Estimating Carbon Impacts and Emissions from Selective Logging
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Field measurements: what is the goal?

• Take measurements in logging gaps to relate total carbon emissions to easily measurable parameters
  – Area of logging gap (m²)
  – **Volume of timber extracted (m³)**

• Components of carbon impact:
  – Log volume → convert to biomass using wood density
  – Incidental damage → relate to m³ volume extracted
  – Infrastructure damage → relate to m³ volume extracted
Different parts of the tree have different fates:

• Timber log:
  – Some of this carbon (~10%) ends up as long-lived (>100 yr) wood products
  – Assume remaining carbon (~90%) is emitted immediately to atmosphere (committed emission - simplifies accounting)

• Rest of timber tree (crown, stump, pieces left behind)

• Other trees damaged by felling

• Trees killed for construction of roads, skid trails and decks
  – All left in the forest to decompose - assume all C emitted immediately (committed emission - simplifies accounting)
Field measurements on timber tree

1. Length of the log \( (l_{\text{Log}}) \)
2. DBH (and diameter of top of the piece – \( d_{\text{Piece-T}} \))
3. Diameter at the top cut \( (d_{\text{Top}}) \)
4. Diameter of the stump \( (D_{\text{Stump}}) \)
5. Height of the stump \( (H_{\text{Stump}}) \)
6. Length of the piece \( (l_{\text{Piece}}) \)
7. Diameter of the bottom of the piece \( (d_{\text{Piece-B}}) \)
8. Diameter of the top of the piece \( (d_{\text{Piece-T}}) \)
9. Length of avoidable merchantable waste \( (l_{\text{AMW}}) \)
10. Diameter at the bottom of the avoidable merchantable waste \( (d_{\text{AMW-B}}) \)
11. Diameter at the top of the avoidable merchantable waste \( (d_{\text{AMW-T}}) \)
Biomass of LOG EXTRACTED: HOW TO ESTIMATE?

What shape best approximates a tree trunk?

Conical Frustum (cone with top sliced off)

Final units are in m³

WHY ÷ by 200?

÷ by 2
Convert DIAMETER to RADIUS

÷ by 100
Convert units from CM to M
What if there are pieces of log left behind?

Length of piece (l piece)

Diameter at bottom of piece (dpiece-b)

Diameter at top of piece (dpiece-t)

\[ V = \frac{1}{3} \times \pi \times L_{log} \times \left[ \left( \frac{D_{bottom}}{200} \right)^2 + \left( \frac{D_{top}}{200} \right)^2 + \left( \frac{D_{bottom}}{200} \times \frac{D_{top}}{200} \right) \right] \]

\( L_{log} \) must be reduced by the sum of the length of log pieces left behind, or else log volume extracted will be overestimated.
Estimating log biomass

- Density = \( \frac{\text{Mass}}{\text{Volume}} \)

Therefore: \( \text{Biomass} = \text{Density} \times \text{Volume} \)

- Once log volume is estimated, easy to convert to biomass
- Average Wood Density for South American forests = 0.60 t m\(^{-3}\) (Brown 1997)
- If the timber species is known, use species-specific wood density
Biomass left behind: how to estimate?

We can estimate the volume of the log extracted and convert volume to biomass...

And we can estimate the total biomass of the tree based on its DBH....

Therefore:
Biomass Remaining in Forest = Total Biomass – Timber Biomass Extracted
How to estimate DBH if it can’t be measured in the field?

If log is cut above DBH, then DBH is easy to measure in the field. But if the log was cut below DBH, how can we estimate it?
Key concept: tree taper

Tree trunks get narrower with height – how can we calculate how much narrower?

Tree taper = Change in diameter (ΔD) / Change in length (ΔL)

Tree taper = \( \frac{D_{\text{bottom}} - D_{\text{top}}}{\text{Length}} \)
Estimating $\Delta$ length

From field measurements, we can calculate a taper factor that tells us how much diameter decreases per centimeter of a tree's length. Now: how many centimeters are between the stump (where diameter was measured) and DBH?

$$\Delta L (\text{cm}) = 130 - H_{\text{stump}}$$
Estimating DBH: PUTTING IT ALL TOGETHER

\[
DBH = D_{stump} - \left[ \frac{D_{stump} - D_{top}}{L_{log} \times 100} \times (130 - H_{stump}) \right]
\]

DBH is estimated as the stump diameter modified by a reduction factor. The reduction factor is based on the tree’s taper and the distance between the measured stump height and DBH (130 cm).
Example of estimating DBH

Field Measurements:
Dstump = 70.8 cm
Dtop = 49.7 cm
Length = 19.9 m
Hstump = 80 cm

Tree taper = \( \frac{70.8 - 49.7}{19.9} = 1.06 \text{ cm/m} \)

Change in length = 130 – 80 = 50 cm

\[
DBH = 70.8 - \left[ \frac{70.8 - 49.7}{19.9 \times 100} \times (130 - 80) \right] = 70.27
\]
biomass left behind: how to estimate?

We can estimate the volume of the log extracted and convert volume to biomass...

And we can estimate the total biomass of the tree based on its DBH....

Therefore:
Biomass Remaining in Forest (crown, stump, pieces left behind) = Total Biomass – Timber Biomass Extracted
Incidental damage

• Biomass of timber tree left in the forest will be emitted as CO$_2$ as it decomposes through time – this is part of incidental damage
• Other trees damaged as a result of felling operations will also decompose and emit CO$_2$
• Biomass of damaged trees estimated based on DBH using allometric equations
• Estimate total incidental damage as t C per m$^3$ extracted
Carbon impacts of logging infrastructure

Roads, Skid Trails, and Decks

✓ Length
✓ Width

Infrastructure Emission Factor

(Skid Trails + Decks + Roads)
Carbon impacts of logging infrastructure

• Need estimates of average forest carbon stocks per stratum
• Calculate area of roads, logging decks, skid trails
• Multiply area by average forest carbon stocks to estimate carbon impact of logging infrastructure
• Estimate total logging infrastructure impact (t C) per m³ extracted
Summary: Equation for estimating emissions from selective logging

\[ \text{C emissions, t C/yr} = [\text{vol} \times \text{WD} \times \text{CF} \times (1-\text{LTP})] + [\text{vol} \times \text{LDF}] + [\text{vol} \times \text{LIF}] \]

Where:
Vol = volume timber extracted over bark per logging block (m³)
WD = wood density (t/m³)
CF = carbon fraction
LTP = proportion of extracted wood in long term products still in use after 100 yr (dimensionless)
LDF = logging damage factor (t C/m³)—dead wood left behind in gap
LIF = logging infrastructure factor (t C/m³)—dead wood produced by construction
Different Tool
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