# Forest Land

(Capacity Building Program for Indian Experts on National Greenhouse Gas Inventory Preparation as per Enhanced Transparency Framework Guidelines, 25 April 2024 – 1 May 2024, Indian Institute of Technology Gandhinagar, Gujarat, India)

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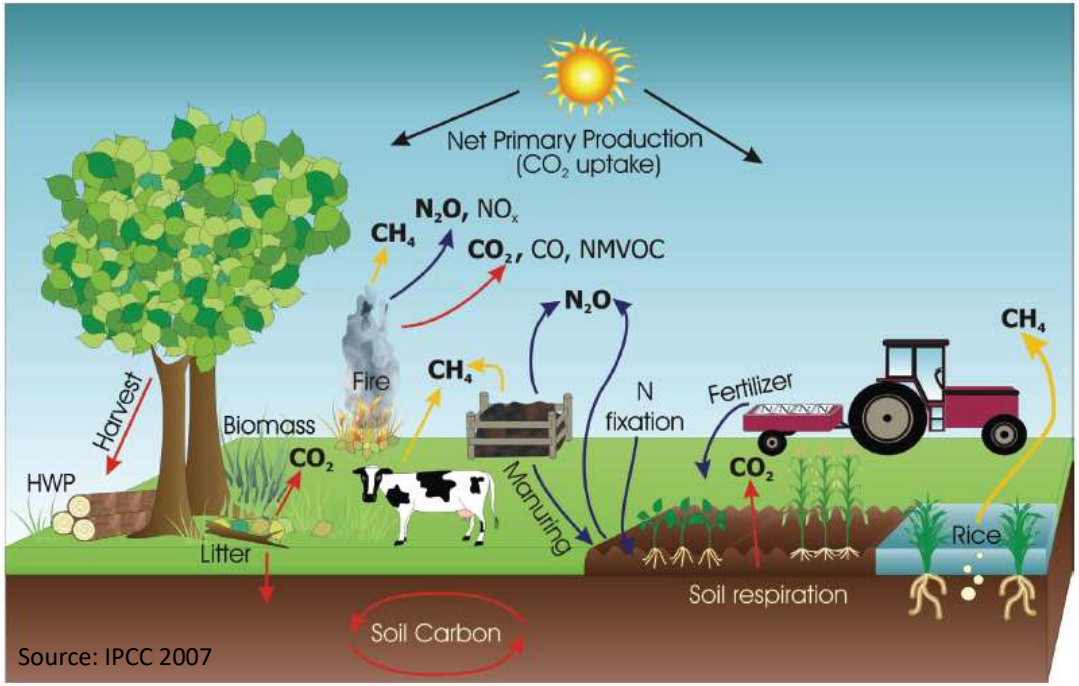
# AFOLU Categories in the 2006 IPCC Guidelines

**Biomass C Stock Changes (3B)**

**GHG Emissions from Biomass Burning [wild fires, crop residues (3C1)]**




**CO2 Emission from Liming (3C2)**

**CO2 Emission from Urea Application (3C3)**

**Soil $N_2O$ Emissions (3C4, 3C5, and 3C6)**

**CH4 Emission from Rice Cultivation (3C7)**

**Soil C Stock Changes (3B)**

**CH4 Emission from Enteric Fermentation (3A1)**

**$CH_4$ and $N_2O$ Emission from Manure Management (3A2)**

# Two Main Elements of GHG Inventory in Land Use

In Land Use and Management, there are two main elements for GHG inventory:

## 1. Changes in C Stocks in Land use categories

**EQUATION 2.1**
**ANNUAL CARBON STOCK CHANGES FOR THE ENTIRE AFOLU SECTOR ESTIMATED AS THE SUM OF CHANGES IN ALL LAND-USE CATEGORIES**

$$\Delta C_{AFOLU} = \Delta C_{FL} + \Delta C_{CL} + \Delta C_{GL} + \Delta C_{WL} + \Delta C_{SL} + \Delta C_{OL}$$

Where:

$\Delta C$ = carbon stock change

Indices denote the following land-use categories:

AFOLU = Agriculture, Forestry and Other Land Use

FL = Forest Land

CL = Cropland

GL = Grassland

WL = Wetlands

SL = Settlements

OL = Other Land

# Two Main Elements of GHG Inventory in Land Use

## 1. Changes in C Stocks in Land use categories (continued…)

**EQUATION 2.3**
**ANNUAL CARBON STOCK CHANGES FOR A STRATUM OF A LAND-USE CATEGORY AS A SUM OF CHANGES IN ALL POOLS**

$$\Delta C_{LU_i} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO} + \Delta C_{HWP}$$

Where:

$\Delta C_{LUi}$ = carbon stock changes for a stratum of a land-use category

Subscripts denote the following carbon pools:

AB = above-ground biomass

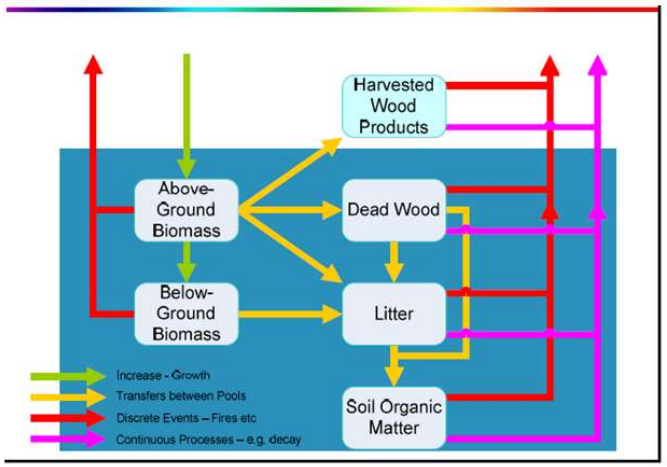
BB = below-ground biomass

DW = deadwood

LI = litter

SO = soils

HWP = harvested wood products




Source: Eggleston 2008

# Two Main Elements of GHG Inventory in Land Use

## 2. Non-CO2 Emissions from Biomass Burning (e.g. prescribed burning, wildfire)

**EQUATION 2.27**
**ESTIMATION OF GREENHOUSE GAS EMISSIONS FROM FIRE**

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

Where:

$L_{fire}$ = amount of greenhouse gas emissions from fire, 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. When Tier 1 methods are used then litter and dead wood pools are assumed zero, except where there is a land-use change (see Section 2.3.2.2).

$C_f$ = combustion factor, dimensionless (default values in Table 2.6)

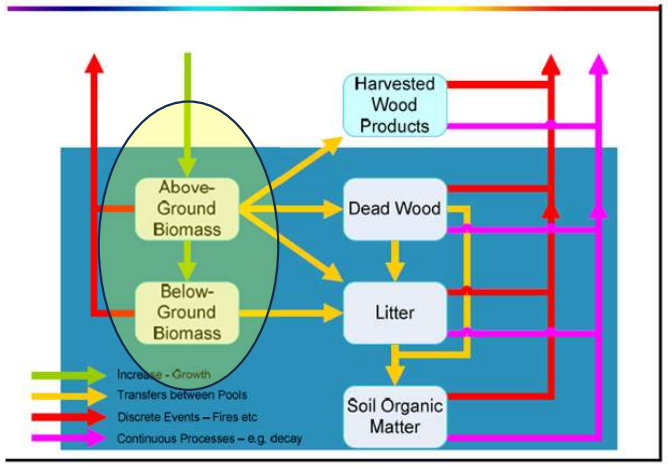
$G_{ef}$ = emission factor, g $kg^{-1}$ dry matter burnt (default values in Table 2.5)

# Methods to Estimate Changes in C Stock in Biomass

## Carbon Stock Changes in Biomass (aboveground and belowground)

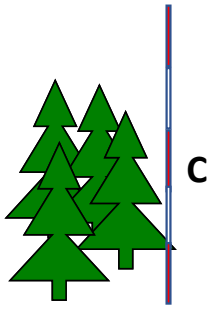
**Two Methods**

1. **Stock- Difference Method**
2. **Gain – Loss Method**




Source: Eggleston 2008

# 1. Stock-Difference Method for Biomass



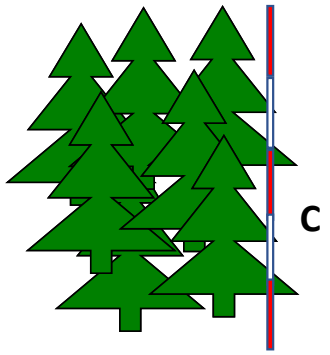

Time 1

$$\Delta C = (C_{t_2} - C_{t_1})/(t_2 - t_1)$$

**ΔC =** change of carbon stock

$C_{t_2}$ = carbon stock at **time 2**

$C_{t_1}$ = carbon stock at **time 1**




Time 2

Source: Ogle 2012

- In general, this method provides **more reliable estimates** for relatively large increases or decreases of biomass
- Applicable in countries that have National Forest Inventory (NFI), and **carbon stock assessment activities**
- More suited to Tier 2 and 3 methods with more data requirements

# 1. Stock-Difference Method for Biomass

**EQUATION 2.8**
**ANNUAL CHANGE IN CARBON STOCKS IN BIOMASS**
**IN LAND REMAINING IN THE SAME LAND-USE CATEGORY (STOCK-DIFFERENCE METHOD)**

$$\Delta C_B = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)} \qquad \text{(a)}$$

where

$$C = \sum_{i,j} \{A_{i,j} \bullet V_{i,j} \bullet BCEF_{S_{i,j}} \bullet (1 + R_{i,j}) \bullet CF_{i,j}\} \qquad \text{(b)}$$

Where:

$\Delta C_B$ = annual change in carbon stocks in biomass (the sum of above-ground and below-ground biomass terms in Equation 2.3 ) in land remaining in the same category (e.g., *Forest Land Remaining Forest Land*), tonnes C $yr^{-1}$

$C_{t_2}$ = total carbon in biomass for each land sub-category at time $t_2$, tonnes C

$C_{t_1}$ = total carbon in biomass for each land sub-category at time $t_1$, tonnes C

C = total carbon in biomass for time $t_1$ to $t_2$

A = area of land remaining in the same land-use category, ha (see note below)

V = merchantable growing stock volume, $m^3$ $ha^{-1}$

*i* = ecological zone i (*i* = 1 to *n*)

*j* = climate domain j (*j* = 1 to *m*)

R = ratio of below-ground biomass to above-ground biomass, tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$

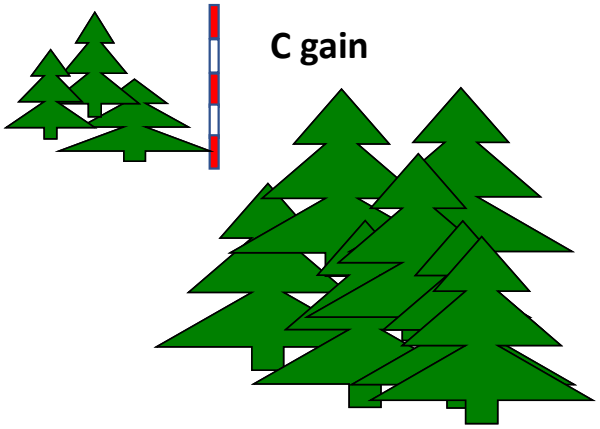
CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$

$BCEF_S$ = biomass conversion and expansion factor for expansion of merchantable growing stock volume to above-ground biomass, tonnes above-ground biomass growth ($m^3$ growing stock volume)$^{-1}$, (see

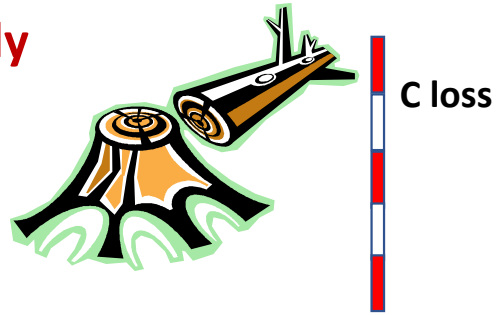
# 2. Gain-Loss Method for Biomass

$$\Delta C = \Delta C_G - \Delta C_L$$

ΔC: change of carbon stocks/yr
$\Delta C_G$: increase due to **gain** of C/yr
$\Delta C_L$ : decrease due to **loss** of C/yr




**Time 1 only**




Source: Ogle 2012

- More suited to Tier 1 and 2 methods with data mostly from **national statistics**

# 2. Gain-Loss Method for Biomass

## Gain in Biomass (aboveground and belowground):

**EQUATION 2.9**
**ANNUAL INCREASE IN BIOMASS CARBON STOCKS DUE TO BIOMASS INCREMENT IN LAND REMAINING IN THE SAME LAND-USE CATEGORY**

$$\Delta C_G = \sum_{i,j} (A_{i,j} \bullet G_{TOTAL_{i,j}} \bullet CF_{i,j})$$

Where:

$\Delta C_G$ = annual increase in biomass carbon stocks due to biomass growth in land remaining in the same land-use category by vegetation type and climatic zone, tonnes C $yr^{-1}$

A = area of land remaining in the same land-use category, ha

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

**See Equation 2.10**

*i* = ecological zone (*i* = 1 to *n*)

*j* = climate domain (*j* = 1 to *m*)

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

# 2. Gain-Loss Method for Biomass

## Gain in Biomass (aboveground and belowground):

**EQUATION 2.10**
**AVERAGE ANNUAL INCREMENT IN BIOMASS**

**Tier 1**

$G_{TOTAL} = \sum \{G_W \bullet (1+R)\}$ Biomass increment data (dry matter) are used directly

**Tiers 2 and 3**

$G_{TOTAL} = \sum \{I_V \bullet BCEF_I \bullet (1+R)\}$ Net annual increment data are used to estimate $G_W$ by applying a biomass conversion and expansion factor

Where:

$G_{TOTAL}$ = average annual biomass growth above and below-ground, tonnes d. m. $ha^{-1}$ $yr^{-1}$

$G_W$ = average annual above-ground biomass growth for a specific woody vegetation type, tonnes d. m. $ha^{-1}$ $yr^{-1}$

R = ratio of below-ground biomass to above-ground biomass for a specific vegetation type, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$. R must be set to zero if assuming no changes of below-ground biomass allocation patterns (Tier 1).

$I_V$ = average net annual increment for specific vegetation type, $m^3$ $ha^{-1}$ $yr^{-1}$

$BCEF_I$ = biomass conversion and expansion factor for conversion of net annual increment in volume (including bark) to above-ground biomass growth for specific vegetation type, tonnes above-ground biomass growth ($m^3$ net annual increment)$^{-1}$, (see Table 4.5 for Forest Land). If $BCEF_I$ values are not

# 2. Gain-Loss Method for Biomass

**Biomass Losses (aboveground and belowground):**

**EQUATION 2.11**
**ANNUAL DECREASE IN CARBON STOCKS DUE TO BIOMASS LOSSES IN LAND REMAINING IN THE SAME LAND-USE CATEGORY**

$$\Delta C_L = L_{wood-removals} + L_{fuelwood} + L_{disturbance}$$

Where:

$\Delta C_L$ = annual decrease in carbon stocks due to biomass loss in land remaining in the same land-use category, tonnes C $yr^{-1}$

$L_{wood\text{-}removals}$ = annual carbon loss due to wood removals, tonnes C $yr^{-1}$ (See Equation 2.12)

$L_{fuelwood}$ = annual biomass carbon loss due to fuelwood removals, tonnes C $yr^{-1}$ (See Equation 2.13)

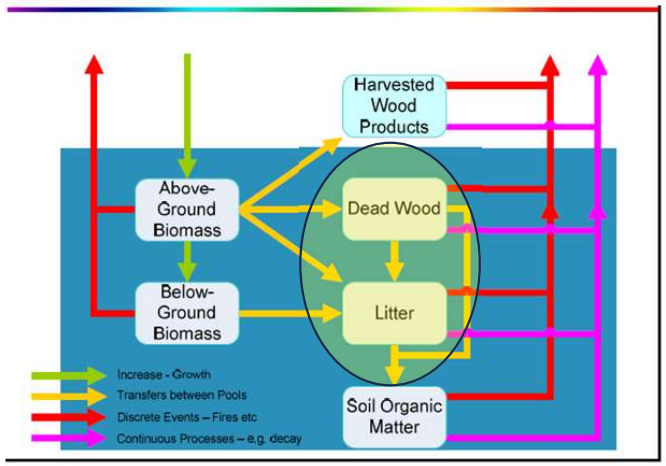
$L_{disturbance}$ = annual biomass carbon losses due to disturbances, tonnes C $yr^{-1}$ (See Equation 2.14)

# Methods to Estimate Changes in C Stock in Dead Organic Matter (DOM)

## Carbon Stock Changes in Dead Organic Matter or DOM

**Two Methods**

1. **Stock- Difference Method**
2. **Gain – Loss Method**

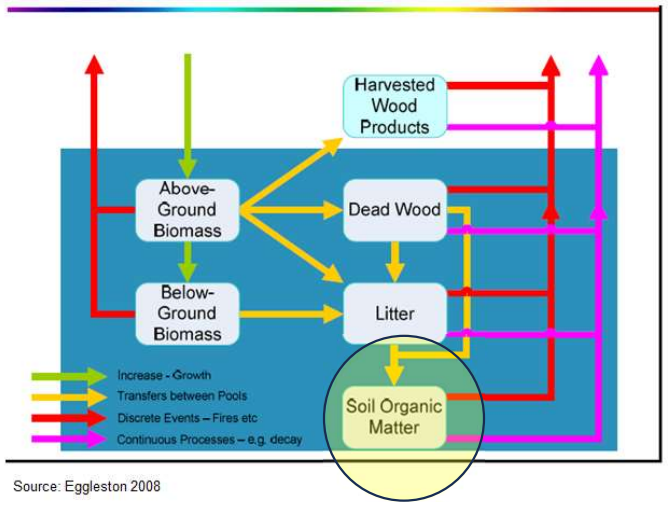



Source: Eggleston 2008

# Methods to Estimate Changes in C Stock in Soils

## Carbon Stock Changes in Soils

1. Mineral Soils
2. Organic Soils
3. Inorganic C from soils

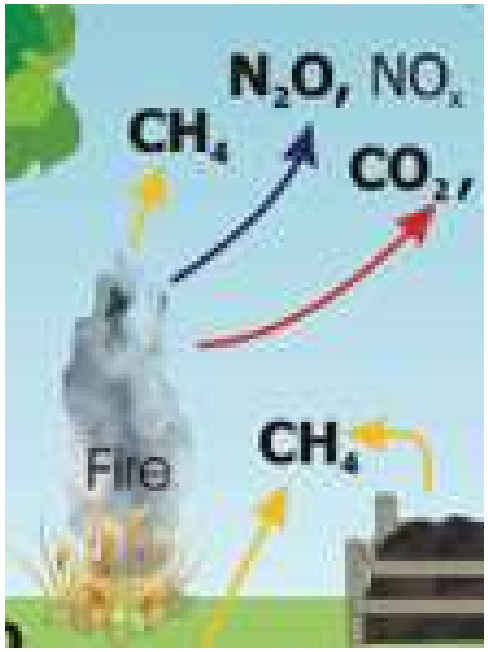


Source: Eggleston 2008

# The Other Main Element of GHG Inventory in Land Use

## 2. Non-CO2 Emissions from Biomass Burning (e.g. prescribed burning, wildfire)

- Emissions from fire include not only $CO_2$, but also other greenhouse gases such as:
  - ✓ carbon monoxide (CO)
  - ✓ methane ($CH_4$)
  - ✓ Nitrous oxide ($N_2O$)
  - ✓ Oxide of Nitrogen ($NO_x$)
  - ✓ Non-methane volatile organic compounds (NMVOC)




- Emissions of $CO_2$ and non- $CO_2$ need to be reported for all fires (prescribed fires and wildfires) on managed lands (the exception is $CO_2$ from Grassland)

# Hands-on exercise …

Using available country-specific data on Forest Land and Cropland, let us use the ALU Software to:

1. Characterize land use in India using the IPCC land use categories and subcategories, with focus on Forest Land and Cropland (annual crops)
2. Select the method to use (Gain-Loss or Stock-Difference method), and populate the required activity data for Forest Land (i.e. forest type, and age/size class)
3. Assign emission factor, including documentation on Forest Land
4. Calculate changes in C stocks and GHG emissions in Forest Land
5. Report activity data, other related information, and estimates in CRT for BTR.