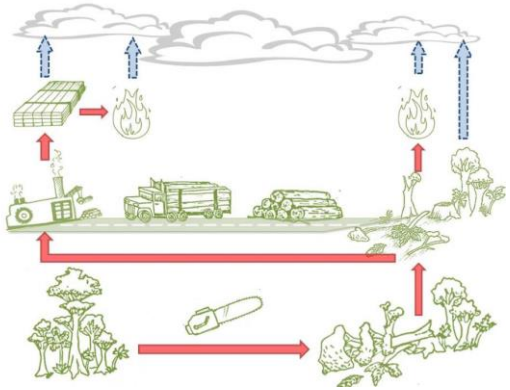
Module 2.5 Estimation of carbon emissions from deforestation and forest degradation



Module developers:

Sandra Brown, Winrock International

Lara Murray, Winrock International

After the course the participants should be able to:

- Make an estimation of C emissions and removals from deforestation and forest degradation in accordance with the requirements from the IPCC guidelines and guidance

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GOFC-GOLD Global Observation of Forest and Land Cover Dynamics

FOREST CARBON PARTNERSHIP FACILITY

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Background documents

- GOFC-GOLD. 2014. *Sourcebook*. Sections 2.5 and 3.1.4.
- GFOI. 2014. *MGD* (*Integrating Remote-sensing and Ground-based Observations for Estimation of Emissions and Removals of Greenhouse Gases in Forests: Methods and Guidance from the Global Forest Observation Initiative*).

Outline of lecture

1. 2006 IPCC AFOLU Guidelines and 2003 GPG-LULUCF land-use categories and subcategories
2. Estimating emissions and removals: Combining emission factors (EFs) and activity data (AD)
3. Methods for estimating C emissions from deforestation (conversion of forests to nonforests): country example of Guyana
4. Methods for estimating C emissions from forest degradation, e.g., selective logging: Country example of Berau, East Kalimantan, Indonesia

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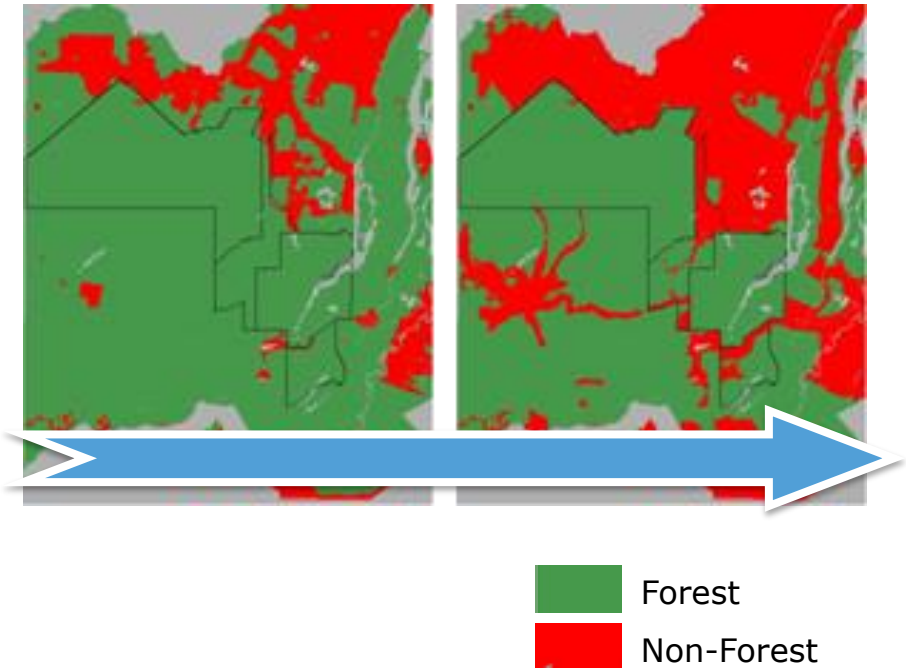
2006 IPCC AFOLU Guidelines

Integrates agriculture and land use, land-use change, and forestry (LULUCF) sectors from previous guidelines (2003 GPG-LULUCF) into one sector called **agriculture, forestry, and other land use (AFOLU)**:

- Maintains same six land-use categories of 2003 GPG-LULUCF
- Covers emissions and removals from the terrestrial biosphere
- Provides carbon/GHG estimation methodologies for carbon pools in land-use categories

Reporting of C emissions/removals

- Emissions/removals of C stocks are reported based on **changes in land-use categories.**
- For each stratum or subdivision within a land-use category, the sum of carbon stock changes in all C pools equals the total carbon stock change for that stratum.



2003 GPG-LULUCF land use categories and subcategories (1/2)

Six land-use categories

2003 GPG-LULUCF land use categories and subcategories (2/2)

LULUCF subcategories:

1. Land remaining in the same category: For example **forest land remaining forest land** = forest degradation and other REDD+ activities
2. Land converted to another land use: For example, **forest land converted to another land use** = deforestation

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Required knowledge for estimating emissions and removals

- To combine EFs and AD, practitioners should already understand GOFC-GOLD (2014) *Sourcebook* sections 2.1, 2.2, 2.3, and 2.4 as well as Modules 2.1, 2.2, and 2.3.
- Practitioners should be able to make an estimation of C emissions and removals from deforestation in accordance with the requirements from the IPCC guidelines and guidance.

Activity Data & Emission Factors

To review:

- **Activity data (AD) – Module 2.1 and 2.2:**
  - Spatial extent of land-cover transition, e.g., ha/yr for deforestation and degradation
  - For degradation due to wood extraction for timber or fuel, can use unit of production e.g. timber extracted in m^3/yr
- **Emission factors (EFs) – Module 2.3**:
  - emissions/removals of GHGs per unit of activity, e.g., t CO_2e/ha or t CO_2/m^3

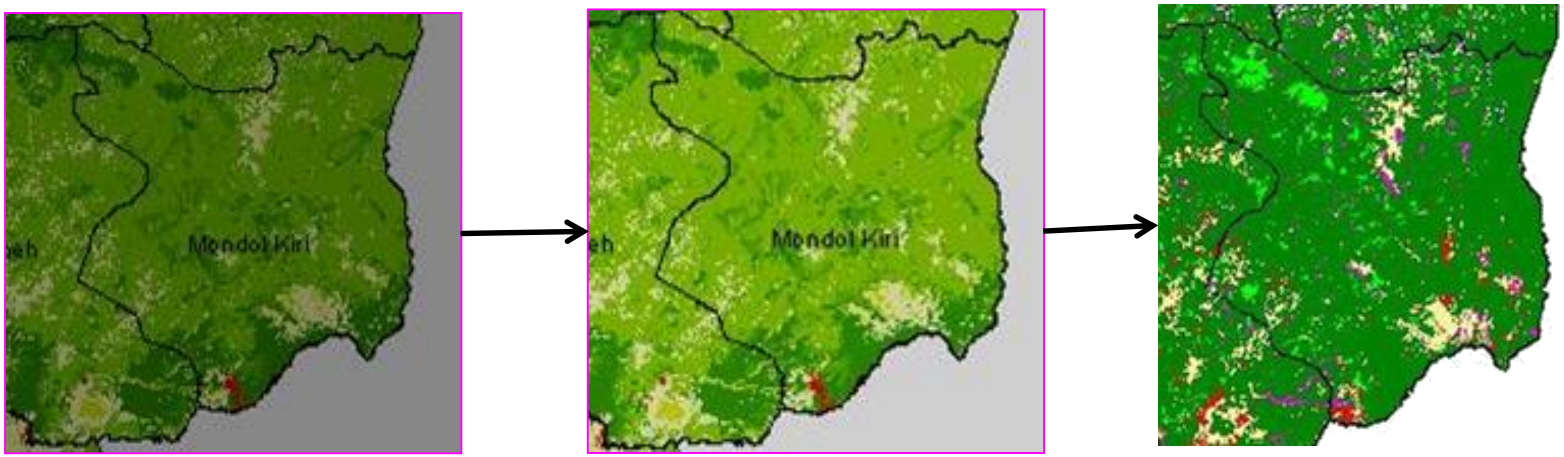
Basic equation for estimating emissions and removals: Combining AD and EFs

Emissions per unit of change (EFs)	**X**	**Area of change (AD)**	**=**	**Net Emissions from Change**

Developing AD for deforestation

See Module 2.1:

- Create land-cover maps for multiple points in time.
- Then track total area of change in each AFOLU land-use class (ha).



Developing EFs for deforestation

See Module 2.3:

- Analyze field data and estimate carbon stocks and associated uncertainty for each land cover/ use.
- Create emission factor for all activity types (t CO_2/ha).

Forest C stocks

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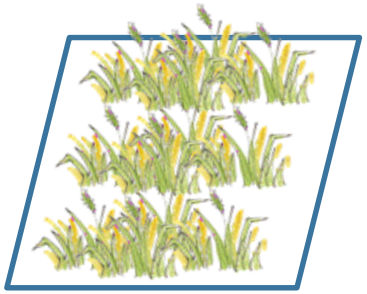
Post-land-use C stocks



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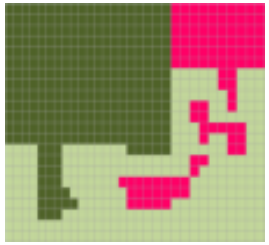
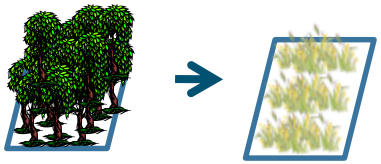
Emissions Factor for Deforestation

Estimating net emissions from deforestation

Area of change (AD)	*	Emissions unit of change (EFs)	=	Net emissions from forest to cropland
1000 ha 	*	895 t CO_2/ha 	=	895,000 t CO_2

Developing AD and EF for forest degradation

See Module 2.3:

- Estimates of AD: volume of timber removed (m^3/ha)
- Estimates of EF:
  - Extracted log emissions (ELE) (t C/m^3)
  - Logging damage factor (LDF) (t C/m^3)
  - Logging infrastructure factor (LIF) (t C/m^3)

Estimating net emissions from degradation by selective logging

- Net emissions = C losses – C gains
- C losses, t C/yr = [vol x ELE]+[vol x LDF]+ [vol x LIF]
- C gains, t C/yr = [Vol x ELE x LTP]+ [G]

  - Vol = volume over-bark of timber extracted (m^3/yr)
  - ELE = extracted log emissions (t C/m^3)
  - LDF = logging damage factor (t C/m^3), dead wood left behind in gap
  - LIF = logging infrastructure factor (t C/m^3), dead wood produced by construction
  - LTP = proportion of extracted wood in long-term products still in use after 100 yr (dimensionless)
  - G = rates of regrowth (t C)

Outline of lecture

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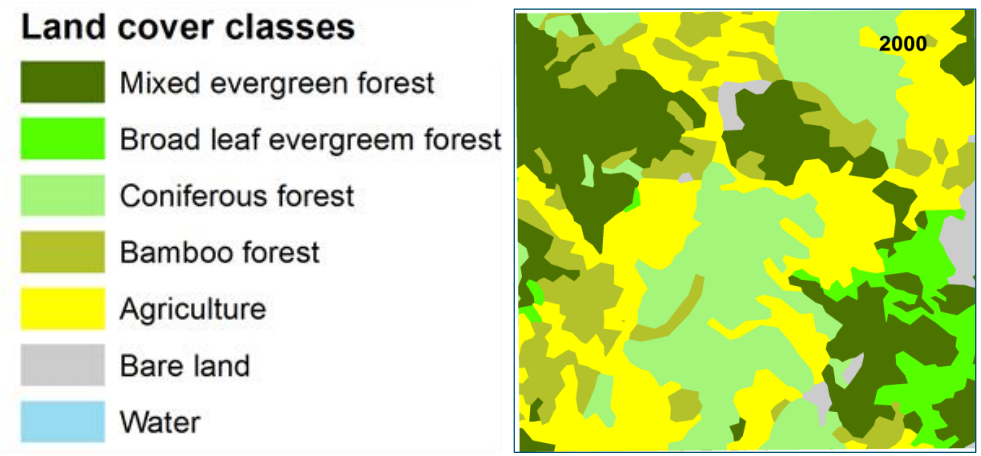
Estimating C emissions from deforestation

Example: Stock-change approach for estimating C emissions from deforestation

Benchmark map:
A national or subnational land-cover/land-use map is developed and a forest mask identified



Stock-change approach for estimating emissions from deforestation

Looking at land-cover/land-use changes and emissions over time (time 2):

- Using remote sensing technology, a new map is developed for year five, and losses in forest cover are calculated in hectares (AD)
- Losses in forest land cover are then multiplied by their corresponding EF to estimate the total C emissions from deforestation between time 1 and time 2 (e.g., year one and year five)

Estimation of C emissions from deforestation in Guyana using the stock-change approach

A. AD from satellite imagery by Indufor and Guyana Forestry Commission (GFC)

Stratum	Drivers	Area of Change (ha)	
		2010	2011
More Accessible (MA)	Forestry infrastructure	70	172
	Agriculture	15	31
	Mining (medium and large scale)	1,423	4081
	Infrastructure	9	493
	Fire-Biomass burning		14
Less Accessible (LA)	Forestry infrastructure	224	61
	Agriculture	498	20
	Mining (medium and large scale)	7,955	4107
	Infrastructure	55	866
	Fire-Biomass burning	32	44

X

B. EF from field measurements of 35 cluster plots (precision about 12% of mean at 95% confidence) by Winrock International and GFC

Stratum	Drivers	Emission Factors
		t CO_2e/ha
More Accessible (MA)	Forestry infrastructure	1,010.6
	Agriculture	1,116.8
	Mining (medium and large scale)	1,010.6
	Infrastructure	1,010.6
	Fire-Biomass burning	744.6
Less Accessible (LA)	Forestry infrastructure	1,448.0
	Agriculture	1,536.5
	Mining (medium and large scale)	1,368.9
	Infrastructure	1,448.0
	Fire-Biomass burning	1,108.6

C. Emissions estimated as the **product of AD and EF** for each stratum by driver and summed across strata to given annual emissions

Assumes instantaneous oxidation—that is, occurs in year of event

Drivers	Emissions (tCO2)	
	2010	2011
Forestry infrastructure	395,594	261,657
Agriculture	781,258	66,215
Mining (medium and large scale)	12,327,673	9,746,426
Infrastructure	88,318	1,752,972
Fire-Biomass burning	35,605	58,738
Subtotal t CO2/yr	13,628,448	11,886,007

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Estimating C emissions from forest degradation, e.g., selective logging

Example: Gain-loss approach for selective logging

- Losses of carbon due to logging:
  - Amount of timber extracted per unit area per year
  - Amount of dead wood produced in a given year from top and stump of the harvested tree and mortality of the surrounding trees caused by the logging
  - Tree mortality from the skid trails, roads, and log landings
- Gains of carbon:
  - Amount of wood that went into long-term storage as products
  - Regrowth of forest

➢ For more details, see Module 2.3

Estimating total net emissions from degradation by selective logging

C losses, t C/yr = [vol x ELE]+[vol x LDF]+[vol x LIF]
C gains, t C/yr = [Vol x ELE x LTP]+ [G]

Where:

Vol = volume over-bark of timber extracted (m^3/yr)
ELE = extracted log emissions (t C/m^3)
LDF = logging damage factor (t C/m^3)—dead wood left behind in gap
LIF = logging infrastructure factor (t C/m^3)—dead wood produced by construction
LTP = proportion of extracted wood in long term products still in use after 100 yr (dimensionless)
G = rates of regrowth (t C)

EFs and AD for estimating emissions from forest degradation by selective logging

Losses: Need estimates of EFs and volume of timber removed (AD)—either total volume or volume per hectare

- ELE = extracted log emissions =0.28 t C/m^3
- LDF = logging damage factor = 0.42 t C/m^3 from felled tree and 0.12 t C/m^3 from collateral damage
- LIF = logging infrastructure factor = 0.39 t C/m^3 from roads, 0.02 t C/m3 from log landings, and 0.20 t C/m^3 from skid trails
- AD—timber volume extracted = 36 m^3 per ha
- Average area logged = 1,500 ha

Assume emissions occur at the time of the event—referred to as *committed emissions.*

Estimating C emissions from forest degradation by selective logging in Berau, East Kalimantan

- ELE, extracted log emissions = 0.28 t C/m^3
- LDF, logging damage factor = 0.42 t C/m^3 from felled tree and 0.12 t C/m^3 from collateral damage
- LIF, logging infrastructure factor = 0.39 t C/m^3 from roads, 0.02 t C/m^3 from log landings, and 0.20 t C/m^3 from skid trails
- AD, timber volume extracted = 36 m^3 per ha
- Average area logged = 1,500 ha
- Total volume extracted = 54,000 m^3
- Total emissions = (0.28+0.42+0.12+0.39+0.02+0.20)*54,000

Emissions= 77,220 t C or 283,140 t $CO_2 yr^{-1}$

Estimating C gains from forest degradation by selective logging in Berau, East Kalimantan

Gains: Must estimate amount of timber going into long-term products (LTP) and rates of regrowth around gaps

- The amount into LTP is a function of the final product class for the timber in Berau—this is 30% sawnwood and 70% wood panels
- A simple method (Winjum, Brown, and Schlamadinger 1998) accounts for losses due to mill inefficiency, fraction into short term products (< 5yr), and fraction emitted between 5-100 yr
    - For sawnwood the fraction into LTP = 0.10 and for wood based panels = 0.02
    - Total LTP for Berau is 0.045

Estimating net C emissions from forest degradation by selective logging in Berau

- Gains:
  - Into LTPs = 54,000 m3 (total volume extracted) x 0.28 (ELE) x 0.045 = 680 t C = **2,495 t CO_2**
  - Regrowth around gaps in existing trees and in new trees is due to the direct human impact, not regrowth over whole forest area:
    - Area of gaps = 14 m^2/m^3 extracted
    - Total area of gaps = [14 x 54,000 (total extracted)]/10^4 =76 ha
    - From literature assume rate is about 3 t C $ha^{-1}yr^{-1}$
    - Regrowth = 76 ha x 3 = **832 t CO_2yr^{-1}**
- **Total gains** = 2,495 + 832 = **3,327 t CO_2yr^{-1}**
- **Net emissions** = 3,327 - 283,140**=-279,813t CO_2yr^{-1}**

In summary

- Estimating C emissions and removals from deforestation and forest degradation follows IPCC 2006 AFOLU guidelines, using 2003 GPG LULUCF land-use categories and subcategories:
    - Deforestation: Forest land converted to another land use
    - Forest degradation: Forest land remaining forest land
- Estimating emissions and removals is a combination of AD and EFs.
- The stock-change approach is used to estimate net emissions from deforestation.
- Estimating emissions from forest degradation needs input on C losses (ELE, LDF, LIF) and C gains (ELE, LTP, G) and volume of wood extracted (m^3).

Country examples and exercises

Country examples:

- Combining emission factors and activity data for Guyana

Exercises:

1. Estimating carbon emissions from deforestation

2. Estimating carbon emissions from degradation by selective logging using the gain-loss method

Recommended modules as follow up

- Module 2.6 to continue with estimating GHG emissions from biomass burning.
- Module 2.7 to continue with estimation of uncertainties.
- Modules 3.1 to 3.3 to proceed with REDD+ assessment and reporting.

References

- Brown, S., F. M. Casarim, S. K. Grimland, and T. Pearson. 2011. *Carbon Impacts from Selective Logging of Forests in Berau District, East Kalimantan, Indonesia*: *Final Report to the Nature Conservancy*. Arlington, VA: Nature Conservancy. http://www.winrock.org/resources/carbon-impacts-selective-logging-forests-berau-district-east-kalimantan-indonesia.

- GFOI (Global Forest Observations Initiative). 2014. *Integrating Remote-sensing and Ground-based Observations for Estimation of Emissions and Removals of Greenhouse Gases in Forests: Methods and Guidance from the Global Forest Observations Initiative*. (Often GFOI MGD.) Geneva, Switzerland: Group on Earth Observations, version 1.0. http://www.gfoi.org/methods-guidance/.

- GOFC-GOLD (Global Observation of Forest Cover and Land Dynamics). 2014. *A Sourcebook of Methods and Procedures for Monitoring and Reporting Anthropogenic Greenhouse Gas Emissions and Removals Associated with Deforestation, Gains and Losses of Carbon Stocks in Forests Remaining Forests, and Forestation*. (Often GOFC-GOLD Sourcebook.) Netherland: GOFC-GOLD Land Cover Project Office, Wageningen University. http://www.gofcgold.wur.nl/redd/index.php.

- IPCC, 2003. *2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry*, Prepared by the National Greenhouse Gas Inventories Programme, Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K., Wagner, F. (eds.). Published: IGES, Japan. http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html (Often referred to as IPCC GPG)

- IPCC 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Volume 4: Agriculture, Forestry and Other Land Use. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html (Often referred to as IPCC AFOLU GL)
- Winjum, J. K., S. Brown, and B. Schlamadinger. 1998. "Forest Harvests and Wood Products: Sources and Sinks of Atmospheric Carbon Dioxide." *Forest Science* 44: 272–284.