2001 Analysis of Leakage, Baselines, and Carbon Benefits for the Noel Kempff Climate Action Project

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The report is divided into two main sections: A) a summary of activities related to this project since 2000, including the new estimates for the baselines and carbon benefits for both the avoided deforestation and stop logging components; and B) leakage analysis of the project for the averted deforestation component and baseline and leakage analysis for the stop logging components. A separate report, attached (Appendix 1), deals with the baseline development for the averted deforestation component using GEOMOD (this work was mainly supported through a cooperative agreement between Winrock International and Office of Atmospheric Programs, US Environmental Protection Agency; Assistance ID No. CR 827293-02).

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Executive Summary

This report provides the final results of the most recent analyses of carbon benefits for the Noel Kempff Mercado Climate Action Project. These results are still subject to review and verification. The Nature Conservancy will evaluate further the report findings with outside experts prior to deciding how to treat them. The key findings are summarized below:

Work since 2000 and revised carbon benefits

- The best current estimates for the 30 year project life based on work since 2000 are:
  - 2,514,384 metric tons of carbon (10,162,647 short tons of CO_2) from avoided deforestation
  - 1,079,900 metric tons of carbon from stop logging (4,364,700 short tons of CO_2)
  - Total carbon benefits are 3,594,284 metric tons of carbon (14,527,347 short tons of CO_2)
  - Annual carbon benefits increased steadily during the project life, from about 13,500 t/yr in year one to 58,000 t/yr in year 30 for the stop logging component and from about 21,600 t/yr in year one to about 222,000 t/yr in year 30 for the avoided deforestation component.

- Re-analysis of the data collected from the 102 carbon impact zone plots installed in 1999 resulted in a new estimate of 3.0 t C damaged per ton of carbon harvested (95% CI was ±10% of the mean); this new estimate was used in the stop logging baseline scenarios.

- The GEOMOD revision of the avoided deforestation baseline increased the carbon benefit estimates from that component because the area projected to be deforested increased from 12,473 ha at the end of 30 years (the original estimate of the amount deforested) to a new estimate of 14,444 ha.

- The revised stop-logging baseline resulted in a large decrease in estimated carbon benefit from this component because of the large decrease in projected timber harvests (from about 12 cubic meters per ha to 3.3 cubic meters per ha cumulative over the 30 years).

- Overall the estimate of carbon benefits decreased significantly, from about 6.5 million metric tons of carbon to 3.6 metric tons of carbon over 30 years.

- Avoided deforestation now makes up the bulk (about 70%) of the offsets for this project.

Baseline and leakage assessment for averted deforestation

- Historical satellite data showing deforestation was incorporated into a multivariate spatial regression analysis through GEOMOD and the results used to project future trends.

- Because the revised baseline is spatially explicit, the precise forest area that would have been cleared has been predicted. The model suggested that, on average, the higher biomass areas would have been more likely to be cleared.

- The establishment of the NKCAP is averting land conversion activities from taking place and therefore creating a risk of 'activity shifting' or 'primary' leakage from occurring. The existing leakage prevention activities of the NKCAP are focused on the land conversion activities of the few communities surrounding the park boundary.

- In the short term, since the establishment of the project, the leakage prevention activities have been successful at limiting conversion (and possible leakage) by these particular communities. Although some deforestation has occurred, it is primarily as a result of implementing natural resource management zoning and allocation of agricultural lands, i.e. planned project activities. Since these activities are planned, the project should consider incorporating them into the carbon flow analysis (project and baseline).

- Provided that the TCO status is achieved and sustainable management plans are implemented, longer-term management of the natural resources by these communities should be sustainable. As a result, leakage from these communities is unlikely to be an issue. This can be monitored in the future by checking that activities on the ground are adhering to the TCO management plans (these are yet to be developed) and could easily be integrated into the project monitoring and verification protocol, potentially by using remote sensing techniques.

- Over the longer term, it is likely that other sources of threats to the project area may become apparent (this is linked to the baseline) and therefore constitutes another source of potential leakage. In particular, this may be from the sporadic colonisation of the area, or from the approach of the agricultural frontier. A number of methods are proposed for trying to analyse, track and quantify this longer-term leakage. However, by the time these threats become a reality it is likely that other factors, such as national or regional policies will have a greater influence on land conversion patterns than the project. It is unreasonable to expect the project to be the cause of activity shifting leakage after a given period (a period of 10 years is suggested).

Baseline and leakage assessment for averted logging

- Changes in Bolivian timber law in 1996 have reduced concession holdings by 75% over the entire country. These reductions in concession holdings appear to have had a small effect on national harvests. The result is that the harvests per hectare of concession holdings have risen nationally from 0.02 m^3 per hectare before 1996 to 0.09 m^3 per hectare on average for the period 1996 to 2000.

- National harvests are projected to rise to approximately 0.93 million m^3 per year by 2026 if prices remain relatively stable to up to 1.0 million m^3 per year if prices rise at projected global rates of increase of 0.6% per year.

- Baseline harvests from the indemnified area are projected to average 73,000 m^3 per year over the period 1996 – 2026. Total potential savings are 2.2 million m^3 timber on the 661,000 hectares indemnified. The productive area that could be harvested comprises 521,000 hectares of this land, suggesting that the extraction rate is projected to be approximately 0.10

m^3 per hectare of concession per year, or 3.3 m^3 per hectare cumulative over the 30 year period, 1996 – 2026.

- If export demand is assumed to be perfectly elastic, and prices are not sensitive to the reduction in concession area caused by the indemnification, as is likely to be the case, leakage from this component is predicted to be 14% of total savings.

- If the indemnification causes prices to adjust, leakage would be higher, approximately 44%.

- Capital constraints do not appear to heavily affect long term investments in Bolivian timber markets, however, capital constraints can affect the time path of harvesting, and consequently, the time path of leakage.

A. Activities Since 2000 and Revised Estimates of Baseline and Carbon Benefits

1. Activities since 2000

The main activities that have taken place on this project since 2000 were a more thorough analysis of leakage for both the avoided deforestation and stop logging components and a more thorough analysis of the baselines for both components. The baseline for the avoided deforestation component had not been revised since the inception of the project back in 1996; the original deforestation estimates have remained constant with only slight modifications of the corresponding changes in carbon stocks.

Revision of logging impacts

In contrast, the baseline for the stop logging component has been revisited several times since the inception of the project. One of the main improvements was the field data collection for estimating the amount of damage produced during harvesting. The original field work in 1997 collected data on logging impacts for 10 plots only. In 1999, an additional 102 carbon impact zone (CIZ) plots were established.

For the calculation of damaged biomass carbon per ton of extracted timber biomass carbon, we needed to estimate the dbh of the harvested tree because the CIZ plots were installed after the timber tree had been extracted. In the 1999 report we used two approaches for estimating the dbh of the extracted tree, but on re-evaluation of the methods, we decided that the following method was the most valid one. First the stump diameter (ds) was measured, then the diameter of the bottom of the crown (dt), and finally the distance between the two was measured. The following formula was then applied to estimate dbh.

- estimate the taper factor of the tree = (ds-dt)/distance (cm per meter)
- estimate dbh = [ds –(the taper factor *1.3)]; where: 1.3 = height where dbh is measured

Using this method for estimating dbh of the harvested tree and the field measurements we obtained the following results (revised from the 1999 report).

Table 1. Results of the 102 CIZ plots measured in Cerro Pelao in 1999.

Statistics	Damage C per t C extracted
Range	0.60 – 11.49
Mean	2.98
S.E.	0.15
95% CI	± 10.1%

The results here are slightly higher than those reported in the 1999 report (mean of 2.21 t damage per t extracted). Although the slightly higher damage implies higher credits when stopping logging, this is somewhat offset by the larger dead wood pool.

Revision of carbon stocks in agricultural vegetation

In previous analyses of the avoided carbon emissions from averted deforestation, we assumed an average carbon stock in the agricultural vegetation of 5 t C/ha. A re-assessment of this based on experience in other carbon pilot projects and a review of the literature, we conservatively estimate the carbon in agricultural vegetation at 2.5 t C/ha. Most of the converted land is used for either annual crops or pastures, with some perennials, and the carbon in most annuals is on average no more than about 1.5 t C/ha (over the annual cycle). Presence of some perennials could raise this on average to 2.5 t C/ha.

2. Revision of baselines and carbon benefits

Stop logging

The work by Brent Sohngen (see section B-3, below) resulted in new harvesting scenarios for the Noel Kempff without-project case. The details and assumptions of the scenarios are presented below in section B-3 (Leakage Analysis). Based on the likely conditions of the timber sector in Bolivia, it was felt that the perfectly elastic export demand with constrained capital scenario was the most reasonable scenario to use for the Noel Kempff without-project baseline.

The annual rates of timber extraction were combined with the damage factor and rates of dead wood decomposition as in the 1999 report to estimate the baseline carbon emissions. As the with-project case causes no change in the project area's carbon stocks, the baselines of what would have been lost essentially represents the carbon benefits from this component.

The estimated carbon benefits from the stop logging component range between 1.08 to 1.10 million t C over the 30-year project life (Table 2; Figure 1). The range here reflects the uncertainty in the decomposition rate, with the higher decomposition rate associated with higher benefits. The carbon benefits increase through time due to increases in expected harvest rates and due to the gradual stabilization of the dead wood pool (new inputs are eventually balanced by emissions from decomposition).

The estimated carbon benefits in Table 2 do not account for losses due to leakage. The analysis of leakage for the logging component is described in Section 2-B below. Accounting for leakage using the 0.07/yr decomposition rate results in an estimated carbon benefit of 0.887 million t over the 30 year project life. The leakage factor decreases through time, representing 29% of the carbon benefits in year one to 7% in year 30.

The estimated carbon benefits from the stop logging component (without leakage) are conservatively estimated at 1,080,000 t C, and increase through time from about 13,500 t C per year in year one to about 58,000 t C per year in year 30 (Figure 1).

The revised carbon benefits reported from this component are about one-fourth of those estimated in previous analyses (Figure 1) due to the revised extraction rate.

Table 2. Calculations of carbon benefits due to stopping logging using the perfectly elastic export demand with constrained capital scenario and without adjustments for leakage (from section B-3 below), and a decomposition rate (k) of 0.07/year.

Live biomass removals							
Year	Volume removed 10^3 m^3/yr	Total C removed 1000 t C/yr	Damaged biomass 1000 t C/yr	Dead wood pool 1000 t C	Change in dead wood pool 1000 t C/yr	Wood products 1000 t C/yr	Benefits (k= 0.07) 1000 t C/yr
1	64.5	53.9	34.6	35	35	6	13.5
2	64.5	53.9	34.6	67	32	6	15.9
3	64.5	54.0	34.6	97	30	6	18.1
4	64.5	54.0	34.6	125	28	6	20.1
5	64.6	54.0	34.6	151	26	6	22.0
6	64.6	54.0	34.6	176	24	6	23.8
7	64.8	54.2	34.7	198	23	6	25.5
8	65.0	54.3	34.9	220	21	6	27.1
9	65.2	54.5	35.0	240	20	6	28.6
10	65.4	54.7	35.1	259	19	6	30.0
11	65.6	54.9	35.2	277	18	6	31.3
12	66.0	55.2	35.4	293	17	6	32.5
13	66.3	55.5	35.6	309	16	6	33.7
14	66.7	55.8	35.8	324	15	6	34.9
15	67.0	56.1	36.0	338	14	6	36.0
16	67.4	56.4	36.2	351	13	6	37.0
17	67.3	56.3	36.1	364	12	6	37.9
18	67.2	56.2	36.0	375	11	6	38.7
19	67.1	56.1	36.0	386	11	6	39.4
20	67.0	56.0	35.9	395	10	6	40.1
21	66.8	55.9	35.9	405	9	6	40.8
22	72.1	60.3	38.6	416	11	6	42.5
23	77.3	64.6	41.4	429	13	7	44.3
24	82.5	69.0	44.2	444	15	7	46.3
25	87.7	73.3	47.0	461	17	8	48.5
26	92.9	77.7	49.8	480	19	8	50.7
27	95.4	79.8	51.2	499	19	9	52.5
28	98.0	82.0	52.6	518	19	9	54.3
29	100.5	84.1	53.9	537	19	9	56.1
30	103.1	86.2	55.3	556	19	9	57.9
Total	**2,191.1**	**1,832.7**	**1,175.3**		**556**	**197**	**1,079.9**

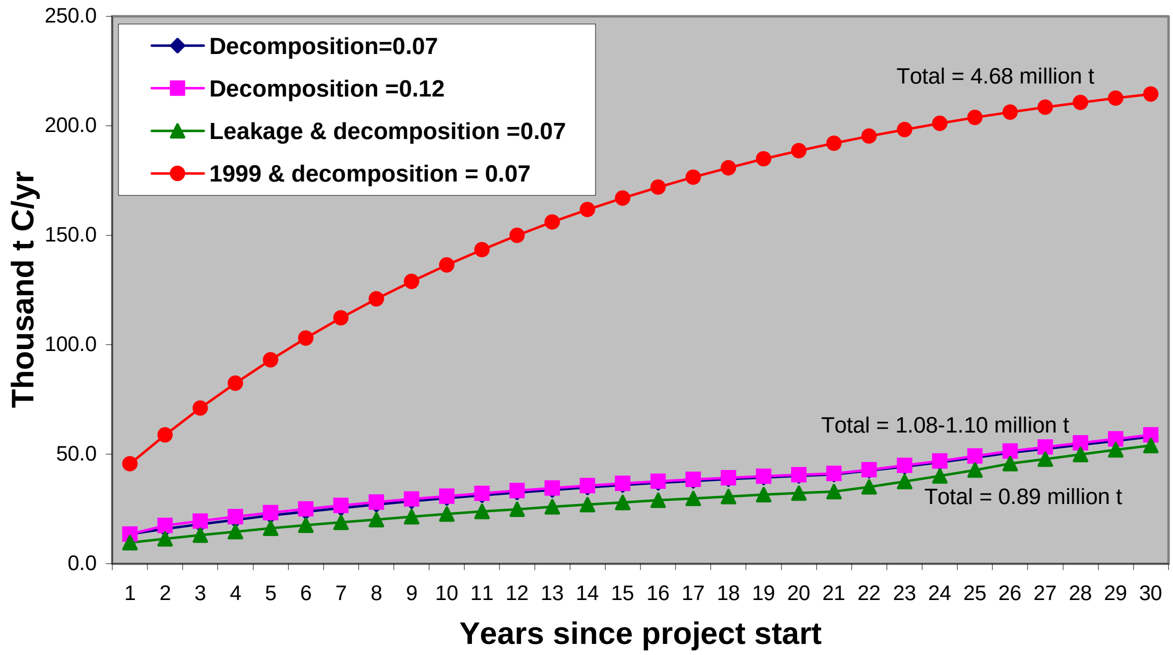


Figure 1. Annual pattern of carbon benefits by the stop-logging component for four scenarios

Avoided deforestation

The new analysis of the projected baseline for the avoided deforestation component resulted in new projections of the deforestation rate, which were matched to the forest type and corresponding carbon content (see Appendix 1). The results given in Appendix 1 do not take into consideration the amount of carbon in replacement vegetation (agricultural crops) and this adjustment has been made here using the data described above under section 1.2.

For comparison, we used the deforestation data generated by GEOMOD and ran several simulations using area weighted carbon densities of the forest vegetation and soil as done in previous analyses (1999 report). This enabled us to determine the sensitivity of estimated carbon benefits to the carbon contents of the forests. For further comparison we include the estimated carbon benefits produced in the 1999 report (Figure 2).

The estimated total carbon benefits from the GEOMOD projections are 2.51 million t C over the 30 year period. This is about 20% higher than that obtained by using the same deforestation rates but the weighted carbon density (2.10 million t C). The 1999 estimate of the carbon benefits was 1.98 million t C; the GEOMOD estimate is about 27% higher than this. The higher estimate of the carbon benefits is due to two reasons: (1) the projected deforestation over the 30 year period from GEOMOD is 14,444 ha compared to 12,473 ha from the original analysis, and (2) GEOMOD matches the area of a given forest type being cleared to the carbon content of that forest, and those forest with higher carbon contents such as tall inundated forests were commonly “cleared”. The area-weighted average carbon density of the forests being cleared using GEOMOD is 174 t C/ha compared to 146 t C/ha using GEOMOD deforestation and the 199 method.

Table 3. Estimates of the carbon benefits from the avoided deforestation component based on rates of deforestation projected by GEOMOD. The total carbon emissions avoided are estimated (1) by the 1999 method that uses a weighted average carbon content in vegetation and soil and (2) by the GEOMOD method that matches the forest type being deforested to the carbon content of that forest type (see Appendix 1).

Year	Cumulative area cleared (ha)	Area cleared (ha/yr)	Total-1999 method (t C/yr)	Total GEOMOD (t C/yr)
1997	137	137	18,776	21,619
1998	377	240	33,288	37,483
1999	527	150	21,595	26,772
2000	676	149	21,810	28,508
2001	840	164	24,280	31,012
2002	1,037	197	28,944	36,026
2003	1,142	104	16,091	19,600
2004	1,205	63	10,278	12,425
2005	1,322	118	17,556	21,027
2006	1,833	511	71,391	80,119
2007	2,360	526	74,301	88,082
2008	3,054	695	98,522	123,946
2009	3,868	813	116,499	146,911
2010	3,881	13	8,583	9,114
2011	4,129	248	39,513	50,359
2012	4,522	393	58,611	71,744
2013	4,668	146	23,933	27,754
2014	5,037	369	52,696	58,375
2015	5,243	207	31,435	38,190
2016	5,504	260	38,670	47,354
2017	5,964	461	65,808	76,952
2018	6,456	491	70,819	85,615
2019	6,959	504	72,861	88,705
2020	7,542	583	84,528	102,761
2021	8,389	847	121,619	147,477
2022	9,284	894	129,129	157,619
2023	10,985	1,701	240,850	299,691
2024	11,857	872	130,332	144,849
2025	13,093	1,237	181,135	212,374
2026	14,444	1,351	197,827	221,921
Total		**14,444**	**2,101,683**	**2,514,384**

The carbon benefits increase through time as deforestation pressures increase—from about 21.6 thousand t C per year in year one to 221.9 thousand t C per year in year 30 (Figure 2). Increasing or decreasing the carbon content of the forest being cleared by the 95% CI increases or decreases the total benefits by about 5%. This is to be expected because of the highly precise measurements of the carbon stocks made in this project (see 1999 report).

The assessment of leakage for this component concluded that no leakage has occurred to date and that if anything their may be some positive spillover effects that could be claimed (see section 3.1). Thus no adjustments were made to the estimated carbon benefits to account for leakage for this component.

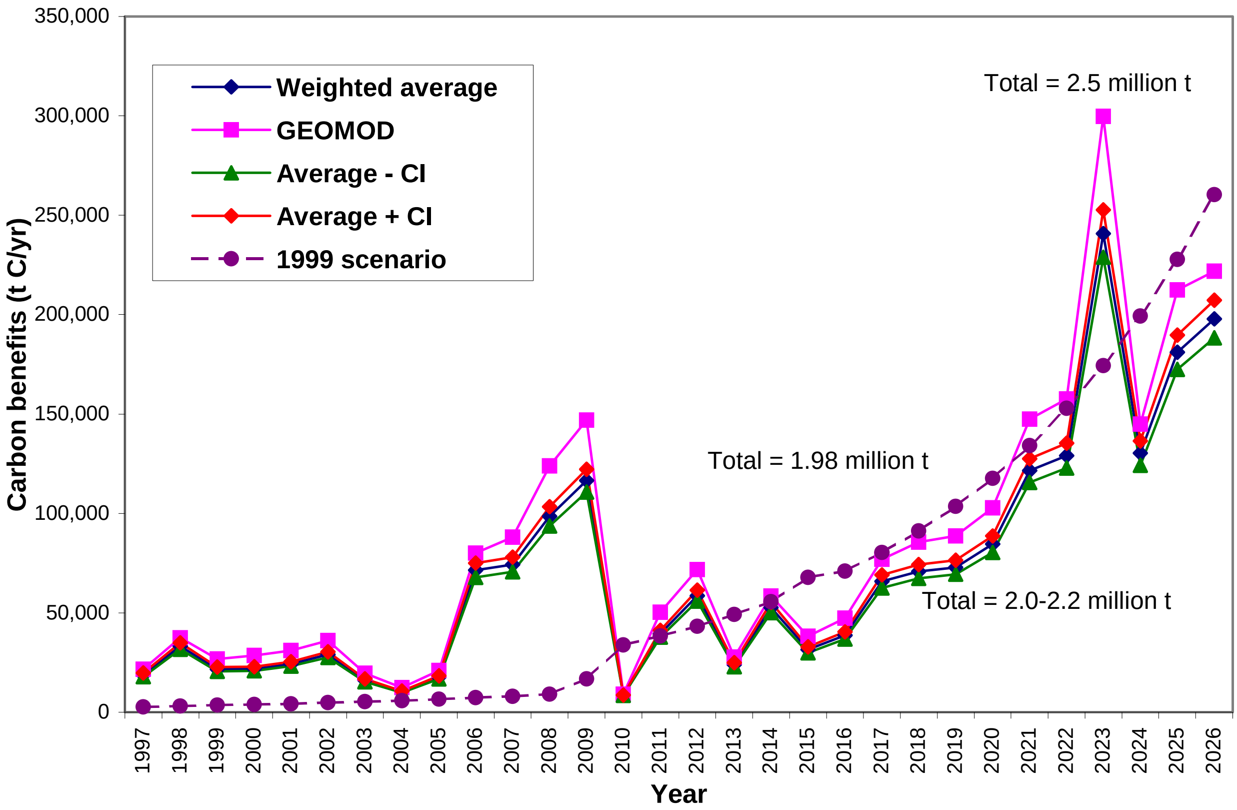


Figure 2. Annual pattern of carbon benefits by the avoided deforestation component for four scenarios.

Total carbon benefits

The total carbon benefits based on these new analyses are 3.59 million t C, and range from 35.2 thousand t C in year one to about 300 thousand t C during the last few years (Figure 3). In the 1999 report, the majority of the carbon benefits were derived from the stopping logging component. However , from this new analysis, 70% of the benefits are derived from the avoided deforestation component.

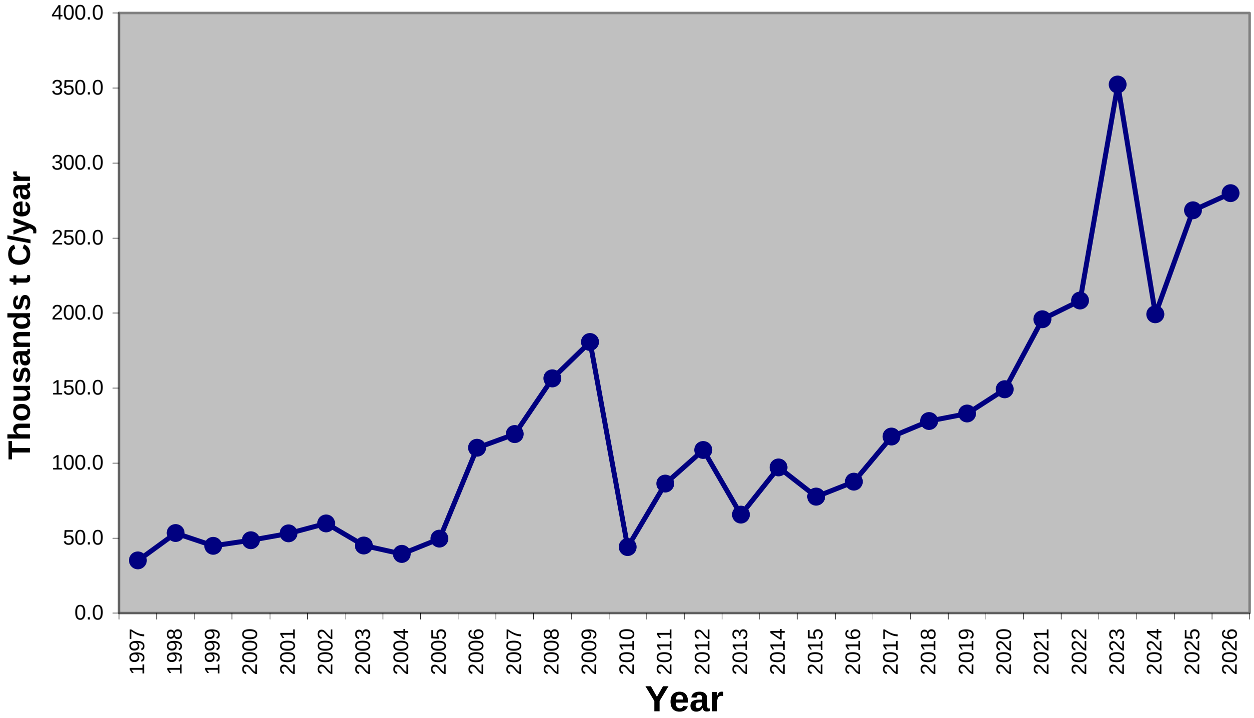


Figure 3. Sum of the annual carbon benefits from both avoided deforestation and stop-logging components over the project life.

B. Leakage Analysis

The goals for this study are summarised as:

1. *An evaluation of the leakage that may have occurred since the establishment of the NKCAP and an estimation of what the longer term extent of leakage might be.*

2. *Analysis of the NKCAP leakage prevention activities to see whether or not they have been effective in preventing or reducing leakage.*

3. *Recommendation for future leakage prevention and monitoring – based on the results of the leakage quantification and the evaluation of existing leakage prevention measures.*

There are two aspects to the leakage analysis for the NKCAP. The first addresses the leakage associated with the averted land conversion and the second aspect is the leakage associated with the averted logging activities. The flow diagrams (Figures 4-6) show a conceptual overview of the possible sources of leakage according to the framework developed by Aukland *et al* in a draft paper (presented in the interim report). The generic framework is presented first, followed by an analysis for the averted land conversion and finally leakage associated with averted logging. These brief analyses are investigated in more detail throughout the subsequent reports.

Figure 4. Decision tree for identifying the types of leakage likely to impact land-use projects.

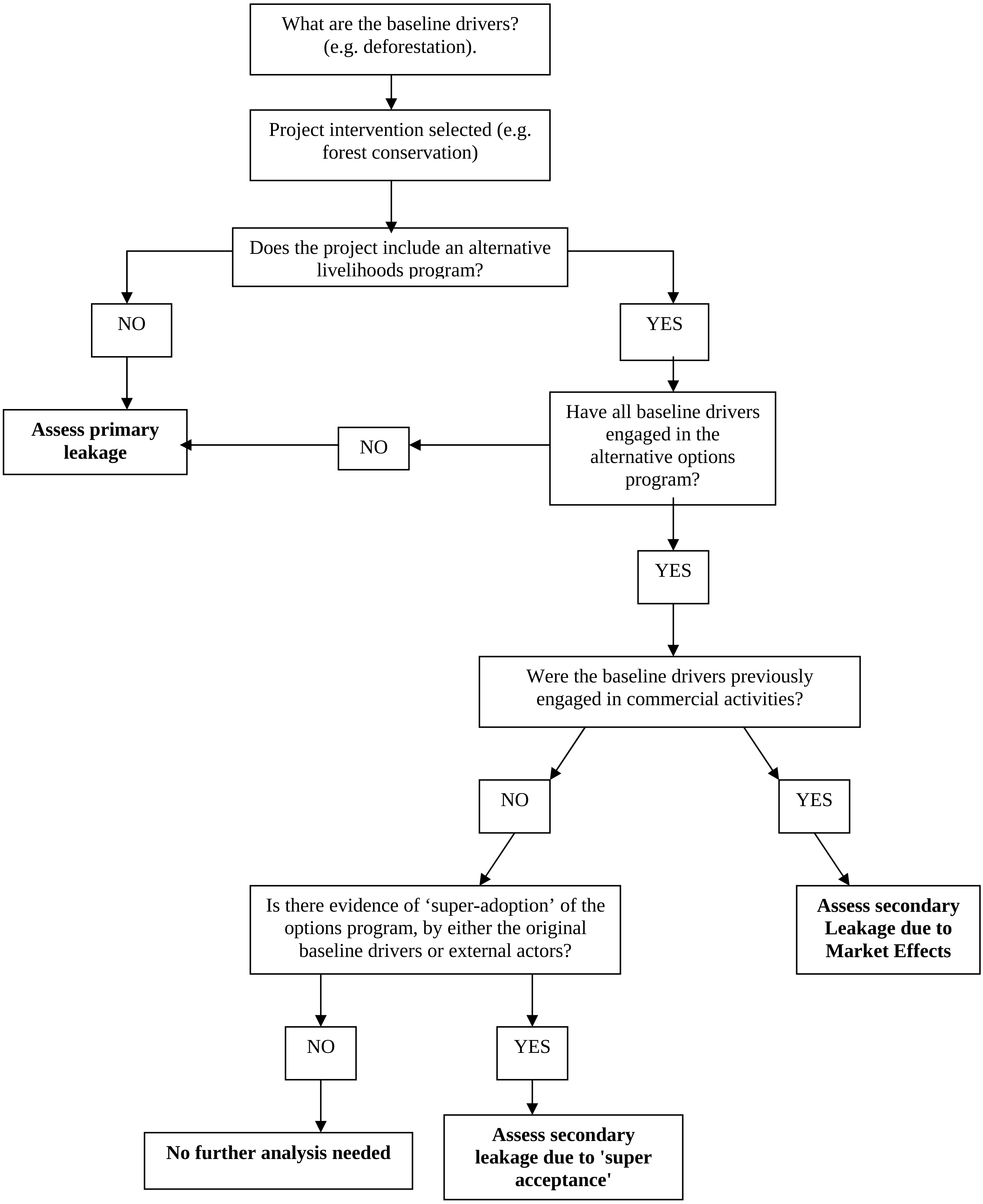


Figure 5. Decision tree for identifying the types of leakage associated with averted land conversion activities.

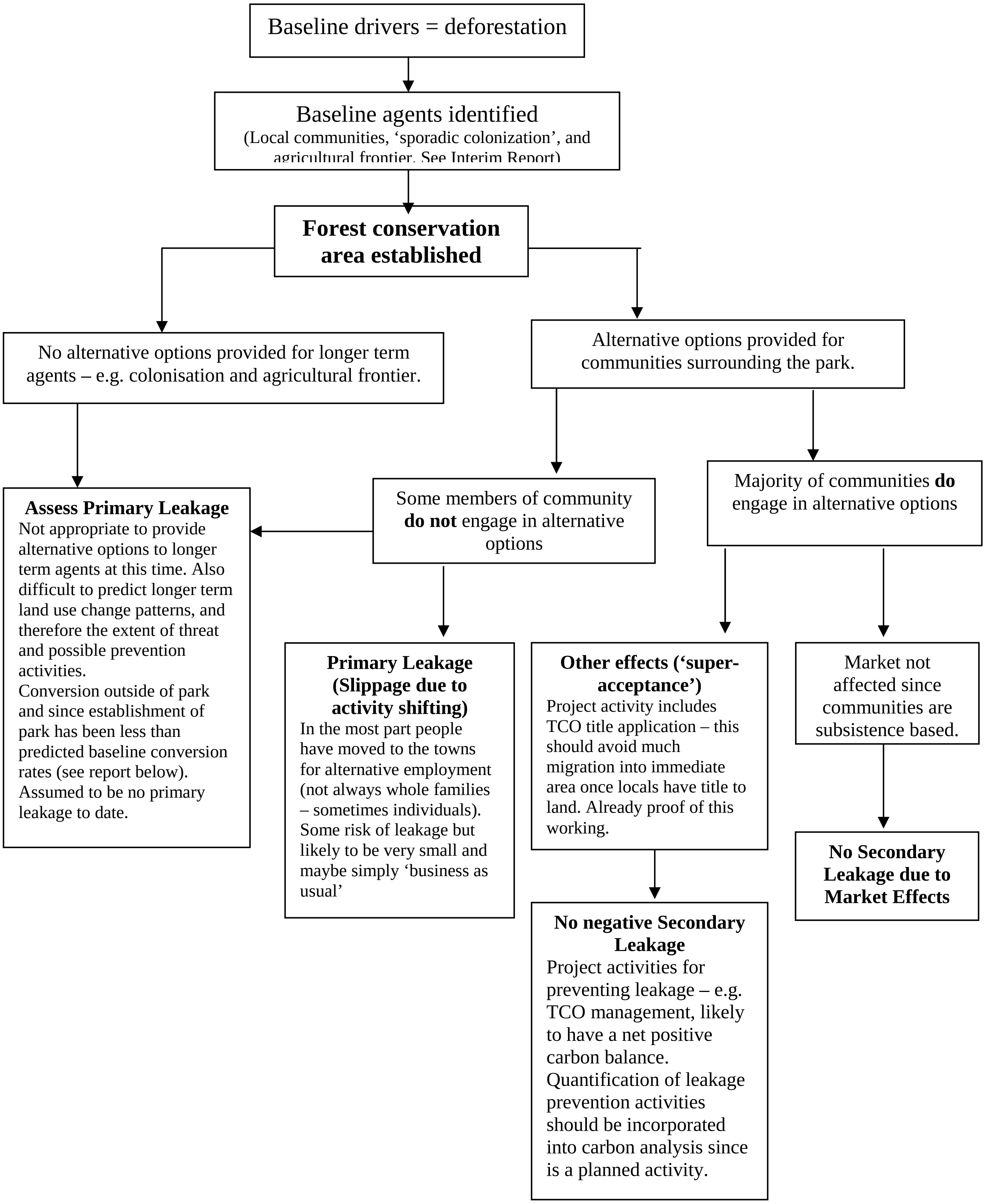
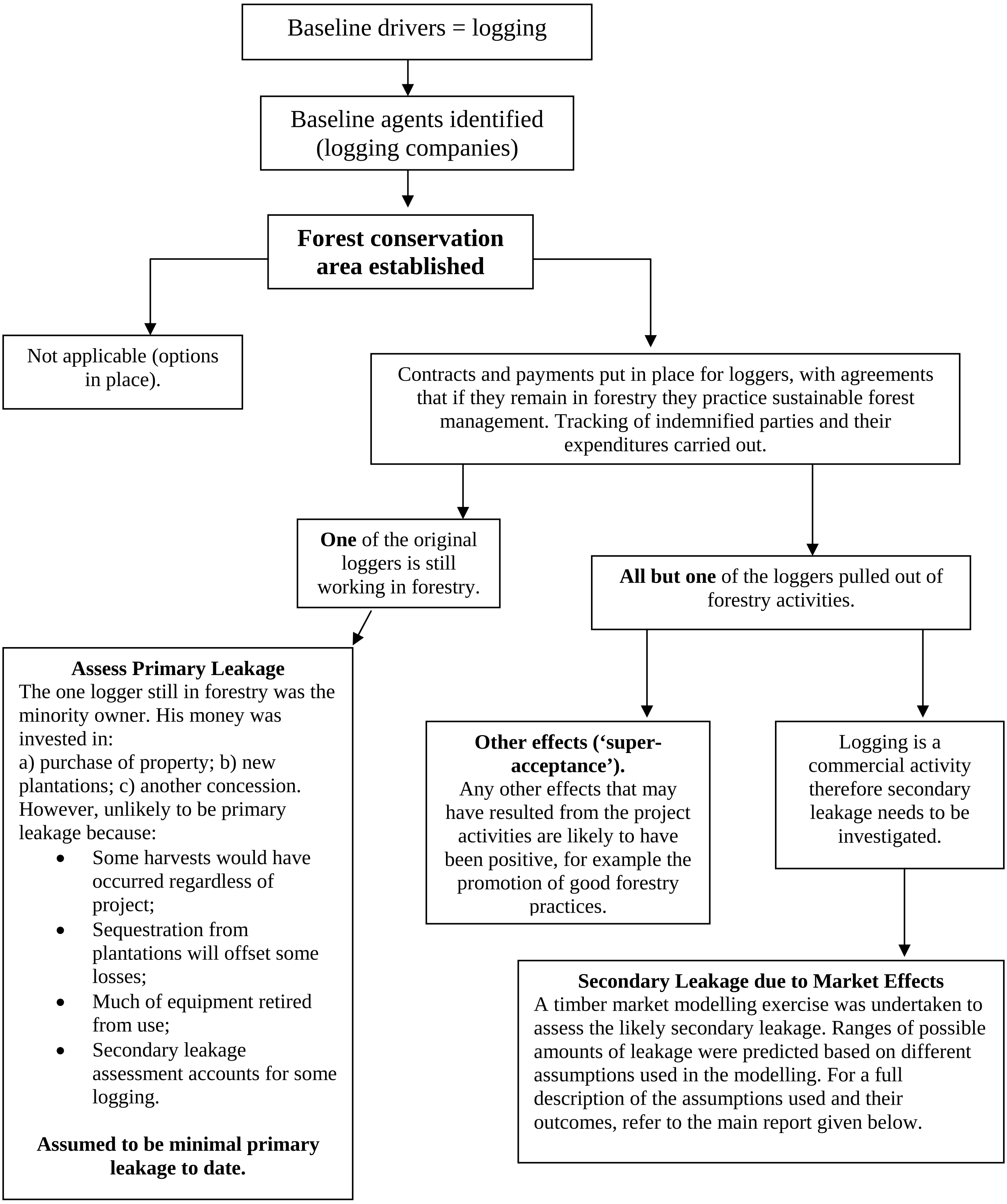


Figure 6. Decision tree for identifying the types of leakage associated with averted logging activities.



3. Leakage Associated with Averted Land Conversion Activities

3.1 An evaluation of the leakage associated with averted land conversion, which may have occurred since the establishment of the NKCAP.

One of the main types of leakage that can occur as a result of forest conservation projects is the shifting of land conversion activities to areas outside of the project, thus partially or entirely negating the GHG benefits associated with the prevention of such activities (Aukland *et al*, 2001). In the few years since the establishment of the NKCAP, the largest threat of leakage associated with land conversion is from the communities living on the border of the park. This is because the area is relatively isolated at present and land use change trends are not particularly evident in the area immediately surrounding the park. As a result, the project has been implementing leakage prevention activities with these communities and these will be assessed further below. This section will evaluate whether or not leakage associated with land conversion has occurred since the establishment of the NKCAP drawing on data collected by the project and from external sources.

The original methodologies suggested by EcoSecurities for assessing whether or not, and how much, leakage has occurred since the establishment of the NKCAP (see interim report section 2.4) proved to be inappropriate at this stage of the project. This was a geographically based approach, using various sources of statistics but due to the limited time that has passed since the project started and therefore the limitation and variability in data sources, the trends that are being investigated are masked. An alternative and simpler method is described below.

The projects “Apoyo Comunitario” or APOCOM programme has been carrying out ongoing monitoring in the 3 main communities surrounding the NKCAP, namely Florida, Piso Firme and Porvenir. The approach used is more ‘people centered’ than geographically based. Data that has been collected include the number of families, forest conversion (mature and disturbed), agricultural data, information relating to health and education, etc. The information has been gathered via interviews with the communities and includes estimates of deforestation and population in years prior to the projects establishment. The results of this monitoring, which relate to land conversion, are given in Quispe and Vaca 2001 and their potential use is discussed in the Interim Report sent in August 2001.

The information relating to land conversion can be used to compare land conversion and carbon loss resulting from the communities’ activities both before and after the establishment of the NKCAP (or ‘project’), as shown in Table 4 below. Average carbon loss per year is calculated by:

$$\text{Average carbon loss per year} = H * C * F$$

Where:
H: average number of hectares converted per family per year
C: average net carbon difference between forest and agriculture per hectare (tC/ha)
F: total number of families in the community

Table 4. Average land conversion and carbon loss per year for the three key communities, before and after the establishment of the NKCAP.

	Forida	Porvenir	Piso Firme	Average
Before project establishment				
Mean deforestation (ha/yr/family)	0.70	0.73	0.46	0.63
Net carbon loss per ha	132.00	132.00	132.00	132.00
Number of families (mean)	45.00	79.00	70.00	64.67
Average carbon loss (tC/year)	*4,158.00*	*7,612.44*	*4,250.40*	*5,340.28*
After project establishment				
Mean deforestation (ha/yr/family)	0.65	0.98	0.97	0.87
Net carbon loss per ha	132.00	132.00	132.00	132.00
Number of families (mean)	24.50	88.75	83.50	65.58
Average carbon loss (tC/year)	*2,102.10*	*11,480.70*	*10,691.34*	*8,091.38*

These data show an increase in the average carbon loss per year since the establishment of the NKCAP when compared with the situation before the project. Population levels in the communities have remained relatively static since project establishment (Quispe and Vaca, 2001) therefore such results are unlikely to reflect an increase in demand for land due to population increases. The change in average carbon loss could be due to a number of factors, including:

a) The increase in land conversion is simply reflecting fluxes in data rather than actual trends in land conversion.
b) Project activities have resulted in increased land conversion in the years monitored so far.
c) Trends in conversion are reflecting expected baseline increases in conversion for the region, i.e. are not as a result of project activities.

The data used in Table 4 are based on interviews and meetings held in the communities. Data prior to the project are limited, whereas post-project data are based on thorough research and sampling and are likely to be accurate. This discrepancy and the fact that it is only 4 years since the project was established, may have contributed to the differences found in average land conversion and carbon loss shown in Table 4.

One of the project activities being carried out by APOCOM is the promotion of agricultural techniques and planning that will reduce the extent of forest clearing in the longer term. However, in the first few years of the programme some land redistribution has occurred in order to select appropriate sites and allocate land to families in preparation for longer term sustainable farming techniques. This may have caused the observed increase in land conversion, but is unlikely to be a long-term trend.

More importantly, it is necessary to consider whether or not the increases in land conversion since the project's establishment are simply a reflection of baseline trends in the Bajo Paragua region. If they are equal to, or less than, predicted trends in land conversion that would have occurred without the project, then no activity shifting leakage associated with land conversion has occurred since the establishment of the NKCAP. A range of published deforestation rates exist that might apply to the region in which the NKCAP is located, many of which are given in Quispe and Vaca, 2001. Table 5 uses these deforestation rates to calculate the number of hectares that would be converted each year for the different deforestation rates and compares it with actual conversion. These calculations use a total forest area of 329,103 hectares, which is the forest area of the Bajo Paragua TCO[1]. It also represents the limit of the area monitored by the APOCOM programme and therefore enables a deforestation rate to be calculated from the data presented earlier in Table 5, as shown below:

Total forest area in TCO (ha)	329,103 ha
Mean annual deforestation in TCO (ha/yr)	184 ha/yr
Deforestation rate (%)	0.056 %

This allows comparison with published estimates of deforestation and land-use change, as shown in Table 5.

Table 5. Application of published baseline deforestation rates to the TCO area and comparison with actual land conversion.

Source*	deforestation rate %	details	deforestation ha/yr**
CUMAT 1992 (cited by Pachecho, 1998)	0.2	Deforestation in Santa Cruz department (1985-2000)	658
CUMAT 1992 (cited by Pachecho, 1998)	0.19	For the Amazon region	625
Morales 1993, 1996 (cited by Pachecho, 1998)	0.08 (1982-92) and 0.19 (1992-94)	For Chiquitania region	263 and 625
Morales 1993, 1996	0.25 (1988-92) and 0.38 (1992-94)	Deforestation in Santa Cruz department	823 and 1251
Davies 1993	1.04	For the Santa Cruz expansion area (under high pressure)	3,423
APOCOM data	0.056	Based on monitoring data for the TCO region	184

** For further information see FAN's final report 2001

*Assuming the TCO as the boundary with total forest cover = 329,100 ha

Note that all the published deforestation rates are higher than the values determined in reality since the establishment of the NKCAP. This would suggest that actual deforestation is less than would have been expected according to baseline conditions, and therefore that we can safely assume that there has been no leakage associated with averted deforestation to date.

In addition to the above comments, it is likely that the end result of the conversion of the forests may be more beneficial in terms of carbon storage in the longer term, than might have been the case in the business as usual scenario. For example, rather than convert for pure agricultural crops or animal grazing, the land may be used for agroforestry activities. If a more thorough analysis of the carbon flows associated with the leakage prevention activities were undertaken, the exact carbon effects would be clearer. Since the leakage prevention activities were planned

[1] Local indigenous groups are allowed to apply for a TCO or 'Tierras Comunitarias de Origen' which will grant them the rights to sustainably manage the natural resources of an area of land. As part of the application for land title rights, the applicants must produce a detailed natural resource management plan. The Bajo Paragua TCO has been applied for by the communities surrounding the NKCAP, and for the purpose of this analysis it has been assumed here that it is representative of the area under the influence of these communities.

activities at the time of project establishment, there is some case for them to be included in the project and baseline carbon quantifications.

3.2 An evaluation of the avoided deforestation leakage prevention activities.

An outline of the leakage prevention activities being carried out by the NKCAP was given in the interim report, and a more thorough description can be found in the project's Technical Operating Protocols (1999). With the assistance of the community programmes "Apoyo Comunitario – APOCOM" and the work of FAN, the communities surrounding the Noel Kempff park have developed a management plan for the natural resources of the Bajo Paragua TCO, for which they are applying for title from the government. The preliminary basis for a management plan (Catari *et al*, 1998) gives a more thorough description of how the TCO region will be sustainably managed, encompassing the leakage prevention activities within it. Assuming the TCO is granted and the communities manage the area as proposed in the management plan[2], it is likely that this will provide an effective buffer to the park, and a mechanism to prevent leakage associated with averted land conversion, because:

- Communities have an incentive to manage the resources sustainably if they have legal title to the land;
- Communities will have a legal right to refuse outsiders access to lands within the TCO;
- The planning and zoning process reduces the risk of uncontrolled forest conversion within the TCO, both through effective site choice for agriculture;
- Resultant sustainable forest management and agroforestry practices ought to ensure that forest products are provided without the need for ongoing forest clearance;

Already, even in the absence of the TCO confirmation, there is evidence that the ongoing activities are providing a mechanism for reducing land conversion in the region. These are outlined in FAN's report (Quispe and Vaca, 2001), but notably, an application by an outsider to clear 200 ha of forest in the Piso Firme area was refused by indigenous authorities as a result of ongoing TCO planning. There are likely to be numerous positive carbon benefits resulting from the projects leakage prevention activities, in particular the establishment of forest reserves within the TCO and a long-term reduction in the clearance of forest compared with predicted baseline scenarios (see section 3.1 above).

Based on this information, there is little doubt that the leakage prevention activities being implemented by the project are eliminating the likelihood of leakage occurring as a result of clearing activities by the communities immediately surrounding the park. They have provided alternative options to forest conversion, within the context of applying for a sustainably managed TCO, which have been successful in preventing leakage to date.

In the longer term, the TCO is likely to continue to be an active prevention mechanism for leakage associated with land conversion by the affected communities, provided that a detailed management plan is proposed and the plans outlined are adhered to. However, depending on the threats to the forest in the longer term and the agents that would have influenced the predicted baseline, the project may require alternative activities in the future (as discussed below).

[2] It is understood that a more detailed and thorough management plan will be written for the TCO Bajo Paragua region.

3.3 Estimating long-term leakage resulting from averted deforestation activities.

Predicting the extent of leakage that might occur in the longer term is a difficult exercise given the range of factors that may affect land use change outside of the project area, many of which may be unrelated to the project itself. The Interim Report discussed a number of tools that could be used to look at long term risks of leakage, including:

1. apportioning leakage to different baseline agents over time;
2. determining land availability for primary leakage, and the issue of time and boundaries;
3. conducting spatial land use change modelling.

The following sections look into each of these options in more detail, building on the work already presented in the interim report:

3.3.1 Apportioning responsibility for carbon offsets to different baseline agents over time

Due to the initial lack of definition associated with the baseline for averted deforestation for the NKCAP and the newly proposed spatial baseline, there have been difficulties in identifying baseline agents, and so this method of analysing the maximum potential for primary leakage may not be appropriate for this project at this stage. This approach, however, does provide a framework from which leakage prevention activities can be designed by focusing on the likely land-use change threats. A hypothetical example of how it can be used was given in the 2001 Interim Report and is shown again below:

Table 6. Hypothetical apportionment of responsibility for carbon leakage to different baseline agents over time

	Short term (0-10 yrs)	**Medium term (10-20 yrs)**	**Long term (20-30 yrs)**
Local communities	2%	3%	5%
Migration 'sporadic colonisation'	0%	25%	0%
Agricultural frontier	0%	5%	60%

Once the baseline is defined, it may be possible to use this method combined with the framework for assessing leakage (Aukland *et al*, 2001) for identifying potential longer-term sources of leakage, and establishing a rapid quantification. An illustration of this is given in the introductory section (Figure 4).

3.3.2 Land availability for primary leakage and the issue of boundaries and time.

The idea of assessing whether or not there is ‘land available’ for primary leakage to occur outside of the project boundaries was introduced in the 2001 Interim Report. Using the data provided in FAN’s report (Quispe and Vaca, 2001), this idea was to be further investigated. However, it was clear from the outset that the size of the total area included in such an analysis would be key to defining the amount of land available (availability being defined in terms of land title, protection, ownership etc.). This issue of ‘boundaries’ with respect to project responsibilities is a key one and is investigated further below in the schematic maps, with reference to the ‘land availability’ idea.

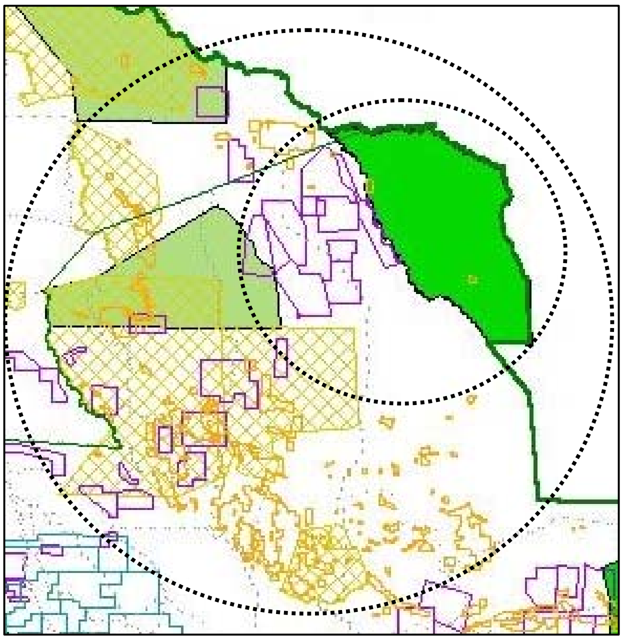


Figure 7: This shows an excerpt from the land use map for Bolivia, which includes international, departmental and municipal borders; oil, mining and forestry concessions; TCO’s, protected areas and proposed protected areas. The Noel Kempff Park is shown in bright green in the middle right of the diagram. If we use this map as an example of how the ‘land availability’ idea can be applied, we could assume that only the white areas would legally be available for colonisation and for activity shifting type activities. Of course the size of the boundary used to calculate the number of hectares will influence the number of hectares available as illustrated by the overlying circles.

Following on from this idea, Figure 8 below focuses in on the inner boundary. Assuming that we take Brazil out of the limits of the project’s responsibilities (shaded red) and any areas with some form of legal title or protection (shaded black), there only remains a limited area of ‘available’ land (the white area). Figure 9, shows the same, but with the proposed TCO included (blue).

Figure 8. Areas of available land (white) without TCO.

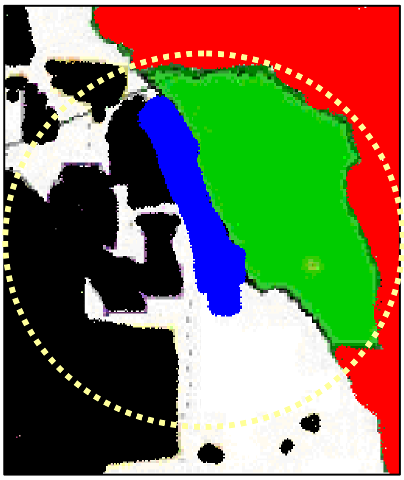


Figure 9. Areas of available land (white) with the TCO (blue).

The original idea had been to potentially use this method to show that instances of activity-shifting would be limited due to the land essentially ‘running-out’, i.e. there is only so much land that could be converted. This simple method is not going to be useful in this case, because it is evident from the maps that forested land is abundant compared with the amount of land that contributes to the carbon credits claimed by the project. It may be a useful tool for projects where the demand for land is much greater. However, if more detailed GIS and spatial modelling tools are used, baseline land conversion rates could be applied to the white areas. After a given number of years (for example the project duration) it may be the case that no forest is left other than the park (Figure 8 and 9--green) and areas already allocated (Figure 8 and 9--black), thus showing that ultimately primary leakage is negated by the time factor.

3.3.3 Spatial modelling – using GEOMOD

Various discussions have taken place as to how GEOMOD can be used to ‘model’ potential leakage over the longer term, by specifying the presence of the project when running the modelling of forest conversion into the future and comparing this with the ‘without project’ model run. The difference between the two images should enable the project to infer what the potential for leakage is, in addition to providing a predictive tool for use in monitoring of actual land conversion over time. Manipulations of some of the variables being used in the modelling in order to reflect project leakage prevention activities, for example, reducing the number of hectares of forest converted annually by each family, would also enable predictions to be made of the likely impacts of the leakage prevention activities. This approach would require further investigation and would result in a prediction that may not necessarily take account of factors that, in the future, might be more important influences on land conversion, for example policies affecting relocation or land tenure.

Using the GEOMOD results, an attempt was made to see whether there is a point in time in the future when the responsibility for land conversion could be apportioned to the broader threats to the forest, for example the sporadic colonisation or agricultural frontier, rather than the communities surrounding the park. Based on the existing results this was not possible.

3.4 Recommendations for future leakage work and monitoring

Through the process of assessing the leakage prevention activities for the Noel Kempff project and attempting to quantify leakage from the averted deforestation activities, it has become ever more apparent that quantifying leakage is not a straightforward process. The numerous factors that affect conversion cannot be separated from those that may have resulted from project activities, particularly after such a limited period of time since project establishment. Generally, we have concluded that it is better to try and prevent and minimise possible sources of leakage than to quantify and account for leakage either before or once it has occurred. In terms of identifying and tracking potential leakage, we felt that understanding the baseline drivers and agents was crucial, thus focusing activities on specific groups of people rather than on the broader issues and geographical statistics. This does not preclude the use of spatial tools in predicting potential leakage and possibly monitoring of leakage prevention activities, but unless the agent causing leakage is identified, how can it be prevented? In the case of the NKCAP, this people based approach is the focus of the existing leakage prevention activities, for example providing alternative livelihood benefits for local communities. Such activities have, to date, been successful.

The following points suggest some activities that could be carried out as part of the NKCAP's future leakage program:

1. Continue monitoring land conversion carried out by communities in the region. This could probably be implemented at less frequent intervals in the future, for example every 5 years, and could be incorporated into the project's monitoring and verification protocol (using remote-sensing tools). Alternatively, communities may in the future be monitoring land management as part of the TCO management plan and such data could be audited on a 5-yearly basis. It is worth considering whether such reviews and monitoring could be incorporated into the more detailed management plan for the TCO which has yet to be developed (R. Vaca, FAN, 2001, pers. comm.). Provided conversion rates do not exceed baseline projections, no further action need be taken. If conversion rates do exceed baseline projections, then action should be reviewed at that stage.

2. Keep records of occasions when the TCO has resulted in the prevention of forest clearance, applied for by community members or outsiders.

3. Estimate carbon benefits resulting from the leakage prevention activities. Since these activities are 'planned' activities, they ought to be incorporated into the project's carbon quantification.

4. Using the spatially generated baseline, e.g. from GEOMOD, then it ought to be possible to monitor actual forest clearance over time (remote sensing tools) and compare against predicted forest clearance (outside of the park) as generated by the model. If actual clearance is less than predicted clearance then it can be assumed that leakage is not an issue requiring further investigation. However, even if forest conversion is higher than the predictions made by GEOMOD, it may be due to factors outside of the control of the project rather than as a result of leakage. It is reasonable to conclude that once the project has been in place for a number of years, factors external to the project, for example national and regional policies will be more important in influencing land conversion than the existence of the project. For this reason, the project should make the case that beyond a given time period (a reasonable period might be about 10 years[3]), the project is no longer responsible for land conversion activities in the surrounding region.

5. Limit project responsibility for quantifying potential land-use change in the future, based on project boundaries and timeframes (see above). Alternatively, review the longer term leakage at a later date when land-use change patterns are clearer and more predictable.

3.5 Conclusions

There is no evidence to suggest that there has been any leakage to date as a result of the averted land conversion activities. The leakage prevention activities working with the communities surrounding the park have contributed to the application for TCO status of the forest surrounding the park. If this is achieved, it should minimise the risk of any future leakage from land conversion by these communities. This can be easily monitored in the future.

The longer-term threats of leakage are less clear and more complex, but it is reasonable to assume that by the time these threats become reality, other factors may outweigh the project in terms of their influence on land conversion.

4. Leakage Associated with Avoided Logging Activities

4.1 Introduction

The NKCAP seeks to secure rights to the gains in carbon arising from a 634,286 hectare expansion of the Noel Kempff Park in Bolivia in 1996. When projects such as this remove productive timberland from the base of economic activity, they can have effects beyond the direct hectares that are conserved by the project itself. For instance, the individuals who previously harvested timber within the confines of the expansion zone of the Park may shift their activities into other regions. Such shifting of activities could eliminate the "carbon" benefits of the project if the same amount of carbon is emitted in the harvesting process of other regions. Activity shifting like this is often called "primary leakage." Alternatively, a reduction in timber

[3] This is only an estimate. It has not been possible to separate the different 'baseline agents' from the GEOMOD results, as a means to apportion responsibility temporally. An alternative approach is to attach this time period to key political events e.g. new land tenure / relocation policies or changes in government that occur in the future and will have a substantial influence on land conversion rates (outweighing the impact of the project).

supply could affect markets by increasing prices. Higher prices would cause producers in other regions to harvest more timber from their lands. Market effects like this, which reduce the effective amount of carbon conserved, are often called “secondary leakage.”

The analysis of primary and secondary leakage for averted is summarized in this section of the report. Some results are provided in detail, while other results are simply summarized from the interim report by Winrock International, titled: “2001 Interim Report on Leakage and Baselines for the Noel Kempff Climate Action Project” in August 2001. This earlier report is referenced as the “interim report” throughout this document. The interim report provides significant background information for the results described in this study. This background information will be relied on and this document will focus on new material, including the results relevant to the measurement of leakage, and synthesis of the results. The overall objectives for the analysis are provided by the “Terms of Reference,” or TOR’s, for this project. The second section of this part discusses these TOR’s and indicates where the results for each are discussed.

The main focus of this final report is to report the results of a modeling exercise to estimate the potential scale of secondary leakage associated with the expansion of the Noel Kempff Mercado Park (TOR 1). As discussed in the interim report, insufficient data are available to statistically measure the potential leakage caused by the initiation of the NKCAP in 1996. Therefore a model of Bolivian timber markets has been developed to estimate potential leakage arising from removing lands from concession holdings. Secondary purposes of this final report are to describe results related to measuring primary leakage, to synthesize the discussion in the interim report about the leakage agreements with the former concessionaires in the park, to evaluate their effectiveness, and to provide recommendations for future agreements.

This rest of this section is organized as follows: **Section 4.2** describes the original goals of this study and where the results can be found. **Section 4.3** describes the model developed for the purposes of this study. **Section 4.4** describes baseline predictions of harvests from the NKCAP region and the rest of Bolivia. **Section 4.5** describes the scenario analysis conducted to provide alternative estimates of leakage, and **Section 4.6** is a discussion and conclusion.

4.2 Discussion of goals and results

1) An evaluation of the leakage that may have occurred since the establishment of the NKCAP, and an estimation of what the longer term extent of leakage might be:

   Results in sections 4.3, 4.4, 4.5, and 4.6

2) Analysis of the NKCAP leakage prevention activities--to see whether or not they have been effective in preventing or reducing leakage.

   Discussed in interim report, and synthesized here in sections 4.3 and 4.6.

3) Recommendation for future leakage prevention and monitoring**.** Based on the results of the leakage quantification and the evaluation of existing leakage prevention measures,

Sylvan Acres will make recommendations for future leakage accounting, prevention and monitoring.

Discussed in section 4.6.

4.3 Methods for analyzing leakage.

Primary Leakage

Primary leakage is defined as the leakage that occurs if the direct participants in the timber indemnification shifted activities from their previous (indemnified) concessions to other concessions. The interim report contains significant discussion on primary leakage, and may be referenced for details. The results of that analysis are synthesized here. For the NKCAP, the methods for analyzing potential primary leakage arising from new activities undertaken by the indemnified parties rely on following the expenditures of the individuals who controlled the concessions. Fundacion Amigos Naturaleza (FAN) has done significant work to track the individuals and to track their expenditures of the indemnification funds. Given the objectives of the NKCAP project, and the intent of the contracts, these tracking activities are sufficient for analysis of primary leakage.

According to the documents provided by FAN, since 1996, the majority owner of the concessions that were indemnified left the industry entirely. The majority owner received 78% of the total $1.69 million. The minority owner invested his portion of the proceeds in three activities. Of the total value of the indemnification, 12.3% went to purchase a property near Santa Cruz, 2.6% was invested in new plantation forests, and 7.3% was invested in a nearby concession (Oquiriqui). According to data provided by Quispe and Vaca (2001), there were no harvests from Oquiriqui in 1995 and 1996, but 15,193 m^3 were harvested in 1997 and 1998. These harvests could be considered primary leakage, but there are a number of reasons not to count these here. First, at least some of this harvest would be included in the measurement of leakage estimated by the timber model below, so counting them in total here would be double counting. Second, it is likely that at least some of these harvests would have occurred regardless of the indemnification. Third, some of the funds were invested in planting, which would offset the carbon losses. Fourth, much of the equipment used for harvesting by the concessionaires was retired from use, and the direct movement of capital from the indemnified region to either existing concessions or other concessions appears to be fairly limited.

More generally, the interim report considered contracting issues in general. As argued there, indemnification contracts should address the following issues:

(1) Focus on three aspects: purchasing concession agreements (retiring land); purchasing equipment on those concessions (retiring equipment); and requiring concessionaires to remain out of forestry for a given period of time (5 years).

(2) Develop performance criteria for the concessionaires for the five years after the contract has been signed.

(3) Tie payments specifically to performance on specific aspects of the contract.

(4) Following funds is useful only to the extent that it enhances the ability to measure and monitor performance on (1) above.

For the purposes of this study, FAN accomplished the fourth item listed above, and this has provided enough information to conclude that primary leakage was minimal. By writing contracts that include performance criteria, and by tying payments to reporting, it may be possible to shift the burden of reporting to the concessionaires who are indemnified. Of course, including this aspect in the contract may require increasing the total payment, but such information could be quite useful for removing concerns about primary leakage.

Secondary Leakage

Secondary leakage occurs if other concessionaires take advantage of the “hole” in timber supply caused by a reduction in concession area by increasing their own production. From an economic perspective, leakage occurs if the set-aside causes timber prices to rise and harvests to increase elsewhere. In the interim report, it was argued that given Bolivia’s role as a price taker on world markets, the set-aside would not have an effect on world prices. Any leakage that arises from the NKCAP project is likely to occur in internal markets if prices rise.

Several methods could be used to statistically estimate potential leakage from the NKCAP set-aside. One approach would be to estimate a supply and demand system for the four main forestry regions in Bolivia, including Santa Cruz, Beni, Cochabamba, and Pando. With data covering the period 1985 - 2000, one could assess whether NKCAP set-aside in 1996 had an effect on harvests. A reduction in harvests in Santa Cruz could be attributed to the NKCAP. Leakage could potentially be measured as a shift in harvests from Santa Cruz to the other departments. This analysis was not conducted for three reasons. First, it was difficult to obtain historical harvest data for the four main forestry departments in Bolivia. Second, it is difficult to obtain internal prices. Note that export prices and national harvests can be determined from the United Nations Food and Agricultural Organization, but these data do not allow for a statically meaningful determination of leakage post-1996. Third, and perhaps most importantly, Bolivian forestry changed dramatically in 1996 with a change in timber law, and the effect of NKCAP set-aside is difficult to separate from the effect of the change in law.

A different approach would be to conduct a more careful analysis of harvests in specific concessions, at different distances from the climate action project. By using data on harvests from these concessions covering the period 1985 - 2000, one could assess whether the project had a differential effect on harvests. Finding that concessions further from the park did not change their harvesting behavior would suggest that little leakage had occurred, i.e. that prices did not rise enough to cause concessionaires to change their harvesting plans. Similarly to the above proposed analysis, obtaining data on harvests in individual concessions, particularly for the period before 1996, proved difficult.

As mentioned above, there would be substantial difficulties with separating the influences of the NKCAP from the dramatic changes in Bolivian forestry law that occurred in 1996. The law changed the way that concessions were granted, and the fee structure. One clear effect was a 75% reduction in the area of land under concession, from 22.5 million hectares in 1995 to 5.7

million hectares in 1997. While such a large change should have had a large effect on timber harvests, harvests have remained relatively high in Bolivia since the law came into effect in 1996 (Figure 10). Previously, landowners were charged for extraction, while the current law charges for holding land in a concession (approximately $1 per hectare). It is likely that many concession holders held large areas of land in concessions, planning to extract timber only if market conditions (i.e. prices) were high enough.

The results of a study of the Mahogany market in Bolivia by Merry and Carter (2001) supports the contention that a change in concession area would have little effect on total harvests. Specifically, they find that a 1% change in the area under concession would reduce harvests by 0.20 to 0.43 %. Harvests were found to be most sensitive to export prices, and economic conditions in two large nearby countries, Brazil and Argentina. Using the results of Merry and Carter, however, we can develop a first approximation of the potential change in harvest arising from the indemnification. This estimate does not tell us specifically how much leakage occurs, however, it does provide an indication of the reduction in harvests arising from the indemnification, the net amount of direct reductions, and the changes elsewhere in the system.

To obtain an estimate of harvest reductions, one can start with the report by Mancilla (Mancilla, 1999) that suggests the area of land lost from concessions is 661,000 hectares, or approximately 9.8% of the total concession area in Bolivia after 1996. This would have caused a 2.0 to 4.3 % reduction in timber harvests in Bolivia. Average annual harvests between 1996 and 2000 were 547,000 m^3 roundwood. The net reduction in harvests arising from the indemnification, according to this estimate, should be approximately 11,000 to 23,521 m^3 per year, or 330,000 to 706,000 m^3 over the 30 year project lifetime.

The results in Merry and Carter (2001), however, represent the period 1977 to 1993, when harvesting intensity from concession areas were small. The changes in Bolivian forestry law in 1996 have increased harvests per hectare of concession held, so it is unclear whether these earlier results can be applied to today's situation. In addition to the changes in managing and allocating concessions, considerable steps have been made to move toward sustainable forestry, and nearly 1 million hectares of land are now managed with sustainable forestry (Superintendencia Forestal, 2001).

Model of Bolivian Timber Markets

Given the difficulties associated with collecting data to estimate leakage directly, and given the large changes in the structure of Bolivian forestry after the new law in 1996, this report will rely on a timber harvesting model that has been developed for Bolivia. The purpose of the model is to estimate baseline timber harvests from the concessions previously in the NKCAP area, as well as harvests in other regions of Bolivia, and then to compare baseline harvests to projected harvests when these areas are removed.

The model is a dynamic optimization model of Bolivian timber markets, following similar efforts in Sohngen et al. (1999), Alig et al (1997), and others. The model has a 125-year time horizon, although only the first 30 years are presented. One implication of the results of Merry and Carter (2000) is that the investment of capital in the forestry sector plays a large role in how much timber is harvested. That is, the industry is more heavily constrained by the capital that is invested in the forestry sector than the area of forestland available for concessions. Thus, it is likely to be important in Bolivia to model not just the progression of harvests over time, but also to model investments in harvesting and processing capital. To accomplish this, we adopt the suggestions of Lyon et al. (1987), who show how both timber harvests and capital intensity in the forestry sector can be modeled in Indonesia.

In the following, we describe several of the components of the model, focusing on the pieces that have the most relevance for the analysis of leakage.

Demand: Demand for forest products in Bolivia is broken into an internal demand and export demand component. Internal demand is assumed to be relatively elastic, with an elasticity of 1.0. Two alternative assumptions are made about export demand. The first assumption is that export demand is perfectly elastic, so that Bolivian markets take global prices as given and they respond to changes in those prices by altering capital investments in the wood processing sector, harvests, and production of wood. The second assumption is that export demand is elastic, but that changes in Bolivian supply can affect prices obtained at the point where wood is exported. Merry and Carter (2001) suggest that demand elasticity ranges from 0.93 to 1.58. We consequently develop a set of scenarios with two demand functions, one for internal markets, and one for export markets. Demand elasticity for export markets is assumed to be 1.3 under this alternative assumption.

There are thus two assumptions about the annual surplus arising from harvesting wood products:

Perfectly elastic export demand:

$$\text{(1)} \qquad S(t) = P^E(t) * EQ(t) + \int D(IQ(t), Z_B(t))dIQ(t),$$

Internal and export demand functions:

$$\text{(2)} \qquad S(t) = \int D(EQ(t), Z_W(t))dEQ(t) + \int D(IQ(t), Z_B(t))dIQ(t),$$

In the equations above, $P^E(t)$ is the export price, EQ(t) is the quantity of export boards, IQ(t) is the quantity of internal boards, $Z_B(t)$ is a demand shifter for the internal Bolivian demand function, and $Z_W(t)$ is a demand shifter for export demand. For the perfectly elastic export demand function, we assume that global prices rise at 0.5 % per year, as suggested in Sohngen and Mendelsohn (2001). For the second scenario, both demand functions are assumed to shift outwards at 0.5 % per year.

It is assumed that each hectare of land in Bolivia can produce products for both internal and export markets. The highest quality boards, however, are assumed to be exported, and prices for internal products cannot rise above export prices. Depending on demand, prices, and the relative costs of extracting timber from different regions, some areas may supply only export products, or a mix of both.

Board Production: Timber extracted from harvesting is assumed to be converted into boards that are sold in export or internal markets. The production function for timber boards is assumed to be constant returns to scale, as suggested by Lyon et al. (1987):

(3) $Q(t) = AK(t)^{B}L(t)^{1-B}$

where

(4) $Q(t) = EQ(t) + IQ(t)$

In equation (3), A is a constant in the production function, and B is a parameter that is assumed to be 0.8. K(t) is capital invested in the timber industry. L(t) is a numeraire good representing other inputs in the production process, including labor. It is assumed that 50% of the logs harvested can be converted into boards useful for internal or export markets (i.e. production efficiency = 50%). Thus, if log harvests are LQ(t), then:

(5) $Q(t) = 0.5*LQ(t) = 0.5*H(t)*V(t)$

where H(t) is the area of land harvested in hectares, and V(t) is the yield of the land harvested. The yield function for timber is assumed to have the following functional form:

(6) $V(a) = \exp(B1 - B2/a)$,

Where B1 and B2 are parameters, and a is the age class. For the most part, harvesting in Bolivia extracts virgin forests that have not been accessed before. However, once timber is extracted from these sites, it is assumed to be available again in the future. The age of harvesting in the future is determined optimally by the timber model. In the initial periods of the model solutions presented below, much of the extraction occurs on virgin timber stands. In future periods, extraction also occurs in second growth stands.

Costs: A number of costs are associated with harvesting and milling timber in Bolivia, including direct harvesting costs, costs of investing in new capital, costs of purchasing other production inputs, L(t), and costs of building roads to extract virgin timber, costs of transporting milled wood to markets, costs of administering concessions and timber sales. These costs are obtained from Mancilla (1999).

Regions: Timber supply in Bolivia is derived primarily from the five regions listed in Table 7. Four of the regions—Santa Cruz, Beni, Pando, and La Paz—account for 84% of total harvests, and 83% of total concession holdings. Cochabamba has minimal concessions, however, it accounts for 14% of total timber harvests, mainly from harvesting on private land. Interestingly, harvesting intensity, as measured by harvests per hectare of concession holding, is highest in Beni. Although timber intensities in Beni are not large, the majority of concessions in Beni are located close to La Paz, and thus to Pacific Ocean transportation routes.

Of interest for this study are the concessions located in the area indemnified by the NKCAP. The estimates for the effect of the NKCAP on concession holdings vary widely. The original area of the four concessions affected by the indemnification was approximately 1.5 million hectares before 1996 (Table 8). The report by Mancilla (1999) suggests that approximately 661,000 hectares was indemnified by the concession agreements. This amounts to less than half of the total area the concessionaires had available. From Table 8, one can see that the remaining concession areas mostly reverted to state control after 1996. The exception is the Paragua concession, which retains approximately 113,000 hectares today.

Table 7 Regional harvests and concession holdings in 1997 (Quispe and Vaca, 2001).

Region	Harvests		Concession Holdings (1997)		Harvests Per ha of Concession
	1000 m^3	%	1000 ha	%	m^3/ha
Santa Cruz	356	45	2,806	49	0.13
Beni	185	23	891	16	0.21
Cochabamba	113	14	--	--	--
Pando	84	11	1,535	27	0.05
La Paz	43	5	400	7	0.11
Total Other	16	2	96	2	0.17
Total Bolivia	797	100	5,728	100	0.14

Table 8 Area of land in concession holdings in the area indemnified by the expansion of the Noel Kempff Mercado National Park.

	Concession Name			
	Paragua	El Chore	El Paso	Moira
Area before Indemnification (1000 ha)	464.5	224.1	371.1	512.4
Area affected by Indemnification (1000 ha)	73.5	140.7	214.9	232.7
Area in 1998 (1000 ha)**	112.9	0	0	0
Volume in area affected (1000 m^3)	1496.3	3631.0	7124.1	1960.7
Volume of five most valuable export species (1000 m^3)	687.1	1610.3	3148.5	1086.9

(Source: Mancilla, 1999). ** Source: Superintendencia Forestal, 2001.

There are two interpretations of these data. First, the indemnification agreements could have led to a larger reduction in actual concession area by causing the original concessionaires to leave timber extraction entirely. Based on the follow-up reports, this is true for one of the individuals. Second, it is possible that these concessionaires would have reduced their concession holdings with the new law in 1996 even if they had not been indemnified. As noted above, there was a 75% reduction in concession holdings throughout the country following the change in law in 1996. For instance, Paragua concession has maintained holdings, although the area it holds is smaller than the area that would have remained after the indemnification (112,900 hectares held now, versus 391,000 that would have remained after indemnification).

For modeling purposes, timber supply from nine regions is modeled in Bolivia. Four of the "regions" are the single concession holdings listed in Table 8. These concessions are separated out to account for more specific information on them available from the Mancilla report (1999). For the baseline, it is assumed that the 661,000 hectares indemnified and the 112,900 hectares now held by Paragua would have remained in concession holding's following the change in Bolivian law. This is consistent with Mancilla (1999), who argued that the indemnified region was rich in valuable timber species. Of these 661,000 hectares, this report follows Mancilla and assumes that only 521,000 of those hectares would have been productive for timber harvesting activities. The other five regions account for the remainder of concession and private landholdings in the five main regions where harvesting occurs in Bolivia: the rest of Santa Cruz, Beni, Cochabamba, Pando, and La Paz.

4.4 Description of baseline

The baseline is the situation that would have prevailed from 1996 forward. Producers throughout the country clearly re-trenched and eliminated excess holdings in order to minimize their concession payments following the change in law in 1996. Despite the large, country-wide reduction in concession holdings between 1995 and 1997, however, national harvests were not noticeably affected. One data source, FAOSTATS, suggests that harvests declined heavily in 1997, but recovered substantially in 1998. Data from local sources (Quispe and Vaca, 2001) suggests that harvests hit an all time high in 1997 but declined back to more normal levels in 1998. There is little evidence that harvests in Bolivia were heavily affected by the reduction in the area of land under concession.

As suggested in the Mancilla study (1999), timber volumes of valuable species are fairly high in the region indemnified. Merchantable volumes of the five main export species range from 5 to 15 m^3 per hectare of land in concession (Table 8), with additional volumes of merchantable species for national markets ranging from 4 to 18 m^3 per hectare. Mancilla concludes that harvests would have occurred in these regions without the indemnification given the relative richness of the timber species and volumes. For the baseline, it is assumed that the concessionaires would have produced timber actively from the 521,000 productive hectares indemnified.

To test the sensitivity of the results to alternative economic assumptions about the structure of markets, four baseline economic models are considered to explore how harvests might have changed under alternative price elasticity and capital constraints. The four baselines are:

(1) Perfectly elastic export demand and unconstrained capital adjustment (PEDUK).

(2) Internal and export demand functions and unconstrained capital adjustment (2DUK).

(3) Perfectly elastic export demand and constrained capital adjustment (PECK).

(4) Internal and export demand functions and constrained capital adjustment (2DCK).

Figure 10 presents historical and projected national harvests. There are small differences between the two capital assumptions, so the results are averaged over these assumptions in Figure 10. The main reason for this is that the study assumes relatively low costs for other inputs, and that the degree of substitutability between capital and these other inputs is fairly high. Thus, even if capital is constrained, markets can maintain harvesting levels by purchasing other inputs relatively cheaply. Harvests rise to higher levels under the price elastic demand scenarios as prices rise from $488 to $546 per m^3 over the next 30 years. Prices remain relatively constant in the scenarios where both internal and export demand functions are used.

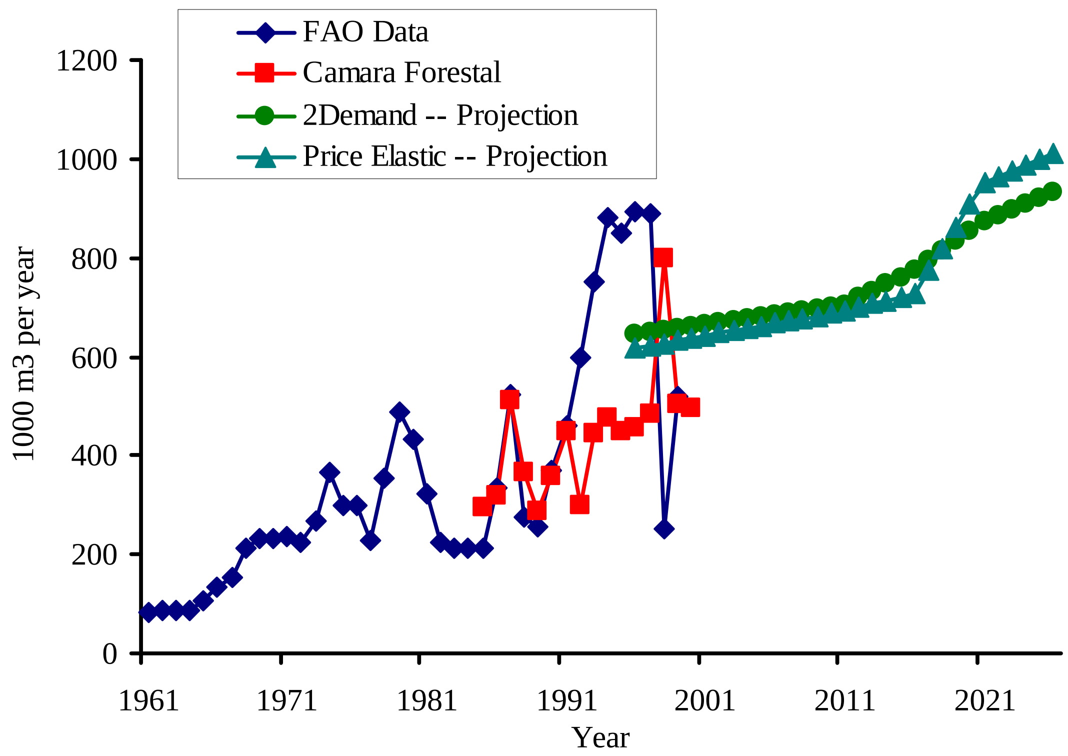


Figure 10. Historical and projected national timber harvests in Bolivia, 1961 – 2026.

Baseline harvests from the 521,000 productive hectares affected by indemnification are shown in Figure 11. Harvests from the four concessions in Noel Kempff region are predicted to begin at approximately 63,000 m^3 per year, rising to approximately 80,000 m^3 in the scenarios where two demand functions are used, and approximately 93,000 m^3 in the price elastic export demand case. Harvests rise more in the elastic export price cases due to higher prices.

These estimates of harvests are considerably lower than those predicted by the Mancilla report (1999). That report suggested that between 217,000 and 283,000 m^3 of roundwood would be harvested per year on average between 1996 and 2026. These estimates seem high given that they are predicted to have occurred only on the 521,000 hectares that were indemnified. Given average annual harvests in Santa Cruz of 235,000 (1999) to 356,000 (1998), the harvests predicted by Mancilla would have amounted to 61 to 93 % of total harvests in the department, even though the actual area indemnified is only 24% of the total concession area in the Department of Santa Cruz.

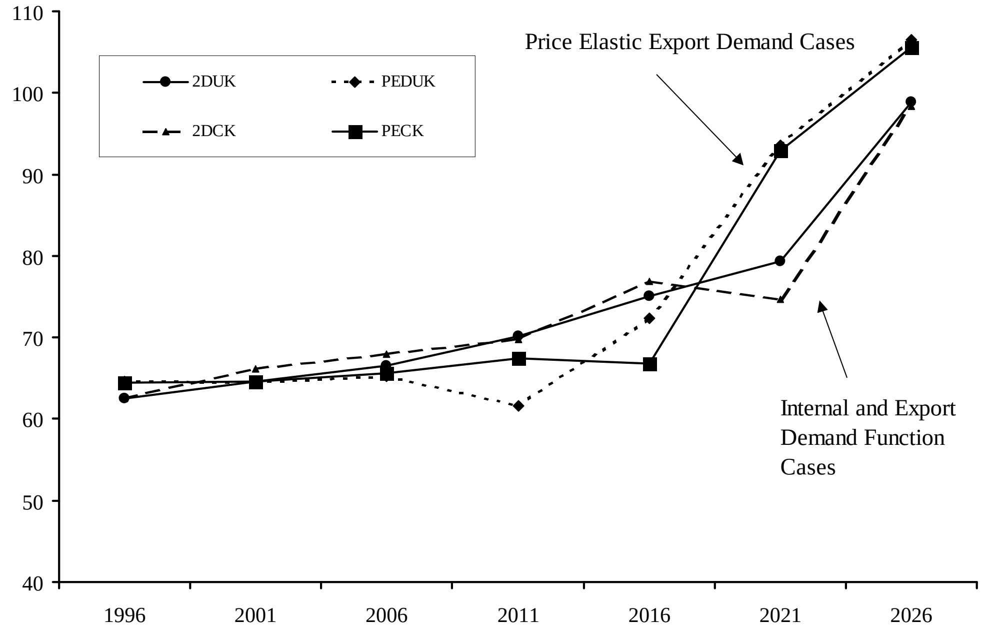


Figure 11. Projected harvests (thousands cubic meters per year) from the area indemnified by the NKCAP, 1996 – 2026.

These estimates are consistent with general trends in Bolivia since the change in law that occurred in 1996. Average harvests per hectare of concession were 0.02 m^3 per hectare per year before 1996. Between 1996 and 2000, they increased to 0.09 m^3 per hectare per year as the area of concessions declined, but harvests remained relatively high. The projected harvest intensity for the entire country is 0.10 m^3 per hectare per year between 1996 and 2026. The projected harvest intensity for the indemnified area is 0.11 m^3 per hectare per year between 1996 and 2026. While the region that was indemnified is fairly rich in species, harvest intensities in Santa Cruz appear to be less in general than other regions of Bolivia (see Table 7).

4.5 Scenario analysis and measurement of leakage

To measure leakage, national level harvests with and without the area indemnified by the NKCAP are compared. This amounts to asking, "what happens to national level timber harvests if the stream of harvests shown in Figure 7 is removed?" As argued in the interim report, leakage should be measured by comparing national level timber harvests to timber harvests under these alternative baselines. For a country like Bolivia, where the carbon pool in forests is contained mostly in late succession tropical forests, the effect of setting-aside land should be to reduce timber harvests. Alternative policies aimed at afforestation can increase both carbon storage and timber supply, thus, it is possible that a country can engage in both activities, reducing deforestation and increasing afforestation, and therefore maintain timber production and consumption. The focus of this research is on investigating only the set-aside option and the resulting effects on timber markets.

Leakage is measured by comparing the reduction in harvests caused directly by the set-aside to the reduction in national level harvests. It is measured over a 30 year period, 1996 – 2026. Total harvests for the four timber concessions affected in the area of the NKCAP are estimated for the baseline situation and then for case where the indemnified concessions are removed. The difference between baseline harvests and harvests in the scenarios are then compared to the difference between national level harvests in the baseline and under the scenario. Technically, leakage is:

Leakage% = (NKCAP Reduction– National Reduction)/(NKCAP Reduction)

Table 9. Estimated leakage for setting aside former concessions in the NKCAP.

Scenarios	Leakage (%)
Two Demand Functions	
Unconstrained Capital	43
Constrained Capital	44
Elastic Export Demand	
Unconstrained Capital	14
Constrained Capital	14

Leakage ranges from a low of 14% to potentially 44%. The higher estimates reflect the scenarios where two demand functions are used, and prices are allowed to adjust to the change in harvests. In these cases, prices rise approximately 2% relative to the baseline, but this induces additional harvests elsewhere, particularly in regions farther away from Santa Cruz. Prices do not change in the elastic export demand case, and therefore leakage is smaller. The constrained capital cases lead to slightly less leakage than the unconstrained capital cases, although the differences are slight.

Given the wide-range of the results, it is important to consider the conditions under which the scenarios above are most likely to apply. First, the elastic export demand function case applies most closely to the Bolivian situation. According to FAO (1999), Bolivia accounts for only 0.2 % to 0.4 % of total timber harvests in South America. Small changes in timber harvests in that country would have little, if any, effect on export prices, while the results in Merry and Carter (2000) suggest that harvests in Brazil can have fairly large effects on the Bolivian situation. This suggests that leakage most likely ranges about 14%.

Second, it is likely that the most important leakage effects from the indemnification would arise from price effects and not migration of capital to other harvesting operations. Since 1996, the majority owner of the concessions that were indemnified left the industry entirely. The minority owner invested his proceeds in three different activities. Of the total value of the indemnification ($1.69 million), 12.3% went to purchase a property near Santa Cruz, 2.6% was invested in new plantation forests, and 7.3% was invested in a nearby concession (Oquiriqui). This last investment could be considered primary leakage, but note that the nearby concession would likely have been undertaken regardless, and some of the funds were used to plant trees as well. Further, much of the equipment used for harvesting by the concessionaires was retired from use. The direct movement of capital from the indemnified region to either existing concessions or other concessions appears to be fairly limited.

In addition to considering the potential leakage, the results also provide information on the net reduction in timber harvests potentially arising from the indemnification (Table 10). These results suggest that over the period 1996 – 2026, harvests from the indemnified forests is likely to range from 2,161,000 m^3 to 2,192,000 m^3 (cumulative). These estimates are consistent with annual harvests of 0.11 m^3 per hectare of total concession area. While these estimates are slightly higher than average for Santa Cruz, they reflect the relative richness of the species available in the concessions indemnified by the NKCAP agreements.

Given the leakage estimates, the net reduction in harvests would range from 1,221,000 m^3 to 1,757,000 m^3. The analysis suggests that the price elastic cases are more likely for Bolivia, so the net reduction in harvests is closer to 1,876,000 m^3. The results of all of the scenarios suggest a much smaller effect than that predicted by Mancilla (1999). The main reason for this is the lower estimate of baseline harvests. Leakage estimates for the price elastic scenarios are not large, although they suggest that some leakage is possible.

The scenario analysis shows that annual leakage is expected to diminish over time (Figure 12). Alternatively, the proportion of annual leakage is expected to be greatest initially, nearly 30% in each scenario, then falling to less than 1% by year 25. Much of the leakage occurs initially as markets adjust to the changes. Over time, these effects decline, and the savings increase. Setting-aside land from concessions, thus, has persistent effects that strengthen over time, as markets adjust but the lands indemnified are held from timber concessions into the future. While the different assumptions about capital constraints do not heavily influence leakage estimates over the entire 30-year period, they do have strong inter-temporal effects.

Table 10. Net effects of the NKCAP on Bolivian timber harvests, 1996 – 2026.

	Baseline NKCAP Harvests	Leakage	Net Reduction
	1000 m^3		1000 m^3
Two Demand Functions			
Unconstrained Capital	2,163	43%	1,223
Constrained Capital	2,2161	44	1,221
Elastic Export Demand			
Unconstrained Capital	2,192	14	1,876
Constrained Capital	2,191	14	1,876
Mancilla	6,532	0	6,532

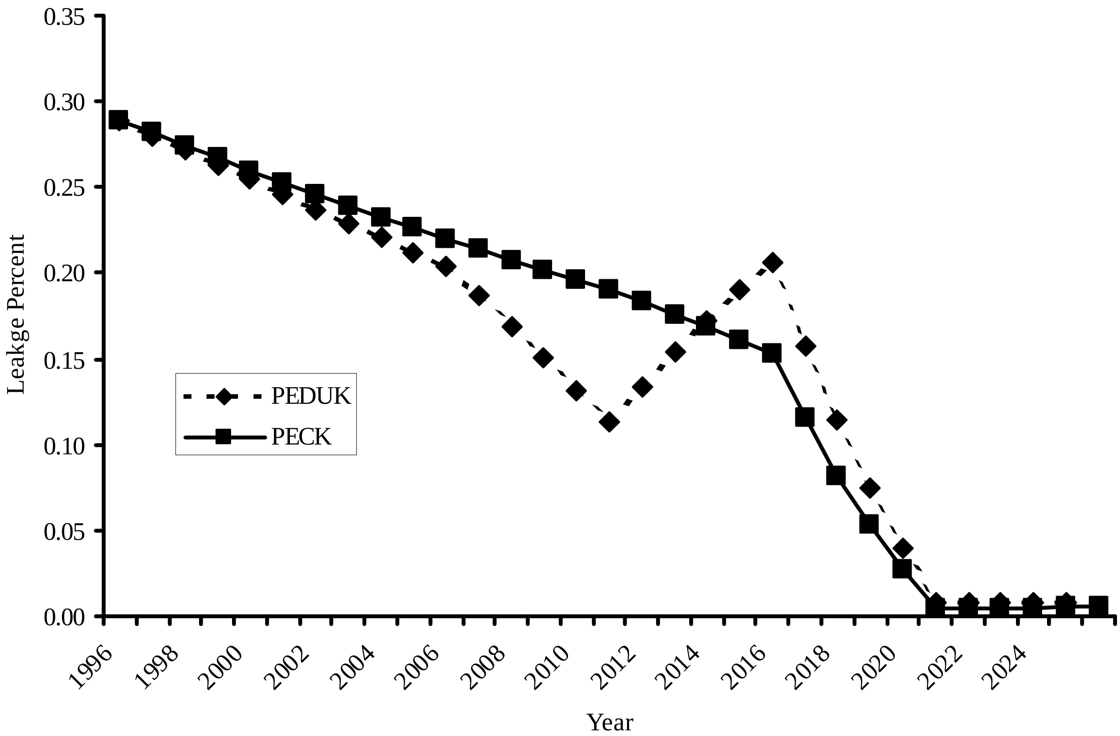


Figure 12. Annual leakage percentage in the perfectly elastic demand case, 1996 – 2026.

An additional issue to consider is the possibility that the indemnification of the concession areas caused an expansion of concessions in other areas. Although the analysis in this study assumes that concession area remains constant over time, it is possible to consider potential shifts by comparing how prices and capital adjust in the scenarios presented. For example, concession areas would expand only if prices rose enough to cause other individuals to enter into timber markets. The scenarios with both internal and external demand functions allow such price adjustments, but they do not indicate substantial increases in prices (2% on average). Thus, one would not expect prices to lead to large expansions in concession area.

Further, increasing concession areas is only one way to expand production. Concessionaires in other regions can also expand production by increasing capital and other inputs, such as labor. In the scenarios presented, fixed capital in other regions increases only 1-2%, while other inputs rise 3-6% relative to the baseline. Thus, it appears that the largest adjustments that concessionaires in other regions of Bolivia may make to shifts in harvests are to increase other inputs to production. Given the fixed costs of holding land imposed on concessionaires by the change in law in 1996, they are more likely to shift other inputs than either capital or land.

4.6 Discussion and Conclusion.

This study investigates the potential leakage arising from setting aside land from concessions in Noel Kempff Climate Action Project of Bolivia. This project set-aside approximately 661,000 hectares of timberland. A model of timber markets was developed to estimate potential leakage arising from the set-aside of valuable forest concession land. The results suggest that leakage could range from as low as 14% to as high as 43%. The most realistic scenarios are those where Bolivia is assumed to be a price taker on international markets, the price elastic scenarios. In these cases, where export demand is perfectly elastic, leakage is about 14%. The more sensitive prices are to supply adjustments, leakage could be higher, approximately 43%. These higher estimates suggest that leakage could be fairly large if prices adjust to changes in the supply of timber.

Leakage must be measured in context of total potential harvests from the indemnified area. The 1999 Carbon Offset report prepared by Winrock International (Delaney et al. 1999) suggests that 5.2 million m^3 of timber would be extracted from the indemnified area of 661,000 (521,000 productive) hectares over the 30 year period, 1996 – 2026, or 174,000 m^3 per year. In contrast, the baseline results in this study suggest a much lower rate of extraction from this area, averaging 73,000 m^3 per year over the next 30 years, amounting to 2.2 million m^3 of timber. Rather than the predicted 12.5 m^3 of timber saved per hectare (cumulative), the results of this study suggest that savings could be no more than 3.3 m^3 per hectare indemnified if leakage is 0. Note that these estimates of the per hectare savings are developed assuming 521,000 productive hectares within the entire 661,000 hectares indemnified.

Considering the range of leakage predicted above, the harvesting savings on each hectare of land set-aside would range from 1.9 m^3 per hectare if leakage is 43% to 2.8 m^3 per hectare if leakage is 14%. The discussion of the differences in the scenarios suggests that the 14% estimate is more realistic given that the Bolivia market is heavily influenced by exports. The net savings from indemnification would be 2.8 m^3 per hectare, or 1.9 million m^3. To put these numbers in context with other available estimates, recall that the results of Merry and Carter (2001) suggest that the net effect of the project would have been an approximate 330,000 – 706,000 m^3 reduction in Bolivian harvests. The results in this analysis suggest larger net reductions for at least two reasons. First, the estimates in this study incorporate region specific information both for the NKCAP concessions and for concessions in other parts of the country. Specifically, they include inventory information specific to the NKCAP, rather than national level average statistics. Second, they are for the period following the change in timber law in 1996, and the study assumes the entire area would have remained in concession. After the change, harvest intensities on hectares held in concessions rose from less than 0.02 m^3 per hectare to more than 0.09 m^3 per hectare.

As argued in the interim report and here, for an indemnification to have a measurable effect, changes in harvests should be measurable at different levels in the economy. That is, if the baseline harvests for a given project are projected to be X m^3 for a given period, an indemnification with no leakage should cause national harvests to decline by exactly X m^3. Typically, data on harvests at a regional or national level can only distinguish net effects of a change in supply (i.e. a change in concession area), they often will not be able to distinguish leakage percentages. Models, such as the one used in this study, can present leakage estimates because they project baseline harvests as well as harvests after a change in supply. While the study has taken considerable care to parameterise the economic model of Bolivian timber markets with data specific to Bolivia, additional statistical analysis with economic data could provide information on the net effects to support this research. Unfortunately, much of the data that could have been used was not available for this study, although potential data for future collection are discussed below.

A central assumption of this study is that the entire area indemnified would have remained in concession after the change in timber law in Bolivia in 1996. This assumption relies on the results of Mancilla (1999), who argues that the areas are timber rich and would continue to be harvested under the new timber law. Nevertheless, available data suggests that concession area declined dramatically (75% country-wide) after the change in timber law. Thus, it is difficult to assess fully the potential impact of the change in Bolivian timber law in 1996 on Bolivian timber market structure, and more specifically, on the concessions indemnified. Such information would be crucial for understanding the baseline harvests from the area indemnified, since both the change in law and the indemnification occurred at the same time. As discussed below, additional data collection could provide more information on the effects of the change in law in 1996, and the indemnification.

To discuss potential future data collection, one must recognize that some data is specific to the situation in Bolivia, and some data would be more general. Data specific to Bolivia are discussed first. One of the key issues for the Bolivian situation is to understand the effect of the change in Bolivian timber law in 1996 on concession area and timber harvests. Given differences among regional timber production, one approach would be to estimate a demand and supply system for timber harvests, as done in Merry and Carter (2001). The results of that study should be updated to include the period from 1977 to 2000, and to include species in addition to Mahogany (the only species studied in that study). The type of data necessary would include: quantity harvested, export and internal market prices, GDP and population, prices for major trading partners (US and Argentina), prices for substitutes, cost of capital (interest rates) and other inputs, concession area, and volumes maintained under concession. Optimally, researchers would prefer to have harvests, exports, and concession data for each region in Bolivia to assess how the departments in Bolivia would respond differentially to price changes in export markets.

For regions where the only effect to be measured is an indemnification (and not a structural change that affects the entire market), estimating a demand and supply system where supply is a function of concession area and timber volume under concession, could be sufficient to assess the net effect of an indemnification, as in Merry and Carter (2001). Unfortunately, obtaining information on concession area and timber volumes is difficult to obtain for many developing countries.

A different type of analysis would be to compare historical harvest rates at concessions, or timber production at mills, at different distances from an indemnification. This type of analysis was originally proposed for this study but was not undertaken given the difficulty of collecting the data in Bolivia. It’s unclear whether such data would be available in other regions. The hypothesis for such a study is that harvests would be more likely to rise in response to an indemnification at concessions or mills closest to the indemnification. Such a change would be considered leakage. While indemnifications of small areas would not be expected to have price effects measurable in export prices, it is possible that displaced labor or capital could migrate to other concessions or mills. The displacement would be expected to have their most pronounced effects, at least initially, on concessions and mills located most closely to the indemnification.

4.7 Recommendations for future leakage work and monitoring

There are two important components for quantifying actual leakage from this project in the future. First, a realistic assessment of baseline harvests from the project area over the period 1996 – 2126 must be developed. This assessment must clearly account for the effect of the change in timber law in 1996 on country level harvest, department level harvests, and harvests near the project. Second, new empirical analysis must be conducted to assess demand elasticity, and how a change in concession area affects the supply function for timber in Bolivia. Conceptual and data needs for each of these are discussed below. This analysis should be conducted at least every 5 years, but note that the data must be collected annually.

1) Assessment of potential baseline harvests from the project area over the period 1996 – 2126 requires understanding the likely harvests from the 661,000 hectares of concessions originally indemnified. Several important pieces of data are suggested for this analysis:

- Area of concessions held each year, including changes in concession holdings for different departments.
- Annual harvests for each concession.
- Timber inventory data for each concession.
- Exports, imports, and quantity consumed within Bolivia.

The key information provided by these results is information on how harvests have proceeded over time in response to international and national trends in harvests and prices. By specifically analyzing harvests on concessions with similar forest characteristics versus those with different characteristics, one can assess whether harvests on the indemnified hectares would likely have increased or decreased over time.

2) Empirical analysis to determine demand elasticity and the effect of concession area on supply should be conducted for the post 1996 period to determine how markets are likely to respond to reductions in concession area. Data needed for this analysis:

- Data suggested in point 1 above (1985 – present).
- Time series of local timber prices in major markets (Santa Cruz, Cochabamba, La Paz) – Needs to be collected locally (1985 – present).
- Time series of export prices and prices in other South American markets – Available from FAO (1985 – present).
- National and Department level economic statistics (GDP, Wages, interest rates) – Needs to be collected locally (1985 – present).

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