Estimating the uncertainty of C stock estimates:

its implication for sampling procedures

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The IPCC Good Practice Guideline (2004) sets requirements to assess uncertainty of the national GHG inventories including for Land Use, Land Use Change and Forestry (LULUCF) sector.

Table 1. Estimated uncertainty values for CO_2

Source category	Emission Factor U_E	Activity Data U_A	Overall uncertainty U_T
Energy	7%	7%	10%
Industrial Processes	7%	7%	10%
Land Use Change and Forestry	33%	50%	60%

Source: *Revised 1996 IPCC Guidelines for National GHG Inventories: Reporting Instruction*

With the LULUCF sector responsible for about 20% of global emissions, the uncertainty in this term is unacceptably high…

Relationships between the errors in 'emission factor' and 'activity data'?

In estimating net C emissions due to land cover change

'emission factor': difference in C stock of the previous and new land cover type (the difference between two C stock estimates),

'activity data': the area where changes occurred.

If the land cover classification is very coarse (forest ⇔ non-forest), the uncertainty in 'emission factor' will be large,

'activity data' are relatively easy to obtain.

If the land cover classification includes many nuances,

the 'emission factors' will be well-defined,

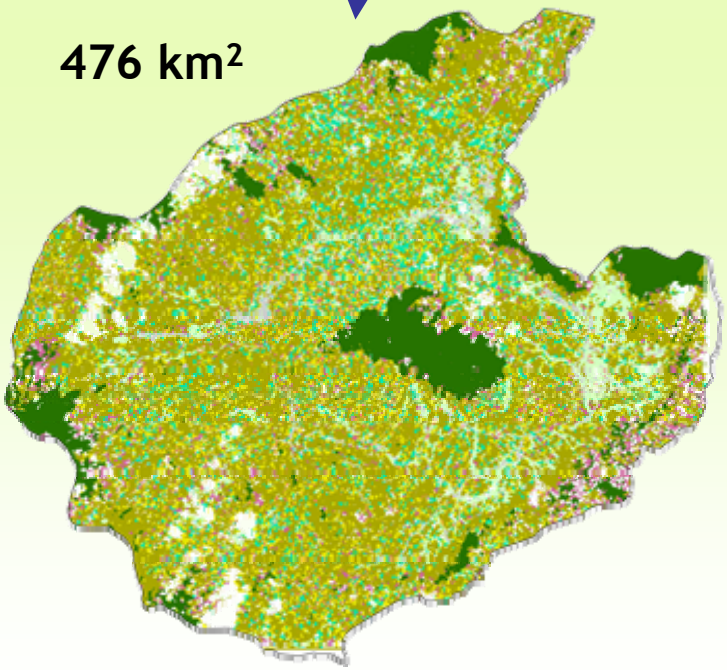
'activity data' will have high uncertainty due to misclassification of points

Is there an intermediate ground of 'optimal' land cover classification with minimal uncertainty in net C emissions?

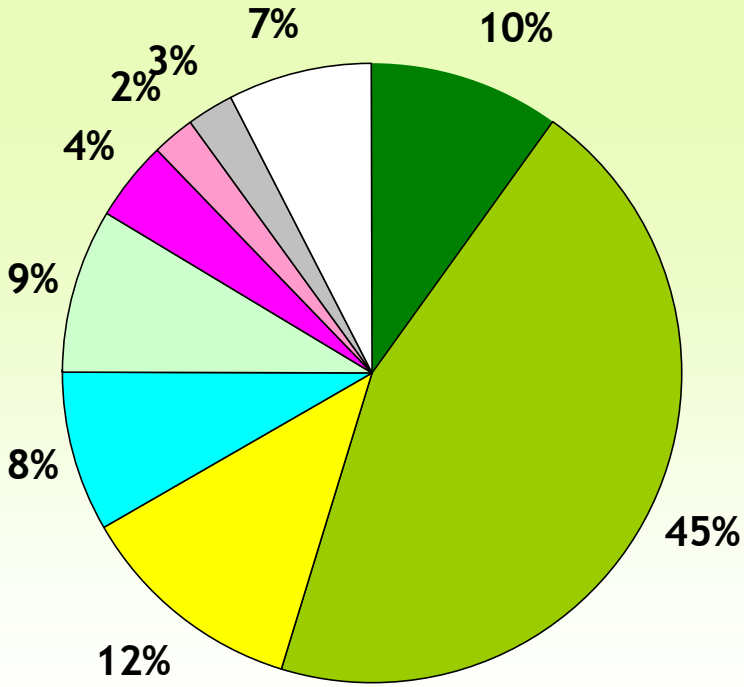
AN EXAMPLE

Estimating uncertainty of C stocks: Sumberjaya catchment

476 km²



- Forest
- Multistrata coffee
- Simple shade coffee
- Sun coffee
- Ricefield
- Shrub
- Horticulture
- Road and settlement
- No data



Land use classification based on Landsat Image 2002 (Ekadinata, 2006)

Uncertainty: Activity factor

Table 2. Classification error matrix

Classified Land Use	Reference Land Use								
	Forest	Multi-strata coffee	Simple shade coffee	Sun coffee	Rice field	Shrub	Horti-cul-ture	Others	Total
Forest	45					2			47
Multistrata coffee		92	36		3	2			133
Simple shade coffee		42	50	7	1				100
Sun coffee	1		1	25		1			28
Rice field		1	4	2	49		1	2	59
Shrub	4	1		1		31			37
Horticulture			1		1		17		19
Others				1	1			23	25
Total	50	136	92	36	55	36	18	25	448

Source: Ekadinata (2002)

Uncertainty: Activity factor

Table 3. Estimated error in land use classification

Land Use	Estimated error in land use classification
Forest	10%
Multistrata coffee	32%
Simple shade coffee	46%
Sun coffee	31%
Ricefield	11%
Horticulture	60%
Shrub	14%
ALL	26%

Based on 448 groundtruth points

Uncertainty: Emission factor

Carbon stock estimates and its error

Land Use	Carbon stock estimate (Mg ha^{-1})	Standard deviation	Mean standard error σ_E
Forest	232.0	133.5	29.1
Multistrata coffee	44.8	34.0	7.2
Simple shade coffee	23.5	12.0	2.9
Sun coffee	16.3	20.8	4.0
Rice field	3.0	1.4	0.6
Horticulture	1.9	1.2	0.5
Shrub	82.0	84.3	2.0

Source: based on 110 sample plots from ASB (1998) and Berlian (2002)

Uncertainty: Activity factor

What happened to the error if we make the land use category coarser?

	Forest	Multi-strata coffee	Simple shade coffee	Sun coffee	Shrub	Rice field	Horti-culture
Estimated error in classifi-cation	0.10	0.32	0.46	0.31	0.6	0.11	0.14
		AF coffee				Agriculture	
		0.04				0.07	
		Tree based (+shrub)				Agriculture	
		0.04				0.07	
		Non-forest					
		0.02					

Calculation is based on agglomeration of the original land use categ

The error substantially decreased

Uncertainty: Emission factor

What happened to the error if we make the land use category coarser?

	Forest	Multi-strata coffee	Simple shade coffee	Sun coffee	Shrub	Rice field	Horti-culture
Mean standard error σ_E	29.1	7.2	2.9	4.0	2.0	0.5	0.6
		AF coffee				Agriculture	
		4.6				0.4	
		Tree based (+shrub)				Agriculture	
		3.1				0.4	
		Non-forest					
		2.9					

Calculation is based on agglomeration of the original land use cat

The error slightly decreased

Estimating landscape carbon stocks: combining both errors

Land Use	Area (km^2)	Plot level C-stock estimates (Mg ha^{-1})	Landscape level C-stock estimates (Gt ha^{-1})	Incorporating classification error		Δ Estimates (Gt ha^{-1})
				Plot C-stock estimate (Mg ha^{-1})	Landscape C-stock estimate (Gt ha^{-1})	
Forest	47.8	232.0	1.11	225.6	1.08	0.03
Multi-strata coffee	212.7	44.8	0.95	38.7	0.82	0.13
Simple shade coffee	57.1	23.5	0.13	31.7	0.18	0.05
Sun coffee	39.4	16.3	0.06	20.6	0.1	0.04
Rice field	41.1	3.0	0.01	5.4	0.02	0.01
Horti-culture	10.7	1.9	0.002	3.1	0.003	0.001
Shrub	19.6	82.0	0.16	95.4	0.19	0.03
Others	11.9					
TOTAL	475.7		2.44		2.4	0.04

What happened if we make the land use category coarser?

	Forest	Multi-strata coffee	Simple shade coffee	Sun coffee	Shrub	Rice field	Horti-culture	Total
Δ Landscape Level Estimates (Gt ha^{-1})	0.03	0.13	0.05	0.04	0.03	0.01	0.001	0.04
		AF coffee				Agriculture		
		0.02				0.01		0.03
		Tree based (+shrub)				Agriculture		
		0.09				0.02		0.07
		Non-forest						
		0.09						0.05

Calculation is ba… of the original land use category

No significant differences

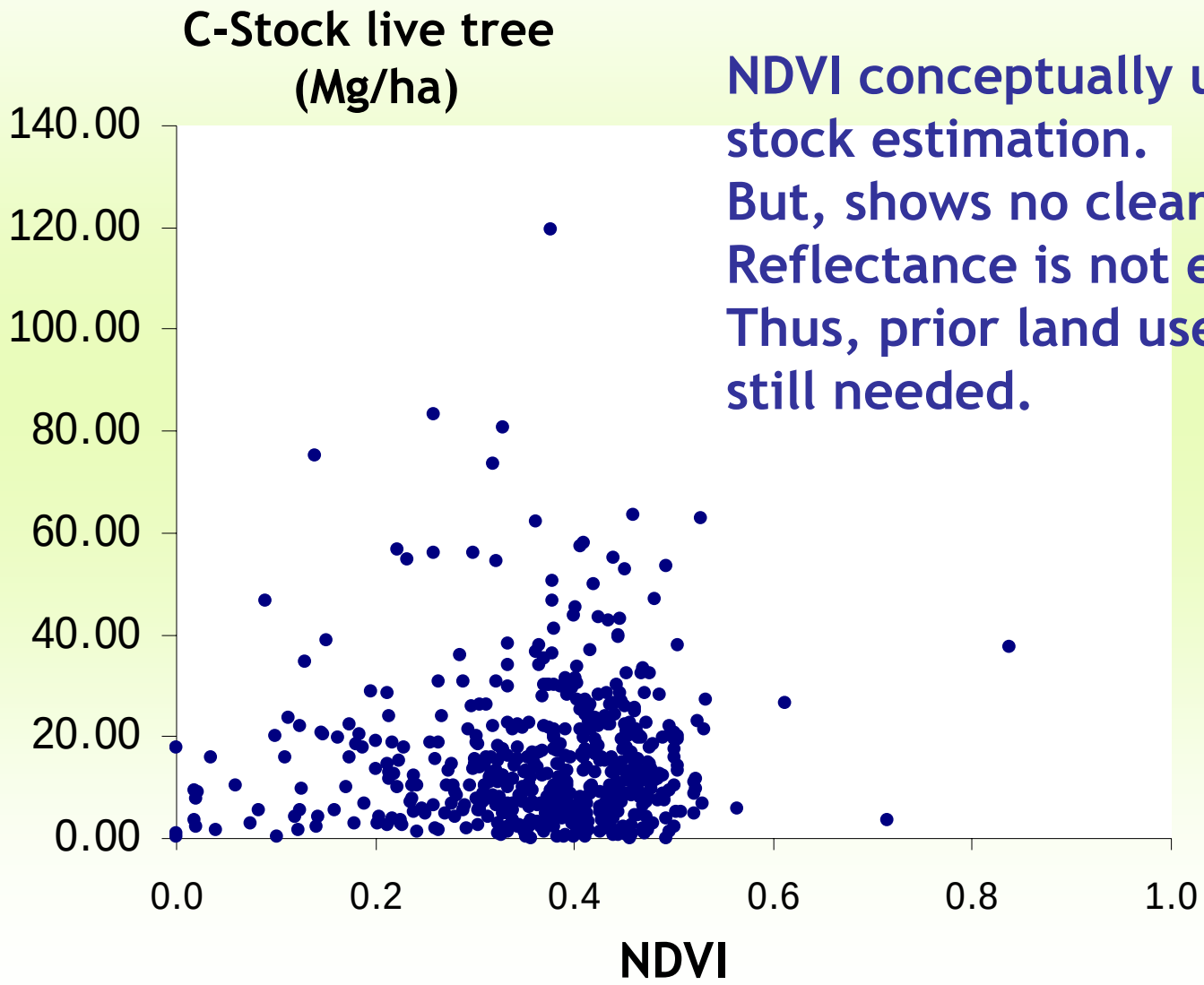
Results from example

- In this particular case, no tradeoff of error:
  → Optimal land use categories in this case 5 (Forest, AF coffee, Sun (mono) coffee, agriculture, bush)

- More sample plots for C stock should be taken for land use category with higher variation → FOREST

- More points for ground truth should be taken for land use category with higher uncertainty → SUN COFFEE

Is there an ‘optimal’ land cover classification?



NDVI conceptually useful for C-stock estimation.
But, shows no clear relationship.
Reflectance is not enough.
Thus, prior land use categories is still needed.

Next steps: estimating uncertainty in carbon stock changes

- To estimate C-stock changes, similar approach can be used.

$$U_A = U_{A\text{-year1}} + U_{A\text{-year2}}$$
$$U_E = U_{E\text{-year1}} + U_{E\text{-year2}}$$

- For efficiency, Year-1 C-stock estimates can still be used in Year-2. Thus efforts can be focused on reducing classification error ('Activity' data)
- To reduce geo-referenced error and increase the ability in detecting spatial changes, sample plots for C-stock should not be taken in edges

Next steps: estimating uncertainty in carbon stock changes

- Broad land use categories are desirable to reduce classification error. Eg. Forest, Tree-based, non tree-based, non-vegetation, settlement
  Nevertheless, C-stocks sample plots should be in finer categories structured in a hierarchy that allows grouping into the broad categories used in image classification

Disclaimer: This is an early version of the calculation.

For more infomation. please contact Betha Lusiana (b.lusiana@cgiar.org)