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DIRECTORATE OF ENVIRONMENT AND CLIMATE CHANGE
GOVERNMENT OF KERALA

KERALA GHG INVENTORY METHODOLOGY NOTE

AGRICULTURE SECTOR

JUNE, 2024

AGRICULTURE SECTOR

Key Highlights

- In Kerala, the Agriculture sector represented ~7% of the gross GHG emissions (excluding LULUCF) in 2021.
- In 2021, GHG emissions from the Enteric Fermentation category was the highest and accounted to 994.10 kt CO_2e, constituting ~63.56% of the total Agriculture sector emissions.
    - Similarly, GHG emissions from Agriculture Soils accounted to 258.89 kt CO_2e, constituting ~16.55% of the total Agriculture sector emissions, in 2021. GHG emissions from Rice Cultivation accounted to 186.52 kt CO_2e, constituting ~11.92% of the total Agriculture sector emissions.
    - GHG emissions from manure management category accounted to 119.58 kt CO_2e, constituting ~7.64% of the total Agriculture sector emissions, in 2021.

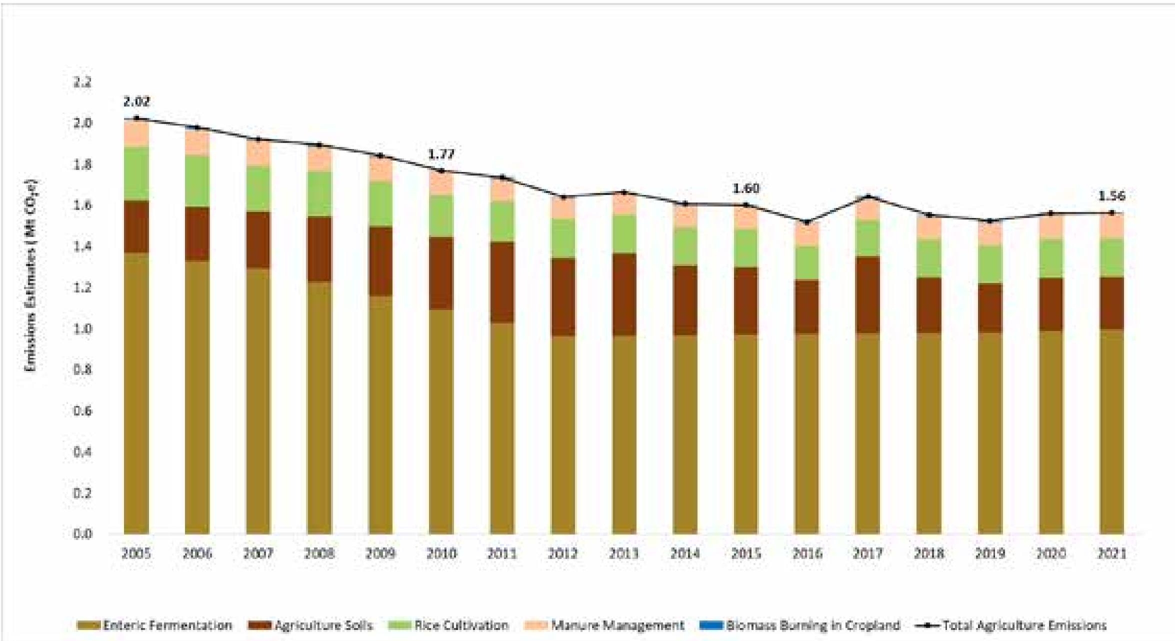

Figure 3 : GHG Emissions Estimates of Agriculture Sector – Kerala (2005 to 2021)

Sector Description

Emissions from the Agriculture sector arise from two main sub-sectors, namely Livestock, and Agriculture Practices.

The key economic sectors/categories included in the emission estimates are:

- 3A Livestock
    - 3A1 Enteric Fermentation
    - 3A2 Manure Management

- Agriculture Practices
    - 3C1b Emissions from biomass burning in croplands
    - 3C4 Direct N_2O emissions from managed soils
    - 3C5 Indirect N_2O emissions from managed soils
    - 3C7 Rice Cultivation

Methodology

The table 50 below details the sources of activity data used for estimating emissions

Table 50: Source of activity data[20] used for estimating emissions from Agriculture sector

Category	Parameter	Year	Source
Livestock	Livestock Population	2003, 2007, 2012 and 2019	Livestock Census of India, Department of Animal Husbandry and Dairying
		2004 to 2006, 2008 to 2011 and 2013 to 2018	Interpolation method
		2020 and 2021	CAGR method
Biomass burning in cropland	Crop production	2004-05 to 2021-22	Department of Economics & Statistics, Government of Kerala Agriculture Statistics
	Groundnut production	2004-05	Directorate of Economics and Statistics, Department of Agriculture and Farmers welfare, Ministry of Agriculture and Farmers Welfare, Govt of India
Agriculture Soils	Nitrogen Consumption	2004-05 to 2020-21	Economics,Statistics and Evaluation Division, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India. 2007 (for 2004-05, 2005-06, 2006-07) 2009 (for 2007-08, 2008--09)

[20] Activity data provided in financial year (FY) format was converted to calendar year (CY) format using the following equations:

CY Activity data = [¼*FY Activity Data$_{\text{Preceding year}}$] + [¾*FY Activity Data$_{\text{Succeeding year}}$]

			2012 (for 2009-10, 2010-11, 2011-12) 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020 and 2021
		2021	CAGR calculated between 2005 and 2020
	Urea Consumption	2004-05 to 2017-18	GHGPI Phase 4 datasheet which is sourced from Indian Fertilizer Scenario, Department of Fertilizers, Ministry of Chemicals and Fertilizers, Govt of India (currently reports are not available on the public domain)
		2018-2021	CAGR calculated between 2005-2017
Rice Cultivation	Rice Cultivated area	2005-2021	Department of Economics & Statistics, Government of Kerala Agriculture Statistics
	The proportions of rice cultivated area under different water regimes.		Directorate of Agriculture Development and Farmers Welfare, Kerala

3A Livestock

3A1 Enteric Fermentation

Category Description

Methane emissions from Enteric Fermentation arise due to the process of ingesting and digesting food eaten by the herbivores, mainly bovines and ovines (Dhingra et al., 2019). Similarly, Methane and Nitrous Oxide emissions from the Manure management systems arise due to decomposition of manure under the anaerobic conditions due to storage and treatment or due to management of large numbers of animals in a confined area such as dairy farms, swines and poultry farms.

The livestock population activity data for both enteric fermentation and manure management emission estimations were obtained from Livestock Census of India. The detailed assumptions and emission factors used for emissions estimation are given below:

Methodology

The emissions resulting from Enteric Fermentation and Manure Management due to Livestock production in Kerala, have been estimated using the Tier 1 and Tier 2 approaches (See Table 51) .

Due to lack of data on excretion of animals, livestock population (N_t) was multiplied by emission factor (for each type of animal category) in order to calculate the N_2O emissions from Manure Management.

Table 51 : Type of emissions factor and the level of methodological tier employed for GHG estimation

Table 51 a: Enteric Management

IPCC ID	GHG Sources and sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
3A1	**Enteric Fermentation**						
a.	Cattle	-	-	T2	CS	-	-
	Dairy (Indigenous and Crossbred Cattle)	-	-	T2	CS	-	-
	Non-Dairy (Indigenous and Crossbred Cattle)	-	-	T2	CS	-	-
b	**Buffalo**	-	-	T2	CS	-	-
c	Sheep	-	-	T2	CS	-	-
d	Goats	-	-	T2	CS	-	-
e	Camels	-	-	T1	D	-	-
f	Horses and ponies	-	-	T1	D	-	-
g	Donkeys	-	-	T1	D	-	-
h	Pigs	-	-	T1	D	-	-
T1 : Tier 1 ;T2: Tier 2; CS:Country Specific ; D:IPCC Default							

Table 51 b : Manure Management

IPCC ID	GHG Sources and sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
3A2	**Manure Management**						
a.	Cattle	-	-	T2	CS	T1	D
	Dairy (Indigenous and Crossbred Cattle)	-	-	T2	CS	T1	D
	Non-Dairy (Indigenous and Crossbred Cattle)	-	-	T2	CS	T1	D
b	**Buffalo**	-	-	T2	CS	T1	D
c	Sheep	-	-	T2	CS	T1	D
d	Goats	-	-	T2	CS	T1	D
e	Camels	-	-	T1	D	T1	D
f	Horses and ponies	-	-	T1	D	T1	D
g	Donkeys	-	-	T1	D	T1	D
h	Pigs	-	-	T1	D	T1	D
T1 : Tier 1 ;T2: Tier 2; CS:Country Specific ; D:IPCC Default							

Emission Factors

1. The country-specific emission factors for indigenous cattle, cross-bred cattle and buffalo were taken from NATCOM 2 (MoEFCC,2012). For the remaining categories, default emissions factors were obtained from 2006 IPCC guidelines (see Table 52).

Table 52: Emission Factors used

Category	Sub-category	Age group	Methane Emission Factor (NATCOM 2 and IPCC Guidelines)		Nitrous Oxide Emission Factor (GHGPI Phase 4)
			Enteric Fermentation (kg/CH_4/head/ year)	Manure Management (kg/CH_4/head/ year)	Manure Management (kg/head/year)
Indigenous Cattle	Dairy Cattle		28	3.5	0.0006

Category	Sub-category	Age group	Methane Emission Factor (NATCOM 2 and IPCC Guidelines)		Nitrous Oxide Emission Factor (GHGPI Phase 4)
			Enteric Fermentation (kg/CH_4/head/year)	Manure Management (kg/CH_4/head/year)	Manure Management (kg/head/year)
Indigenous Cattle	Non-Dairy Cattle	0-1 year	9	1.2	0.0004
Indigenous Cattle	Non-Dairy Cattle	1-3 year	23	2.8	0.0004
Indigenous Cattle	Non-Dairy Cattle	Adult	32	2.9	0.0004
Crossbred Cattle	Dairy Cattle		43	3.8	0.0006
Crossbred Cattle	Non-Dairy Cattle	0-1 year	11	1.1	0.0004
Crossbred Cattle	Non-Dairy Cattle	1-3 year	26	2.3	0.0004
Crossbred Cattle	Non-Dairy Cattle	Adult	33	2.5	0.0004
Buffalo	Dairy Buffalo		50	4.4	0.0006
Buffalo	Non-Dairy Buffalo	0-1 year	8	1.8	0.0004
Buffalo	Non-Dairy Buffalo	1-3 year	22	3.4	0.0004
Buffalo	Non-Dairy Buffalo	Adult	44	4	0.0004
Sheep	-	-	5	0.2	0
Goat	-	-	5	0.22	0
Horses and Ponies	-	-	18	2.19	0
Donkeys	-	-	10	0.9	0
Camels	-	-	46	2.56	0
Pigs	-	-	1	4	0.0074

Category	Sub-category	Age group	Methane Emission Factor (NATCOM 2 and IPCC Guidelines)		Nitrous Oxide Emission Factor (GHGPI Phase 4)
			Enteric Fermentation (kg/CH_4/head/ year)	Manure Management (kg/CH_4/head/ year)	Manure Management (kg/head/year)
Poultry	-	–	0	0	0.0025

Equation Used

3A1 Enteric Fermentation

$$CH_{4\ Enteric} = \sum EF_{(T)} \bullet (N_{(T)} / 10^6) \quad \textit{(IPCC 2006 Equation 10.19)}$$

Where,

Emissions = methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = the number of heads of livestock species/category T in the country

T = species/category of livestock

3A2 Manure Management

I. Methane Emissions from Manure Management

$$\text{Total } CH_{4\ Manure} = EF_{(T)} \bullet (N_{(T)} / 10^6) \quad \textit{(IPCC 2006 Equation 10.22)}$$

Where,

$CH_{4\ Manure}$ = methane emissions from Manure Management, Gg CH4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = the number of heads of livestock species/category T in the country

T = species/category of livestock

II. Nitrous Oxide Emissions from Manure Management*

$$N_2O_{animals} \text{ Emissions } \textit{(Gg/ Year)} = EF_{(kg/\ head/\ year)} \times \text{population} / 10^6 \text{ (kg/ Gg)}$$

Where,

N_2O Emissions = N_2O emissions from Manure Management, Gg N_2O yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg N_2O $head^{-1}$ yr^{-1}

** Slightly modified version of equation 10.25 provided in the IPCC was used due to the type of EF provided in Indian Literature*

Emissions in terms of CO_2e (both GWP and GTP) were calculated using the following equations

$$Emissions_{CO2e}\ (GWP) = Emissions_{CO2} + (GWP_{CH4} \times Emissions_{CH4}) + (GWP_{N2O} \times Emissions_{N2O})$$

$$Emissions_{CO2e}\ (GTP) = Emissions_{CO2} + (GTP_{CH4} \times Emissions_{CH4}) + (GTP_{N2O} \times Emissions_{N2O})$$

Agriculture Practices

3C1b Biomass burning in Cropland

Category Description

From a climate change perspective, the combustion of crop residues leads to the release of N_2O and CH_4 gases. It is important to note that CO_2 emissions are not factored in, as they are offset by the absorption of CO_2 during the photosynthesis process that initially prompted the growth of biomass (IPCC, 2006).

Methodology

The crops considered for biomass burning in cropland are rice, wheat, cotton, maize, millets, sugarcane, jute, mustard and groundnut.
The methodological tiers adopted for estimating emissions from Biomass Burning in Cropland are as under:

Table 53: An overview of tier and emission factors used for biomass burning in cropland

IPCC ID	GHG Source and sink categories	CH_4		N_2O	
		Method applied	Emission factor	Method applied	Emission factor
3C1b	Biomass Burning in Cropland	T1	D	T1	D
T1: Tier 1, D: IPCC Default					

In the absence of data on the amount of area burnt the methodology used here for estimating emissions from biomass burning in cropland is adopted from the MoEFCC,(2012).

Steps followed

Emissions from crop residue burning was calculated using the following equation from Bhatia et al., (2013)

$$FBCR = \sum Crops(A \cdot B \cdot C \cdot D \cdot E \cdot F)$$

Where,
FBCR is the emissions from residue burning (t)

A is the crop production (t)
B is the residue to crop ratio
C is the dry matter fraction,
D is the fraction burnt
E is the fraction oxidized
F is the emission factor for CH_4 and N_2O (g/kg)

Residue to crop ratio and dry matter fraction was taken from TIFAC & IARI,(2018), millet and jute were taken from MoEFCC, (2021) (see table 54). Fractions burnt for rice were taken from Gadde et al. (2009), and for the rest of the crops from MoEFCC, (2021) (see table 54). Fractions of residues oxidized were obtained from Garg et al. (2011). (see table 54)

Table 54: Fractions used for estimation of emissions from biomass burning in cropland

Parameter	Rice	Wheat	Maize	Cotton	Sugarcane	Jute	Rapeseed & mustard	Groundnut	Millets
Residue to crop ratio	1.60	1.70	1.50	1.00	0.43	2.15	3.0	2.10	1.50
Dry matter fraction	0.86	0.88	0.88	0.80	0.88	0.80	0.80	0.80	0.88
Combustion factor	0.80	0.90	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Fraction burnt	0.10	0.10	0.10	0.10	0.25	0.10	0.10	0.10	0.10

Default emission factors for different pollutants emitted from residue burning were taken from IPCC 2006, Chapter 2 (see table 55).

Table 55: Emission factors used for estimating biomass burning in cropland

Category	CH_4 (g/kg)	N_2O (g/Kg)
Biomass burning in cropland	2.7	0.07

Limitations

- The fraction of rice burnt used for these calculations could be updated.

Estimation of Emissions from Agricultural Soils, including from:

3C4 Direct N_2O emissions from managed soils and

3C5 Indirect N_2O emissions from Managed Soils

Category Description

Soil N_2O emissions can be categorized into two types: direct and indirect. A portion of nitrogenous fertilizers applied in agricultural soils are lost into the atmosphere through direct emissions of N_2O through nitrification and denitrification. In addition, there are also indirect emissions of N_2O through volatilization losses, leaching and runoffs (IPCC, 2006).

Methodology

The fertilizer consumption data used for estimating emissions from this category for the year 2019, 2020, 2021 is detailed in table 57 .The methodological tiers adopted for estimating emissions from Biomass Burning in Cropland are given in table 56:

Table 56: Methodological tier and emission factors used for biomass burning in cropland

IPCC ID	GHG Source and sink categories	N_2O	
		Method applied	Emission factor
3C4	Direct N_2O emissions from Managed Soils	T1	CS
3C5	Indirect N_2O emissions from Managed Soils	T2	CS
T1: Tier 1, T2: Tier 2, CS: Country specific			

Table 57 : Fertilizer consumption Data used for Emission Estimation (‘000 tonnes)

Consumption of Fertilizer	2019	2020	2021
Urea	128.77	129.03	129.29
Nitrogen	77.73	85.86	85.99

Steps followed

Total N_2O = N_2O direct + N_2O indirect [21]

21 The equations used for estimating direct N_2O emissions is slightly modified from IPCC equation based on the format of available dataset

Calculation of direct N_2O emission

Step 1:
Quantity of nitrogen in other nitrogen fertilizers= Total N quantity consumed - Quantity of N in urea consumed
For calculating the quantity of nitrogen in urea, the total urea consumption was multiplied by 46 percent as urea contains 46% nitrogen. So, N consumed by other fertilizers was found by subtracting the N consumed in urea from the total N consumption.

Step 2:
Fraction loss= (Quantity of N in urea consumed *Fraction of gas loss through volatilised N from urea application) + (Quantity of nitrogen in other nitrogen fertilizers *Fraction of gas loss through volatilized N from Other fertilizer application)

Step 3:
N_2O direct= (Total N quantity consumed – Fraction loss) *Emission factor (EF1) * (44/28)

Calculation of indirect N_2O emission:

Indirect Emission from NH_3 Deposition on Soil from Urea = Quantity of N in Urea Consumed* Fraction of gas loss through volatilized N from Urea application* Emission factor (EF4)* (44/28)

Indirect Emission from NH_3 Deposition on Soil from Other fertilizer = Quantity of N in Other Nitrogen Fertilizers* Fraction of gas loss through volatilized N from Other fertilizer application* emission factor (EF4)* (44/28)

Indirect Emissions from Leaching of Fertilizers = Total N Quantity Consumed* Fraction of leaching loss of N applied fertilizer * emission factor (EF5) * (44/28)

The country specific emission factors and fractions used for estimating emissions from Agriculture Soils are as in Table 58

Table 58 : Emission factor used for Emissions Estimation of Agriculture Soil category

Parameter	Gas	Emission factor
Direct Emissions	N_2O	0.0058 Kg N20-N/Kg N
Indirect Emissions - Atmospheric Deposition, Urea or Other fertilizers		0.005 Kg N20-N/Kg N
Indirect Emissions - Leaching		0.005 Kg N20-N/Kg N

Fraction of gas loss through volatilized N from Urea application		0.15 Kg N/kg N
Fraction of gas loss through volatilized N from Other fertilizer application		0.15 Kg N/kg N
Fraction of leaching loss of N applied fertilizer		0.1 Kg N/kg N

Source: BUR 3 (MoEFCC,2021)

Limitations

N_2O emissions could not be estimated due to the lack of availability of data for the following sub-categories :

- Nitrogen from compost
- Nitrogen from crop residue
- Manure nitrogen other than poultry
- Nitrogen input from below-ground biomass

3C7 Rice Cultivation

Category Description

This category includes emissions of methane by the anaerobic decomposition of soil organic material in flooded rice paddies (IPCC, 2006).

Methodology

The proportions of rice cultivated area under different water regimes as per the data provided by Directorate of Agriculture Development and Farmers Welfare, Kerala (see table 59) was applied to the cultivated area from 2005-2021 to get the area of rice under different water regimes from 2005-2021.

Table 59: Area of rice cultivated under different water regimes

Region	Area of rice cultivated	Water Regime
Kuttanad	33801	Single aeration (SA)
Pokkali	507	Single aeration (SA)
Kole	14724.3	Single aeration (SA)
Kaippad	3740	Single aeration (SA)
Palakkad plains and other paddy region	40736.7	Multiple aeration (MA)
Upland rice	511	Upland

Of the total land under rice cultivation, 56.13 per cent is under single aeration, 43.33 per cent under multiple aeration, and 0.54 percent is upland

The methodological tiers adopted for estimating emissions from Rice Cultivation are given in Table 60:

Table 60: An overview of tier and emission factors used for Rice Cultivation

IPCC ID	GHG Source and sink categories	CH_4	
		Method applied	**Emission factor**
3C7	Rice Cultivation	T2	CS
T1: Tier 1, T2: Tier 2, D: IPCC Default, CS: Country specific			

The methodology used was the same as that used in MoEFCC, (2012). It has been referred from Gupta et al., (2009) and Pathak et al., (2010) using 2006 IPCC guidelines. The methane emissions are estimated by multiplying the total paddy rice area under different water management regimes (ha) with corresponding Emission Factor.

Equation Used

$$E_{RC} = A_C \times EF_W \times 10^{-6}$$

Where, E_{RC} = CH_4 emissions from rice cultivation (Gg year^{-1}),
A_C = area of rice cultivation under management C (ha)
EF_W = factor applied for different types of water management (kg CH_4 ha^{-1})
10^{-6} = to convert Kg into Gg

The specific emission factors used were as follows:

Table 61: Country specific emission factors used for estimating emissions from Rice Cultivation

Water Regime	Type of gas	Emission factor
Single aeration	CH_4	66 kg CH_4/ha
Multiple aeration	CH_4	18 kg CH_4/ha
Upland	CH_4	0 kg CH_4/ha

Source: Pathak, et al. (2010)

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