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Assessment of the Advantages and Limitations of Ground-Based Surveys and Inventories



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What can ground-based inventories measure?

- Can sample for measures needed to estimate:
 - Carbon stocks of forest pools to known levels of precision and accuracy
 - Change in C stocks in all forest pools to known levels of precision and accuracy
- Robust models exist to convert tree measurements to estimates of C stocks
- Existing suite of satellites cannot provide credible measures of forest C stocks
- Can be used to verify interpretation of remote sensing analysis of land cover

Importance of ground-based measures

IPCC Tier	Data needs/examples of appropriate biomass data
Tier 1	Default ... forest biomass stock for broad continental forest types— <u>includes 6 values for each continental area;</u>

- For C stock estimates could use Tier 1 with principle of conservatism
- Large uncertainty around Tier 1 default values, up to +/-70%, could result in a large deduction
- How to know being conservative without measures?

Goals of a ground-based inventory for forest carbon stocks

- Produce estimates of carbon stocks that do not overestimate the true value and have low uncertainty
- Focus on estimating C stocks for forests most likely to be deforested and degraded
- Produce estimates of C stocks cost effectively
- Contribute to other national monitoring needs as needed (biomass and commercial volume are related)

What level of uncertainty should be targeted for ground-based measures

- Emissions = area deforested \times C stock of forest
- Can monitor area change accurately and need to be matched with low uncertainty in carbon stock estimates, otherwise the advantage of the area accuracy is lost

Area deforested from remote sensing Uncertainty	Carbon stock Uncertainty	Total Uncertainty
5 %	50 %	21 %
5 %	30 %	17 %
5 %	15 %	11 %

Steps to improve cost effectiveness of ground-based surveys

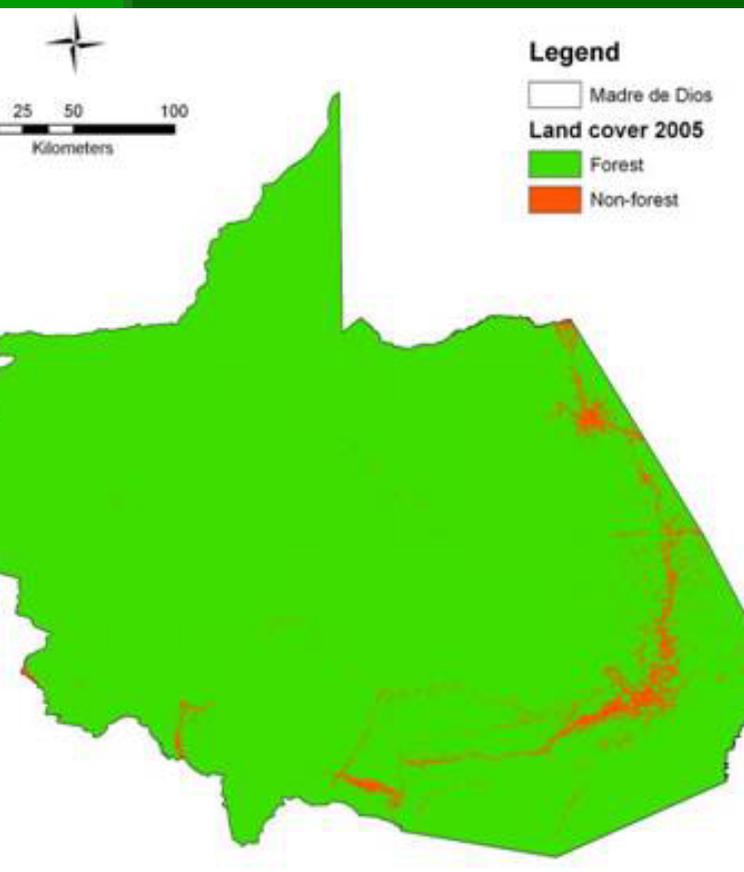
- ✓ Stratification is key step to reduce uncertainty and costs
 - ✓ By C Stock not necessarily by forest type
 - ✓ By area under most threat for deforestation
 - ✓ Provides linkage between the remote sensing imagery estimates of area change and estimates of carbon stocks

Understanding patterns of deforestation can be used to stratify ground-based measures

- Deforestation within a country can be:
 - Planned -designated and sanctioned,
 - Area known and ground-based inventory straight forward
 - Unplanned—unsanctioned on lands not designated for such activities or on poorly defined and managed communal lands
 - Where occurs is less predictable and inventorying is more challenging

Deforestation occurs in different forest landscape configurations

Frontier-type pattern-forest less accessible

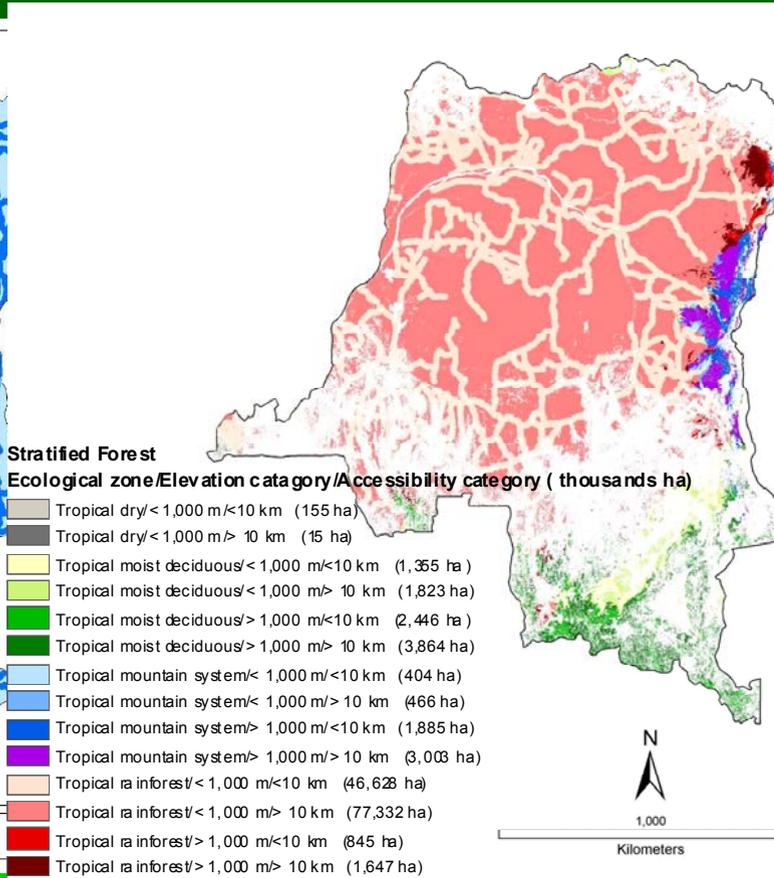
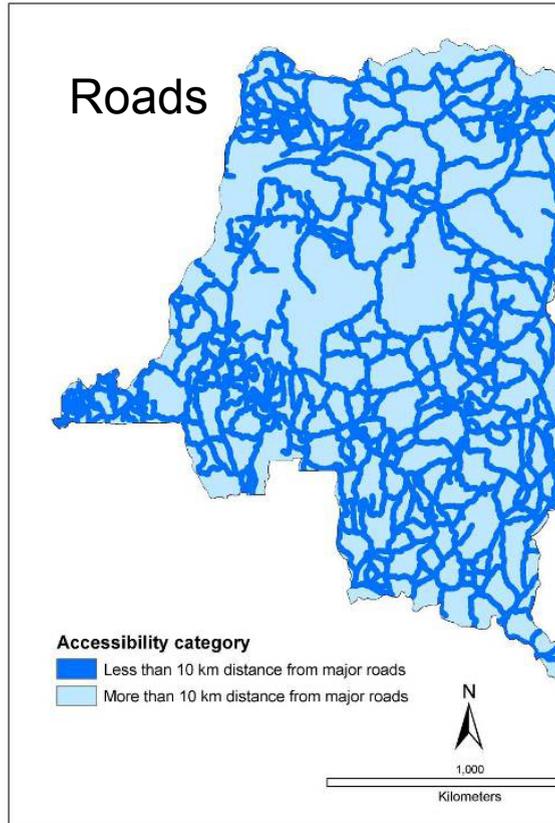
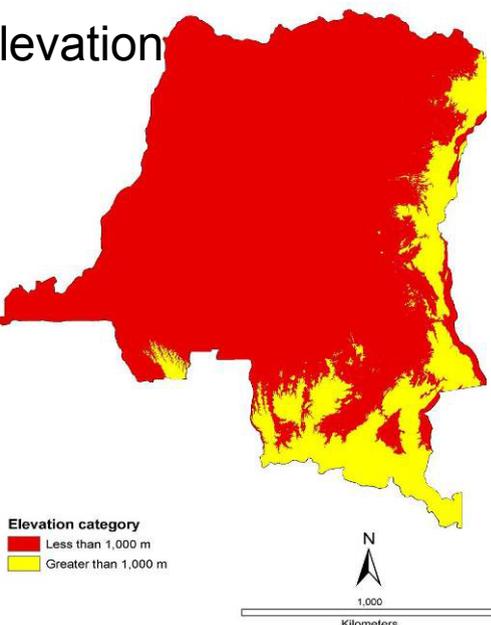
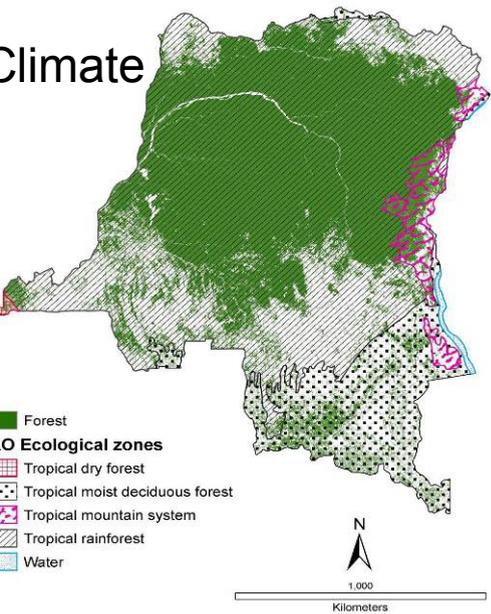


Also needs to be taken into account in designing & stratifying a ground-based inventory

Mosaic-type pattern-forest accessible



Other factors to stratify assessment of carbon stocks



General approaches to improving estimates of carbon stocks cost effectively

- Assess existing data quality
 - e.g.—less than 10 years old, derived from multiple plots, sampled from good coverage of the strata, all species and minimum diameter at least 20-25 cm included if using forest inventory data
- REDD Sourcebook and IPCC GPG provides guidance on how to convert forest inventory data to carbon stock estimates

General approaches to improving estimates of carbon stocks

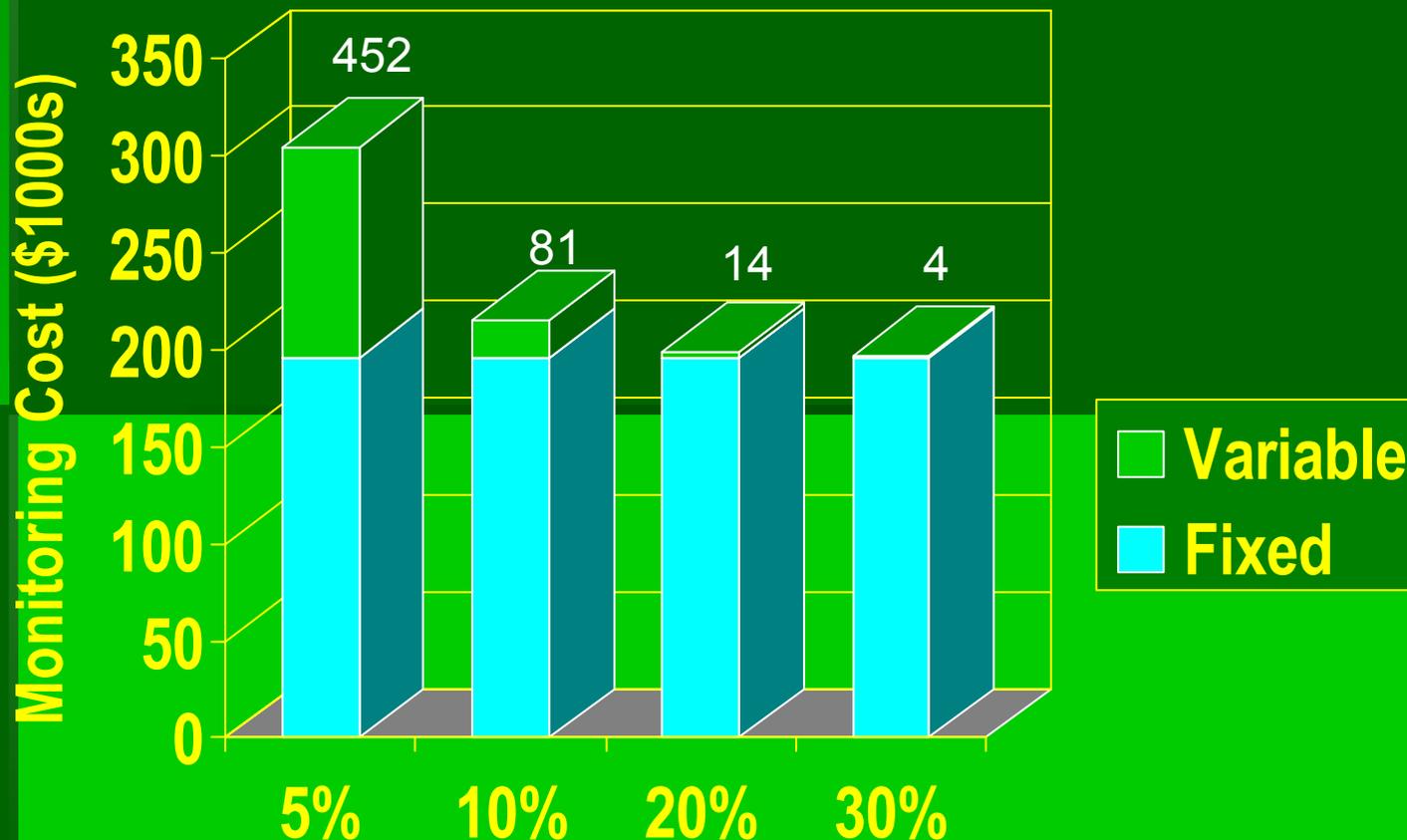
- Collect missing data
 - For strata at risk of deforestation or degradation in the future
 - Many tools and specific guidance available for designing and implementing field measurement of carbon stocks
 - The FAO National Forest Inventory Field Manual provides guidance on sample design and is available at: <http://www.fao.org/docrep/008/ae578e00.pdf>
 - Chapter 4.3 of IPCC GPG LULUCF
 - World Bank's BioCarbon Fund Sourcebook for Land Use, Land-Use Change and Forestry (available at http://www.winrock.org/Ecosystems/files/Winrock-BioCarbon_Fund_Sourcebook-compressed.pdf)

Example of a C inventory for Noel Kempff pilot project

Strata	Area (ha)	Above-ground woody biomass	Palm biomass	Standing dead biomass	Lying dead biomass	Understory	Litter	Below-ground biomass	Soils	Mean
t C/ha										
Tall evergreen	226,827	129.1	0.5	4.1	11.0	2.0	3.6	25.8	26.9	203
Liana	95,564	55.5	0.5	2.3	4.7	3.8	4.0	11.1	39.9	122
Flood Tall	99,316	131.8	1.1	3.2	11.3	1.9	3.1	26.4	44.8	224
Flood Short	49,625	111.7	0.2	3.0	9.6	2.1	2.9	22.3	55.5	207
Mixed Liana	159,471	89.6	1.5	4.4	7.7	2.6	4.3	17.9	24.4	152
Burned	3,483	56.9	0.2	1.6	4.9	0.9	4.2	11.4	36.0	116
Weighted mean		106.7	0.8	3.6	9.1	2.4	3.7	21.3	33.3	181
Total	634,286 ha									
95% confidence limit (% of mean):	4.2									
Project Total Carbon Content	114,852,218									

What is cost for ground-based measurements?

Trade off between uncertainty and resources available—e.g. for Noel Kempff area of Bolivia (several strata and ~640,000ha)

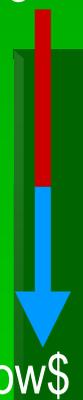


Cost to measure and monitor

- Costs for establishing plots and measuring trees is mainly a function of coefficient of variation (SD/mean) of C stock estimates
- For large sampling areas, area has little effect on number of plots needed

Project size (ha)	Coefficient of Variation (%)		Number of plots for 95% CI of +/-10% mean					
			10		20		30	
	Sample size	Cost \$/ha	Sample size	Cost \$/ha	Sample size	Cost \$/ha	Sample size	Cost \$/ha
10	3	327.18	7	328.78	8	329.18	9	329.58
100	4	32.76	14	43.88	26	55.07	39	66.31
1,000	4	3.28	16	4.40	34	5.54	58	7.78
10,000	4	0.33	16	0.44	35	0.55	62	0.89

High\$



Low\$

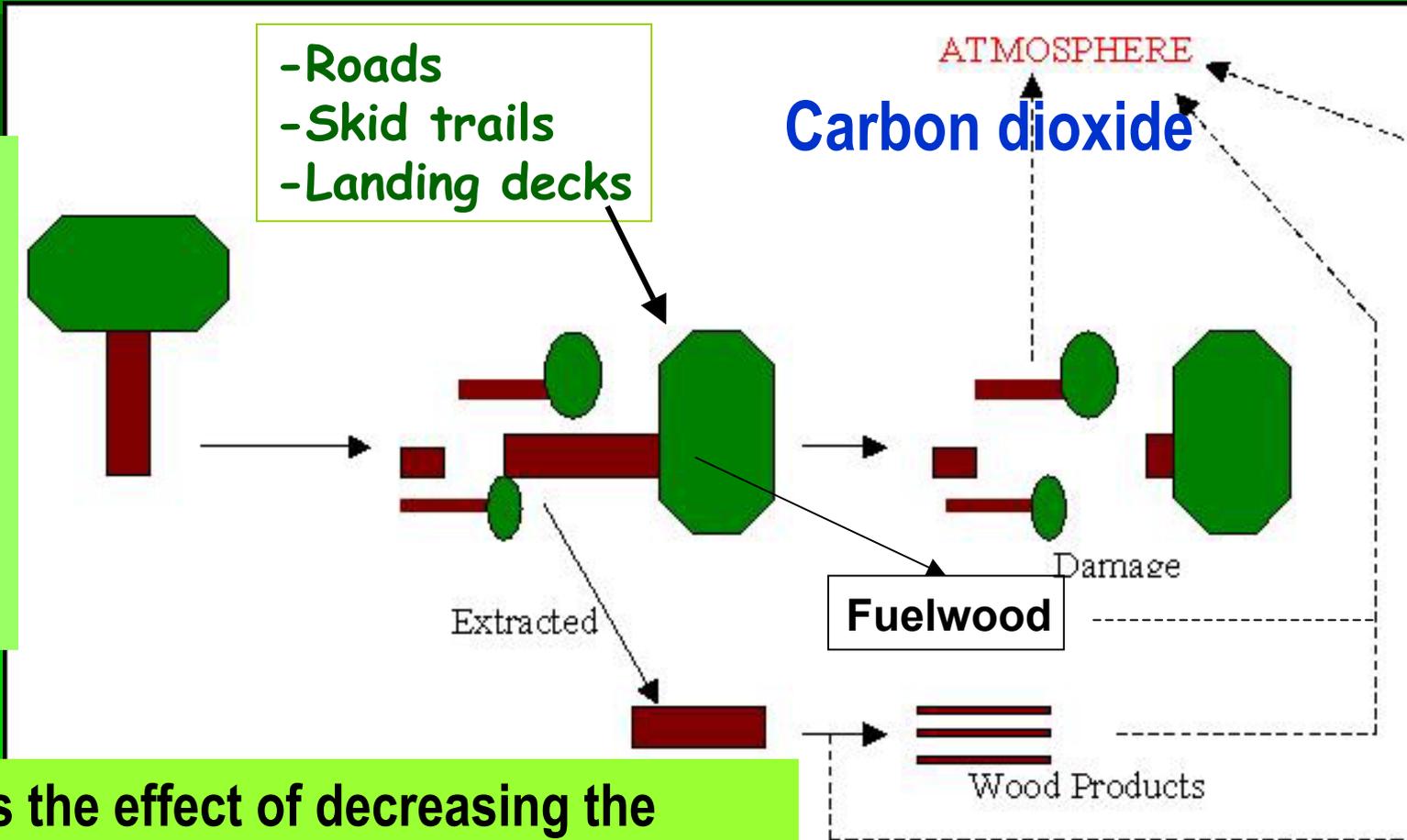
\$15
/plot

Ground-based measures for degradation?

- General framework for estimating impacts of forest degradation on C stocks exist in IPCC for many causes
 - Changes in C stocks in "forests remaining as forests"
 - Applicable to monitoring logging impacts and sustainable forest management
 - "Gain and loss" approach
 - ΔC stock = Gain in C - Loss in C
 - Loss from harvest of logs, fuelwood, etc.
 - Gain from regrowth of degraded forest

Change in live and dead C stocks of forest obtained from field measures

Need area
logged per
year
Timber
extraction
rates per
unit area



Logging has the effect of decreasing the
stocks in live biomass and increasing the
stocks in dead wood and wood products



Quantify change in live and dead C stocks

- Collect measurements on felled trees to estimate the Δ live C and the Δ dead C
- Use biomass regression equations to estimate biomass of felled trees
- Dead biomass (top) = total minus biomass in logs

Extracted volumes

Estimate carbon in log based on volume and density



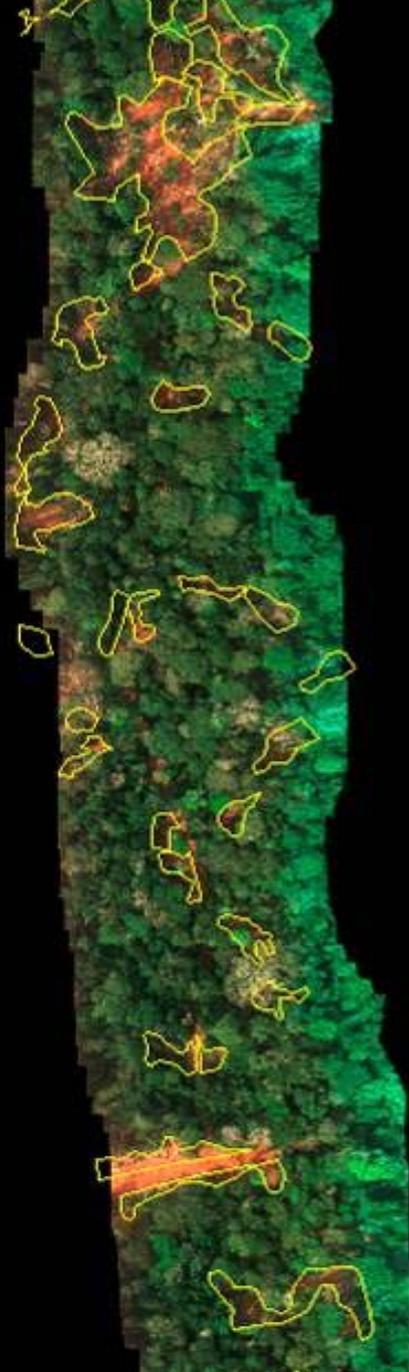
Tree fall damage

Measure diameter of collateral damage trees and estimate biomass from regression equations



Strips of aerial imagery showing logging damage

- Left with gaps delineated automatically
- Right-without
- Use imagery to estimate area of gaps, roads and length of skid trails
- Estimate proportion of total sample area covered by gaps to get total gap area
- Useful for verification



Combining field data, extraction rates, and estimates of area logged: Republic of Congo (results based on 100 logging plots)

	Total carbon impact		Impact per ha of concession	
	t C	95% CI	t C/ha	95% CI
Extracted biomass carbon	3,824	± 248	2.60	± 0.17
Damaged biomass carbon in logging gap	5,698	± 343	4.01	± 0.23
Damaged biomass carbon in skid trails	126	± 10	0.09	± 0.007
Biomass carbon impact of logging roads	3,194	± 598	2.17	± 0.41
TOTAL	13,042	± 1,199	8.86	± 0.81

Conclusions

- Ground based measures needed to go beyond a Tier 1 approach of unknown certainty
- Stratify forest lands by appropriate factors to design cost-effective carbon inventory
- Cost of ground-based measures are modest to achieve reasonable level of certainty
- Ground based methods for measuring and estimating C stocks for changes to sustainable forest management exist

Thank You!

- Support: US Agency for International Development, US Environmental Protection Agency, The Nature Conservancy
- For more information see:
 - <http://www.winrock.org/Ecosystems/>
- Or contact me:
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