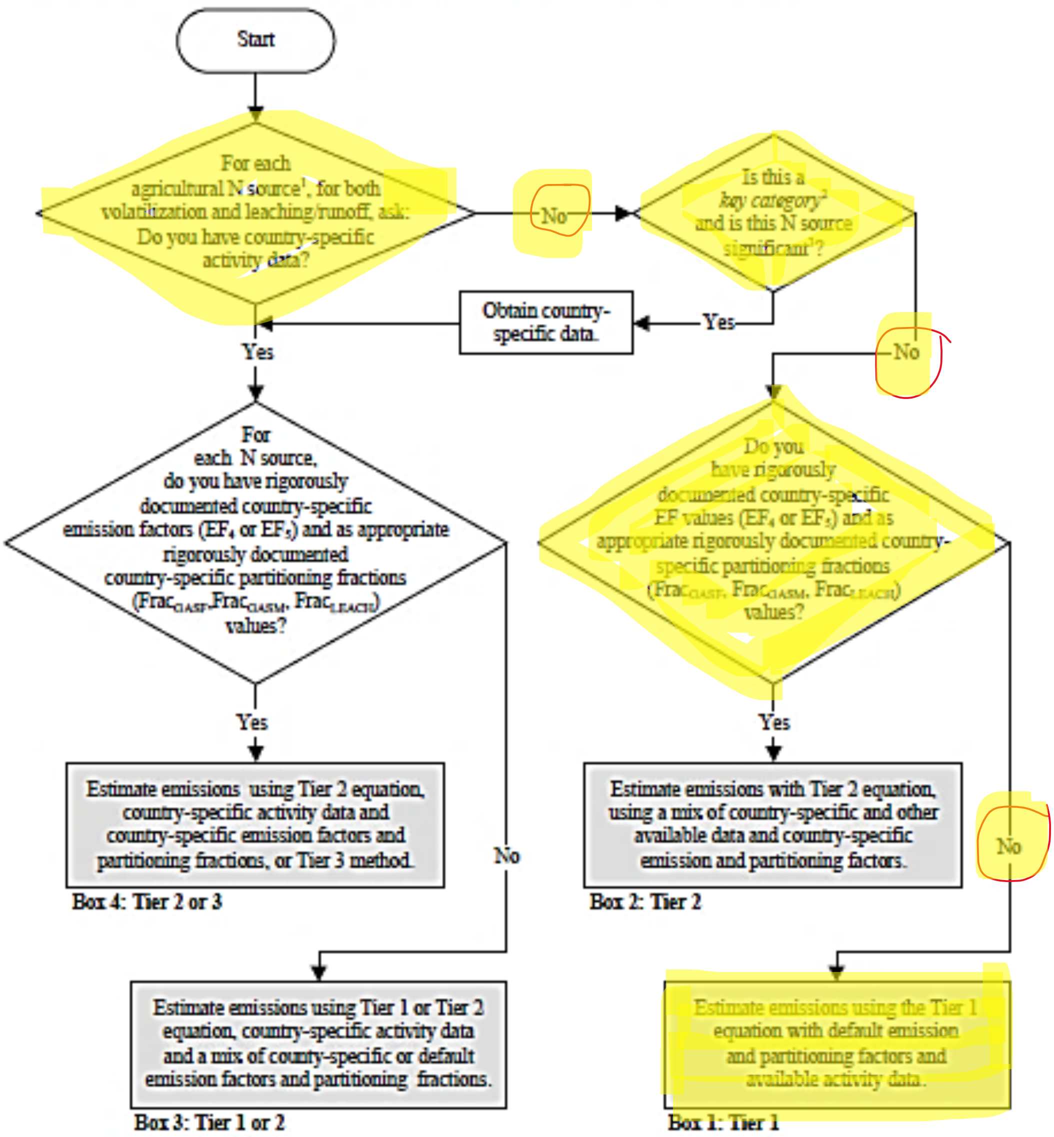
4.0 Indirect N2O emissions from managed soils

In addition to the direct emissions of N2O from managed soils that occur through a direct pathway (i.e., directly from the soils to which N is applied), emissions of N2O also take place through two indirect pathways:

volatilisation of N as NH3 and oxides of N (NOx), and the re-deposition as NH4+ and NO3 onto soils and the surface of lakes and other waters;

leaching and runoff from land of N:

Figure 11.3 Decision tree for indirect N_2O emissions from managed soils



Note:Pathway indicated in yellow has been followed for Fiji calculation.

TABLE 11.3 DEFAULT EMISSION, VOLATILISATION AND LEACHING FACTORS FOR INDIRECT SOIL N_2O EMISSIONS		
Factor	Default value	Uncertainty range
EF_4 [N volatilisation and re-deposition], kg N_2O–N (kg NH_3–N + NO_X–N volatilised)$^{-1}$ [22]	0.010	0.002 - 0.05
EF_5 [leaching/runoff], kg N_2O–N (kg N leaching/runoff)$^{-1}$ [23]	0.0075	0.0005 - 0.025
$Frac_{GASF}$ [Volatilisation from synthetic fertiliser], (kg NH_3–N + NO_x–N) (kg N applied)$^{-1}$	0.10	0.03 - 0.3
$Frac_{GASM}$ [Volatilisation from all organic N fertilisers applied , and dung and urine deposited by grazing animals], (kg NH_3–N + NO_x–N) (kg N applied or deposited)$^{-1}$	0.20	0.05 - 0.5
$Frac_{LEACH-(H)}$ [N losses by leaching/runoff for regions where Σ(rain in rainy season) - Σ (PE in same period) > soil water holding capacity, OR where irrigation (except drip irrigation) is employed], kg N (kg N additions or deposition by grazing animals)$^{-1}$	0.30	0.1 - 0.8
Note: The term $Frac_{LEACH}$ previously used has been modified so that it now only applies to regions where soil water-holding capacity is exceeded, as a result of rainfall and/or irrigation (excluding drip irrigation), and leaching/runoff occurs, and redesignated as $Frac_{LEACH-(H)}$. In the definition of $Frac_{LEACH-(H)}$ above, PE is potential evaporation, and the rainy season(s) can be taken as the period(s) when rainfall > 0.5 * Pan Evaporation. (Explanations of potential and pan evaporation are available in standard meteorological and agricultural texts). For other regions the default $Frac_{LEACH}$ is taken as zero.		

4.1 Volatilisation (N2O) – Tier 1

$$N_2O_{(ATD)}–N = \left[\left(F_{SN} \bullet Frac_{GASF} \right) + \left(\left(F_{ON} + F_{PRP} \right) \bullet Frac_{GASM} \right) \right] \bullet EF_4$$

Where:
N2O(ATD)–N = annual amount of N2O–N produced from atmospheric deposition of N volatilised from
soils, kg N2O–N yr-1
FSN = annual amount of synthetic fertiliser N applied to soils, kg N yr-1
FracGASF = fraction of synthetic fertiliser N that volatilises as NH3 and NOx, kg N volatilised (kg of N
applied)-1
FON = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N yr-1
FPRP = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr-1
FracGASM = fraction of applied organic N fertiliser materials (FON) and of urine and dung N deposited by grazing animals (FPRP) that volatilises as NH3 and NOx, kg N volatilised (kg of N applied or deposited)-1
EF4 = emission factor for N2O emissions from atmospheric deposition of N on soils and water surfaces, [kg N–N2O (kg NH3–N + NOx–N volatilised)-1]
Equation 11.9 (2006 GL)

4.2 Leaching/Runoff (N2O) – Tier 1

$$N_2O_{(L)}–N = \left(F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM} \right) \bullet Frac_{LEACH-(H)} \bullet EF_5$$

Where:
$N_2O_{(L)}–N$ = annual amount of $N_2O–N$ produced from leaching and runoff of N additions to agricultural soils in regions where leaching/runoff occurs, kg $N_2O–N$ yr^{-1}
F_{SN} = annual amount of synthetic fertiliser N applied to soils in regions where leaching/runoff occurs, kg N yr^{-1}
F_{ON} = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils in regions where leaching/runoff occurs, kg N yr^{-1}
F_{PRP} = annual amount of urine and dung N deposited by grazing animals in regions where leaching/runoff occurs, kg N yr^{-1}
F_{CR} = amount of N in crop residues (above- and below-ground), including N-fixing crops, and from
forage/pasture renewal, returned to soils annually in regions where leaching/runoff occurs, kg N yr^{-1}
F_{SOM} = annual amount of N mineralised in mineral soils associated with loss of soil C from soil organic
matter as a result of changes to land use or management in regions where leaching/runoff occurs, kg N yr^{-1}
$Frac_{LEACH-(H)}$ = fraction of all N added to/mineralised in soils in regions where leaching/runoff
occurs that is lost through leaching and runoff, kg N (kg of N additions)$^{-1}$
EF_5 = emission factor for N_2O emissions from N leaching and runoff, kg $N_2O–N$ (kg N leached and
Runoff)$^{-1}$ Equation 11.10 (2006 GL)

4.3 Methodological Tiers
Tier 1. **-Applies to countries in which either indirect N2O emissions managed soils are not a key category or country-specific emission factors do not exist.** **-Uses IPCC defaults with national statistics or data from international datasets.**
Choice of emission factors **Emission factors and parameters required for indirect N2O from soils are:** **EF associated with volatilised and re-deposited N (EF4)** **EF associated with N lost through leaching/runoff (EF5)** **fractions of N that are lost through volatilisation (FracGASF and FracGASM) or leaching/runoff (FracLEACH-(H))** **Country-specific values for EF4 should be used with great caution because of the special complexity of trans-boundary atmospheric transport.**
Choice of Activity Data **The activity data requirements for indirect N2O are the same as those for direct N2O from managed soils.**

4.4 Check list for Agriculture information compilers
Activity Data for INDIRECT N2O emission in Managed soils
✓ **Harvested area and yield of rice ecosystems for each type rice cultivations and quantities produced per year. disaggregated by three baseline water regimes as listed below:** ✓ **Irrigated.** ✓ **Upland** ✓ **Rainfed and Deep Water**
✓ **Annual amount of synthetic fertilizer N applied to soil in each ecosystems per year** ✓ **Irrigated.** ✓ **Upland** ✓ **Rainfed and Deep water**

5. CO2 Emissions from Urea Fertilization

Adding urea to soils during fertilisation leads to a loss of CO2 that was fixed in the industrial production process. Urea (CO(NH2)2) is converted into ammonium (NH4 +), hydroxyl ion (OH-), and bicarbonate (HCO3 -), in the presence of water and urease enzymes. Similar to the soil reaction following addition of lime, bicarbonate that is formed evolves into CO2 and water. This source category is included because the CO2 removal from the atmosphere during urea manufacturing is estimated in the Industrial Processes and Product Use Sector (IPPU Sector). Inventories can be developed using Tier 1, 2 or 3 approaches, with each successive Tier requiring more detail and resources than the previous. It is good practice for countries to use higher tiers if CO2 emissions from urea are a key source category

EQUATION 11.13
ANNUAL CO_2 EMISSIONS FROM UREA APPLICATION

$$CO_2\text{–}C\ Emission = M \bullet EF$$

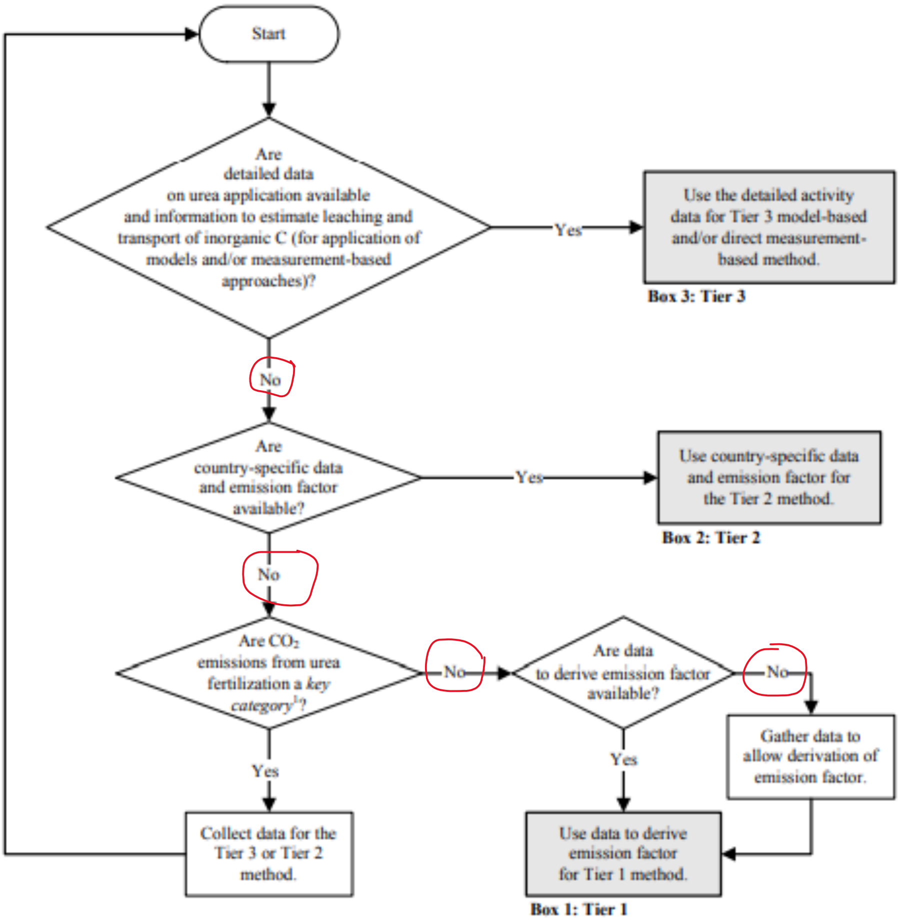
Where:

CO_2–C Emission = annual C emissions from urea application, tonnes C yr^{-1}

M = annual amount of urea fertilisation, tonnes urea yr^{-1}

EF = emission factor, tonne of C $(\text{tonne of urea})^{-1}$

Figure 11.5 Decision tree for identification of appropriate tier to estimate CO_2 emissions from urea fertilisation



Note:Highlight Fiji pathway.

Urea is applied to soils during fertilization and leads to loss of CO2 that was fixed in the industrial production process

- CO2 recovered for urea production is estimated in IPPU sector, CO2 emissions from the application of urea are estimated and reported where they occur (Energy, AFOLU, Waste)
- Inventories can be developed using tier 1, 2 and 3 approaches
- It is good practice for countries to use higher tiers if CO2 emissions from Urea fertilisation are a key source category.

5.1 Methodological Tier 1 used for CO2 emissions from Urea fertilization in Fiji
- Estimate the total amount of urea applied to soils in the country (M) -Apply an overall EF of 0.20 for urea (equivalent to the carbon content of urea on atomic weight basis. -Estimate the total CO2-C emission based on the product of the amount of urea applied and the emission factors Multiply by 44/12 to convert CO2-C into CO2

Choice of emission factors Tier 1 The default emission factor (EF) is 0.20 for carbon emissions from urea applications
Choice of Activity Data Tier 1 Domestic production records and import/export data on urea can be used to obtain an approximate estimate of the amount of urea applied to soils on an annual basis (M) Supplemental data on sales and/or usage of urea can be used to refine the calculation, instead of assuming all available urea in a particular year is immediately added to soils

5.2 Check list for Agriculture information compilers
Activity Data for CO2 emissions from Urea fertilization in Managed soils
✓ **Harvested area and yield of rice ecosystems for each type rice cultivations and quantities produced per year. disaggregated by three baseline water regimes as listed below:** ✓ **Irrigated.** ✓ **Upland** ✓ **Rainfed and Deep Water**
✓ **Annual amount of Urea applied for different ecosystems per year** ✓ **Irrigated.** ✓ **Upland** ✓ **Rainfed and Deep water**

Uncertainty assessment

- ✓ Uncertainty assessment (Volume 1, Chapter 3)
- ✓ Cause of Uncertainty
- ✓ Lack of completeness
- ✓ Inappropriate models
- ✓ Lack of data
- ✓ Lack of representative data
- ✓ Statistical random sampling error
- ✓ Measurement error
- ✓ Misclassification

6.0 QA/QC and Verification (Volume 1, Chapter 6)
Quality Control (QC) are routine technical activities to assess and maintain the quality of the inventory:Consistency checks to ensure data integrity, correctness, and completeness.
Identify and address errors and omissions.
Document and archive inventory material, accuracy checks on data acquisition and calculations, and the use of approved standardised procedures.
Quality Assurance (QA) is a system of review procedures preferably by independent third parties upon a completed inventory.
Verification is a collection of activities and procedures normally conducted after completion of an inventory that can help to establish its reliability for the intended applications of the inventory.

7.0 COMPLETENESS Tier 1 Tier 1 inventories are complete if emissions are computed based on a full accounting of all urea that is applied to soils. Urea usage statistics or sales provide the most direct inference on applications to soils, but production and import/export records are sufficient for making an approximate estimate of the amount of urea applied to soils. If current data are not sufficient due to incomplete records, it is good practice to gather additional data for future inventory reporting, particularly if urea-C emissions are a key source category.

8.0 TIME SERIES CONSISTENCY Tier 1 The same activity data and emissions factors should be applied across the entire time series for consistency. At the Tier 1 level, default emission factors are used so consistency is not an issue for this component. However, the basis for the activity data may change if new data are gathered, such as a statistical survey compiling information on urea applications to soils versus older activity relying strictly on domestic production and import/export data. While it is good practice for the same data protocols and procedures to be used across the entire time series, in some cases this may not be possible, and inventory compilers should determine the influence of changing data sources on the trends. Guidance on recalculation for these circumstances is presented in Volume 1, of Chapter 5.

Conclusion

This Manual shows which data, emission factors and computation procedures are necessary and sufficient to build a simplified yet robust GHG national Inventory at Tier 1for rice cultivation.

ANNEXURE

Details for Sources for Activity Data in Fiji

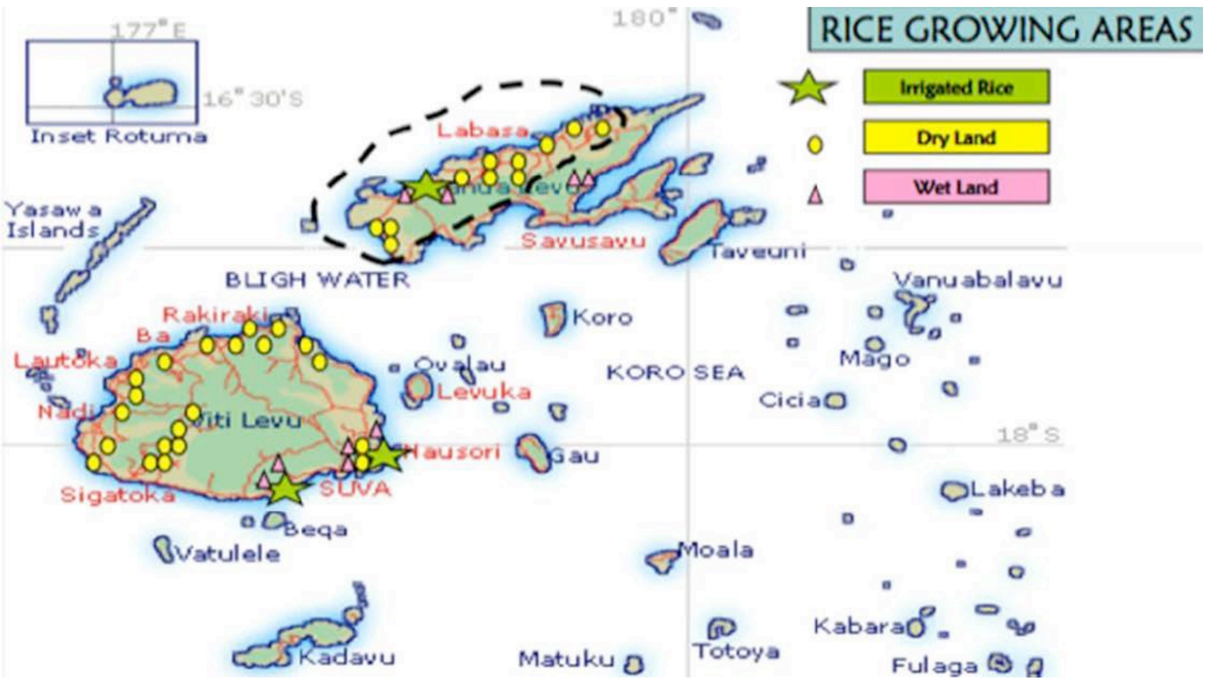
Data Sources	**Website**
Fiji Bureau of Statistics (FBoS)	**https://www.statsfiji.gov.fj/index.php**
FAO STAT	**http://www.fao.org/faostat/en/#home**
Fiji Data source 2020 Census	

MPI Fiji (Rice Division)

MPI officials	**Email Contact**
Ms. IRENE SINGH :	irenerozika@yahoo.com
Ms. Morien M. Prasad :	prasad.morien@yahoo.com
Mr. Krishneel Chand (MPI LABASA) :	krishneelchand1993@gmail.com
Ms .Nileshni Devi :	devinileshni12@yahoo.com

References :

- "Good Practice" is to use advanced methodologies (Tier 2 or Tier 3) for Key Categories (depending on data availability for the specific country)
- https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf
- Chand, D., Mani, F.S., Maata, M., Macanawai, A. (2017). Evaluation of methane emissions from the agricultural sector in Fiji. Suva, Fiji: USP.
- IPCC. (2006a). Agriculture, Forestry, and other Land Use. Eggleston, S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds.). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4. Japan: IGES.
- Republic of Fiji. (2009). National Agricultural Census - 2009 Report. Suva: FAO,Fiji Department of Agriculture; and Ministry of Agriculture. (2015).\
- 2006 IPCC Guidelines, Volume 4, Chapter 5: Cropland
- Bong et al 2017 Review of the development of the rice industry in Fiji FAO



Activity Data for Rice Cultivation –Fiji