Effect of Inventory Precision and Variance on the Estimated Number of Sample Plots and Inventory Variable Cost: The Noel Kempff Mercado Climate Action Project

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Under Contract to the World Bank

July 28, 1999

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Introduction

This study looks at the effect of different levels of inventory precision and variance on the estimated number of sample plots and their associated costs in the Noel Kempff Mercado Climate Action Project in northeastern Bolivia. This 30-year, $9,00,000 project is co-funded by American Electric Power, PacifiCorp, BP America, The Nature Conservancy, Friends of Nature Foundation and the government of Bolivia. In 1997, Winrock International was contracted by The Nature Conservancy to develop a carbon inventory and monitoring plan, help conduct the baseline inventory, and calculate the potential offsets over the life of the project. To estimate these carbon quantities, Winrock International used inventory methods and procedures based on commonly accepted forestry, soil science, and ecological survey principles and practices. The monitoring system is designed to provide a commercial inventory of carbon in biomass and soils at a level of precision specified by the project sponsors, in this case an estimate within 20% of the mean at 95% probability.

The Noel Kempff project area (634,286 ha) contains woody vegetation that can be grouped into six general classes: 1) tall evergreen forest; 2) mixed liana forest; 3) liana forest; 4) tall flooded forest; 5) short flooded forest, and; 6) burned forest. In 1997, Winrock International, in collaboration with the Noel Kempff Mercado Museum of Natural History in Santa Cruz, established 625 permanent sample plots in the six vegetation types and measured the four main carbon pools: above-ground biomass; understory biomass; standing litter; and soils. Below-ground biomass was estimated to be 25% of above-ground biomass.

To determine above-ground biomass, the diameter of all woody vegetation of greater than 5 cm in dbh (diameter at breast height, 1.3 m) was measured using standard metric diameter tape techniques. Smaller diameter woody vegetation (dbh less than 5 cm) was assessed using circular clip plots. Individual dbh values per plot were converted to biomass using single-entry biomass equations. Soil organic carbon was determined from soil samples collected from the 0-30 cm horizon. Biomass was converted to carbon using a factor of .5. A summary of the main carbon pools is presented in table 1.

Carbon benefits will result primarily from the cessation of logging and conversion of forested lands to agriculture. Carbon conserved will come from the following sources:

Averted logging (Component 1):

- removal of commercial timber will be halted
- damage of unharvested trees will be eliminated

Averted conversion of forested lands to agricultural uses (Component 2):

- loss of carbon in forest biomass will be halted
- loss of carbon from soil will be eliminated

Table 1. Summary of carbon stocks in the Noel Kempff Mercado project area (1997 inventory).

Strata	Area (ha)	Aboveground woody biomass t C ha^{-1}	Understory biomass t C ha^{-1}	Belowground Biomass t C ha^{-1}	Litter t C ha^{-1}	Soils t C ha^{-1}	Mean t C ha^{-1}	SD	Total Project Case t C
Tall Forest	226,827	139.6	2.0	34.9	3.6	28.5	208.6	103.6	47,316,112
Liana Forest	95,564	62.4	3.8	15.6	4.0	40.5	126.3	45	12,069,733
Flooded Tall	99,316	139.1	1.9	34.8	3.1	46.3	225.2	84.9	22,365,963
Flooded Short	49,625	120.2	2.1	30.0	2.9	55.5	210.7	87.6	10,455,988
Mixed Liana	159,471	101.8	2.6	25.5	4.3	24.5	158.7	80.6	25,308,048
Burned Forest	3,483	66.1	0.9	16.5	4.2	36.0	123.7	82.1	430,847
Total	634,286								117,946,691
Weighted Mean		117	2.4	29	3.7	34	184		

Statistics

Calculated precision (error as % of mean):	4.0
Confidence interval (minimum)	112,868,348
Confidence interval (maximum)	122,324,901

In addition, forest biomass losses due to road construction will be halted and fuel consumption for both road construction and logging activities will be reduced. These potential sources of carbon offset benefits were not included in the calculation of project benefits but are important additional measures of conservatism.

The project is designed in two Components. Component 1 conserves stored carbon through the aversion of logging that has resulted from the indemnification of timber concessions in the project area. Component 2 achieves carbon storage benefits by preventing biomass carbon losses from conversion of forests to agriculture. These benefits begin to accrue immediately and are projected to last 30 years. Future measurements of sample plots will be done in years 3, 5, 10, 15, 20, 25 and 30.

The model used for calculating carbon offsets in the Noel Kempff Mercado Climate Action Project is:

Component 1: $Net_c = C_p - C_L$ Component 2: $Net_c = C_P - C_{AG}$

Where: Net_c = net carbon conservation or avoidance

C_P = carbon stocks in preservation area (project case)

C_{AG} = carbon stocks in areas converted to agriculture (baseline or without- project case)

C_L = carbon stocks in logged forests (without-project case)

Sensitivity analysis was done for the estimated number of sample plots and total inventory cost at different levels of allowable error for total carbon (above-ground biomass; below-ground biomass; understory biomass; standing litter; and soil carbon) in all 625 sample plots[1] . The estimates for total inventory cost are based on the first inventory in 1997 and include variable costs only (field personnel, equipment, and logistics required to measure plots in each vegetation type). The plot establishment cost in the 6 vegetation types ranges from $230/plot in the burned forest to $281/plot in the very dense liana forest, with an average $241/plot for the six strata.

When fixed costs from the first inventory are also considered, the average per plot establishment cost for all strata increases to $560. Estimating future monitoring costs based on the first inventory is difficult because different sampling methods and sampling intensities will probably be used at each measurement event. However, each future monitoring event will probably be less intensive and less expensive than the first inventory.

The effect of significance level and allowable error (as a percent of the mean) on the estimated number of sample plots and total inventory cost is shown in table 2 and table 3. The greatest number of plots is needed when the target allowable error is 10% of the mean (CI +/- 5%). The fewest number of plots is needed when the target allowable error is 60% of the mean (CI +/- 30%).

Table 2. Effect of allowable error on number of sample plots and total inventory variable cost at 95% probability.

Stratum description	Area (ha)	Cost per plot	Fixed precision level as % of mean P=.05 *Estimated number of plots* +/-5	+/-10	+/-20	+/-30
Tall Forest	226,827	$235	200	36	6	2
Liana Forest	95,564	$281	33	6	1	0
Flooded Tall Forest	99,316	$235	72	13	2	1
Flooded Short Forest	49,625	$235	37	7	1	0
Mixed Liana Forest	159,471	$241	108	19	3	1
Burned Forest	3,483	$230	2	0	0	0
TOTALS	634,286		452	81	14	4
Total variable cost (US$)			$108,385	$19,314	$3,388	$1,014

[1] See optimum allocation with varying sample costs in *Forestry Handbook* (2nd edition), ed. K.F. Wenger (New York: John Wiley and Sons, 1984), pp. 372-73.

Table 3. Effect of significance level (P=.01, P=.05 and P=.10) on number of sample plots and total inventory variable cost.

Stratum description	Area (ha)	Cost per plot	Fixed precision level as 10% of mean *Estimated number of plots* P=.01	P=.05	P=.10
Tall Forest	226,827	$235	62	36	25
Liana Forest	95,564	$281	10	6	4
Flooded Tall Forest	99,316	$235	22	13	9
Flooded Short Forest	49,625	$235	11	7	5
Mixed Liana Forest	159,471	$241	33	19	14
Burned Forest	3,483	$230	1	0	0
TOTALS	634,286		139	81	57
Total variable cost (US$)			$33,435	$19,314	$13,591

The effect of natural variation in the vegetation types on the estimated number of sample plots and total inventory cost is shown in table 4. Assuming that each vegetation type occupies the whole project area (634,286 ha), the burned forest would require the greatest number of plots and have the highest inventory cost. The liana forest would require the least number of plots, but the per plot establishment cost would be higher than the other vegetation types.

Table 4. Effect of variation in strata on estimated number of total plots and total inventory variable cost.

Assumes each strata is full area (634,286 ha)	Allowable error (% of mean)	Estimated number of plots to achieve allowable error	Total inventory variable cost
Tall forest	+/-10	96	$22,479
Liana forest	+/-10	49	$13,773
Tall inundated forest	+/-10	56	$13,094
Short inundated forest	+/-10	67	$15,686
Mixed liana forest	+/-10	100	$24,059
Burned forest	+/-10	169	$38,898

Increasing and decreasing the calculated variance of the sample by 50% increases and decreases the estimated number of sample plots and total inventory variable cost by the same amount (Table 5).

Table 5. Effect of variance on estimated number of total plots and total inventory variable cost.

Variance (calculated on all 625 sample plots)	Allowable error (% of mean)	Estimated number of plots to achieve allowable error (all strata)	Total inventory variable cost
original	+/-10	81	$19,314
.5 of original	+/-10	40	$9,657
1.5 of original	+/-10	121	$28,971