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DIRECTORATE OF ENVIRONMENT AND CLIMATE CHANGE
GOVERNMENT OF KERALA

KERALA GHG INVENTORY METHODOLOGY NOTE

LAND USE, LAND-USE CHANGE AND FORESTRY SECTOR

JUNE, 2024

LAND USE, LAND-USE CHANGE AND FORESTRY (LULUCF) SECTOR

Key Highlights

- In Kerala, the Land Use, Land-Use Change and Forestry (LULUCF) sector remained a sink between 2005 and 2021.
- Forestland was the major contributor to GHG removals between 2005 and 2021. However, these GHG removals declined at a rate of 1.7 % (compounded annually) in the evaluation period, from -13.14 Mt CO_2e to -9.99 Mt CO_2e.
- The GHG removals from Settlements increased between 2005 and 2021 at a rate of 6.01% (compounded annually) from -0.02 Mt CO_2e to -0.05 Mt CO_2e.
- The Grassland and Other Land* category remained a sink until 2011. However, during the period 2012 - 2021, total annual emissions from these categories were 0.014 Mt CO_2e.

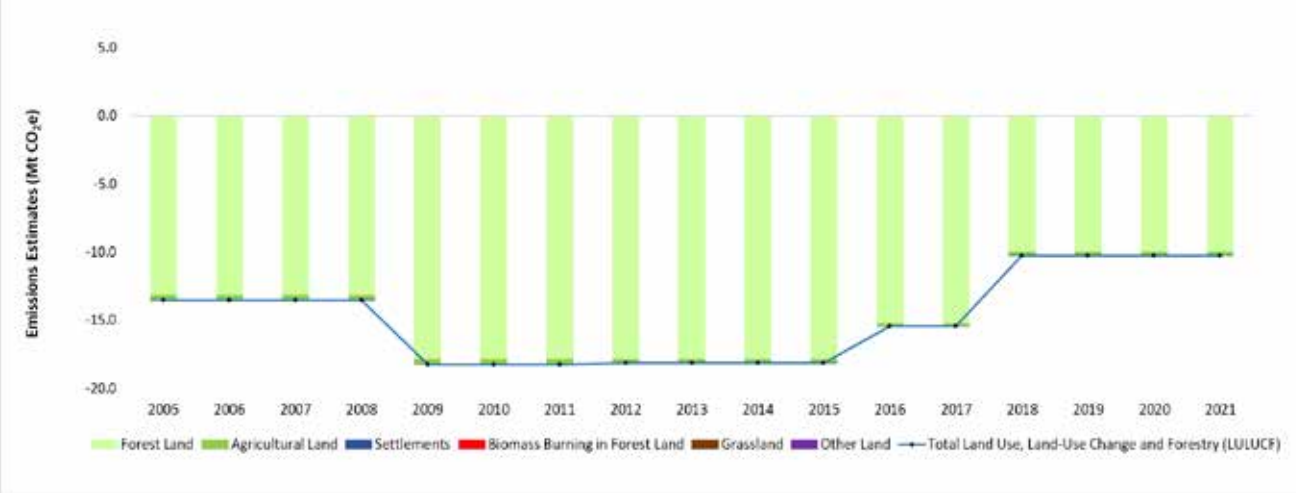

Figure 4: GHG Emissions Estimates of LULUCF Sector - Kerala (2005 to 2021)

Sector Description

Emissions from the Land Use, Land Use Change and Forestry (LULUCF) sector were estimated for Forest land and land conversions. The sub-sectors covered under LULUCF sector are listed below:

3B1. Forest Land
3C1a. Biomass burning in Forest Land
3B2 Cropland
3B3 Grassland
3B5 Settlements
3B6 Other Land

**Other Land includes Barren Land/ Unculturable/wastelands*

Methodology

The table 62 below details the sources of activity data used for estimating emissions:

Table 62: Source of activity data[22] used for estimating emissions

Category	Parameter	Year	Source
Forest Land	Forest Cover	2004, 2006, 2008, 2010, 2013, 2015, 2017 and 2019 (reported assessment years)	India State Forest Reports, Forest Survey of India 2005 , 2009, 2011, 2013, 2015, 2017 2019, 2021
	Carbon Stock Density	(a) 2008 (b) 2015, 2017 and 2019	(a) Carbon Report, Forest Survey of India (b) India State Forest Reports, Forest Survey of India
Biomass burning in Forestland		2004-05 to 2008-09	Forest Statistics 2009, Kerala Forest Department
		2009-10 to 2020-21	Kerala Forest Department
		2021-22	CAGR method
Land	Cropland, Grassland, Settlements and Other Land	LULC matrix of (a) 2005-06 to 2011-12 (b) 2011-12 to 2015-16	(a) Envistats Reports 2018 (b) Envistats India 2020 (Ministry of Statistics and Programme Implementation , Government of India, 2020)

3B1. Forest Land

This category presents the emission estimates from Forest Land due to changes in dead organic matter, biomass and soil organic matter. The forest land data and the emission factor were obtained from the 'India State of Forest Report' and emissions from this category were estimated using the Tier 2 (T2) approach of IPCC Guidelines (see Table 63).

[22] 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 $_{\text{Succeeding year}}$]

Table 63 :Type of emission factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO_2	
		Method Applied	Emission Factor
3B1	Forest Land	T2	CS
T2: Tier 2, CS: Country specific			

Methodology:

a. Emissions Estimation

The year-on-year carbon stock was calculated by multiplying the carbon stock density and the forest cover data. The carbon stock density (CSD) data was available for the assessment years 2008, 2015,2017 and 2019 from the Carbon Report and Forest Survey of India (FSI) reports.

The Carbon Stock Density was applied in the following format: 2008 CSD was applied between 2005 and 2008, 2015 CSD was applied between 2009 and 2015, 2017 CSD was applied for 2016-2017, 2019 CSD was applied for the years between 2018 and 2021.

The GHG emissions from the forest land is estimated by applying Stock-Difference Method along with the activity data and emission factors, in-line with section 4.2.1.1 – choice of method, in Volume 4, Chapter 4, 2006 IPCC Guidelines.

The following Stock-Difference Method has been used for assessing the carbon stock changes

$$\Delta C = (Ct_2 - Ct_1) / (t_2 - t_1) \quad \textit{(IPCC 2006 Equation 2.5)}$$

Where,

ΔC = Annual Carbon stock change in pool (tonnes C yr^{-1})

Ct_1 = Carbon stock in the pool at time t1 (tonnes C)

Ct_2 = Carbon stock in the pool at time t1 (tonnes C)

3C1a Biomass Burning in Forest Land

Category Description

The non-carbon dioxide emissions viz. Methane (CH_4) and Nitrous oxide (N_2O) were estimated for this category. The non-carbon dioxide emissions from biomass burning in forest land

caused by both uncontrolled (wildfires) and managed (prescribed) fires. The activity data of this category were obtained form Kerala Forest Department. The data sources, assumption, methodology and emission factors are detailed below:

Methodology

The emissions from this category were estimated using the Tier 2 (T2) approach (see Table 64)

Table 64: Type of emissions factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CH4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor
3C1a	Biomass Burning in Forest Land	T2	CS	T2	CS
T2: Tier 2, CS: Country specific					

Table 65 :Factors used and sources

Parameter	Value	Source
Mass of fuel available for combustion (t/ha)	5.483[#]	BUR 3
Combustion Factor	0.36	2006 IPCC Guidelines

[#]***Scope for improvement*** *: The estimations can be refined if the mass of fuel available for the combustion is replaced with the corresponding state-level equivalent. The mass of fuel available for combustion (5.483) is the average of biomass burnt in mild fire areas, moderate fire areas and heavy fire areas as provided in the BUR 3 report.*

Emission Factor

Country specific emission factors for methane (CH_4) and nitrous oxide (N_2O) were obtained from NATCOM 2 (MoEFCC, 2012).

Table 66: Emission Factor Used

Parameter	Methane (CH_4)	Nitrous Oxide (N_2O)
Emission factor (g/kg dry matter)	9	0.11

Limitations:

Tier 3 estimation requires use of detailed State forest inventories with details on ecological zone and climate domain specific fuel dynamics in forests (growing stock, above ground biomass, dead organic matter).

Equation used to estimate the emissions

$$L_{fire} = A \bullet M_B \bullet C_f \bullet G_{ef} \bullet 10^{-3}$$

Where,

L_{fire} = amount of greenhouse gas emissions from fires, tonnes of each GHG e.g. CH_4, N_2O etc.

A = area burnt, ha

M_B = mass of fuel available for combustion, tonnes ha^{-1}. This includes biomass, ground litter and dead wood.

C_f = combustion factor, dimensionless

G_{ef} = emission factor, g kg^{-1} dry matter burnt

3B2,3B3,3B5 & 3B6 Land sub-sector

Category Description

The emissions from the Land sub-sector were estimated for the Cropland, Grassland, Settlements and Other land. The emissions from this category is caused due to changes in biomass carbon stock and soil organic carbon stock due to various land use practices – Land remaining Land as well as Land converted to any other Land category.

Methodology

1. The Land Use Land Cover Change Matrix of Kerala for the years between 2005-06 to 2011-12 and 2011-12 to 2015-16 were obtained from Envistats Reports 2018 and 2020 (Supplement on Environmental Accounts) – Ministry of Statistics and Programme Implementation (MOSPI), Govt. of India.
2. The rate of change of biomass (0.045 tC/ha/year) was obtained from BUR 3 report; Soil organic carbon stocks for Grassland and Other Land were obtained from Sreenivas et al (2016) ; Soil organic carbon stock for Cropland was obtained from Gladis et al (2020); Soil organic carbon stock for Settlements was obtained from Sarkar et al (2022) and the Soil organic carbon for Wetlands was obtained from IPCC Guidelines.
3. The default stock change factors were obtained from IPCC Guidelines.

The emissions from this category have been estimated using the Tier 2 approach and country-specific emission factors (see Table 67)

Table 67 :Type of emission factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO_2	
		Method Applied	Emission Factor
3B2	**Crop Land**	**T2**	**CS**
3B2a	Cropland Remaining Cropland	T2	CS
3B2bi	Forestland converted to Cropland	T2	CS
3B2bii	Grassland converted to Cropland	T2	CS
3B2biii	Wetland converted to Cropland	T2	D
3B2biv	Settlements converted to Cropland	T2	CS
3B2bv	Other Land converted to Cropland	T2	CS
3B3	**Grassland**	**T2**	**CS**
3B3a	Grassland Remaining Grassland	T2	CS
3b3bi	Forestland converted to Grassland	T2	CS
3b3bii	Cropland converted to Grassland	T2	CS
3b3biii	Wetland converted to Grassland	T2	D
3b3biv	Settlements converted to Grassland	T2	CS
3b3bv	Other Land converted to Grassland	T2	CS
3B5	**Settlements**	**T2**	**CS**
3B5a	Settlements Remaining Settlements	T2	CS
3B5bi	Forestland converted to Settlements	T2	CS
3B5bii	Cropland converted to Settlements	T2	CS
3B5biii	Grassland converted to Settlements	T2	CS
3B5biv	Wetland converted to Settlements	T2	D
3B5v	Other Land converted to Settlements	T2	CS

IPCC ID	GHG Sources and sink categories	CO_2	
		Method Applied	Emission Factor
3B6	**Other land**	**T2**	**CS**
3B6a	Other Land Remaining Other Land	T2	CS
3b6bi	Forestland converted to Other Land	T2	CS
3b6bii	Cropland converted to Other Land	T2	CS
3b6biii	Grassland converted to Other Land	T2	CS
3b6biv	Wetland converted to Other Land	T2	D
3b6bv	Settlements converted to Other Land	T2	CS
3B4	**Wetlands**	**Not Estimated**	
T2: Tier 2 ; CS: Country specific ; D: IPCC default			

The biomass factor used for the emission estimation have been detailed below in Table 68

Table 68 : Biomass Factor

Years applicable	Factor	
For LULC upto 2011-12	Rate of change in biomass carbon in tC/ha/yr	0.045
For LULC upto 2015	Rate of change in biomass carbon in tC/ha/yr	0.045

Source : BUR 3

Assumptions:

The biomass factor obtained from BUR 3 was derived using country specific biomass conversion and expansion factors.

Scope for improvement

Tier 3 inventories for Land (except Forest Land) can be developed using measurements and modeling – accounting for deadwood, litter along with above and below ground biomass, wood harvested products, soil organic carbon.

Equations used for emissions estimation:

The equations used to estimate the emission from Land sub-sector (except forest land) due to Land Use and Land cover Change has been explained below

Emissions from Land sub-sector (except forest land) = Change in biomass carbon stock + Change in organic carbon stock in mineral soils

The equations of Change in biomass carbon stock and Change in organic carbon stock in mineral soils is detailed below:

(a) Change in biomass carbon stock

$$\Delta C_G = \sum_{i,j} (A_{i,j} \bullet G_{Total\ i,j}\ CF_{i,j} \quad \textit{(IPCC 2006 Equation 2.9)}$$

Where,

ΔC_G = annual increase in the biomass carbon stocks in land remaining land or land changing to another land use (tonnes of C yr^{-1})

A_i = area of land remaining in land use category or area of land changed to another land use category (ha)

G_{Total} = mean annual biomass growth tonnes d. m. ha^{-1} yr^{-1}

CF = carbon fraction of dry matter , tonnes C (tonne d.m.) $^{-1}$

(b) Change in organic carbon stock in mineral soils

$$\Delta C_{Mineral} = (SOC_0 - SOC_{(0-T)}) / D$$

$$SOC = \Sigma (SOC_{REF} \bullet F_{LU} \bullet F_{MG} \bullet F_i \bullet A)$$

(IPCC 2006 Equation 2.25)

Where,

SOC_0 = soil organic carbon in the last year of the inventory period-final land use type (tC)

$SOC_{(0-T)}$ = soil organic carbon in the beginning of the inventory period-initial land use type (tC)

T = number of years over single inventory period

D = default time period (assumed to be 20 years)

SOC_{REF} = reference carbon stock (tC ha^{-1})

F_{LU}, F_{MG}, F_i = stock change factors for particular land use, management regime and input organic matter (dimensionless)

A = area of land stratum being estimated (ha)

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