Understanding and Managing Leakage in Forest-Based Greenhouse Gas Mitigation Projects

By Reimund Schwarze, John O. Niles, and Jacob Olander

Prepared for the Nature Conservancy

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Executive Summary

Activities that increase forest cover or decrease deforestation can help reduce atmospheric carbon dioxide levels. Concerns have been expressed, however, that land use, land-use change and forestry (LULUCF) projects may only produce greenhouse gas benefits that are illusory due to a phenomenon known as "leakage". *Leakage is the unanticipated decrease or increase in greenhouse gas benefits outside of a project's accounting boundary resulting from the project's activities*.

Leakage can potentially be significant compared to the scale of planned GHG changes in mitigation projects. Thus, leakage constitutes a key challenge to sound climate change policy formulation. In this paper we review the literature on leakage and pay special attention to LULUCF projects in developing countries.

Leakage is complex and poorly understood

Leakage is an intricate and diverse phenomenon. Market impacts, people moving from place to place, ecological feedbacks and product life cycle changes are some of the ways leakage can be manifested.

To illustrate: an avoided deforestation project may cause *activity-shifting leakage* (people leaving a project area to go cut trees elsewhere) or *market leakage* (less timber available due to the project, more pressure to cut elsewhere). These two types of leakage are the most commonly cited, and are often perceived as *negative* (resulting in more emissions or less sequestration – that is, more atmospheric greenhouse gases). Both of these processes are intricate, difficult to monitor and complicated by many outside influences.

At the same time this hypothetical project could have unintentional consequences that lead to *more* greenhouse gas abatement (*positive leakage*). One protected forest may help adjacent forests stay healthy (an example of *ecological leakage*) or industries may re-gear production methods to be less polluting as a result of the forest project (*life-cycle leakage*). For different projects the relative magnitude of these types of leakage, both positive and negative, will vary.

Leakage is not restricted to LULUCF projects

Leakage can arise from specific projects as well as policies, it can be positive or negative and it can occur in any type of mitigation activity. While some modeling evidence shows that LULUCF activities are at a greater risk for leakage than other sectors of the economy, results are speculative at this point. For instance, fossil fuel leakage has been estimated in the range of 4-40% of the original project carbon offsets, a range similar for LULUCF leakage (~0-100%). However, no study has

shown that real-world leakage is more pronounced in certain projects types than others. Most modeling studies of LULUCF leakage have focused on market leakage and none are based on realistic implementation rates of projects in developing countries.

Leakage in LULUCF projects

Two broad categories of LULUCF activities are considered: conservation projects and reforestation/aforestation projects.

Conservation projects

In projects that avoid deforestation or modify forest management practices, activity-shifting leakage risk will depend on project design and local conditions. If a conservation project's design does not address underlying drivers of deforestation, activities may shift outside project boundaries. This may be particularly true in areas where accessible forests are nearby and where the activity curtailed by a project is mobile. Conversely, well-designed projects and certain circumstances (e.g., all other nearby forests have been removed or the area is highly inaccessible) seem to be intrinsically less prone to activity-shifting leakage. Protecting native forests will often likely generate positive ecological leakage.

Reforestation/Aforestation projects

The magnitude of activity shifting from reforestation or aforestation projects will depend (again) primarily on local conditions and the project design. If carried out on lands with other productive uses, tree-planting projects could be especially prone to activity-shifting leakage. Meanwhile, projects that plant trees on degraded lands with little or no other productive use will likely produce less leakage.

Market leakage from reforestation/aforestation projects might conceivably be either positive or negative. For example, large-scale timber plantations could depress timber prices. This in turn could reduce the incentive to establish new timber plantations elsewhere. Equally plausible, timber plantations might reduce timber prices and lessen harvesting on other natural forests. Whether market forces will lead to a decline in forest harvesting (positive leakage) or the abandonment of plantations (negative leakage) will depend on local market conditions and circumstances.

In general, small-scale reforestation/afforestation projects focused on environmental restoration and/or local community needs should have more positive leakage profiles than large-scale commercial plantations, mainly because they aim to minimize the drivers and scale of potential leakage.

Options for Responding to Leakage

At the project level, tools exist for preventing leakage, detecting leakage, and adjusting for leakage. Options for responding to leakage at the project level include: *site selection*, *project design*, *leakage contracts*, *monitoring*. Good project design and careful site selections will minimize negative leakage and maximize positive leakage. Projects that integrate activities (forest conservation, forest restoration, community development, plantations, etc.) will probably be more successful in reducing leakage (and overall). Leakage contracts can specify actions to deter activity shifting and/or to encourage desired actions. Monitoring can be used to estimate leakage, and once leakage is detected, project carbon offsets should be adjusted accordingly.

Other broader policy tools can be used to address leakage. These include: *discounting*, *project-eligibility criteria*, and the use of *"aggregate baselines"*. Baselines, the development of national, regional or sector 'standards' have been one proposed way to address leakage. This tool is hampered by poor background information for many developing countries as well as political opposition. Project-eligibility criteria and discounting (or adjustment coefficients) have also been proposed for grouping project types together and making broad generalizations and adjustments.

At the broadest level, policy makers also have several other options including *a cap on certain types of mitigation and a balanced portfolio of mitigation types*. Negotiators to the Kyoto Protocol have agreed to limit the volume of carbon offsets that can be achieved through LULUCF and/or in developing countries. Although these restrictions were not set primarily to address the risk of leakage, limiting the scope and number of projects may effectively keep in check the impact of projects on local and/or global timber markets respectively, and thus limit market leakage. Nevertheless, given the level of the cap, it is not clear that it will actually constrain projects, nor market leakage.

Combining a "correct" number of avoided deforestation projects with plantations in a balanced portfolio could result in counter-balancing amounts of timber supply restrictions and expansions. However, in practice a balanced portfolio approach would be difficult to accurately implement and would also need to compensate for differences in carbon flux timings between project types and other factors.

Leakage is a significant, but by no means insurmountable, risk for climate change mitigation. Both project-level and macro-level approaches can effectively manage leakage. Many pilot LULUCF projects are already using many of these tools on the ground, although, not for long enough periods to make robust conclusions.

There is a way to combine project-based calculations and general principles in a way that rewards positive actions in terms of leakage. A decision-tree framework (as proposed by Aukland et al, 2002) for appraising leakage would be able to combine many of the positive aspects of most of the possible tools for addressing leakage. Policy makers can abbreviate leakage management based on first-order principles, project appraisal, monitoring, discounting and other techniques. A decision-tree framework could allow certain types of projects easier certification while placing higher standards on projects that raise 'red flags". Doing so would appropriately combine general principles that can be inferred about leakage risks with project-specific evaluations.

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1 INTRODUCTION

Projects that increase forest cover or decrease deforestation can help reduce atmospheric carbon dioxide. This principle underpins the inclusion of certain land use, land-use change and forestry (LULUCF) activities in both the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Concerns have been expressed, however, that LULUCF projects may only produce greenhouse gas benefits that are illusory due to a phenomenon known as "leakage".

The most frequently cited example of leakage is a LULUCF forest protection project to reduce greenhouse gas (GHG) emissions. The leakage concern is that forest protection could cause deforestation to move from the protected forest to a nearby forest, with no net GHG benefit. Although this example pertains to the LULUCF sector, project activities in virtually all sectors of GHG mitigation (energy, transportation, etc) have the potential to cause leakage. As such, leakage constitutes a key challenge for policy makers and project developers to address in forthcoming climate change policy formulation.

Leakage would not be of great concern if every country measured every GHG flux in its borders. Any unintended consequences (leakage) of a climate change project or policy in one area would be registered in another area's GHG accounting system. But under the principle of "common but differentiated responsibilities" (Art. 3 of the UNFCCC), developed nations under the Kyoto Protocol assume binding limits on their GHG emissions, while developing countries do not. This differentiated approach inevitably creates the risk of leakage since the world is increasingly economically interconnected; changes in economic activity and prices reverberate locally and around the world. Without comprehensive monitoring, emissions *reductions* by a project in one area may be measured, while project-induced emissions *increases* outside project boundaries may not be measured.

This paper analyses leakage in the LULUCF sector since, rightly or wrongly, leakage risk is perceived as more severe for this sector than for energy, transport or industry. Our analysis emphasizes, but is not limited to, the use of LULUCF projects in the Kyoto Protocol's Clean Development Mechanism (CDM). Effectively managing leakage will also be necessary for projects and policies that evolve independent of, or in parallel to, the Kyoto Protocol. [1]

2 WHAT IS LEAKAGE?

The Intergovernmental Panel on Climate Change (IPCC) Special Report on LULUCF defines land use leakage as "…the indirect impact that a targeted land use, land-use change and forestry activity in a certain place at a certain time has on carbon storage at another place or time" (IPCC 2000, section 2.3.5.2, p. 71). In another section of this report the IPCC defines leakage as the "unanticipated decrease or increase in GHG benefits outside of the project's accounting boundary … as a result of the project activities." (ibid., section 5.3.3, p. 246). Various types of leakage are listed in **Table 1.**

[1] As may be the case if the United States remains opposed to the treaty and forges other greenhouse gas partnerships.

Table 1: Types of leakage

Causes	Project Policy
Effects	Positive Negative
Mechanisms	Activity shifting Market effects Life cycle effects Ecological
Scales	Local Regional National Global
Sectors	Energy (fossil fuels) LULUCF (biomass)

2.1 Causes: projects or policies

Although leakage is often thought of primarily as a project-based concern, unintended GHG fluxes can occur with the adoption of regulations or policies. The Kyoto Protocol as currently interpreted could push certain commercial forestry operations to relocate to developing countries where they would be unencumbered by GHG liabilities (Niesten et al. 2001). The same concern also affects energy-intensive industries (Wiener 1997).

2.2 Effects: positive or negative

Leakage is often considered undesirable or bad; in the case of GHG fluxes, "bad" meaning more emissions or less sequestration. In this paper, this type of leakage is called *negative leakage* and would ideally be avoided. There are also situations where unintentional outcomes may be *positive* (more emission reductions, more sequestration). For example, emissions-reducing activities may be adopted voluntarily outside project boundaries, as has apparently been the case with reduced-impact logging techniques in a carbon-offset project sponsored by the New England Power Company in Sabah, Malaysia (UtiliTree 2000).

2.3 Mechanisms

Unintended GHG fluxes arise through two principal avenues: (IPCC 2000; Brown et al. 1997; Vine et al. 1999, SGS no date given).

Activity shifting: A project or policy can displace an activity or change the likelihood of an activity outside the project's boundaries. One example of negative activity-shifting leakage would be a plantation project that displaces farmers and leads them to clear adjacent forests.

Market effects: A project or policy can alter supply, demand and the equilibrium price of goods or services, causing an increase/decrease in emitting activities elsewhere. For example, if a large forest conservation project reduces the local timber supply so that demand is unmet, this may increase prices and pressures on forests elsewhere.

In economic terms, market-driven leakage is mediated by a change in the price of goods; whereas activity shifting is when human or other capital changes location. Importantly, these two leakage types may in some cases be inversely related (notably in the case of forest conservation). If a project displaces people and activities to adjacent areas, market leakage may diminish. This is because activity-shifting leakage moves economic activity while market leakage occurs through net changes in production for a given regional distribution of activities.

Two other types of leakage bear mentioning.

- **Life-cycle emissions shifting**: Mitigation activities increase emissions in upstream or downstream activities (e.g. a forest conservation project leads to increased road traffic from tourists or a reforestation project increases the operation of machinery creating fossil-fuel emissions);

- **Ecological leakage**. Ecological leakage is a change in GHG fluxes mediated by ecosystem-level changes in surrounding areas. In an example of positive ecological leakage, stopping deforestation can prevent carbon emissions in forests *adjacent* to the intended protected forests. An example of negative ecological leakage would occur if a carbon plantation introduces a pathogen to surrounding forests, leading to their decline and a net carbon release to the atmosphere. The magnitude of ecological leakage compared to other types of leakage has not been studied.

POSITIVE ECOLOGICAL LEAKAGE AND TROPICAL FOREST CONSERVATION

Within project areas, tropical forest protection results in reduced emissions and at times, sustained uptake of carbon. Tropical forest conservation can also lead to increased sequestration or less emissions (positive ecological leakage) in areas outside the project boundary.

Deforestation in one area can lead to "edge effects" on forests left standing. Edge effects are changes in a forest community occurring at the border of forests left standing. Edge effects are often damaging to the remaining forests. One study showed that deforestation caused tree mortality in the area deforested and contributed to substantial biomass declines, and therefore greenhouse gas emissions, in *surrounding* forests (Laurance et al, 1997) Protected forests in a project area may also maintain favourable micro-climatic conditions that aid the resiliency of other regional forests (Lawton et al, 2001).

Core protected forests also can support pollinators and insectivores (such as bats) that make nearby agricultural areas more productive. Maintaining forests can also control flood and erosion. These factors may negate the need for new land conversion. Thus, there are numerous ecosystem feedbacks from forest conservation that may secure secondary benefits that ultimately can reduce emissions or increase uptake in areas outside the strict project boundary.

2.4 Scale: local to global

Leakage can manifest itself at various scales. If a project or policy alters local prices or behaviors, then local markets and activities may be changed. Though it is unlikely that any single project would significantly alter world timber or crop prices, the sum total of many similar individual projects might *conceivably* impact global markets. Similarly, ecological impacts of avoiding deforestation from any single project will not likely alter global circulation patterns. However, numerous projects to stop deforestation could *theoretically* serve to maintain historical global circulation patterns (McGuffie et al. 1995).

2.5 Sectors: fossil fuel or biomass

Leakage can occur in all sectors of the economy where GHG mitigation is conducted. For convenience sake, one can divide the economy into two sectors – parts of the economy that produce primarily fossil fuel emissions (energy, transport, industry) and parts that produce emissions from some form of biomass (vegetation, forests, soils, etc). LULUCF projects are often perceived as being particularly leakage-prone. Energy projects, however, also face risks of activity-shifting and market leakage that will need to be considered at the policy and project level.

Globally, it has been argued that the Kyoto Protocol may drive some energy-intensive industries to relocate to developing countries. Unencumbered by the constraints and costs of GHG emissions limits, this form of international leakage could undermine the apparent reductions. At the project level, clean-energy projects may displace capital stock or change relative prices of fuels, and cause leakage of emissions. A climate change mitigation project that builds relatively clean-burning natural gas plants (an existing market trend in many countries) could increase the price of natural gas in this area. This in turn could drive other investments to use coal or oil for new generating capacity, negating some, but not necessarily all, of the GHG benefits of the gas plant.

Estimates of market leakage for forestry activities (see **Table 3**) are generally higher than market leakage estimates in the energy sector of 4-15% (Chomitz 2000, p.9). Other studies, however, set energy sector market leakage at a comparable level. For example, *Sedjo 2000* mentions estimates of up to 40% for the energy sector.

3 LEAKAGE AND FORESTRY PROJECTS

Several types of forestry projects can mitigate GHG accumulation in the atmosphere, and each may be subject to different kinds and degrees of leakage. For simplicity's sake we divide LULUCF projects into two broad categories in our analyses[2]:

- Projects that avoid carbon dioxide emissions by avoiding deforestation or reducing forest degradation ("*conservation*" projects). Included in this broad category would be a wide range of activities, from outright conservation to reduced impact logging and improved forest and fire management.
- Projects that increase carbon sequestration, removing atmospheric CO_2 by growing trees on previously forested areas (*reforestation*), or areas that have not historically supported trees (*afforestation*).

For each of these broad project types we will examine the kinds of leakage that might occur. Our results from a review of the literature on the *types of leakage* for these broad project types are summarized in **Table 2**. Where possible, we also discuss the *magnitude* of potential leakage. Our review of the scale of concern is hampered by the fact that most LULUCF projects have not been operational long enough to allow detailed examination. The Noel Kempff Mercado Climate Action Project in Bolivia is the project with the most comprehensive leakage analysis thus far (Report pending, Winrock International 2002). What modeling has been done has been primarily on market effects of global scale carbon sequestration (see **Table 3**).

[2] We do not discuss projects that use biomass to substitute for fossil-fuel intensive products or processes (e.g. biofuels) as a separate category. Emissions reductions from displaced fossil-fuel emissions pertain essentially to the energy sector, while biomass plantations as a source of supply can be considered under reforestation and afforestation.

Table 2: Leakage and forest projects in developing countries

Project Type	Type of activity	Drivers of leakage[3]	Leakage mechanisms	Leakage Scale	Positive (+) negative (-) neutral (N);
Conservation[1]	Replace or prevent subsistence agriculture	Subsistence needs (+ or -)	Activity shift	Local	-/N/+
			Ecological	Local	+
			Market	Local	-/N/+
	Replace or prevent commercial agriculture	Cash crop markets (-)	Activity shift	Local/Global	-/N/+
			Ecological	Local	+
			Market	Local/Global	-/N/+
	Stop commercial logging	Timber markets (-)	Activity shift	Local/Global	-
			Ecological	Local	+
			Market	Local	-
	Stop forest products harvest for local needs	Subsistence needs (-)	Activity shift	Local	-
			Ecological	Local	+
			Market	Local	-
	Reduced impact logging, enhanced forest mgmt.	Technology transfer (+)	Activity shift	Local	+
			Ecological	Local	+
			Market	Local/Global	N
Reforestation & afforestation[2]	Ecosystem restoration	Resource and land availability (+ or -)	Activity shift	Local	+/N/-
			Ecological	Local	+
			Market	Local	+/N/-
	Small-scale reforestation for local needs	Land avail-ability (-) timber supply (+)	Activity shift	Local	N/-
			Ecological	Local	+
			Market	Local	N
	Commercial plantations	Timber markets (+ or -), land availability (-)	Activity shift	Local	+/N/-
			Ecological	Local	+/N/-
			Market	Local/Global	+/N/-

1) Excluded from the Clean Development Mechanism for first commitment period (2008-2012) of the Kyoto Protocol in negotiations as of November 2001.
2) Allowed in the Clean Development Mechanism with limitations.
3) Considering only socio-economic drivers of leakage, not ecological leakage drivers. A (**+**) sign refers to a driving factor for positive leakage and a (**-**) sign refers to a driver of negative leakage.

3.1 Conservation Projects

Land use and land-use change projects may reduce emissions from forests by avoiding deforestation or through the introduction of management practices that lead to increased carbon storage in forests (for example, by increasing rotation length and reducing harvest intensity). Avoided deforestation and proactive forest management have been specifically excluded as eligible project types under the Kyoto Protocol's Clean Development Mechanism (CDM) for the first commitment period (UNFCCC 2001). Comprehensive efforts to curb global warming will eventually need to promote these tools since deforestation and forest degradation, mostly in the developing world, constitute some 20-25% of global GHG emissions (Schimel et al. 1996).

Deforestation results from a mix of economic, social and political causes that vary from site to site. In general, the primary *proximate causes* of deforestation in the tropics are logging and conversion to agriculture or grazing. These activities span a spectrum from subsistence agricultural, to production of globally traded commodities (e.g., vegetable oil, wood pulp, cacao, rice etc). Behind the proximate deforestation causes are *driving forces* such as policies, attitudes and institutions that influence production and consumption (Turner et al. 1993). Deforestation is often a complex process influenced by cultures, markets, government policies, property rights and local politics. Deforestation is often driven by rural poverty and basic needs such as food, shelter, and fuel. Effective leakage control measures will need to address both the proximate causes (land-use changes) as well as underlying forces (poverty, land tenure, etc) of deforestation on a case by case basis.

The magnitude of **activity shifting leakage** will vary greatly across conservation projects. If neighboring forested lands are easily accessible and the displaced activity is mobile, activity-shifting leakage is likely. Where forested land is not readily available (in regions where land use is already consolidated) or where capital or labor are not mobile, the risk of activity-shifting leakage may be quite low. Projects that improve forest management rather than eliminate forest harvest altogether will be far less vulnerable to activity-shifting leakage. When new GHG-friendly ideas or technologies are economically competitive, projects may cause positive leakage. For instance, if reduced impact logging (RIL) is more profitable for timber companies than traditional techniques, positive activity-shifting leakage could easily occur as RIL disseminates beyond the project boundary.[3]

The risks of **market leakage** will depend on the nature of the market and the scale of any project. While a single conservation project is unlikely to affect global markets, it may affect local markets. In most cases, leakage risk will be less than 100%. For every forest protected, it is unlikely that there will be an equal expansion in production into other forest areas. Factors such as intensification, product substitution and reuse will likely replace some of the displaced output.

Little analytical work has been conducted on the magnitude of possible leakage from individual forestry projects. Most modeling has evaluated market effects of global scale carbon sequestration, and only two studies specifically address forest conservation (see **Table 3**).

In terms of leakage, conservation projects that eliminate logging activities could constrain supply and lead to increased demand for wood from new sources. *Sohngen et al. (1999)* studied the effect of an increased worldwide timber demand on harvesting rates in inaccessible northern forests such as Siberia, and in tropical South American and African rain forests. Their study suggests that higher timber prices would produce a stronger response in harvesting northern inaccessible forests than it does in additional logging in the tropics despite similar characteristics (low productivity, long rotation periods). Moreover, they show that an increasing timber price will more likely lead to an intensification of forest management in existing temperate zone forests (e.g. shorter-rotation periods) or to the new establishment of plantations in emerging subtropical regions (i.e., South and Central America, Africa and the Asia Pacific region). The latter results from greater harvest productivity in temperate zones and subtropical plantations compared to logging of inaccessible tropical forests. These results illustrate the enormous complexity of estimating leakage. Projects that stop deforestation caused by logging can reduce timber supply, raise prices and lead to more logging in temperate forests (negative leakage). Or, they can cause more plantations to be established (possibly positive leakage). Interestingly, the former scenario is not a leakage problem since it displaces emissions to where they would be accounted, e.g., within Annex I boundaries.

[3] Although if RIL makes logging more profitable, more logging may result.

Climate change mitigation projects that minimize harm from logging operations (RIL techniques) could be assumed to result in no or little market leakage since RIL essentially seeks to maintain a given timber output but with less damage. Differently, *Brown et al. (1997)* derived a considerable leakage potential of RIL techniques based on data of a carbon-offset project in Sabah, Malaysia. This project caused leakage because on one-third of the project area, timber production *initially* decreased by approximately 50m^3 per ha relative to conventional logging. The total timber shortfall was set at 22,050 m^3. They calculated the *maximum* leakage potential by estimating the additional area that must be logged to make up for this deficit. Assuming that RIL techniques would be used to compensate this shortfall, they arrived at an offsite carbon emission of 23,112 t C, equal to 60% of the annual gross carbon benefits of the project (38,700 tC). This maximum figure is useful in demonstrating a simple means of quantifying potential leakage. The true leakage effect of this project will most likely be less since *over time* RIL should increase timber output compared to conventional logging by sustaining less damage to young trees.

3.2 Reforestation and afforestation

Tree-planting projects run the gamut from diversified, community-based agroforestry systems that meet local needs, to restoration of degraded grazing land, to large-scale, commercial monocultures that supply global markets. Without adequate empirical data, it is difficult to say whether certain types of sequestration project may be more or less leakage prone. In general, small-scale reforestation/afforestation projects focused on environmental restoration and local community needs should have more positive leakage profiles than large-scale commercial plantations, mainly because they aim to minimize the drivers and scale of potential leakage.

If carried out on currently productive land, reforestation or afforestation may cause **activity-shifting leakage** as displaced people migrate to other forest areas. Displacement of local communities from lands has been a frequently cited concern, especially in the case of large-scale commercial reforestation projects (World Rainforest Movement 1999; Sawyer 1993). In Honduras, for example, thousands of small farmers and ranchers were reportedly displaced from the north coast valleys to make way for the establishment of oil palm cooperatives (CFAN 2001). While oil palm plantations would most probably *not* be considered forestry, under the Kyoto Protocol, this case demonstrates the enormous displacement potential of large-scale mono-component land-use projects.

As a rule, activity-shifting leakage will depend on whether reforestation engages or displaces landowners. If reforestation is an alternative or complementary land use for existing landowners, and economic benefits are comparable to non-forest alternatives, then the risk of negative activity-shifting leakage will likely be low. Projects that yield valuable environmental services may lead to additional carbon and other benefits, outside the project boundary (e.g., positive leakage). One example would be an agro-forestry project that improves water quality and enhances agricultural production, leading to additional communities practicing agro-forestry.

Market leakage from reforestation/afforestation projects can potentially be either positive or negative. In certain circumstances, however, reforestation/afforestation projects will be virtually free of market leakage risk. This would be the case for projects that serve exclusively to sequester and store carbon for the long-term and/or produce other environmental services, such as restoration projects for watershed protection or biodiversity conservation, *on previously degraded lands*. Second, if a reforestation/afforestation project generates products that are substitutes for others that come exclusively from natural forest sources (e.g. firewood for local use), this should tend to produce positive market-based leakage by creating a new supply of locally available resources.

Large-scale timber plantations may be particularly prone to market leakage. They could depress timber prices by increasing supply, which in turn could reduce the incentive to establish new timber plantations elsewhere. This could lead to either positive leakage (if the "foregone" plantations would have replaced carbon-rich native forests), or negative leakage (if the "foregone" plantations would have taken place on degraded lands with a lower carbon content). Equally plausible, timber plantations might reduce timber prices and lessen harvesting on other natural forests. Whether market forces will lead to a decline in forest harvesting (positive leakage) or the abandonment of plantations (negative leakage) will depend on local market conditions and circumstances. Reforestation/afforestation projects also may lead to negative market leakage if they reduce agricultural or livestock output or increase agricultural land rents.

Although still relatively limited, virtually all research on the amount of leakage has been done on market leakage from commercial plantations projects. The most advanced study in this field, done by *Sohngen and Sedjo (2000)*, is based on modeling a high additional input of 50 million hectares (ha) of carbon plantations established over a 30-year period. This is roughly equivalent to a doubling in the current rate of plantation establishment.[4] The general result of this model is that potential leakage from this program could be considerable. This study suggests that 50 million ha of new carbon plantations would decrease sequestration outside the new forests by around 50%. This effect is largely due to accompanying adverse changes in age classes of trees and increased management intensity rather than a diminished incentive to establish new plantations.[5]

An even more drastic result was derived by *Alig et al. (1997)*. They found a leakage rate for carbon sequestration projects exceeding 100% following a 4.9 million hectares afforestation program in the U.S. Their result is driven by an increase of agricultural land rents that results in a more than one-to-one conversion rate of forestry to agriculture. Afforested lands in this study were not required to remain in forestry (i.e. permanent set-asides) but also exposed to economic pressures from increased agricultural land and output prices.

The Cintrafor Global Trade Model (CGTM) (*Perez-Garcia 1994*) resembles Alig et al.'s work in some respects, but analyzes the impacts of a U.S. tree planting programs on the forest sector using an economic model of *world* forest products markets. This study examines impacts of a large tree-planting program in the southern U.S. on the forested land base in the U.S.'s north and west regions as well as Canada (*regional effects*), and on U.S. forest products trade with countries around the Pacific Rim and with European markets (*global effects*). The local effects in this study are found to be significant but there is almost no perceivable global impact from this tree-planting program due to existing trade links.

Kadekodi/Ravindranath (1997) show in a separate study that a nationwide teak tree-planting program in India, while tripling the output value of forest products and reversing the forest product

[4] The current worldwide rate of newly established of plantations is 1.6 Mio per year according to FAO (FAO 2000). If simply extrapolated it is equal to 48 Mio. ha over a 30 years period .

[5] The 50 million hectars impulse of this study would reduce land areas in commercial (i.e. "non-carbon") plantations only by 0.2 - 7.8 million hectares (less than 15%).

trade in favour of India, would also reduce global teak prices. Leakage results from this program since the global price decline would cause *existing* teak planters to face a smaller return on their investments.

Table 3: Magnitude of LULUCF Market Leakage

CDM Activity	*Study*	*Study Method*	*Study Period*	*Leakage Potential*	*Driving factors*
Plantations	Sohngen/ Sedjo 2000	Top-down	100 years[6]	50%	Increased timber supply, adverse changes in age classes of trees and forest management intensity
Plantations	Alig/Adams/McCarl/ Callaway/Winnett 1997	Top-down	50 years	100%	Rising agricultural land rents
Plantations	Perez-Garcia 1994	Top-down	50 years	Regionally high, but no global impact	Increased timber supply
Plantations	Kadekodi/Ravindranath 1997	Top-down	50 years	Non negligible	Increased timber supply
Averted deforestation	Sohngen/Mendelsohn/ Sedjo 1999	Top-down	125 years	Little or no perceivable impact	Intensification of existing forest management & additional plantations in subtropics
Reduced Impact Logging	Brown/Cabarele/ Livernash, 1997	Bottom-Up	1 year	60%	*Maximum* leakage potential based on a complete substitution of decreased timber production

4 OPTIONS FOR RESPONDING TO LEAKAGE: PROJECT LEVEL RESPONSE AND POLICIES

Leakage is a potentially significant risk for project activities. But as well-designed pilot projects around the world have demonstrated, leakage is not insurmountable. We divide the tools used to reduce and manage negative leakage in LULUCF projects into *project-level approaches* and *macro-level approaches*.

[6] Figures do not change considerably when looked at a shorter period of 50 years.

4.1 Project-level options for reducing and managing leakage

At the project level the two main categories for addressing leakage are *project-specific approaches* and *standardized approaches*. Project-specific approaches address case-by-case local circumstances such as fuel wood scarcity or ecosystem characteristics. Standardized approaches are broad measures applied across classes of projects to compensate for leakage. For example, a standardized "leakage discount" may apply to carbon offsets generated in forest conservation projects reflecting average leakage rates for this class of projects.
Approaches at the project level taken in various projects to date are summarized in **Table 4** and then discussed individually.

Table 4: Leakage Control and Monitoring in LULUCF Projects (*)

Policies / Projects	*Project Specific Approaches*: Site selection	*Project Specific Approaches*: Multi-component project	*Project Specific Approaches*: Leakage Contracts	*Project Specific Approaches*: Off site monitoring	*Standardized Approaches*: Discounting	*Standardized Approaches*: Aggregate baselines
Noel Kempff, Bolivia	-	✔	✔	✔	-	-
Rio Bravo, Belize	-	✔	-	✔	-	-
CARE, Guatemala	-	✔	-	-	-	-
Krkonose, Czech Rep.	✔	-	-	-	-	-
Ecoland, Costa Rica	✔	-	✔	-	-	-
Costa Rican National Parks	-	✔	-	-	✔	✔
Scolel Te, Mexico	-	✔	-	✔	-	-
RIL/Sabah, Malaysia	-	-	✔	-	-	-

*) Compiled from Noel Kempff Technical Operating Protocols 1999, Brown et al. 1997 (Rio Bravo, CARE, Krkonose), Trexler et al. 2000 (Ecoland), Chacon et al. 1999 (Costa Rican National Parks) and E-Mail communications with Richard Tipper (Scolel Te) and Francis Putz (RIL/Sabah).

4.1.1 Project-specific approaches

4.1.1.1 Site selection

At the project level, sound leakage management begins during the design of a project. Projects should be structured to maximize positive leakage (increased sequestration, reduced emissions) and minimize negative leakage (decreased sequestration, increased emissions). An obvious way to do this is for project developers to carefully seek out and consult communities with sincere interest in enhancing management of their forestlands. Thoughtful site selection might also entail locating a project in an area with few or no competing uses (such as degraded lands) or limited access (such as remote forests threatened with new logging roads) to minimize the risk of displacing people or causing negative market leakage. An example of a careful site selection is the *Krkonose* reforestation project in the Czech Republic where the project developer chose an isolated location with virtually no risk of encroachment or displacement (Brown et al. 1997). Another example is the *Ecoland* forest conservation project in Costa Rica, where virtually no forest was left standing outside the project area, making activity-shifting leakage improbable (Trexler et al. 2000, p. 147).

4.1.1.2 Multi-component projects

Projects should create incentives for local people to maintain the project and its GHG benefits by providing a range of socio-economic benefits (CIFOR 2000). Multi-component projects may help realize this and avoid leakage by integrating measures to meet local needs and provide sustainable access to resources (timber, fuel wood, cropland, etc). For example, project developers of the *Noel Kempff Mercado* forest conservation project in Bolivia control leakage with demand-management activities. These mitigation activities include agroforestry to provide sustainable sources of wood, employment opportunities, and equipment retirement schemes (Noel Kempff Technical Operating Protocols 1999). Similarly, the *CARE Guatemala project* increased fuel wood supply and agricultural productivity by providing trees through tree nurseries (Brown, et al. 1997). These components minimize negative activity shifting and negative market leakage (less pressure on the original forest) while encouraging additional positive ecological leakage. Other advantages to multi-component design include: possible enhanced profitability, increased local employment, numerous ecological positive feedbacks and overall higher likelihood of community support and success (Niles and Schwarze 2000).

4.1.1.3 Leakage Contracts

The *Noel Kempff Mercado Climate Action Project* forest conservation project in Bolivia uses contracts that prohibit leakage. The logging concessionaires bought out by the project signed contracts committing them to technical assistance and training in sustainable forest management practices for their remaining concessions (supporting positive activity-shifting leakage). To decrease activity shifting, concessionaires also agreed not to use money received from the project to purchase new concessions and to abandon logging equipment onsite (Noel Kempff Technical Operating Protocols 1999). To monitor possible activity shifting by loggers, the *Noel Kempff Mercado Climate Action Project* is scheduled to follow the investments and actions of timber concessionaires who were displaced by the project. Other contractual approaches might require (and possibly compensate) farmers to plant trees or use more efficient cooking stoves. It is likely that enforcement of leakage contracts will be easier with a smaller number of stakeholders.

4.1.1.4 Monitoring

All types of climate mitigation projects and policies should monitor leakage to a degree commensurate with the risk and possible scale of leakage. Since project design will not always be able to prevent leakage altogether, careful monitoring and measurement can provide the basis for adjusting GHG benefits accordingly.

There are several ways to monitor for potential leakage. This may involve *expanding the geographic scale of monitoring* beyond project boundaries to capture regional effects through a combination of remote sensing and sample plots in non-project areas. This method has been explored in the *Scolel Te Project* in Mexico (Tipper and de Jong 1998). Although expanding the boundaries for monitoring may capture activity-shifting and market leakage effects, it is often difficult to isolate impacts of project leakage from other exogenous factors that affect markets and land use (e.g. demographics, access, policies, markets for agricultural products or a host of other factors). The definition of boundaries for monitoring and the interpretation of results thus represent a special challenge.

The scope of monitoring may also be expanded to examine *market linkages* beyond the immediate project vicinity. Project managers can try to track effects of a project on the supply, price and sources for timber or agricultural products. However, markets are hard to model and are notoriously difficult to predict, even under the best of circumstances. Analyzing markets for timber, crops or livestock in many developing countries is complicated by the predominance of the informal sector and the lack of accurate and current data.

Another approach, proposed by Brown et al. (1997), is to track *selected indicators* rather than monitoring leakage directly. The use of indicators can alert monitoring agents as to the risk of leakage. This approach emphasizes key indicators of demand driving baseline land-use change. If demand for timber, fuelwood or farmland is left unmet due to a project, this would signal a risk of leakage. This in turn could trigger a burden of proof for project management of no-leakage (or any other type of so-called ‘seller liability’) similar to the traffic-light-approach for non-compliance (Wiser and Goldberg 1999). The indicator approach has the advantage of being relatively straightforward and transparent. Key indicators may be defined beforehand and can be objectively evaluated over time. Such an approach is likely to be more qualitative than quantitative. It remains a challenge to precisely measure how a decreased supply of farmland or forest products translate into carbon leakage.

Though laborious, tracking *activities of resource users* affected by project activities may be an effective means for capturing activity-shifting leakage. Activity shifting will often be easier monitored at the local level (although, for example, some logging companies could migrate to other countries) and it may be more tractable at the project scale. A variety of social and economic assessment methods, including surveys, follow-up interviews, and review of land transactions, can be used to estimate activity-shifting leakage. As mentioned prior, the *Noel Kempff Mercado Climate Action Project* follows investments and actions of timber concessionaires displaced by the project.

4.1.2 Standardized approaches

4.1.2.1 Discounting

If leakage is effectively monitored and calculated, then greenhouse gas benefits from a project may be adjusted accordingly. If projects monitor leakage in detail, any discount can be based on the specific outcomes of project implementation and monitoring. As previously illustrated, however, monitoring and calculating all possible leakage effects will be practically impossible. In order to address leakage from a practical standpoint and to simplify leakage accounting, standard coefficients could be used to adjust the GHG benefit estimates of projects. Some observers (Lee et al. 1997) have suggested applying a standardized discount to LULUCF projects. These adjustment coefficients will vary for different project types and different national or regional circumstances (IPCC 2000, p. 314). Case studies (IPCC 2000, Sec. 5.3.3.2., p. 264) indicate that certain broad landscape characteristics could be used to establish these varying leakage discounts. For example, a plantation project on severely degraded lands with few alternative uses and no occupants will almost certainly be less prone to leakage than a plantation carried out on productive lands with many users and/or occupants. Establishing appropriate adjustment coefficient(s) to cover diverse leakage risks merits further research, but ultimately will require policy decisions that balance the needs for accuracy and workability.

4.1.2.2 Project Eligibility Criteria

A drastic form of "discounting" would be to rule out projects that are perceived as particularly leakage prone. For example, if forest conservation projects in developing countries are set non-eligible for CDM projects (as under the current Art. 12 ruling of COP 6-bis) potential carbon credits from these activities are effectively discounted at a rate of 100%.

Given that leakage will mostly be project-specific and can be addressed through careful project-design, removing whole suites of objects would risk eliminating projects that yield positive GHG benefits and net local benefits. A favorable alternative approach would be to grant projects with appealing leakage profiles a streamlined approval and monitoring process similar to the preferential treatment of small-scale renewables and energy efficiency CDM projects decided at COP6-bis (UNFCCC 2001, 9).

4.1.2.3 Aggregate baselines

Another way of expanding a project's accounting boundary is to use aggregate baselines. This technique would entail developing national, regional or sectoral baselines on land-use change and management. Experience with standardized baselines, however, has shown that calculating national or sector-type baselines brings in tertiary and other indirect effects that can overwhelm any attempt at project-caused calculations (Trexler 1999, p.46). This problem is further aggravated by the fact that land-use change data for most developing countries is very incomplete. For example, deforestation rate estimations can typically vary greatly for the same country according to different sources and methods (Mathews 2001). Aggregate baselines are also rejected by many developing countries on the grounds that such national procedures could be a "back-door" way to coerce developing countries into a regime of quantified emission reduction targets.

4.2 Macro-Level Options for Reducing and Managing Leakage

At the macro level, we identify two major proposals that can minimize LULUCF leakage. First, a *ceiling* or cap can be placed on the volume of forestry projects for climate change mitigation. This approach serves to minimize the perceived scale of leakage risks. The second option is a *balanced portfolio approach*. It aims to offset, or balance, market leakage effects by combining reforestation/afforestation and avoided deforestation projects at the policy level.

4.2.1 The 1%-ceiling on CDM sinks

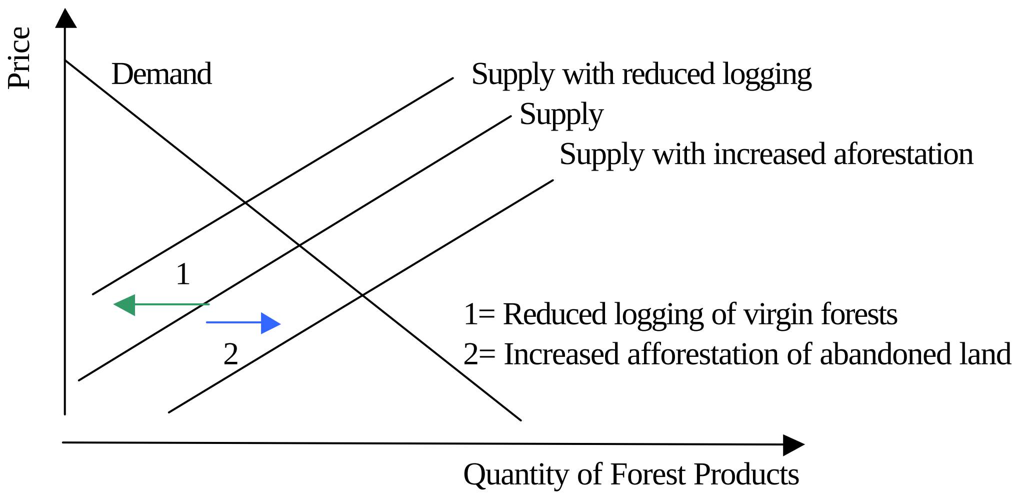
The resumed session of the Sixth Conference of the Parties, Part 2 (COP-6 bis) limited the number of credits developed countries may gain via CDM forestry projects. During the first commitment period (2008-2012), developed countries may only use CDM forestry projects to meet 1% of their respective 1990 emissions per year, for each of the five years in the first commitment period (UNFCCC 2001). Furthermore, at COP-6 bis, a decision was taken to restrict the type of forest projects to those that involve reforestation and afforestation ("sinks") and limited the size of individual projects. Although these restrictions were not set primarily to address the risk of leakage, limiting the scope and number of projects may effectively keep in check the impact of projects on local and/or global timber markets respectively.

The COP-6 bis ceiling will probably not have a great impact, as it appears to have been set above the threshold likely to be reached by CDM reforestation and afforestation projects. These results are discussed in a separate forthcoming paper (Niles and Vrojlik 2002)

4.2.2 A balanced LULUCF portfolio

Plantations may have opposite effects on local or global timber markets compared to forest conservation projects (see figure 2). Reduced logging of natural forests decreases the supply of forest products (price increase) and accelerated planting of trees increases the supply (price decrease). Some authors (e.g. Chomitz 2000, p.7) have argued that these counter-acting forces could lead to a leakage-neutralizing situation, where market effects of halting deforestation offset opposite market effects of plantations and/or reforestation. While there is no empirical evidence to support this notion, basic economic rational suggests this possibility may have some merit. The possibility of such "counteracting" forces makes an argument for trying to "balance" the ratio of these projects. This would imply that the recent decision by policy makers to exclude forest conservation from forest projects in developing countries could exacerbate leakage. Thus, the CDM executive board will not have this policy tool at its disposal, at least in the first commitment period.

Figure 2: Market effects of LULUCF projects



Such a balanced-portfolio approach, while useful to some degree, assumes a similarity in market effects of tree planting and tree protection that may not exist. First, industrial plantations operate on different time-scales compared to forest conservation projects. It can take 10 years or more for plantations to increase the wood supply whereas projects that stop logging reduce timber supplies in the short term and decades into the future. Interestingly, a relative symmetry could be achieved if avoided deforestation was allowed in the 2nd commitment period when new timber plantations will start being harvested. Second, harvest intensities vary greatly among (high yielding) industrial plantations and (low yielding) logging of tropical forests. There is also substantial variability within similar project types across regions and ecosystems (IPCC 2000, chapter 5). A balanced portfolio approach would need to take these differences into account, something not practical on a simple per-project basis. Finally, logging is only one factor behind tropical deforestation so carbon conserved through forest protection may only be loosely related to its effects on timber markets. The "balancing" approach therefore seems more promising at the project level, as discussed in section 4.1.1.2.

4.3 A Decision-Tree Approach for Managing Leakage

No approach to addressing leakage will be perfect. Methods will have to balance the need for accuracy with the desire for transparency and simplicity. Developing tailor-made methods for measuring and accounting leakage on a project-by-project basis may result in greater seeming accuracy. However, a profusion of approaches will undoubtedly be more opaque and subject to gaming—not to mention more costly and complex. Standardized approaches such as discounting may be less accurate, but their criteria can be conservatively defined and will be far less subject to gaming.

Several guidelines might serve for dealing with leakage in a transparent and uniform way across projects. Aukland et al (2002) lay out a conceptual "decision-tree" framework for describing in qualitative terms the potential leakage dynamics of a project. This framework could be combined with project-specific and/or standardized factors to make quantitative adjustments or discount project GHG benefits. A sample decision tree employing these guidelines for an avoided deforestation project, modified from Aukland et al (2002), is included in **Appendix 1**.

In conservation projects, activity-shifting and market leakage for conservation projects have partially countervailing effects. If activities simply shift place, market leakage will be reduced since the net change in the output of goods will decline. Total leakage for avoided deforestation projects is therefore the sum of activity-shifting leakage and market leakage adjusted for the effect of activity-shifting leakage.

$$\text{TOTAL LEAKAGE} = (L_{AS} + ((100 - L_{AS}) \times L_M) * GPB$$

Where:
L_{AS} = Activity shifting leakage (%)
L_{AM} = Market leakage (%)
GPB = Gross Project Benefits (tC or tCO_2)

For reforestation and afforestation projects, activity shifting does not necessarily mitigate market leakage as for conservation projects. A commercial reforestation project could simultaneously displace baseline agricultural activities into new forest areas (activity-shifting leakage) and depress investments in new forestry plantations by increasing supply (market leakage). In this case, total leakage is therefore the sum of activity-shifting leakage and market leakage.

$$\text{TOTAL LEAKAGE} = (L_{AS} + L_M) * GPB$$

Reforestation projects can also lead to less harvesting in natural areas (more timber, more fuel wood), whereby activity shifting would be negative and market leakage would be positive.

5 CONCLUSIONS AND RECOMMENDATIONS

Unintended consequences arise in virtually every type of activity. Climate change mitigation and sustainable development are no different. Discrete projects or policies may cause impacts that extend over a broad scale, through complex and dynamic causes and effects.

Devising solutions and rules for leakage is hampered by a dearth of substantial quantitative studies. There are no long-term, peer-reviewed evaluations of climate change mitigation leakage for actual projects. Until more studies are conducted, leakage is a legitimate concern in terms of its magnitude, although results from studies are highly variable. They also may not turn out to resemble real leakage rates that eventually are measured. There is no evidence that forestry as a sector is more prone to leakage than are other sectors, such as energy or transportation (although there are some indications for this belief). Nor is there concrete evidence that any one type of forestry project is more or less susceptible to leakage than others (although there are reasons to suspect that plantations may be particulary prone to market leakage).

Leakage will probably be most determined by project-specific activities, not broad categorical groupings. *Together, these findings suggest that all climate mitigation projects – plantations, transportation, forest conservation and energy - should monitor for and address leakage at the project level*. There is no apparent and compelling reason to shun any one type of climate change mitigation based solely on leakage.

Notwithstanding the lack of data, modeling scenarios, case studies, and general observations can provide insight into preventing negative leakage and fostering positive leakage. Projects should try to maintain the same long-term output of products (or substitutes) of baseline activities to account for market leakage. Multi-faceted projects may have advantages in terms of minimizing negative leakage and maximizing positive leakage. Integrated projects that use reforestation, plantations *and* forest conservation programs, seem well suited to create sustained, diverse economies that will not cause severe market disruptions or unwanted migration or displacement. Project diversity should also extend to non-forestry dimensions, such as clean energy, reliable transportation and other aspects. Other instruments, such as wise site selection and leakage contracts, may also help prevent negative leakage and bad projects.

At regional, national or global scales, leakage can also be addressed with complimentary project types. There is some evidence, for example, that reforestation programs and forest protection programs could have balancing influences on the global timber market. However, important asymmetries between growing new forests and not cutting down old ones must be addressed (timing of impacts, per area timber effects) for the value of multiple project activities to scale up.

Ensuring the integrity of climate change policies will also entail measuring leakage when it does occur. Monitoring will allow appropriate adjustments to be made to the amount of carbon offsets claimed by a project. Yet, measuring leakage with a high degree of precision will often be costly and inconclusive. The boundaries defined, the mechanisms posited and the assumptions employed will all be subject to contradicting opinions. It is not so much a problem of not having ways to map and measure leakage—a host of economists, sociologists, geographers and foresters can develop plausible approaches for each project. The problem lies precisely in this variety—and the resulting variety of possible outcomes.

Several approaches are available for managing leakage that does occur in an affordable and sufficiently accurate manner. First, monitoring beyond the project boundaries for selected indicators of leakage is one practical solution. Second, discount factors may be applied in the short term. They should be conservative (i.e., high) as the CDM market becomes operational, and can be refined as the market matures and further information becomes available. Well-reasoned discount coefficients will be different for different regions, project types and/or markets. For activity-shifting, this discount might be based on the likelihood of engaging local people. For markets, elasticities of demand and supply will be useful parameters for estimating leakage (cp. Chomitz 2000, p.8/9). Projects that have an appealing leakage profile – that minimize negative undesirable unintended consequences while promoting positive ones – could also be granted a preferential treatment in the proces of approval and monitoring to reward efforts in project-design.

It is also worth recalling that many projects will potentially have positive spillover effects. Positive activity shifting leakage (e.g. broader adoption of project technologies), market leakage (e.g. reduced pressure on natural forests as timber sources) and ecological leakage (ecosystem stabilization) may end up on par with negative leakage. These positive and unaccounted GHG benefits may also “buffer” against negative leakage that is not captured by monitoring.

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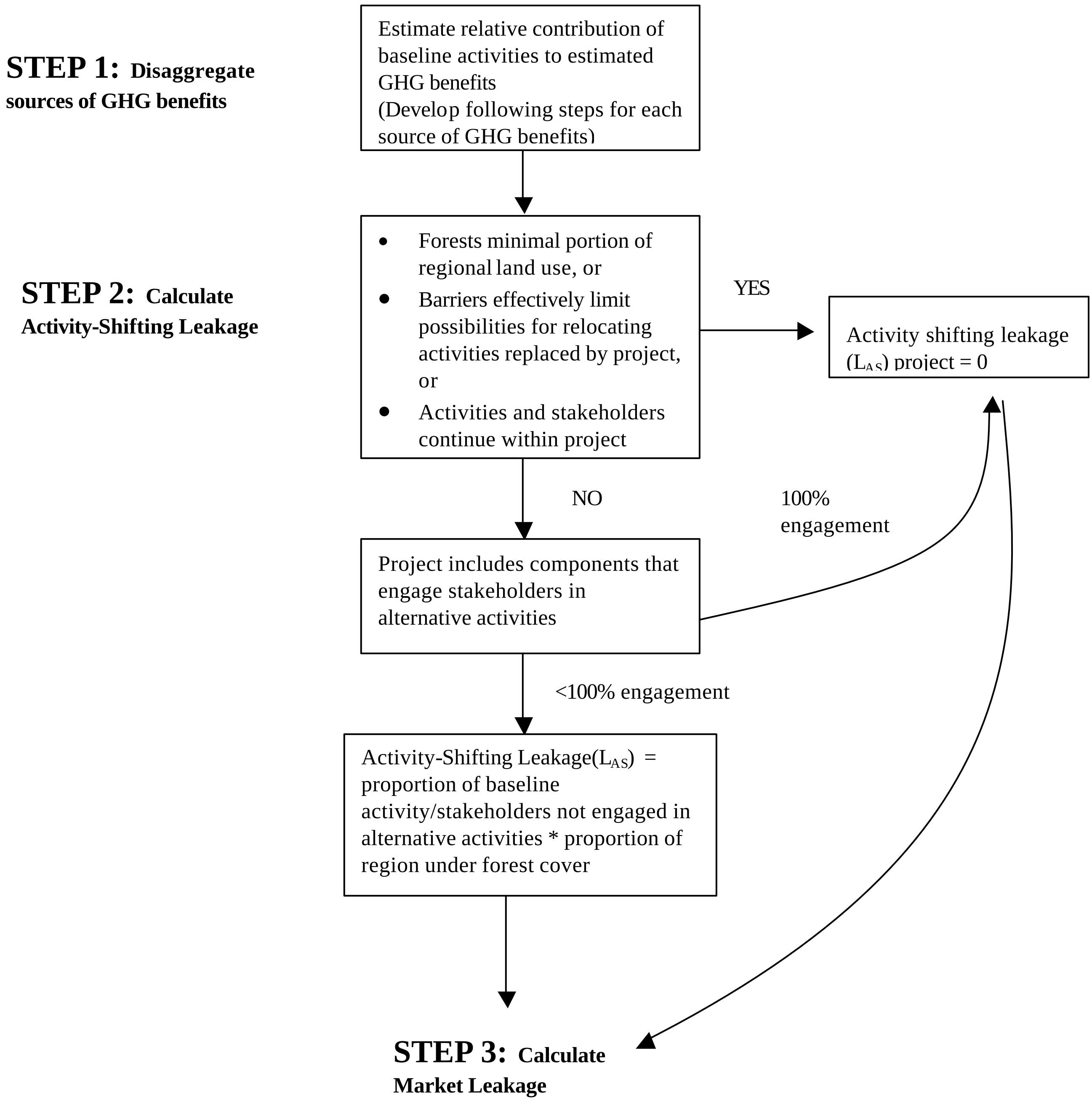
APPENDIX 1: ESTIMATING LEAKAGE FROM AVOIDED DEFORESTATION PROJECTS

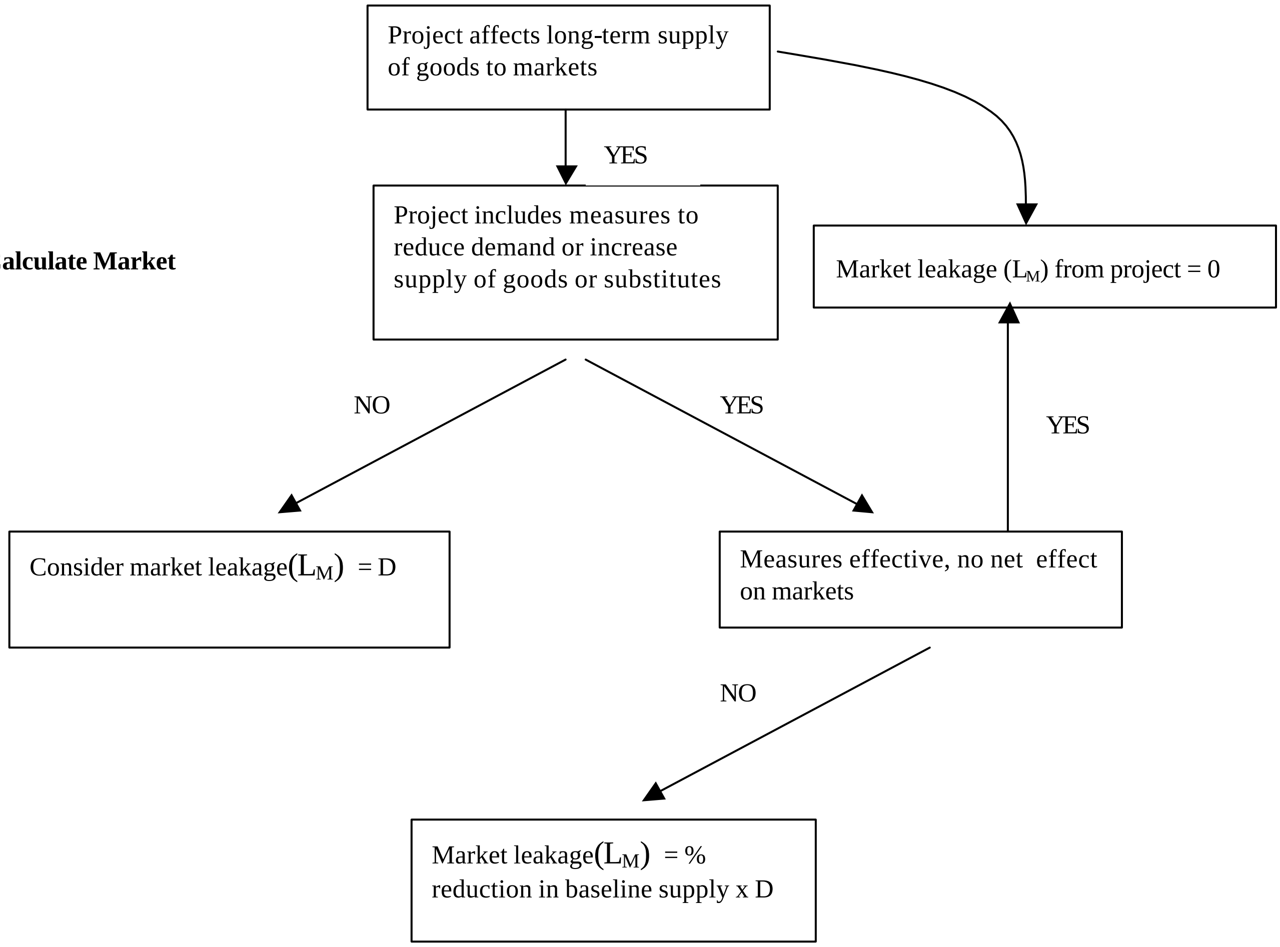
(BASED ON DECISION-TREE APPROACH OF AUKLAND ET AL 2002)



ESTIMATING LEAKAGE FROM AVOIDED DEFORESTTION PROJECTS

2

STEP 3: **Calculate Market Leakage**



STEP 4: **Calculate Total Leakage**

$$\text{TOTAL LEAKAGE} = (L_{AS} + ((100 - L_{AS}) \times L_M) * GPB$$

Where,
L_{As} = Activity shifting leakage (%)
L_{AM}= Market leakage (%)
D = Standard adjustment coefficient for market leakage by project type and/or region(%)
GPB = Goss Project Benefits (tC or tCO_2)