Estimating Mean Annual Increments of Aboveground Living Biomass and Uncertainty Analysis

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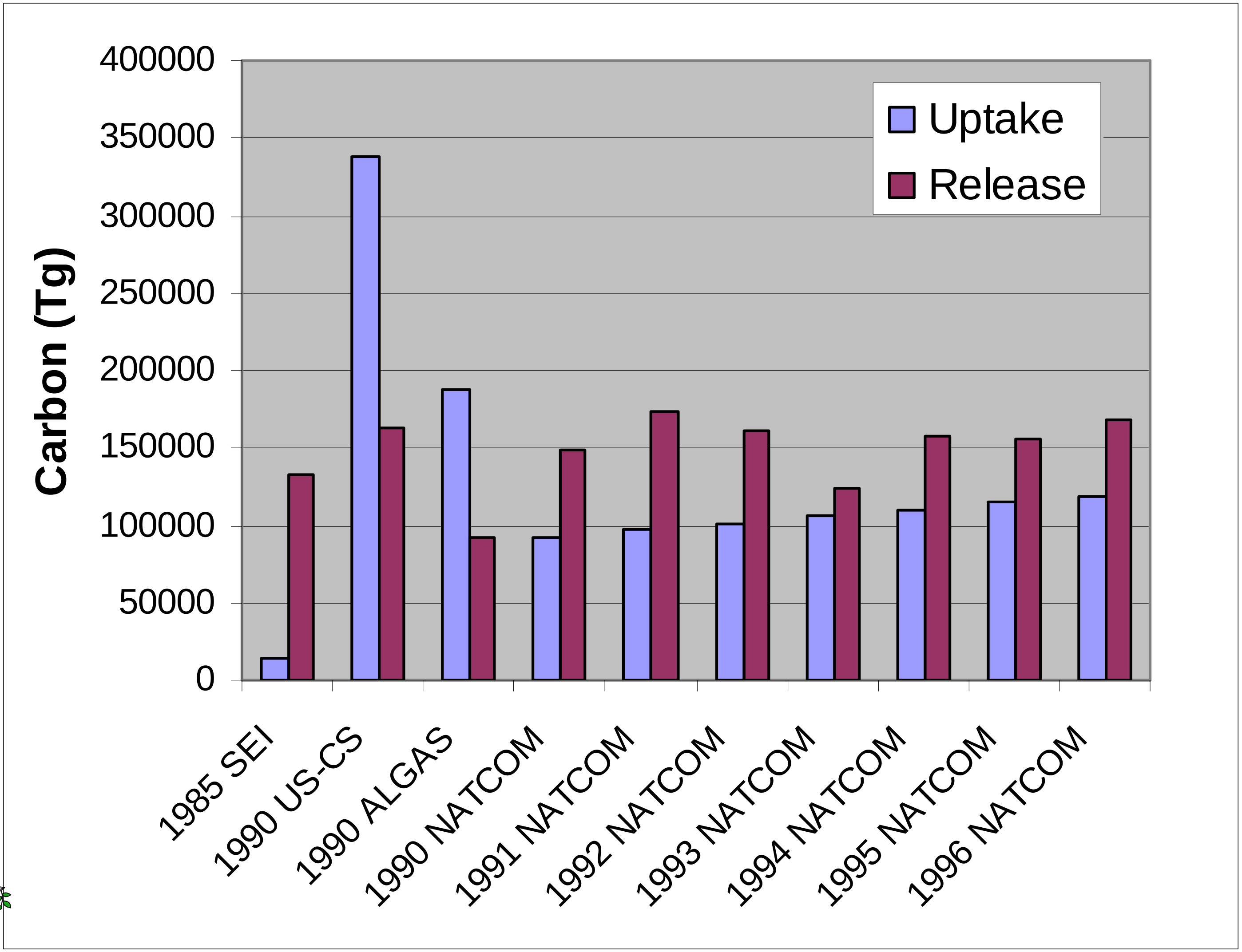
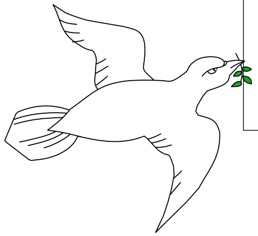
Background

- **All Parties to the UNFCCC are required to report national GHG inventories**
- **GHG inventory reports the estimate of GHG emission and uptake, therefore country should able to assess the long-term impacts of different land development and land-use management practices on GHG emissions and removals.**
- **Quality of activity data and emission factor from LULUCF is quite poor. In Indonesia, the estimates of carbon emission and uptake from this sector varied consederably from study to study due to change in assumption, activity data, emission factor and methodology.**
- **There is need to improve quality of activity data and emission factor as well as methodology**

GHG Inventory: Forestry Sector





Data that need to be improved

Priority data domains	**Importance**
Converted forest area per forest type	*3*
Growth rate of forest and vegetation types (including plantations)	*3*
Forest typology (biomass-based, floristic, ecology, climatic, administrative)	*3*
Wood harvest (legal + illegal, half-life time by use)	*2.5*
Biomass of each forest and vegetation type	*2.5*
Root biomass per vegetation / land use land cover type	2.2
Wood to biomass expansion factor, allometrics	2.2
Abandoned land: area + growth rate (increment)	1.7
Soil C stock (including organic soils + LU impacts)	1.1
On-site (in situ) burning	0.5

Source: Murdiyarso (2002)

Approach to Estimate MAI

- Estimated from common available data such as
  - mean annual diameter increment collected by forest concession companies
  - yield table or wood volume data from plantation companies or from result of forest inventory conducted by the Ministry of Forestry etc.

Approaches to Estimate Above ground Biomass and MAI of logged over forests using diameter increment data

Diameter class (D in cm)	Mean number of stems/ha	Volume of stem (V in m^3)[1]	Total Volume of stem (m^3/ha)	Diameter after growing (Dg in cm)[2]	Volume of stem after growing (V in m^3)[1]	Total Volume of stem (m^3/ha)	Volume increment (m^3 ha^{-1} yr^{-1})[3]
(1)	(2)	(3)	(4)=(2)x(3)	(5)=(1)+*Di*	(6)	(7)=(2)x(6)	(8)=(7)-(4)
14.50	249.4	0.087	21.8	14.82	0.093	23.1	
24.50	104.1	0.347	36.1	24.91	0.362	37.7	
34.50	50.2	0.852	42.8	34.93	0.880	44.2	
44.50	22.2	1.662	36.9	44.92	1.704	37.8	
54.50	10.4	2.831	29.4	54.90	2.887	29.9	
64.50	5.2	4.407	22.7	64.92	4.484	23.1	
70.00	3.6	5.464	19.7	70.47	5.560	20.1	
			209.3			215.9	**6.5**

[1]Allometric equation for estimating volume of wood is $V=0.00007771D^{2.267}$, and [2]$Di=0.000006D^3 - 0.0008D^2 + 0.0335D - 0.0178$ (R^2=48%). [3]Using BEF of 1.5 (Ruhiyat, 1995) and wood density of 0.6, the mean annual biomass increment of logged-over forest was about 5.9 t ha^{-1} yr^{-1}

Another approaches using wood volume data

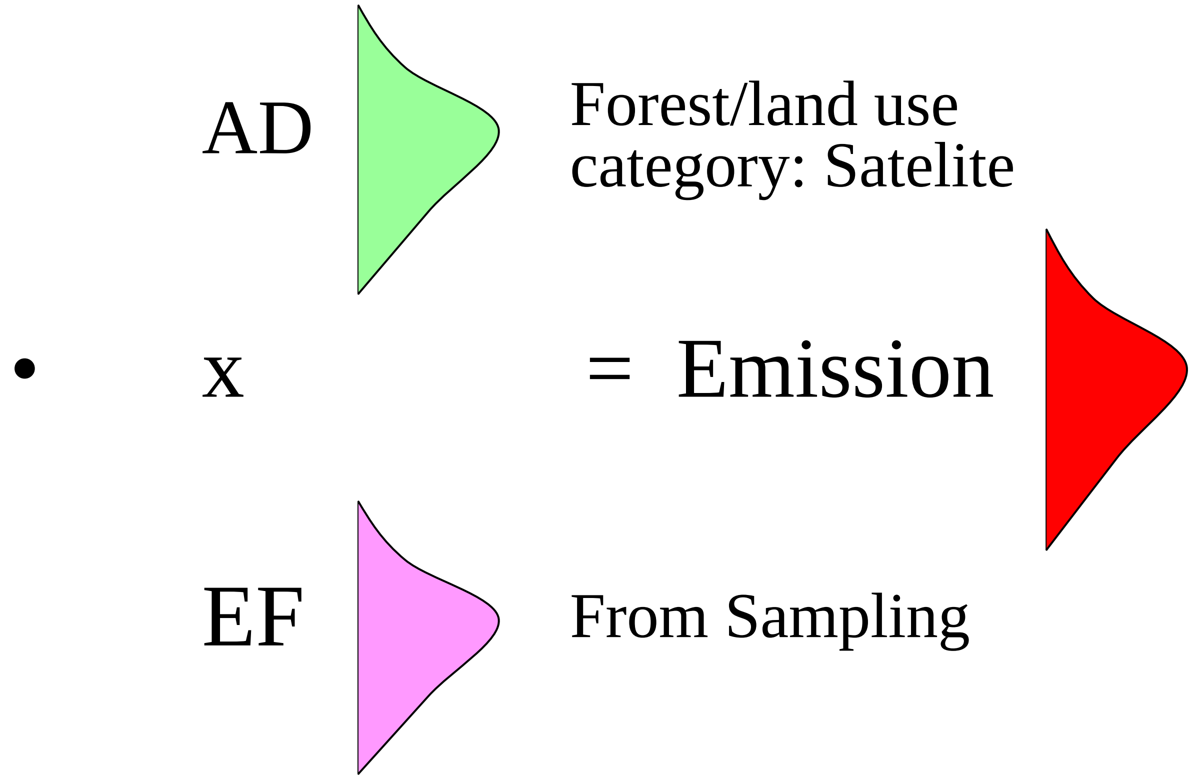
- $MAI_{LoF}=((WV_{VF}–WV_{LoF})/Rotation)*WD*BEF$
  - wood volume of virgin (WV_{VF}) and logged-over (WV_{LoF}) forests
  - WD wood density and BEF Biomass expansion factor (1.5 for natural forest: Ruhiyat, 1995)
- MAI = (SY * CF * BEF)/(Age of stand)
  - SY stand yield in m^3
  - CF correction factor: ratio between stand yield table and observed data collected through forest inventory

Forest Category	Forest types by function	Area (1000 ha)		Volume (m^3/ha) dbh 20cm+	
		Virgin Forest	Logged-over forest	Virgin Forest	Logged-over forest
Lowland forest	PF+CnF	18363,7	5966,2	165,4	66,9
	LPF+NCF	23012,9	16645,3	162,0	106,8
	CF	8211,7	6711,5	141,4	56,8
Swamp	PF+CnF	1777,4	1067,9	117,6	32,1
	LPF+NCF	4224,6	3540,4	132,8	83,8
	CF	3542,2	3090,0	100,8	47,0
Mangrove	PF+CnF	904,5	194,9	115,0	-
	LPF+NCF	446,6	609,4	103,4	2,4
	CF	624,6	304,4	84,6	39,2
Total	**PF+CnF**	**21045,6**	**7229,0**	**159,2***	**60,0***
	LPF+NCF	**27684,1**	**20795,1**	**156,6***	**99,8***
	CF	**12378,5**	**10105,9**	**126,9***	**53,3***
			=		
		Un-logged	**Logged**	**Un-logged**	**Logged**
Unproductive dry land	PF+CnF	2305,2	2341,6	89,4	15,6
	LPF+NCF	2299,1	4963,9	104,2	34,5
	CF	1370,9	4319,5	119,5	16,6
Unproductive wet land	PF+CnF	674,0	232,5	41,6	0,2
	LPF+NCF	469,7	750,4	80,7	22,4
	CF	385,4	1203,3	65,6	12,9
Agriculture	PF+CnF	753,6	1172,1	86,6	8,9
	LPF+NCF	796,6	1774,6	157,3	33,6
	CF	824,5	2955,0	91,1	14,0
Plantation	PF+CnF	-	-	-	-
	LPF+NCF	131,1	422,3	-	16,5
	CF	116,4	1087,1	-	10,6
Total	**PF+CnF**	**3732,8**	**3746,2**	**80,2***	**12,5***
	LPF+NCF	**3696,5**	**7911,2**	**109,0***	**32,2***
	CF	**2697,2**	**9564,9**	**98,0***	**14,6***

* The values are area weighted average. Source : Dephut (1998a).

By using WD of 0.65 t m-3 and BEF of 1.5, the mean annual increment of logged-over forest in Indonesia ranged from 1.71 to 2.96 tB ha-1 yr-1.

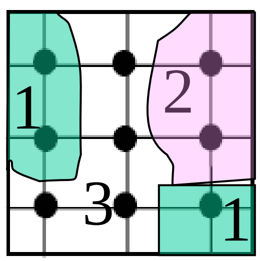
Uncertainty Analysis Using Monte Carlo Simulation



Approach to estimate uncertainty when the total area of an inventory region is generally known (Source IPCC-GPG2000):

Table 5.3.1 provides an example of this procedure. The standard error of an area estimate is obtained as $A\sqrt{(p_i \bullet (1-p_i))/(n-1)}$, where p_i is the proportion of points in the particular land-use class, A the known total area, and *n* the total number of sample points.[4] The 95% confidence interval for A_i, the estimated area of land use class *i*, will be given approximately by ±2 times the standard error.

TABLE 5.3.1
EXAMPLE OF AREA ESTIMATION VIA PROPORTIONS

Sampling procedure	Estimation of proportions	Estimated areas of land use classes	Standard error	
	$p_i = n_i / n$	$A_i = p_i \cdot A$	$s(A_i)$	
	$p_1 = 3/9 \cong 0.333$	$A_1 = 300$ ha	$s(A_1) = 150.0$ ha	50 %
	$p_2 = 2/9 \cong 0.222$	$A_2 = 200$ ha	$s(A_2) = 132.2$ ha	66 %
	$p_3 = 4/9 \cong 0.444$	$A_3 = 400$ ha	$s(A_3) = 158.1$ ha	40 %
	Sum = 1.0	Total = 900 ha		

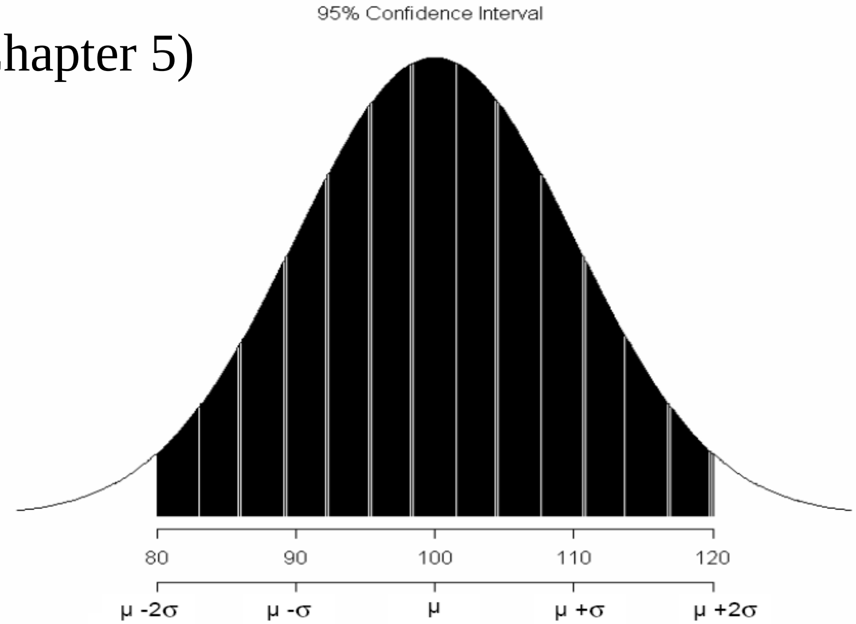
n_i = number of points located in land-use class *i*

n = total number of points

Increase number of samples →

Total Area	900	ha			Error		Uncertainty	
	ni			pi				
n1	5		p1	0.26	93	ha	39.4	%
n2	5		p2	0.26	93	ha	39.4	%
n3	9		p3	0.47	106	ha	24.8	%
n	19			1.00				

Source: IPCC-GPG (Chapter 5)



In the *GPG 2000*, the percentage uncertainty is defined as:

$$\% \text{ uncertainty} = \frac{\frac{1}{2}(\text{95\% Confidence Interval width})}{\mu} \times 100$$

For this example:

$$\% \text{ uncertainty} = \frac{\frac{1}{2}(4\sigma)}{\mu} \times 100 = \frac{2\sigma}{\mu} \times 100 = \frac{20}{100} \times 100 = 20\%$$

Where:

σ = standard deviation

$\sigma = \sqrt{\text{variance}} = 10$

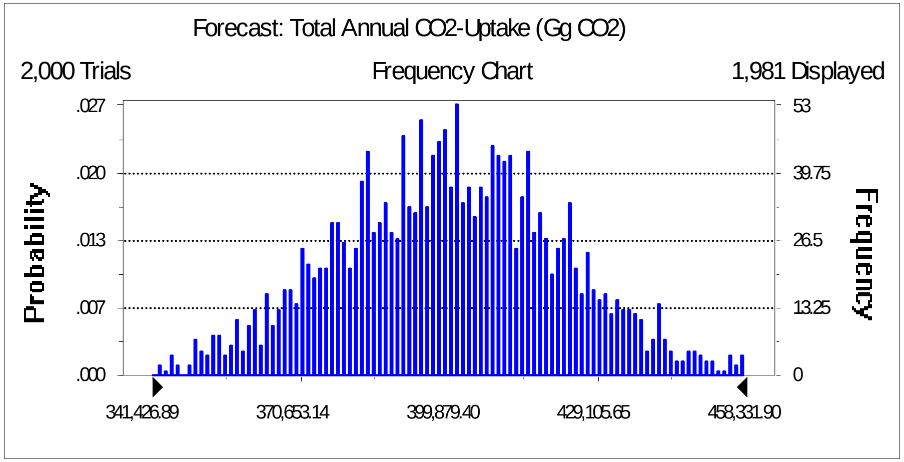
μ = the mean of the distribution.

Note that this uncertainty is twice the relative standard error (in %), a commonly used statistical estimate of relative uncertainty.

			(kt C)	
			E=(CxD)	
Forest Land	Forest Plantation (Java	*Tectona grandis*	2,124.01	1.28
		Pinus merkusii	1,590.91	0.96
		Swietenia spp.	139.70	0.08
		Paraserienthes falcataria	64.59	0.04
		Rimba	380.25	0.23
	Timber Estate (Outside	*Acacia spp.*	16,811.42	10.15
		Paraserianthes falcataria	5,441.42	3.29
		Dipterocarp	594.63	0.36
	Reforestration	*Pinus mercusii*	631.33	0.38
		Tectona grandis	99.80	0.06
		Acacia spp.	724.67	0.44
		Eucalyptus spp.	173.92	0.11
		Others	1,638.18	0.99
	Other Forests	Production Forest	16,703.20	10.09 ←
		Conversion Forest	10,661.11	6.44
		Protection + Conservation Forest	10,047.61	6.07
		Others*	23,777.38	14.36 ←
Non Forest land	Afforestration	*Pinus spp.*	2,776.07	1.68
		Acacia spp.	8,549.13	5.16
		Eucalyptus spp.	3,556.44	2.15
		Paraserenthis falcataria	7,266.57	4.39
		Others	567.17	0.34
	Estate	*Havea Brazillianceae*	17,871.04	10.79 ←
		Coconut	27,029.13	16.32 ←
		Oil Palm	3,694.44	2.23
		Others	2,693.80	1.63
			165,607.93	

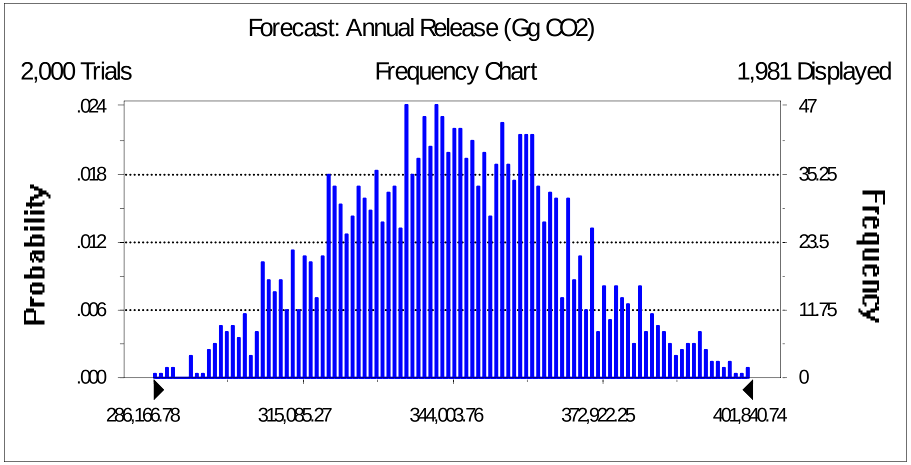
Assumed uncertainty levels are 20% for AD and EF

Similar for F&G Conversion, i.e. Converted area, biomass before and after conversion

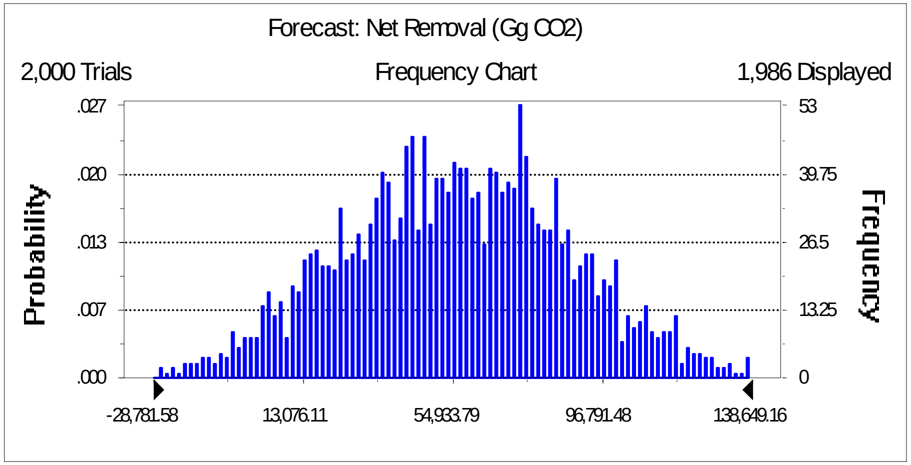


Uncertainty for AD and EF: 20%

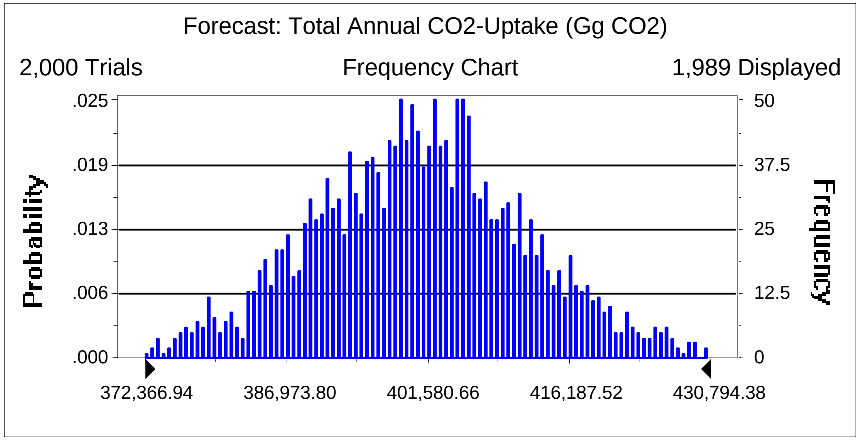
Mean = 400,653 Gg CO_2
SDev = 22,606 Gg CO_2
Uncertainty 11.2%



Mean = 343,664 Gg CO_2
SDev = 22,357 Gg CO_2
Uncertainty 13.2%

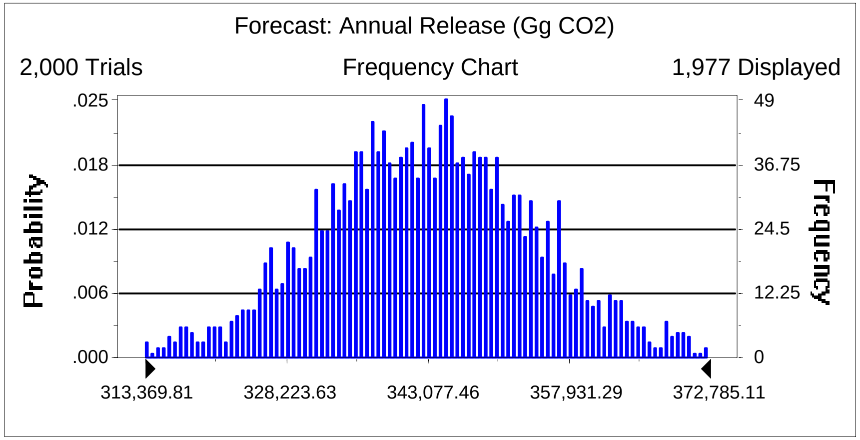


Mean = 59,989 Gg CO_2
SDev = 32,250 Gg CO_2
Uncertainty 107%

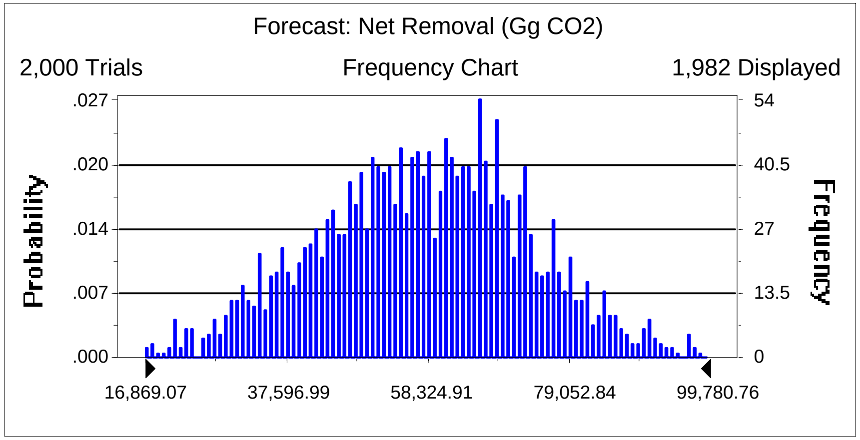


Uncertainty for AD and EF: 10%

Mean = 400,653 Gg CO_2
SDev = 11,089 Gg CO_2
Uncertainty 5.5 %



Mean = 343,664 Gg CO_2
SDev = 11,531 Gg CO_2
Uncertainty 6.7%



Mean = 59,989 Gg CO_2
SDev = 15,844 Gg CO_2
Uncertainty 52%

Level of uncertainty would depend on

- the complexity of LULUCF (number of land use categories)
- Size of area under study
- Resolution of images ~ area estimates of LULUCF
- Method of averaging MAI, Biomass density (non-weigthed or weigthed mean)

Future Works

- Assessing the impact of changing resolution of satelite image on:
  - area estimates
  - above gound biomass estimates ~ allometric equations, expansion factor (rules: as simple as possible)
  - Level of uncertainty of C-emission and C-uptake estimates ~ cost effectiveness
- Development of model for estimating MAI
- Development of more effective and efficient procedures for estimating AD and EF


THANK YOU