



# INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

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## Estimation of Emission/Removal of Greenhouse Gases - Forests

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Workshop on reducing emissions from deforestation in developing countries  
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# Introduction

- Will describe the basic approach in the IPCC Guidelines to estimating emissions or removals from forests and deforestation
  - ❖ methods focus on NATIONAL, ANNUAL Emissions and Removals
- Describe how this approach retains the same basic method but has been refined over time
- Discuss the data needed to describe land use and land-use changes





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# IPCC Methods

- Revised 1996 Guidelines approach – Land-Use Change and Forestry (LUCF)
- Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG LULUCF)
  - ✓ Expanded Guidance covering all carbon pools
  - ✓ Guidance on the representing Land Areas
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories
  - ✓ Now Agriculture, Forestry and Other Land Use (AFOLU)
  - ✓ Essentially the same as to GPG LULUCF but integrating Agriculture and LULUCF sectors
  - ✓ Extended default values.





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# General Method

- There are large uncertainties in estimating fluxes of CO<sub>2</sub>.
- Direct measurements are extremely difficult (small differences of large numbers) and inherent heterogeneity.
- More practical first order approach is to make assumptions about effects of land use change on carbon stocks and the subsequent biological response to a given land use.

**Flux of C assumed = changes in carbon stocks in existing biomass and soils.**

- ✓ Note: C stocks in HWP, landfills etc. Some C emitted as CH<sub>4</sub>, CO etc.





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# Major Forestry Sources in Revised 1996 Guidelines

- Changes in forest and other woody biomass stocks (inc. commercial management, harvest of logs and fuel-wood, production and use of wood commodities, plantations and trees in non- forest locations.)
- Forest and grassland conversion: conversion to pasture, cropland or other managed lands
- Abandonment of croplands, pastures, plantation forests or other managed lands which re-grow into their prior forest conditions.
- Changes in soil carbon





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# Forest types and activities

## ➤ Significant Forest types identified

- ✓ Natural, undisturbed forest - assumed to be in equilibrium.
- ✓ Forests re-growing on abandoned land. A sink of Carbon attributable to previous human activities.
- ✓ All other forests.





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# Changes in Forest and Other Woody Biomass Stocks

## EQUATION 1

- (1) hectares of land in a particular category (e.g., plantations)  
 X  
 average annual growth per hectare in biomass  
 =  
 gross annual growth increment.  
*total biomass increment is the sum of all relevant categories .*
- (2) total harvest by category (including fuelwood gathering)  
 X  
 expansion ratio to treat slash  
 =  
 gross annual biomass loss.  
*total harvest and other biomass loss is the sum of all relevant categories of harvest.*
- (3) total annual growth increment - total annual biomass loss  
 =  
 annual biomass change (positive or negative).





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# Forest and Grassland Conversion

## ➤ Biomass cleared –

- ✓ either burned on- or off-site or used for products.
- ✓ Some remains on-site as slash and slowly decays. (Termite decay gives rise to  $\text{CO}_2$  and  $\text{CH}_4$ . Here  $\text{CH}_4$  assumed 0 and all emission is  $\text{CO}_2$ .)

## ➤ Calculation steps:

-  Net change in above ground biomass
-  The portion of this that is burned in first year (on- or off-site) v amount left to decay over longer period.
-  For burned portion loss to atmosphere - Small fraction stored as charcoal (lasts >100yrs.)
-  Current emission from decay of biomass cleared over previous decade
-  Current releases/removals from soils due to conversion (decomposition of soil organic matter)







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# Forest and Grassland Conversion

## EQUATION 2

average annual land clearing over the period (default of 10 years)

x

the average quantity of aboveground dry biomass per hectare remaining on site as slash but not burned (either oxidised or converted to charcoal)

x

carbon content of dry biomass

=

flux in the Inventory Year from historical land clearing of the aboveground vegetation





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# Good Practice Guidance (GPG)

- Good Practice inventories are defined as “those that contain neither over- nor under-estimates so far as can be judged, and in which uncertainties are reduced as far as is practical”
- Guidance on:
  - ✓ Choice of methodology with context of IPCC Guidelines (Key Categories and Tiers)
  - ✓ QA/QC procedures
  - ✓ Data and Information to be documented, archived and reported
  - ✓ Quantification of uncertainties of inventory as a whole as well as at the source/sink level
  - ✓ Three approaches for representing land areas
- Retains consistency with Revised 1996 Guidelines





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# GPG LULUCF

## ➤ “Land Use” categories:

- ❖ Forest Land
- ❖ Grassland
- ❖ Settlements
- ❖ Cropland
- ❖ Wetlands
- ❖ Other Land

*Good practice to define these nationally and subdivide as needed*

## ➤ Estimated for “Land Use” Remaining “Land Use” and Land Converted to “Land Use”

## ➤ Managed land v Unmanaged Land

- Production, ecological or social functions...





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# Carbon Pools

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<b>Living Biomass</b>	Above-ground biomass	All living biomass above the soil including stem, stump, branches, bark, seeds, and foliage. (If forest understorey is a relatively small component it is acceptable for some tiers to exclude it, provided the tiers are used in a consistent manner throughout the inventory time series )
	Below-ground biomass	All living biomass of live roots. Fine roots of less than (suggested) 2mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter.
<b>Dead Organic Matter</b>	Dead wood	Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country.
	Litter	Includes all non-living biomass with a diameter less than a minimum diameter chosen by the country, lying dead, in various states of decomposition above the mineral or organic soil. Live fine roots (of less than the suggested diameter limit for below-ground biomass) are included in litter where they cannot be distinguished from it empirically.
<b>Soils</b>	Soil organic matter	Includes organic carbon in mineral and organic soils (including peat) to a specified depth chosen by the country and applied consistently through the time series. Live fine roots (of less than the suggested diameter limit for below-ground biomass) are included with soil organic matter where they cannot be distinguished from it empirically.





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# Non-CO<sub>2</sub> Emissions in GPG LULUCF

- Non-CO<sub>2</sub> (N<sub>2</sub>O and CH<sub>4</sub>) from forest fire (Section 3.2.1.4);
- N<sub>2</sub>O from managed (fertilized) forests (Section 3.2.1.4);
- N<sub>2</sub>O from drainage of forest soils (Appendix 3a.2);
- N<sub>2</sub>O and CH<sub>4</sub> from managed wetland (Appendix 3a.3);  
and
- Soil emissions of N<sub>2</sub>O following land use conversion (Sections 3.3.2.3 and 3.4.2.3).





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# Forest Land Remaining Forest Land

## EQUATION 3.2.1

ANNUAL EMISSIONS OR REMOVALS FROM FOREST LAND REMAINING FOREST LAND

$$\Delta C_{FF} = (\Delta C_{FF_{LB}} + \Delta C_{FF_{DOM}} + \Delta C_{FF_{Soils}})$$

- Treat biomass, dead wood and soils separately.
- Fuel wood non-CO<sub>2</sub> emissions reported in energy sector if possible
- Default assumes of no net change in HWP





# Living Biomass

## EQUATION 3.2.2

ANNUAL CHANGE IN CARBON STOCKS IN LIVING BIOMASS  
IN FOREST LAND REMAINING FOREST LAND (DEFAULT METHOD)

$$\Delta C_{FF_{LB}} = (\Delta C_{FF_G} - \Delta C_{FF_L})$$

- ✓ **Method 1** (also called the **default method**) requires the biomass carbon loss to be subtracted from the biomass carbon increment for the reporting year

## EQUATION 3.2.3

ANNUAL CHANGE IN CARBON STOCKS IN LIVING BIOMASS  
IN FOREST LAND REMAINING FOREST LAND (STOCK CHANGE METHOD)

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

and

$$C = [V \cdot D \cdot BEF_2] \cdot (1 + R) \cdot CF$$

- ✓ **Method 2** (also called the **stock change method**) requires biomass carbon stock inventories for a given forest area at two points in time. Biomass change is the difference between the biomass at time t2 and time t1, divided by the number of years between the inventories





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# Dead Wood and Litter

- Similar methods – either based on transfers into and out of pools or stock change approach
  - ✓ Tier 1: Default is that inputs and outputs balance so stock change is zero – significant changes, disturbances or changes in management should use Tier 2/3.
  - ✓ Tier 2: Country specific data should be developed or, Tier 3, Countries should develop own methods from national measurements







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# Soils

- Need to treat mineral and organic soils separately

### EQUATION 3.2.14

ANNUAL CHANGE IN CARBON STOCKS IN MINERAL SOILS  
IN FOREST LAND REMAINING FOREST LAND

$$\Delta C_{FF_{MINERAL}} = \sum_{ij} [(SOC_j - SOC_i) \cdot A_{ij}] / T_{ij}$$

Where,

$$SOC_i = SOC_{ref} \cdot f_{forest\ type(i)} \cdot f_{man\ intensity(i)} \cdot f_{dist\ regime(i)}$$

### EQUATION 3.2.15

CO<sub>2</sub> EMISSIONS FROM DRAINED ORGANIC FOREST SOILS

$$\Delta C_{FF_{Organic}} = A_{Drained} \cdot EF_{Drainage}$$





# Land Converted to Grassland

- An example of deforestation

## EQUATION 3.4.13

ANNUAL CHANGE IN CARBON STOCKS IN LIVING BIOMASS IN LAND CONVERTED TO GRASSLAND

$$\Delta C_{LG_{LB}} = A_{\text{Conversion}} - (L_{\text{Conversion}} + \Delta C_{\text{Growth}})$$

$$L_{\text{Conversion}} = C_{\text{After}} - C_{\text{Before}}$$

- With conversion from forest land, land clearing will usually result in losses of C in dead organic matter (surface litter and coarse woody debris). Any litter and coarse woody debris pools should be assumed oxidized following land conversion.

## EQUATION 3.4.17

ANNUAL CHANGE IN CARBON STOCKS IN SOILS IN LAND CONVERTED TO GRASSLAND (LG)

$$\Delta C_{LG_{\text{Soils}}} = \Delta C_{LG_{\text{Mineral}}} - \Delta C_{LG_{\text{Organic}}} - \Delta C_{LG_{\text{Lime}}}$$





# Other Emissions from Conversion

- Emissions from fires, CH<sub>4</sub>, CO, N<sub>2</sub>O, NO<sub>x</sub>, NMVOC;

## EQUATION 3.2.19

### ESTIMATION OF NON -CO<sub>2</sub> EMISSIONS FROM C RELEASED

CH <sub>4</sub> Emissions	= (carbon released) _ (emission ratio) _ 16/12
CO Emissions	= (carbon released) _ (emission ratio) _ 28/12
N <sub>2</sub> O Emissions	= (carbon released) _ (N/C ratio) _ (emission ratio) _ 44/28
NO <sub>x</sub> Emissions	= (carbon released) _ (N/C ratio) _ (emission ratio) _ 46/14

## EQUATION 3.2.20

### ESTIMATION OF GHG S DIRECTLY RELEASED IN FIRES

$$L_{\text{fire}} = A \_ B \_ C \_ D \_ 10^{-6}$$

- N<sub>2</sub>O emissions from mineralisation of soil organic matter;
- N<sub>2</sub>O from fertiliser use;
- Increase in N<sub>2</sub>O emissions and reduction in CH<sub>4</sub> emissions from drainage of organic soils; and
- Reduced CH<sub>4</sub> sink in aerobic soils due to fertiliser use.





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# Data Needs

- Guidelines give default values for parameters. These can be used at Tier 1 or nationally specific data used at higher tiers.
- May need to be local surveys - e.g. fuel wood is often an informal sector. Management practices can vary...
- Significant data requirement is areas of each land use and areas of transitions.
  - ✓ Exact definitions may vary within the broad definitions. Countries should define sub- categories as needed
  - ✓ Can be very data intensive
  - ✓ Three approaches (or mixture)





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# Representing Land Areas

- Approach 1 identifies the total area for each individual land-use category,
  - ✓ but does not provide detailed information on changes of area between categories
  - ✓ and is not spatially explicit other than at the national or regional level.
- Approach 2 introduces tracking of land-use changes between categories.
- Approach 3 extends Approach 2 by allowing land-use changes to be tracked on a spatial basis.





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# Approach 1

Land-Use	Land Area Mha		
	Initial	Final	Net Change
<b>Forest land total</b>	<b>18</b>	<b>19</b>	<b>1</b>
<i>Forest land (Unmanaged)</i>	<i>5</i>	<i>5</i>	<i>0</i>
<i>Forest land zone A</i>	<i>7</i>	<i>4</i>	<i>-3</i>
<i>Forest land zone B</i>	<i>6</i>	<i>6</i>	<i>0</i>
<i>Afforestation</i>	<i>0</i>	<i>4</i>	<i>4</i>
<b>Grassland total</b>	<b>84</b>	<b>82</b>	<b>-2</b>
<i>Unimproved grassland</i>	<i>65</i>	<i>63</i>	<i>-2</i>
<i>Improved grassland</i>	<i>19</i>	<i>19</i>	<i>0</i>
<b>Cropland total</b>	<b>31</b>	<b>29</b>	<b>-2</b>
<b>Wetlands total</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>Settlements total</b>	<b>5</b>	<b>8</b>	<b>3</b>
<i>Existing Settlements</i>	<i>5</i>	<i>5</i>	<i>0</i>
<i>New Settlements</i>	<i>0</i>	<i>3</i>	<i>3</i>
<b>Other land total</b>	<b>2</b>	<b>2</b>	<b>0</b>
<b>Balancing term</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>TOTAL</b>	<b>140</b>	<b>140</b>	<b>0</b>





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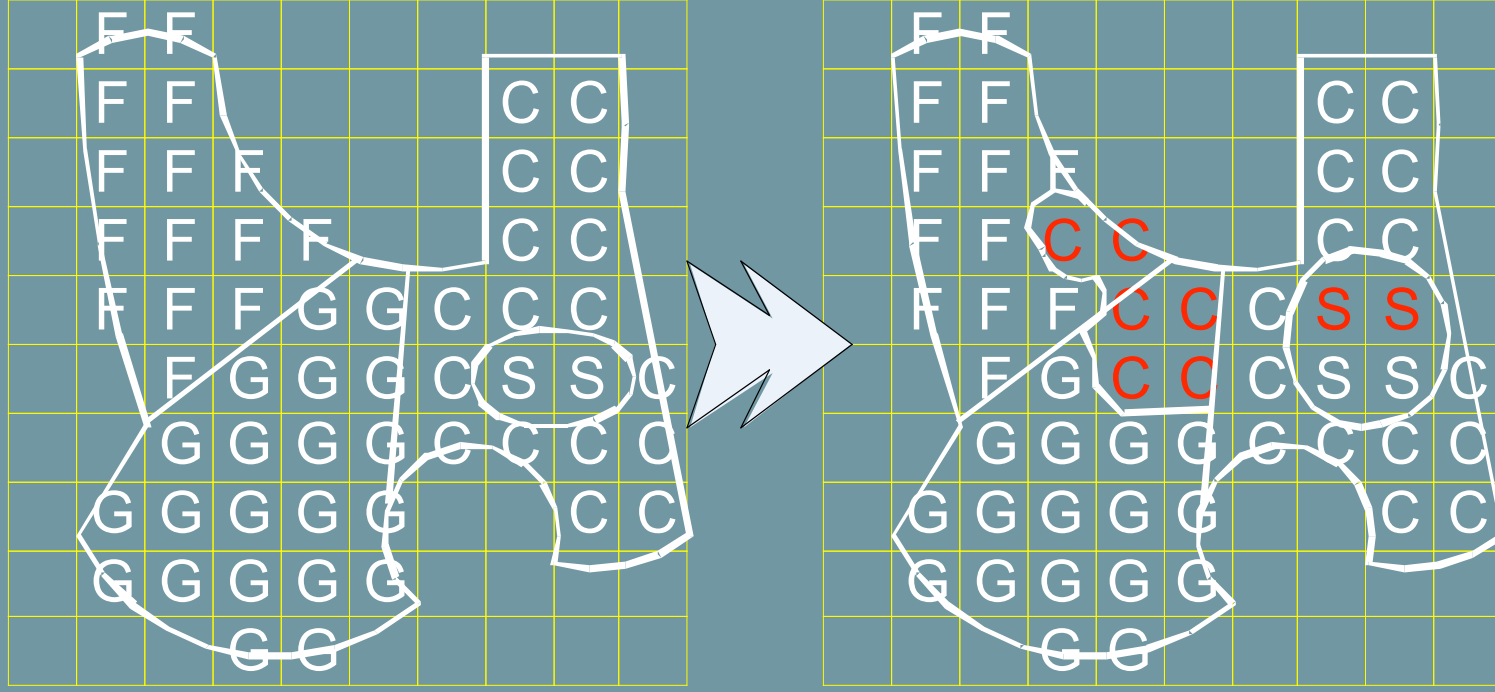
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# Approach 2

	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC	PFC	SF <sub>6</sub>	Other	Total
CO <sub>2</sub>	■							■
CH <sub>4</sub>		■						■
N <sub>2</sub> O			■					■
HFC				■				■
PFC					■			■
SF <sub>6</sub>						■		■
Other							■	■
Total	■	■	■	■	■	■	■	■



# Approach 3







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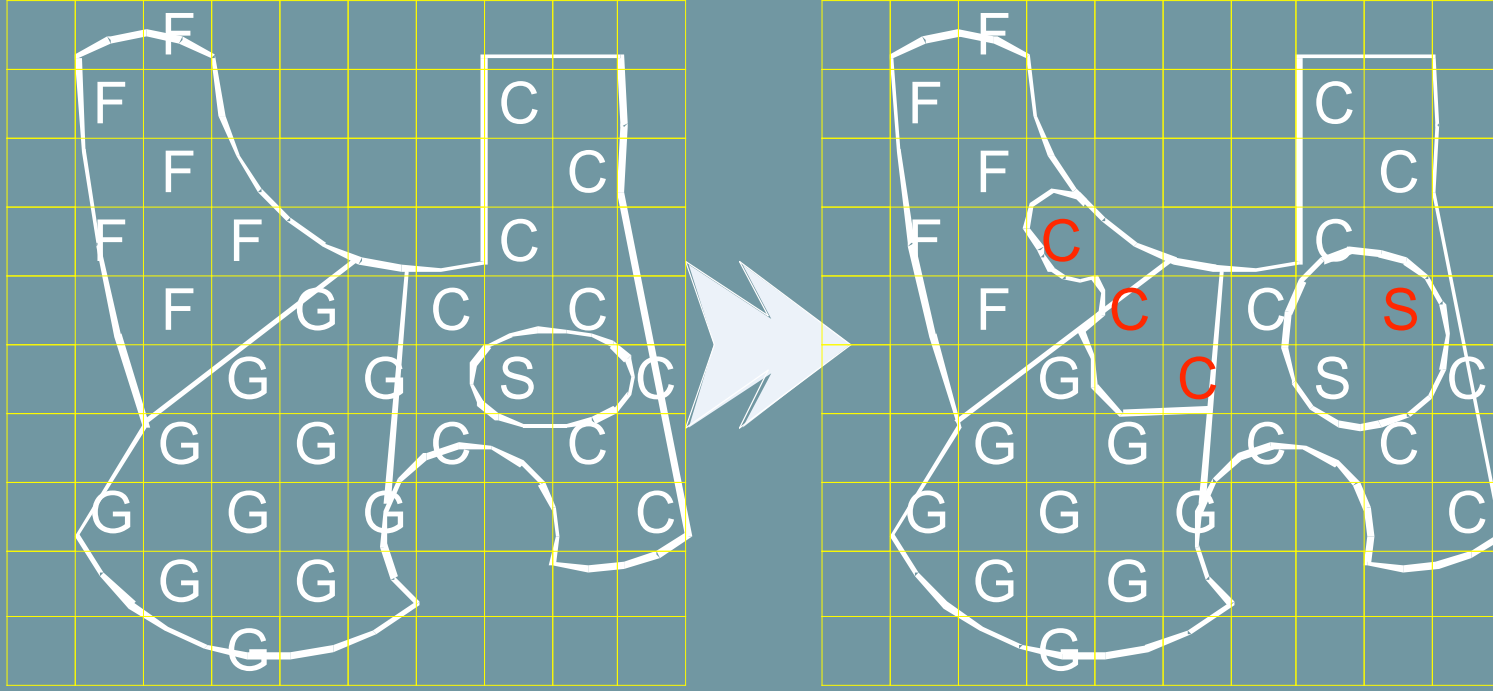
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# Approach 3 - Regular Sampling





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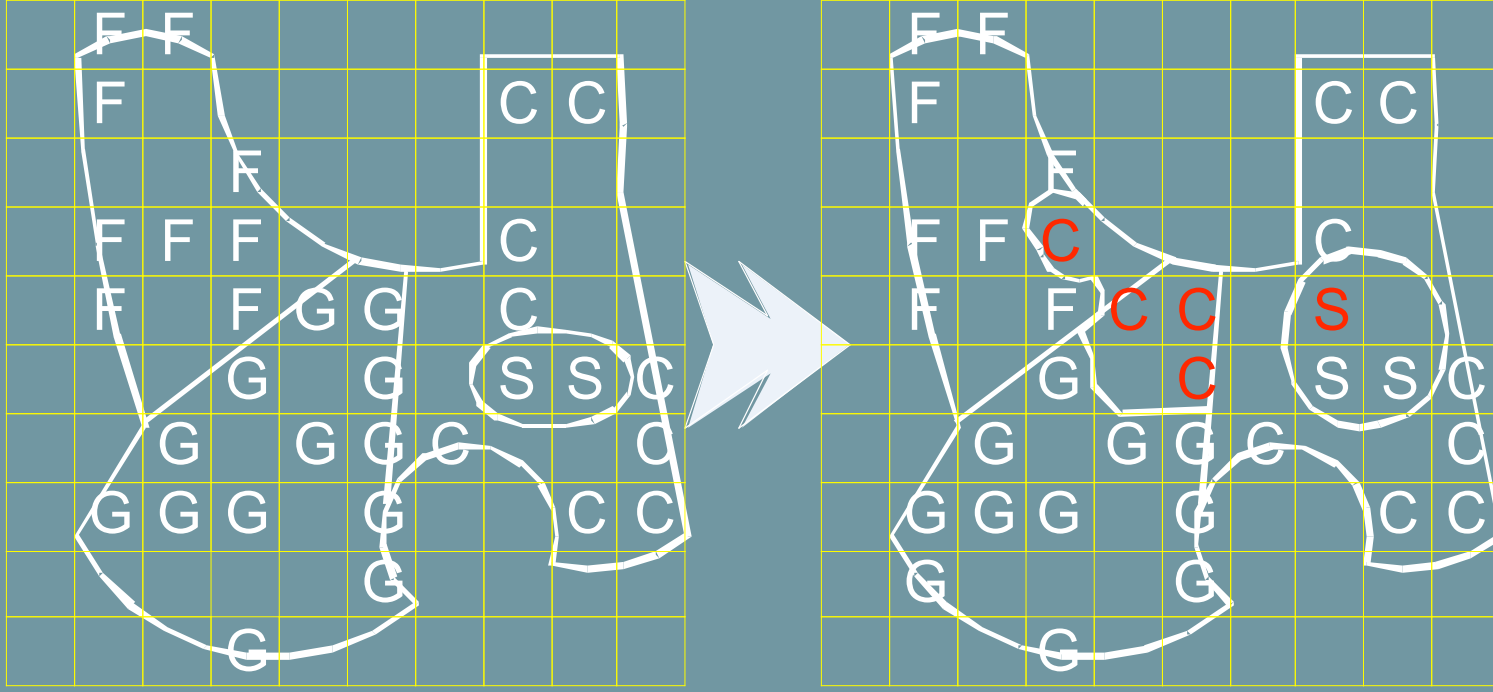
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# Approach 3 - Random Sampling





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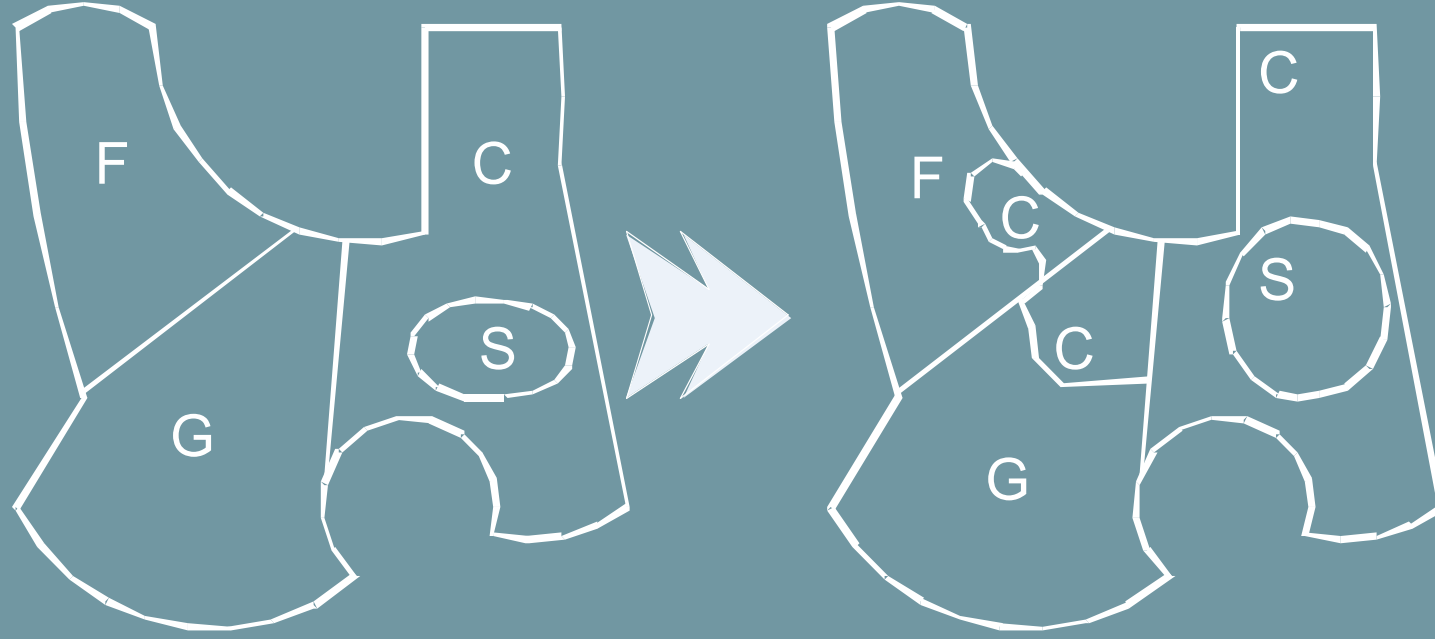
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# Approach 3 - Areas Identified





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# Development of Land-Use Databases

- Three broad ways to construct the needed land-use database
  - ✓ Use of Existing databases prepared for other uses
    - National or International
    - Typically approaches 1 and 2 use these
  - ✓ Use of Sampling
  - ✓ Use of complete land inventories.
    - Can use remote sensing and ground surveys





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# Summary

- Flux of C assumed = sum of changes in carbon stocks in existing biomass and soils.
- Changes in stocks estimated by either:
  - 📁 Inputs (e.g. growth) - outputs (e.g. harvest)
  - 📄 Total Stock at end minus Total stock at beginning
- General approach remains the same - LUCF > LULUCF > AFOLU
- LULUCF & AFOLU consider all carbon pools
- Identifying land areas and areas of transitions is major task
- Information on national management practices and specific conditions and how these impact C stocks is needed to improve estimates.





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**Thank-you.**





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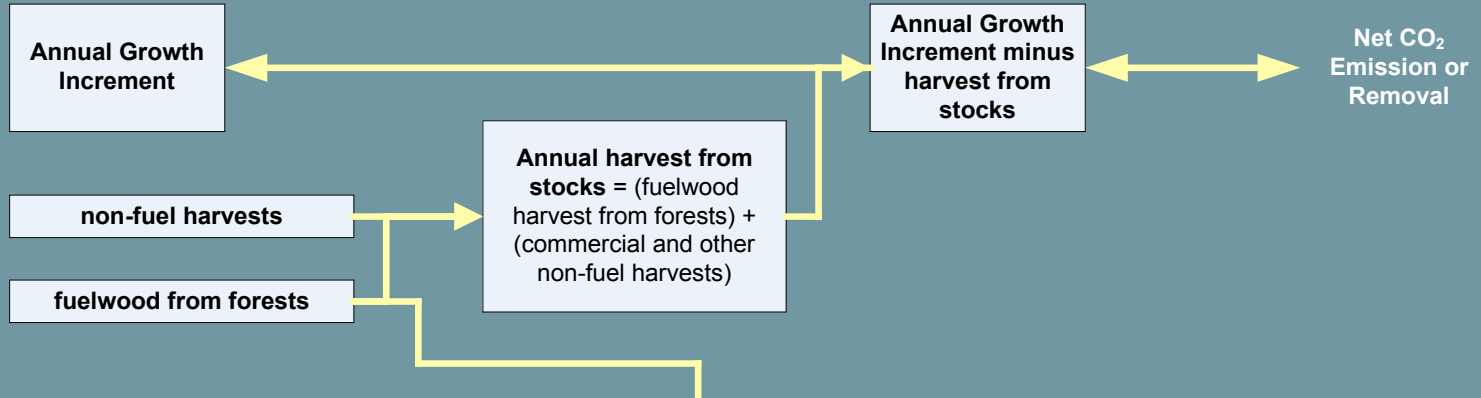
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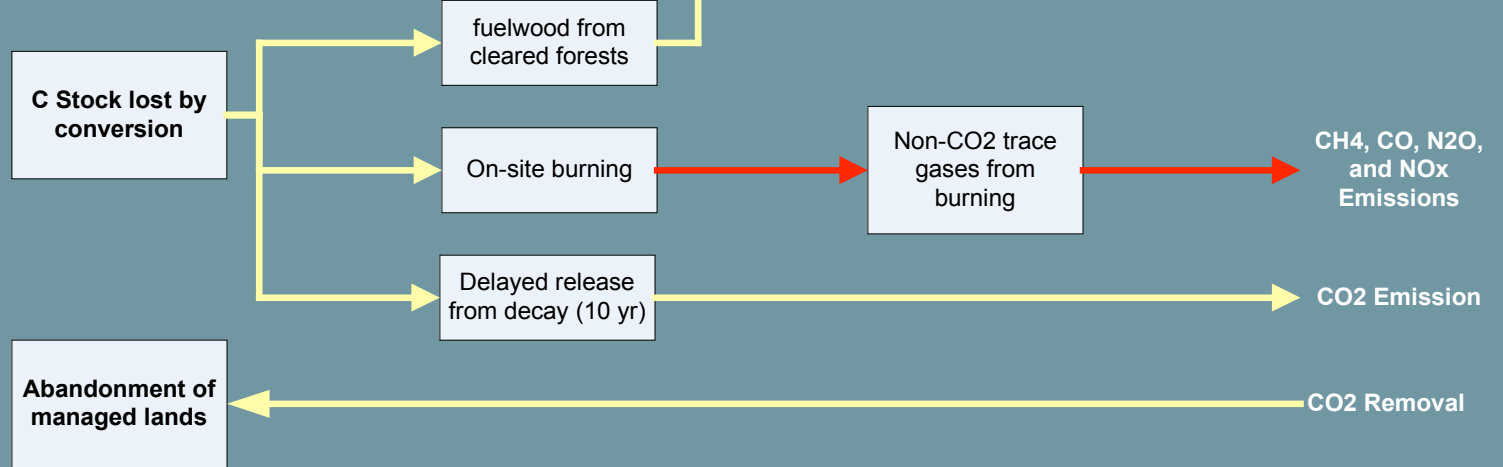
Changes in Forest and Other Woody Biomass



Non-CO2 Emissions from Biomass Fuel Combustion (ENERGY SECTOR)



Forest Conversion



CO2 Emissions and Uptake by Soils from Land-Use Change and Management





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