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This document is an extracted chapter from the report, Project Standards Development for the Amazon Forest Carbon Partnership: An Assessment of Options for Additionality, Permanence, and Leakage (October 2010), prepared for the Amazon Forest Carbon Partnership by the Economics and Finance Advisory Team, led by Duke University's Nicholas Institute. The AFCP reports were used to develop The Rainforest Standard™ protocol and the Leakage chapter presented here provided the underpinning of The Rainforest Standard™ Leakage standard discount methodology.

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4. QUANTIFYING LEAKAGE

4.1. Summary Recommendations

Avoided deforestation projects essentially mean the cessation of forest clearing within the designated project areas. Current and future activities causing deforestation will potentially be displaced, at least in part, to locations outside of the project areas. Leakage is the induced shifting of GHG emissions attributable to the activity displaced by RED projects. Although leakage is not necessarily under the control of the project proponent, it can undermine the GHG benefits of a project if not properly accounted for in the AFCP crediting mechanism. Supported by the assessment in this chapter, we summarize our recommendations on how to address leakage below.

Leakage is addressed in the chapter by decomposing it into the two types: activity-shifting and market-effects. The activity-shifting variant is "local" leakage, which is undertaken by local deforestation agents whose activities, such as subsistence agriculture, have been displaced by the RED project. Market leakage is generally more "distant" leakage that occurs when stable or rising demand interacting with decreased product supplies caused by the RED project may create market pressure and possibly price increases. Other producers have financial incentivize to grow supplies from other places, which can translate to new deforestation or other forms of emissions. With these types in mind, the recommended options for leakage are presented as follows.

4.1.1. Leakage assessment approach.

For each type of leakage, there are two principal assessment approaches—discount and reconcile. The discount approach involves assigning a discount factor upfront that reflects the expected rate of leakage and reduces the credits generated by a project by that fraction. The reconcile (or monitor and reconcile) approach assumes that displaced GHG emissions and/or activities will be monitored on the project or local or national level and that crediting will be adjusted by the observed level of leakage at the end of the crediting period. For addressing each leakage type, we recommend applying a discount factor approach to carbon credits earned. In sum, it would be simpler, quicker, and cheaper for the project developers, reviewers, and administrators to use. The discount factor will be created by summing estimates from the two leakage types. It will serve as a stopgap until better estimates from new studies become available and/or national or state accounting comes on line, which will allow for comprehensive reconciliation of projects and national or state accounts.

4.1.2. Leakage assessment steps

We propose the following stepwise method for calculating project leakage:

1. Weighting local and market leakage effects – Assign weights to each type based either on an independent assessment of deforestation drivers in the project area or a submission by the project proponent that is reviewed by AFCP
    - **a.** S_L = share of potential displaced activity that is local in nature
    - **b.** S_M = share of potential displaced activity that will affect commodity markets. This can be further share-weighted by commodity group, so that $S_M = \sum S_{Mi}$ where i represents the relevant commodity
    - **c.** $S_L + \sum S_{Mi} = 1.0$
2. Estimate local leakage (L_L) using method described below
3. Estimate market leakage (L_{Mi}) for each commodity using method described below
4. Estimate total leakage $L = L_L * S_L + \sum L_{Mi} * S_{Mi}$

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4.1.3. Local activity-shifting leakage (L_L)

A model predicting local leakage based on region- and project-level factors and generating standard activity-shifting leakage discount values would be ideal, though such a model, to our knowledge, has not been developed yet. Nevertheless, using a fixed leakage discount value or values has distinct advantages over the monitoring options. Unlike monitor and reconcile, there would be no question about consistency in application of the discount values. Credit producers and buyers would likely prefer having the certainty of a leakage discount, fixed for at least each crediting period, versus the uncertainty of the reconcile-after-monitoring system. For these reasons, and despite an admittedly thin empirical foundation at this point, we recommend that a small discount (e.g., 10%) for activity-shifting leakage be assessed on all projects. To date, the best empirical findings for activity-shifting leakage in the AFCP region suggest no local spillover effects from previous forest protection initiatives, suggesting a local leakage effect of 0% might be appropriate. However, using a modest discount would be more conservative in the absence of the preponderance of evidence. In the meantime, AFCP could commission studies to be conducted at project sites to evaluate directly whether activity-shifting leakage is occurring and could gather data that could be used to improve a discount factor for local leakage or parameterize a predictive model for it that could be applied in different settings. The leakage belt and/or activity monitoring methods used by other standards could be employed to do so. The predictive modeling for local leakage could be developed in conjunction with the baseline estimation modeling efforts, saving time and resources. Once developed, a predictive model of local leakage could be readily updated and adjusted as conditions change and new data become available.

4.1.4. Market leakage for each commodity (L_{Mi})

National monitoring and reconciliation would be the ideal way to detect all leakage, but that option is still years out for the whole AFCP program area. Market models are really the only credible option for estimating market-effects leakage that can be implemented now. Given that commodity production is a main driver of the Amazonian deforestation, not accounting for market leakage could mean missing a substantial portion of the potential leakage.

Values from a market leakage equation derived from Murray et al. (2004) are available for immediate use. Using commodity market share data and elasticity estimates drawn from international secondary data sources and the economics literature, both country-specific (i.e., the extent of market leakage within country) and AFCP-wide (the extent of market leakage within all five AFCP countries) estimates for market leakage have been produced for the commodities most pertinent to deforestation—soybeans, cattle, timber, and sugarcane. The commodity list could be lengthened if needed. We recommend using an AFCP-wide market leakage factor for all projects because it is simpler and ensures consistent treatment across AFCP countries. In Table 4.1, we present draft proposed default leakage parameters, which will be refined as needed during the standards development process.

Table 4.1. AFCP-wide market leakage estimates[1]

	Leakage estimate
Soybeans	30.9%
Cattle	20.2%
Timber	8.7%
Sugarcane	21.7%

[1] The AFCP-wide estimates are based on commodity market shares aggregated across all 5 member countries. For lack of data, we make the assumption that the supply elasticities facing each country are equivalent. Also, it is assumed here that the productivity and carbon stocks in locations receiving market leakage are equivalent to those in the RED project area. This can be adjusted by computing and applying the carbon displacement ratio, discussed in more detail in Section 4.5.

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One factor to consider when evaluating the leakage values in Table 4.1 is that these capture leakage that occurs within and across all AFCP countries. So the leakage estimate for a project in Bolivia captures displacement not only within Bolivia, but to the other AFCP countries. We recommend this because it treats projects consistently across all countries in the AFCP basin. We also have estimates for the market leakage contained within each individual country for each commodity, which could be used instead of the AFCP-wide estimates if the AFCP so chooses. The implication of using the country-specific measure for each commodity is that while there is ample opportunity for leakage within a large country like Brazil, there is very limited opportunity for it within a small country like Ecuador, where most leakage would be extramural. This would mean that Brazil's leakage estimate would be substantially higher than Ecuador's and projects in Brazil would be discounted more substantially merely because they are in a larger country.

One of the key parameters needed to develop the leakage estimates in Table 1 is the carbon displacement ratio associated with the forests or other land uses to which new commodity production may be shifted. It is the product of two components: land displacement ratio and the carbon density ratio. The land ratio accounts for any change in acreage, whether up or down, required to meet the foregone output level of the RED project area. The carbon density ratio reflects the differential carbon stock values across the landscape, so that the carbon loss from deforesting a new hectare may be greater or lesser than if a hectare of the RED project area were cleared. The yield potential and carbon density of the hypothetical leakage-receiving area could be estimated by using the distribution of growing areas and their corresponding market shares for the commodity of interest across regions in the AFCP countries to create weighted averages of those factors. This will require coordination with the STAT team.

AFCP should consider developing new econometric market models to replace the default values in Table 1 over time. This would require more data and expert time, though would be more rigorous overall and most tailored to the AFCP program area. The appropriate scale of modeling efforts should either be at the country-level or the Amazon basin-level. Global models can be used to estimate international leakage if that is desired; however, we have been operating under the assumption that AFCP is primarily interested in capturing leakage within its own member countries.

4.1.5. Leakage prevention activities

These activities, while well-intentioned, would divert scarce time and resources to establishing and monitoring activities with questionable efficacy at mitigating leakage. Moreover, they actually carry the potential of creating additional leakage. It may be best to avoid these, at least as part of the leakage protocol. It should be noted that the Climate, Community, and Biodiversity Standard (CCBS) requires local peoples' consent for projects' existence and participation in project design and that these measures could help guard against activity-shifting leakage by ensuring community buy-in. These issues are addressed in the Socio-economic Team report, for which checklists are being developed to cover key issues pertinent to fair and informed community participation.

4.2. Issue Background

4.2.1. What is leakage and why is it important?

Leakage is the induced shifting of GHG emissions outside the boundaries of the implemented project, program, or accounting system. Emitting activities, such as agriculture or logging, that previously took place within the project area are discontinued and potentially displaced through space (and time) to other locations or sectors.[2] Broadly, leakage is a consequence of incomplete coverage, where rules, regulations, and incentives for action affect only part of the potential pool of participants or emission sources (Murray

[2] Activity-driven emissions within the project area that are not included in the baseline are at times called "on-site" leakage. These emissions will be accounted for with project monitoring. We do not consider these emissions leakage, which is solely those emissions displaced outside of the project area.

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2009, Jenkins et al. 2009, Wunder 2008).[3] This chapter focuses on leakage as a key concern for offset projects involving reduced deforestation. This focus is similar to but separate from competitiveness-driven leakage that may arise from increased prices for industrial or electricity producers in countries/regions under a GHG regulation regime, potentially leading to production shifts to countries/regions with less stringent or without GHG regulation (Alain and Vielle 2009; Chen 2009).

Leakage is largely an economic phenomenon and often not directly observable. For example, by halting production activities within its boundaries, an avoided deforestation (RED) project will have the effect of reducing the supply of agricultural or forest commodities, while demand for those commodities remains unchanged. Given a fixed land base and the multi-scale nature of many commodity markets (local up to global scales), market forces can translate changes in the supply of commodities promoted by policies in one location into changes in the demand for and supply of commodities in other, distant locations. Even without well-integrated markets, parties may respond to restrictions in one place by shifting activities (and therefore emissions) locally to meet basic needs.

The relevant types of leakage introduced above are activity-shifting and market effects leakage.[4] Activity-shifting typically occurs on the local scale, with displaced deforestation agents finding other nearby unprotected areas in which to be active.[5] Market leakage stems from responses to commodity market signals and generally involves agents who deforest outside of the forest carbon project area. It is a largely "distant" rather than "local" effect, being categorized by the scale at which it operates—regional/national or international. "Distant" leakage indicates that product supply shocks from RED efforts are such that new production is triggered at the regional or national levels. When market leakage takes place in isolated, local markets, it is functionally equivalent to activity-shifting leakage.

Addressing leakage is crucial to RED project standard design; otherwise, GHG emission reductions or removals would be illusory to some degree. Published values of leakage magnitude range from 0% to over 90%, with the considerable variability owing to contextual factors such as market connectedness and availability of alternative lands for production. Leakage is indicative of climate change as a global environmental issue, in that emissions released at the same time have the same effect on the atmosphere no matter where they are emitted. The temporal element can be critical though; emissions leaked closer to the present have different impacts on the atmosphere than those released in the more distant future since it will lead to different concentrations over time. Similar to non-additionality and impermanence, leakage can work to undermine the environmental and economic effectiveness of mitigation actions if not adequately addressed.

4.2.2. Key factors in leakage

Box 4.1 presents an example of how leakage, both activity-shifting and market-effects, may impact the crediting for a RED project.

4.2.2.1. Activity-shifting

Leakage due to activity-shifting would principally be associated with the displacement of the following local-scale activities: grazing, agriculture, logging of timber, fuelwood collection or charcoal production, conversion to settlements, forest fires set by local communities. Agents who graze pasture animals, engage in agricultural production for subsistence, or log timber for local and domestic use may seek alternative venues for those pursuits or purchase those products through local markets. With biomass the

[3] Although negative leakage like this is most frequent, positive leakage can also occur, such as when a policy induces emission reductions outside of the targeted area (e.g., more efficient practices or technologies). Decreases in emissions due to positive leakage are not credited under VCS or other standards.
[4] An alternative typology of leakage uses the terms primary leakage, which is directly attributable to the deforestation agents, and secondary leakage, not directly attributable to the original deforestation agents (Aukland et al. 2003).
[5] An exception can be when a project proponent owns land in other areas and shifts emitting activities to those other lands, though that should be covered by leakage protocols.

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fuel of choice in many areas, displacing fuelwood collection could result in more local market purchases or increased use of non-renewable biomass elsewhere[6]. Depending on the structure of the RED project, specific levels of fuelwood collection or of conversion of local forest to settlements may be permitted within project boundaries. Fires induced by hunters or beekeepers of local communities as part of their trade could be shifted to uncontrolled areas. In addition, RED projects could displace other livelihood activities, such as the collection of non-timber forest products (NTFPs), that may not have significant GHG emission implications.

4.2.2.2. Market effects

Depending on myriad factors, such as soil quality, tree species composition, and travel cost to markets, some agricultural and timber products harvested in a proposed forest carbon project area may have been sold into local, regional, national, or international markets. To a lesser extent, this could also be the case for fuelwood/charcoal, though sales would likely be more localized in the Amazon Basin (relative to Africa, for example). Stable or rising demand interacting with decreased product supplies caused by the offset project(s) or program may create market pressure and possibly price increases, giving other producers financial incentive to grow supplies from other places, whether they are near or distant from the project area(s).[7,8] A rise in commodity production elsewhere often translates to additional deforestation or degradation, though this impact can be lessened or avoided through certain means, such as agricultural intensification in existing croplands, new cultivars, increased livestock stocking rates, etc. Land used to grow products with segmented, localized markets will generally have lower potential for leakage—or at least it would be easier to detect the leakage—than land producing commodities more integrated with outside markets. Homogeneous products traded in international markets would likely have the highest potential rates of leakage because decreases in supply could be filled easily given the substantial amount of similar supplies from other producers globally.

The relative emission potential of different production regions can significantly affect the GHG impact of the spatial shift in production of these commodities. In the case where avoided deforestation in one place induces deforestation elsewhere, this is determined mainly by the carbon stocks of the impacted forest types (or other land uses), which will vary across the regions (see Figure 9 of Science and Technology Assessment Team draft report – *to provide a more specific citation when that report is final*). Carbon stock averages are determined by the potential forest type and site productivity. A RED project displacing agricultural production from a highly carbon dense forest to non-forested land or low carbon forest elsewhere would have a lower leakage rate than in the reverse case, all else equal. Factors based on the distribution of forest types and their corresponding carbon stocks can be used to estimate leakage. In the case of logging, one needs to estimate both the biomass carbon of the timber extracted as well as the biomass carbon of the forest damages caused by the extraction (from damage to other trees, road building, skid trails, etc.) (Putz 2008). The extent of collateral damage will depend upon the relative abundance per hectare of commercially important tree species, carbon stocks, the topography of the terrain, and other variables.

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[6] Reductions in local fuelwood gathering could also induce switching to non-biomass fuels such as gas stoves, but the carbon consequences of this shift are not directly addressed here.

[7] Internal demand is most likely to grow in the coming decades in AFCP countries, given positive population and GDP per capita growth rates (UN data).

[8] Multiplier effects associated with increased economic activity in the area generating the new product supplies could also mean greater GHG impacts and thus an even higher rate of leakage from the project. Estimates of these effects are not found in the literature and are not included in this analysis.

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Box 4.1. Avoided deforestation leakage example.
Building off the hypothetical RED project described in **Error! Reference source not found.** of the permanence chapter, there is a 20,000 hectare project for which the baseline deforestation rate is 2% per year, equivalent to 400 hectares annually. The forest stores 500 tons of CO_2e per hectare, meaning that 200,000 tCO_2e would be avoided annually with a project that stops the deforestation.

Leakage may occur in two spatially distinct ways: "local" activity-shifting and "distant" market effects. These leakage types can be distinguished by their respective drivers. Forest clearing for products with local end use is associated with activity-shifting, while clearing to produce commodities traded on geographically broad markets creates market effects. The impacts of the two forms of leakage are additive and their sum will be subtracted from the GHG benefits of the project.

An analysis of the deforestation drivers for the project area reveals that 50% of anticipated forest clearing (or 200 hectares) would have been used for subsistence agriculture and the other 50% would have gone into soy production. Monitoring or modeling indicates that a quarter of the forgone subsistence agriculture (50 ha) is displaced to parcels near the project area. This 25% leakage rate for activity shifting implies leaked emissions of 25,000 tCO_2e per year (50 ha *500t/ha). Regarding the market-effects leakage, it is estimated that 40% of the forgone soy production (80 ha) occurs in another region of the Amazon basin to partially fill the demand gap created by the RED project. The region in which the new soy crop is grown has a carbon stock of 250 tons of CO_2e per hectare, which is half of the carbon density of forests in the project area. This means that the leakage due to markets is 20,000 tCO_2e per year (80 ha *250t/ha). Overall, 45,000 tCO_2e are leaked each year, for a total leakage rate of 22.5%. This leaves 155,000 tCO_2e of avoided emissions to be credited to the project each year, pending any further adjustments (e.g., for permanence).

	Hectares	tCO_2e/ha/yr
Avoided emissions due to project	400	200,000
• Forgone subsistence production	200	100,000
• Forgone soy production	200	100,000
- Activity-shifting leakage	50	-25,000
- Market-effects leakage	80	-20,000
Creditable avoided emissions	-	155,000

4.3. Options for Addressing Leakage

Table 4.2 indicates the approaches to leakage with regard to RED and other forest carbon projects taken by the major offset standards. For comprehensiveness, if the standard does not currently allow RED projects, then the forest carbon project type it permits is included instead. Note that specific methodologies or methodology modules dealing with leakage for various project circumstances are being developed by Avoided Deforestation Partners (ADP), Terra Global Capital LLC (TGC), and the BioCarbon Fund (BCF). These methodologies work within the framework of VCS's three avoided deforestation project types[9] and are presently making their way through the double approval process required by VCS to authorize new Agriculture, Forestry, and Other Land Use (AFOLU) methodologies.[10] They will be referenced in the discussion of specific options below.

[9] The Voluntary Carbon Standard (VCS) recognizes and provides guidance for three types of REDD projects: (1) Avoiding planned deforestation (APD), (2) Avoiding unplanned frontier deforestation and degradation (AUFDD), and (3) Avoiding unplanned mosaic deforestation and degradation (AUMDD).

[10] VCS Double Approval Process guidelines found at http://www.v-c-s.org/docs/VCS Program Normative Document - Double Approval Process.pdf.

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Table 4.2. Major offset standards and their approaches to leakage.

Standard	Forest carbon project type	Leakage type addressed	How estimate leakage?
Chicago Climate Exchange (CCX)	Soil carbon sequestration	Activity-shifting	No project-specific leakage assessment required
	Forest carbon (A/R; SFM)	Activity-shifting	No project-specific leakage assessment required (for SFM, confirm which, if not all, entity-owned lands included in project area)
	Sustainably managed rangeland soil C sequestration	Activity-shifting	Confirm enrollment (in CCX) of all eligible land by project owner Confirm stocking rates on owned/controlled rangelands outside project have not increased due to project
CDM	A/R	Activity-shifting	Measure displacement of grazing, agricultural, or fuelwood collection activities
VCS	Avoided Planned Deforestation (APD)	Activity-shifting	Monitoring activities on landowner's other lands (document review)
	Avoided Unplanned Deforestation – Frontier, Mosaic (AUFDD; AUMDD)	Activity-shifting Market effects (only where timber production is significantly affected or those projects claiming credits for avoiding illegal logging)	Activity-shifting: measured using approved methodologies - - none yet, but under development Market effects: discount credits based on leakage look-up tables provided (discount depends on where timber harvest is likely to shift to); other discount values from similar projects could also be used
CAR	Avoided Conversion	Activity-shifting	"Conversion displacement risk" formula used to estimate leakage Estimated Leakage = (State/region "Conversion displacement risk" value) x (gain in onsite carbon) x (-1)
Plan Vivo	Avoided deforestation	Activity shifting	Must list potential leakage risks (e.g., fuelwood extraction)
CCBS	Avoided deforestation	Activity shifting, market effects, and leakage due to leakage mitigation activities	Procedures for estimation not detailed, but must (1) document leakage mitigation activities, (2) estimate how much leakage might still occur, and (3) subtract this likely leakage from total carbon benefits claimed.

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The basic approach to accounting for leakage is to estimate leaked emissions and subtract them out from the carbon benefits attributable to a project. For avoided deforestation, the magnitude of leakage would be expressed in proportional or percentage terms for this relationship:

$$Leakage = \frac{GHG\ emissions\ shifted\ elsewhere}{GHG\ emissions\ avoided\ by\ project\ or\ program}$$

In the example in Box 4.1, 200,000 tCO_2e are avoided by the project while 45,000 tCO_2e leak outside of the project boundaries. Thus, the leakage rate is 22.5% (45,000/200,000). Credits issued are equivalent to 155,000 tCO_2e once leakage is accounted for.

The RED program administrator would set the timeline to estimate leakage and take the appropriate deductions; most likely this would be aligned with verification events, which determine the amounts of credits available for trade. For each type of leakage, activity-shifting or market-effects, there are two different approaches to select from— “reconcile” or “discount” (see Figure 4.1). In the first case, crediting would be contingent on the leakage directly observed through monitoring, whether project-level monitoring for activity-shifting or national-level monitoring for all potential leakage effects within country. Since national reconciliation would cover any and all leakage, it is listed as an option under both activity-shifting and market effects in Figure 4.1. Observed leakage (*ex post*) would then be reconciled with *ex ante* leakage estimates, which may have been used to establish a fixed percentage of credits to be placed in a set aside account. If this is the case, then the project proponent could get some of those credits back if the measured leakage was less than the set aside; however, additional credits could be owed if the set aside turned out to be too small. Alternatively, no credits could be issued until the reconciliation was complete and the proper deduction for the observed leakage was taken. One other possibility would be a “rolling” reconciliation, in which future crediting or set asides can be adjusted but earned credits are not modified after the crediting period.

Following the discount approach, a leakage discount would be applied to the project up front and the discounted credits could not be recovered through direct reconciliation, as in the previous approach. The discount rate would be developed by predictive models, which would differ according to which type of leakage was being analyzed. For activity-shifting, there could be a flat rate for all projects or project-specific rates based on a checklist of key parameters related to the project context (e.g., forest configuration, human population density). Regarding market-effects leakage, predictive modeling could be done through a market connectedness assessment, econometric analysis, or project location assessment. Market connectedness refers to the scale of the markets to which the forgone commodity production pertains (manioc may be local, while soy is international). Rather than reconciliation, there would be a parameterization process through which the predictive models are adjusted as conditions and drivers change and more experience and data are accumulated. Over time, the modeling would improve and the discount rate should become more accurate and thus less likely to under-credit projects (i.e., discount rate greater than actual leakage) or over-credit them (discount rate less than actual leakage). But, in contrast to most reconciliation options, the number of credits previously issued would not be adjusted.[11]

Following the structure laid out in Figure 4.1, the options are discussed by the type of leakage they target, namely activity-shifting or market-effects leakage, and then by the chosen approach, either reconcile or discount. The two types of leakage estimates are assumed to be mutually exclusive and therefore additive (see Box 4.1), save for the case of national monitoring and reconciliation. The national reconciliation

[11] “Recovery” of credits could, however, come in the form of reduced leakage discounts in future crediting periods if the empirical evidence supports it.

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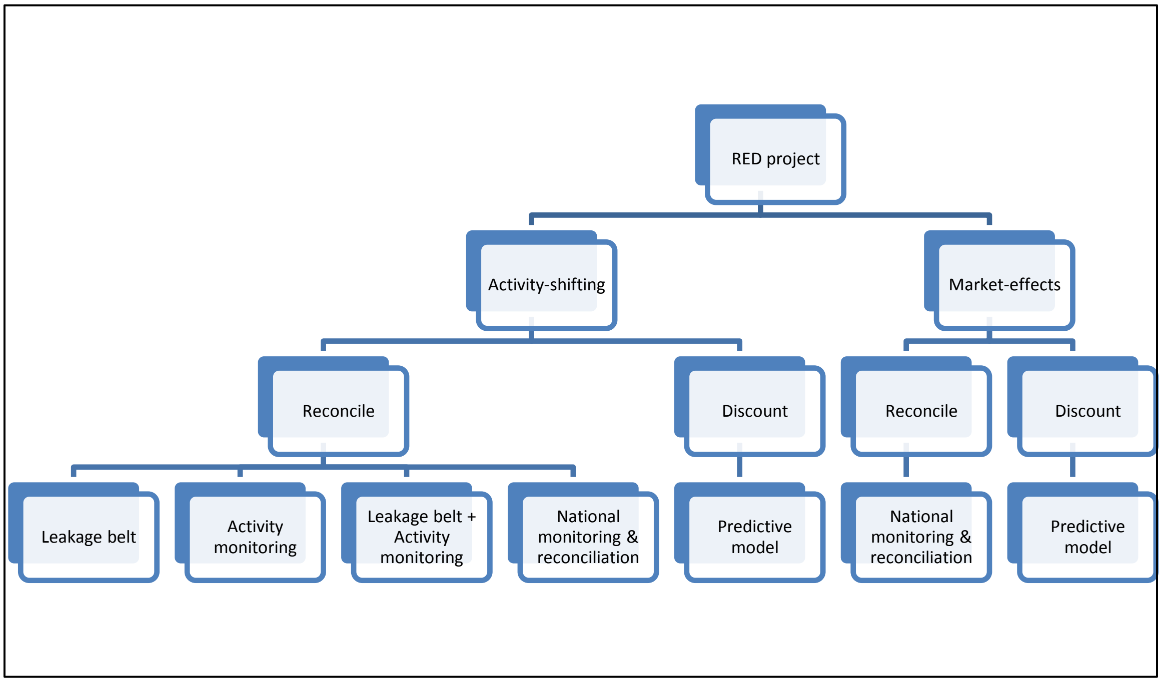
approach would capture both activity-shifting and market-effects leakage and therefore it could be applied by itself. There is no reason that one approach must be selected for addressing both types of leakage; a mixed approach is a viable possibility, e.g., reconcile for activity-shifting and discount for market-effects. In addition, if it is judged that the majority of leakage is due to one of the two types, then it may be appropriate to simply focus on that type in standard design.

Figure 4.1. Decision tree detailing the options for addressing activity-shifting and market-effects leakage. For each leakage type, the discount or reconcile approach can be selected. Note that National reconciliation would cover both types of leakage.



4.3.1. Activity-shifting

A number of approaches have been put forward to address leakage from local displacement of emitting activities, which are generally not part of broader markets. Four options fall under the reconcile approach, as shown in Figure 4.1. The first three—leakage belt emissions monitoring, activity monitoring, and leakage belt activity monitoring—involve a local, project-level effort to evaluate the degree of activity displacement from the RED project. National or state monitoring and reconciliation would necessarily take place at the national or state level and therefore detects both activity-shifting and market-effects leakage within the entire jurisdiction. As for the discount approach, determining appropriate discounts through predictive models is the main option.

4.3.1.1. Reconcile approach

4.3.1.1.1. Leakage belt emissions monitoring

Assuming that activity-shifting leakage will occur close to project areas, a fixed geographic region surrounding or adjacent to each discrete project area parcel will be defined. That "leakage belt" will be monitored for changes in GHG emissions during the RED project implementation, and those changes will be compared annually to a baseline emission profile for the belt in order to detect the presence and magnitude of any leakage.

Central to establishing the boundary of the leakage belt is an analysis of the deforestation drivers and the mobility of the potential (local) deforestation agents. ADP's module states that with the information from this analysis, the project proponent can "establish the boundary of the leakage belt using transparent

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criteria that can be independently verified."[12] This guidance is somewhat vague and leaves this option susceptible to being applied inconsistently across projects. Providing more details, TGC states that the "size and location of the leakage belts is determined using a cost-of-transportation-based GIS approach and participatory rural appraisals" and provides six steps.[13] To be conservative, TGC indicates that, if there is more than one agent, the "most mobile deforestation agent" determines the spatial extent of leakage belt.

Once the leakage belt is determined, the changes to carbon stocks and other non-CO_2 emissions are monitored using several other ADP modules that estimate changes in forest cover, in carbon pool components, and in non-CO_2 gas emissions. It should be noted that this method is only applicable when the baseline of carbon stock changes and GHG emissions has been established for the leakage belt area (see Additionality Chapter). In addition, it is plausible that this approach could lead to overlapping leakage belts, in which one project's leakage belt overlaps that of another nearby project. This issue would mean difficulties in separating out changes in the GHG emissions due to one project from those due to the other in the overlapping area.

4.3.1.1.2. Activity monitoring

This option entails monitoring the displacement of specific emitting activities wherever they might go, rather than tracking GHG emissions within the leakage belt area. For the ADP module, they are grazing activities, agricultural activities, and the use of non-sustainable biomass (i.e., fuelwood collection). If deemed critical, other activities (e.g., local timber usage) could be considered as well. For each activity assessed to be present, the most recent version of the CDM Executive Board-approved methodology for determining leakage for A/R projects for that particular activity is employed.[14] The CDM methodologies seek to account for both increases in GHG emissions and decreases in carbon stocks outside of the project boundary attributable to the project. Activity-monitoring involves an assessment of the pre-project activities, including surveys of the livestock, agricultural production, fuelwood collection, local households and/or communities, and areas available for those activities outside the project boundaries. These activities are then tracked for five years after initiation of the RED project. For leaked grazing or agricultural production, estimates for the amount of land converted for these activities are figured using the survey and monitoring data. The converted area is multiplied by the carbon stock of its previous land cover type (e.g., mature forest) to find the total carbon emitted. Emissions of non-CO_2 gases associated with aboveground biomass burning often used to clear the area is added to the carbon figure to arrive at the overall GHG values for leakage.

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[12] Page 5 in http://www.netinform.net/KE/files/pdf/14_LK-ASU%20Leakage%20activity%20shifting%20unplanned%station%20v1.0.pdf.
[13] Page 103 in http://www.netinform.de/KE/files/pdf/VCS REDD methodology Terra Global Capital - revised v2 clean.pdf.
[14] For example, pages 17-31 in A/R methodology AR-AM0004 "Reforestation or Afforestation of Land Currently Under Agricultural Use" at http://cdm.unfccc.int/UserManagement/FileStorage/KYBDLQFMI6R20X58OGH3Z71N9TSU4A.

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Box 4.2. leakage belt activity monitoring example.
The leakage assessment of the 20,000 hectare RED project described in Box 4.1 found that 25,000 tCO_2e per year of leakage was due to local activity shifting. This example demonstrates how one would arrive at the 25,000 t/yr estimate using the leakage belt activity monitoring option detailed in this section.

We assume that three activities (grazing, crops, and fuelwood collection) are present in the RED project area and will potentially be displaced by the project. Under the reconcile approach, we observe project emissions relative to a project baseline to start the crediting. Using the CDM methodologies, leakage for all three activities is estimated at 28,000 tCO_2e at the beginning of the crediting period. At the end of the crediting period (e.g., year one), leakage associated with the monitored activities is reassessed within the leakage belt. The leakage detected is 25,000 tCO_2e across the three activities. We adjust the crediting based on these local emissions outside of the project area within the leakage belt (less the baseline emissions outside the project area within the belt).

Activity	Leakage estimates, beginning of crediting period	Leakage estimates, end of crediting period
Subsistence grazing	12,000	10,000
Subsistence crops	12,000	12,000
Fuelwood collection	4,000	3,000
Total	28,000	25,000

Since no credits are issued until after project emissions are monitored and verified, there will not be an exchange of credits to account for a lower leakage estimate at the end of the crediting period than at the beginning. The beginning estimate provides an idea of the approximate leakage discount that the project proponent should expect to be applied, but is not used for the issuance of credits.

4.3.1.1.3. Leakage belt activity monitoring

This option combines the preceding two methods by requiring activity monitoring to be performed in a specified leakage belt area established around the project area. The Terra Global Capital approach involves monitoring five geographically constrained drivers within the belt area; those drivers are fuelwood collection, conversion of forestland to cropland by local communities, conversion of forestland to settlements, logging of timber for local and domestic use, and forest fires induced by local communities. BioCarbon Fund's approach[15] recommends using the CDM A/R methodologies for finding leakage induced by displaced grazing, agricultural production, or biomass harvesting (same as in 4.3.1.1.2 Activity Monitoring).

An assessment of the deforestation drivers in the project area identifies the relevant drivers and how many project area hectares they impact. Under the Terra Global Capital approach, a leakage rate is determined for each driver based on expert knowledge, participatory appraisals, and past project experience. Those rates are multiplied by the area impacted by the corresponding deforestation driver to find the leakage attributable to each driver. The leakage amounts for each driver are summed to arrive at total leakage. This figure is adjusted down by the baseline rate of deforestation in the leakage belt to arrive at the leakage due to the project. Box 4.2 provides a numerical example of this option.

4.3.1.1.4. National monitoring & reconciliation

See discussion below in 4.3.2.1.1.

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http://unfccc.int/files/methods_science/redd/methodologies/other/application/pdf/biocf_redd_mosaic_methodology_15_dec_2008.pdf

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4.3.1.2. Discount approach

4.3.1.2.1. Predictive model

Climate Action Reserve (CAR) utilizes a "conversion displacement risk" value to estimate leakage stemming from RED projects (which CAR calls "Avoided Conversion" projects).[16] The value is a percentage representing the maximum annual forestland conversion rate by county in each U.S. state. The maximum rate is used in order to be conservative. To date, only the state value for California, which is 3.6%, is available. Based on the historical forestland conversion data, the rate reflects the annual risk of conversion of any given forestland in the state and does not take into account particular circumstances or factors that may mean higher or lower risks of conversion for some forests. Leakage effects of a RED project are equal to the conversion displacement risk multiplied by the annual gain in onsite carbon (after accounting for the baseline onsite carbon). Operationally, if 1,000 tCO_2e of emissions were avoided in year one of a RED project (registered with CAR), then 36 tons would be subtracted as leakage (0.036 * 1000) leaving 964 tCO_2e to be credited to the project. In our judgment, however, this approach is not tied conceptually to a leakage effect. Rather, it gives a general deforestation rate for a region and interprets this as leakage. While this may be an appropriate way to develop a rough local deforestation baseline rate, it is not tied to the notion that reducing clearing in one place *induces* clearing in another and thus is not an appropriate measure of leakage.

It could be possible to develop standard local leakage values for different regions in the Amazon Basin (or one value for the whole basin). A predictive model could be used to generate these values and this option would allow them to be updated on a consistent basis as conditions change and new data becomes available. Following an approach similar to that presented in Motel et al. (2009) to estimate baselines, it could include key variables, such as population density, population growth rates, initial forest area, local road network, and activity type displaced. For example, these variables would vary depending on where along the forest configuration type continuum (frontier to mosaic) the RED project takes place and thus produce leakage rates reflecting specific localized circumstances. Resulting leakage values would be organized by region in a look-up table for easy use by project proponents, verifiers, and program administrators. A modification to this option would be to generate a simple equation into which a project proponent could input data relevant to her project area in order to calculate a leakage estimate for the RED project. Importantly though, this approach would require a certain amount of observed leakage data to run the model and establish the relationships with the other variables. That data is currently scarce.

A model predicting local leakage for Amazon projects would be ideal, though such a model, to our knowledge, has not been developed yet. There currently exists little activity-shifting leakage data that would be necessary to parameterize that model. Nevertheless, while the predictive model is developed, a modest fixed discount for leakage (e.g., 10%) could be applied to all AFCP projects to cover a low level of anticipated local leakage. Even though three recent studies in Latin America have failed to find activity-shifting leakage effects associated with forest carbon projects or protected areas, a small discount would be a more conservative choice relative to no discount at all. Regarding those studies, De Jong et al. (2007), which assessed activity-shifting leakage from Plan Vivo forest carbon projects in Chiapas, Mexico, found no leakage between years 2000 and 2003. Andam et al. (2008) observed that Costa Rica's protected area network were effective in reducing deforestation and that forest clearing spillover effects from protected to unprotected areas were negligible. Soares-Filho et al. (2010) used remote sensing data to evaluate the effectiveness of 595 Brazilian Amazon Protected Areas (PA) established since 1997. They found neither evidence of activity-shifting leakage by deforestation agents displaced by the PAs, nor of leakage driven by migrant agents coming in from outside the area.

[16] CAR Forest Project Protocol 3.1 can be found at http://www.climateactionreserve.org/how/protocols/adopted/forest/current/.

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4.3.2. Market-effects leakage

Less attention has been given this type of leakage in the methodologies, though it may be argued that it can easily surpass activity-shifting leakage in magnitude since it encompasses much greater geographic scope. Moreover, there is evidence that cattle ranching and soy production for distant markets have become the principal drivers of deforestation in the Brazilian Amazon post-1985 (Rudel et al. 2009). Of the methodologies reviewed, only ADP addresses market leakage with a specific module, which focuses on wood extraction for timber and/or fuelwood.[17] Several studies in peer-reviewed journals have estimated market leakage associated with timber markets (e.g., Wear and Murray 2004, Sohngen and Brown 2004), though only one study (Murray et al. 2004) thus far has looked specifically at agricultural and land markets in relation to leakage from forest carbon programs.[18] Agricultural commodities, such as soybeans, beef or oil palm, represent well-integrated markets, extending from regional to global, and thus require analysis incorporating this broader scale of supply and demand. In contrast, subsistence crop production and certain forms of grazing only meet local demand; therefore, these activities are generally considered outside of markets and any pertinent leakage can be measured through activity-shifting options. Although even subsistence production could contribute to market leakage if the subsistence farmer were to switch from growing their own products to buying them off of the market. But this situation has not been explored in the literature and, for now anyway, is beyond the scope of this report.

A key issue regarding market leakage is the geographic scale of the analysis to measure it. On one hand, if national reconciliation were implemented, then clearly the monitoring boundaries would be drawn at national borders. On the other, the use of predictive models could be applied at varying scales. The modeling could seek to estimate market leakage on the following scales: each AFCP country individually, the whole Amazon Basin (i.e., the AFCP program area), the five member countries in AFCP, or international. The advantages and disadvantages of each scale is discussed further below.

4.3.2.1. Reconcile approach

4.3.2.1.1. National reconciliation

International forest carbon policy is moving gradually toward national reconciliation in part to deal with intranational leakage. Using this approach, the GHG balance associated with the forest sector would be monitored at the national level and a reconciliation assessing the overall impacts of the RED program would be done annually. Leakage adjustments would be derived from this reconciliation. Note that a national reconciliation would capture market leakage that remains within the country as well as local non-market activity shifting within country. National accounting and reconciliation is beyond the scope of the AFCP and would have to be carried out by the individual member countries.

4.3.2.2. Discount approach

4.3.2.2.1. Market models

4.3.2.2.1.1. Fixed rate based on previous study. A set discount for market leakage could be applied to any RED project. Determining the discount level could be based on the econometric results of a market modeling exercise. To date, the only market leakage study conducted on an Amazon Basin country was one that modeled timber leakage associated with a stop timber harvesting project in Bolivia (Sohngen and Brown 2004). The authors sought to estimate leakage at the national level, that is, within Bolivia's borders. The study created a model of the Bolivian timber markets and tested the effects of key variables, such as project length, future global sequestration policies, capital constraints, demand elasticity, and deadwood decomposition rates. The results suggest that, depending on the scenario, carbon emission leakage could range from 5% to 42% within Bolivia (or 2% to 38% when carbon is time-discounted). The

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[17] TGC expects activity-shifting to be the main source of leakage, with market leakage being negligible. Coefficients from VCS AFOLU guidance are used for any market-induced leakage in the TGC methodology.

[18] Leakage has been asserted with the USDA's Conservation Reserve Program (CRP) in which land retired via CRP may induce non-cropland acres elsewhere to go into crop production. One study (Wu 2000) shows a slippage rate of about 20% on CRP land, but subsequent research by Roberts and Bucholtz (2005) suggests a much smaller effect, which is negligible in some regions.

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AFCP could simply apply a mid-range estimate from the market leakage rates found in this study to all projects in the program. In order to arrive at one leakage rate from the estimated range, the set of assumptions (i.e., model inputs) will be selected that seems most appropriate or more conservative.

4.3.2.2.1.2. Market leakage equation. Murray *et* al. (2004*)* present a leakage effect equation which may provide a consistent starting point for modeling market leakage:

$$L=[e/(e-E*(1+\varphi))]*(C^N/C^R)$$

where

- e = the price elasticity of supply in the commodity market impacted by the project
- E = the price elasticity of demand
- C^N = the carbon emissions per unit of output from a non-protected area (receiving leakage)
- C^R = carbon sequestration per unit of forgone output gained by protecting the forest
- Φ = the preservation parameter, which represents the ratio of the baseline supply quantity from the protected forest over the baseline supply quantity from the non-protected forest

The project location option is incorporated by having the carbon lost through leakage divided by the carbon maintained through avoided deforestation. It should be noted that these parameters may need to be customized so that they only capture national or regional leakage. Also, this equation could be used for commodities other than timber, such as soy or beef. If the price elasticities of supply and demand for the commodity of interest were available, this equation would allow a first-order estimate of leakage without having to conduct a new econometric modeling effort. Through collaboration with experts, the AFCP could provide the elasticities for common commodities in a look-up table. The carbon density of the area receiving the new production (i.e., the leakage recipient) could be determined using a method similar to that outlined in the project location option below. Alternatively, the carbon density of the receiving area could be estimated by using the distribution of growing areas for the commodity of interest across regions in the Amazon basin to create a carbon stock weighted average. The proportion of the commodity production grown in each region would be multiplied by the average carbon stock of that region to calculate the carbon density of the hypothetical leakage-receiving area. The carbon density associated with the principal commodities could be furnished by AFCP, via the STAT team. We provide a more detailed application of this modeling approach below in Section 4.5.

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4.3.2.2.1.3. New Models. Econometric models similar to the one used in Sohngen and Brown (2004) could be constructed for timber or important agricultural commodities in the Amazon Basin to determine market leakage discount rates. The appropriate geographic scale for the modeling effort (e.g., national or regional) would first need to be determined. Although a few modeling efforts have estimated international leakage[19] for timber, when moving to that scale projects appear to be responsible for just about everything. In addition, international policy is moving in the direction of using national boundaries for as the geographic limits for responsibility for GHG emissions. However, given the 5-country configuration of the AFCP, and the appeal of treating projects within each of these countries consistently, one can make the case that estimating the leakage flow within and among the 5-country AFCP region is most appropriate. We explore both national and AFCP country-level scale estimation below in Section 4.5, but we defer to the AFCP for final judgment on this issue.

Another pertinent issue involves whether modeling should be performed at the project level versus the program level. Given that projects may be small and may not noticeably impact markets on an individual basis,[20] it may be preferable to consider programmatic leakage. This would mean modeling the impacts on commodity markets of all of the projects aggregated to the AFCP program level. The estimated market-effects leakage for the entire program area could then be attributed proportionally to individual projects.

4.3.2.2.2. Connectedness ratings

The connectedness of the markets for the product supply displaced by the RED project could be assessed to generate estimates of leakage potential. The assumption here is that leakage is positively correlated with the degree of integration of the product markets and that market connectedness is a key variable influencing the magnitude of leakage. Thus, if the product markets are very localized, then "distant" market leakage would be basically zero and picked up by the local activity-shifting measures. Commodities trading on national or multi-national markets would tend to have higher leakage potential than those limited to regional markets.

To operationalize this option, market data for all the commodities of interest would be reviewed in order to understand the volume of trade in the each commodity between the economic regions within the Amazon and perhaps between the non-Amazonian regions of the AFCP countries and the Amazon basin. This analysis could also potentially extend to trade between the Amazon basin and world markets. A scale of connectedness would be developed based on the trade volume and each commodity would receive a connectedness rating depending where it fell on this scale. The scale could run from 1 to 10, with 1 representing little or no market integration and 10 very high integration. For example, if manioc were lightly traded between two regions but nowhere else, then it may be assigned a rating of 2; whereas, if much of the Amazonian soy production is traded internationally, then it would be rated with a 9. Leakage rates would be associated with the ratings, e.g., a rating of 2 would mean 20% leakage. Thus, if it were determined that 100 hectares of manioc production would be forgone due to a RED project, then a leakage discount of 20% would be applied to credits generated on that land.

This option would generate estimates of market-effects leakage for a variety of agricultural and timber commodities without having to build market models and determine supply and demand elasticities for each commodity. This has some appeal, but it also requires a way to link these ratings to an empirically meaningful estimate of leakage, which is not all that plausible without some model. To our knowledge, no study has empirically linked leakage to degree of market connectedness to date. The published leakage

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[19] Sohngen and Brown (2004) only covered national market leakage, but two recent studies take on international leakage. Gan and McCarl (2007) utilize a general equilibrium model of the global forest products market to quantify leakage stemming from forest conversation policies. The results indicate that 42-95% of decreased forestry production implemented in a country or region can be displaced elsewhere. Focusing on timber markets, Acosta and Sohngen (2009) find international leakage rates of only 2% to 14% when developing regions obtain carbon credits.

[20] Although Sohngen and Brown (2004) looked at the effect of one very large project, encompassing over 600,000 hectares, this is likely to be the exception rather than the rule.

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estimates, such as those for timber in Bolivia, could serve as a foundation for establishing the quantitative link between the connectedness ratings and leakage rates. This approach could be a simple means of incorporating international leakage, which may be too challenging to be estimated via a market modeling approach. Though, given the direction of international climate policy, there may be good reason to forgo accounting for leakage occurring outside of national borders.

4.3.2.2.3. Simple leakage adjustment based on project location

ADP presents a module dealing with market-effect leakage resulting from extraction of wood for timber, fuelwood or charcoal,[21] though it could be adapted for agricultural products or grazing too. Rather than constructing a market model, this approach simply begins with an assumption that commodity production activity leakage (not emissions) will be approximately 40%. This is similar to the upper end of the leakage estimates from the Bolivia timber study, though it is not cited by the module. Because the destination of leaked emitting activities will likely remain unknown (as will its carbon density), the key information is where the RED project takes place and what the carbon density is there. If the carbon stock in the project area is relatively equal to the mean national (or basin-level) forest carbon stock, then leakage rate is simply 40% (the base assumption). If the project area carbon stock is markedly lower or higher than the mean national forest carbon stock, then the leakage rate will be 20% or 70%, respectively. The assigned leakage rate is then multiplied by the emissions from forgone harvests and from collateral damage associated with them to calculate the overall market-effect leakage in units of CO_2e. Box 4.3 provides a numerical example of this option. It is not clear from where 20% and 70% were derived for the module; perhaps some empirical carbon stock or leakage data could be used adjust the percentages to better reflect the AFCP program area.

Box 4.3. Market leakage example.
Return to the Box 4.1 example, where a RED project avoids the release of 200,000 t CO_2e per year. Using APD's "project location" method, we can estimate market-effects leakage by knowing the forest carbon stock of the project area and the mean forest carbon stock for the nation or Amazon basin. This assumes that all project-related market leakage occurs within the country or basin. The carbon density of the project area is 500 tCO_2e/ha. If the average basin-level carbon density is about 500 tCO_2e/ha, then the leakage rate would be 40% and thus carbon leakage would be 80,000 t CO_2e (0.4 * 200,000). Were the mean basin carbon stock 350 or 650 tCO_2e/ha, then the leakage rate and leaked emissions would be 20% or 70% and 40,000 or 140,000 t CO_2e, respectively. Creditable avoided emissions is found by subtracting the leakage emissions from the 200,000 t CO_2e protected by the project.

	Carbon stock	Leakage rate	Leaked emissions	Creditable avoided emissions
Project area	500	-	-	200,000
Mean basin stock – lower	350	20%	40,000	160,000
Mean basin stock – similar	500	40%	80,000	120,000
Mean basin stock – greater	650	70%	140,000	60,000

4.3.3. Leakage prevention activities

Many standards, including VCS, Plan Vivo, and CCBS, require the implementation of leakage mitigation activities that would, at least partially, address the socio-economic factors driving leakage. The basic concept is that measures are taken to enhance output in cropland and grazing land areas or to provide sustainable livelihood options and thus mitigate leakage from displaced activity in the project area(s). Agricultural intensification would include increased fertilization and use of new cultivars or genetically modified crops. The distribution of more fuel-efficient woodstoves or propane stoves could reduce pressure to gather fuelwood. In addition, community woodlots could alleviate displaced fuelwood

[21] http://www.netinform.de/KE/files/pdf/15_LK-ME%20Leakage%20market%20effects%20v1.0.pdf

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collection or local-use logging. Alternative livelihood options (e.g., eco-tourism or protected area staff) would potentially diminish reliance on forest or agricultural commodity production.

The flip side of these activities is that their implementation could result in additional GHG emissions, which would have to be tracked and subtracted from a project's GHG benefits. In other words, leakage prevention activities could increase the total leakage incurred by a project. The TGC methodology provides equations to estimate GHG emissions from the leakage prevention activities of increased rice production, increased fertilization, and from increased livestock stocking rates (for N_2O and CH_4 emissions). BCF discusses calculating emissions for the latter two options as well as for increased consumption of fossil fuels engendered by leakage prevention activities. In each case, BCF stipulates the use of CDM-EB approved tools.

One other relevant issue is that the super-acceptance of these leakage prevention options, when people other than the deforestation agents adopt them, can lead to an influx of people to the general project area from other regions.[22] This is reminiscent of the experiences of Integrated Conservation and Development Programs (ICDPs) over the years. Leakage could result both if these people take up options that increase GHG emissions and if the area population has grown and there are more people engaged in emitting activities. However, it is possible that the opposite could also happen if people (already in the area) switched to lower-emitting activities due to the project implementation (i.e., "good" leakage from these positive spillover effects). TCG states that potential negative leakage effects associated with super-acceptance (many adopters) must be tracked in the project monitoring plan. However, GHG benefits from positive leakage are not eligible for crediting.

On a related note, CCBS requires local peoples' consent for projects' existence and participation in project design. These measures could help guard against activity-shifting leakage by ensuring community buy-in. These issues are addressed in the Socio-economic Team report, for which checklists are being developed to cover key issues pertinent to fair and informed community participation.

4.4. Assessment

This report has described various options to address leakage within the context of a forest carbon standard for the Amazon basin. In Table 4.3, an assessment of the reviewed options to address leakage is conducted with regard to the following three criteria: credibility, practicability, and acceptability. For each criterion, a rating is given for each option on a scale of 1 to 5, with 1 being the least favorable and 5 most favorable.

4.4.1. Activity-shifting

4.4.1.1. Credibility

Although appealing on the surface, the leakage belt emissions monitoring option suffers from several weaknesses. The methods for establishing leakage belt boundaries are vague and could easily be applied inconsistently across projects, resulting in variation in leakage measurements. Most importantly, it is not clear that the leakage belt option would ensure that the measured changes in carbon stocks could be attributed to the RED project with high confidence. For instance, leakage belts from different projects may overlap and confound each others' leakage measurements. Moreover, carbon stock changes could also be due to natural variation and/or economic activity unrelated to the activities displaced by the project.

Although likely producing somewhat more credible measurements than the leakage belt option, given the complicated methodologies, the activity-monitoring option may be challenging to apply consistently across projects. The upshot would be variation in estimated leakage rates across projects due solely to that

[22] Pages 97-98 in Terra Global Capital LLC methodology.

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methodological complexity and not related to the “true” leakage. Activity-monitoring does have the merit of actually identifying the pre-project emitting activities and attempting to track their displacement in order to forecast leakage. If conducted correctly, this could result in a meaningful measure of leakage. That said, since the activity monitoring must continue over some period after the project begins (CDM methodology AR-AM0004 uses a five-year period), it may become difficult to distinguish GHG emission changes associated with displaced activities from the project and those changes due to other economic forces and decisions. Leakage occurring after the monitoring period ends would not be accounted for and could undermine the long-term effects of the RED project. In addition, it seems unlikely that activity monitoring will be able to effectively track the actions of households that decide to move far from the project area. The idea of limiting the activity monitoring to within a leakage belt is more logical from this standpoint, though a leakage belt could embrace a relatively large area and still be difficult to monitor well.

No predictive models have been developed for activity-shifting leakage to date. It is difficult to assess the credibility of models not yet in existence, but the modeling process would be similar in some ways to that done to model baselines (see BAU Modeling in Chapter 2, Additionality) and therefore would be feasible for experts commissioned to work on it, once they extend such models to capture local activity shifting *induced* by a project, rather than a continuation of *status quo*. Leakage estimates produced by predictive models will also be uncertain; however, over time, the parameterization process should allow models to become more accurate as more data and experience accumulate. The estimates from predictive models should be able to incorporate changing conditions on the landscape more readily than the monitoring approaches. In addition, using standard values from a lookup table or values generated by the same leakage function has the advantage of consistent treatment across all RED projects.

4.4.1.2. Practicability

The leakage belt approach essentially serves to expand the monitoring boundaries of the project, thereby incurring additional costs solely for the purpose of finding ways to reduce the project’s credits. Both leakage belt and activity-shifting would be expensive in time and resources for the project proponents, thus increasing transaction costs, cutting into project profit margin, and potentially reducing the total number of projects developed. Although economies of scale enjoyed by large projects could lower per credit costs, these costs could be especially burdensome for smaller projects. Given the amount of information to be assessed, leakage belts and especially activity-monitoring would require potentially time- and resource-intensive evaluations by reviewers. This would drive up the validation/verification costs and lengthen the time from project start to crediting. Also relative to using standard values generated by a predictive model, reviewers would need to be more experienced and/or have more extensive training to reliably assess the leakage belt and activity monitoring options. And given that the reviews would be time-consuming, the overall quantity of reviewers may need to be greater to obviate delays.

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Table 4.3. Assessment of approaches to leakage.

Option	Assessment Criteria			Comments
	Credibility	Practicability	Acceptability	
Activity-shifting leakage				
Leakage belt	2	3	3	Expensive; increases transaction costs; a lot of effort for project proponents; still would be not certain that observed change in carbon stocks actually caused by RED project leakage
Activity monitoring	3	3	3	Could be accurate if done well; time-consuming; increases transaction costs; a lot of effort for project proponents; relevant time period over which to continue monitoring unclear
Leakage belt + Activity monitoring	3	3	3	Same as above
Predictive model	3	4	4	No predictive model currently available for activity-shifting leakage. Once developed by experts, can easily be adjusted to new data and conditions. Model development could be facilitated by AFCP, saving project proponents costs and time vs. other options.
Market-effects leakage				
National reconciliation	4	1	5	Ideal, but expensive and the realization potentially many years off. AFCP would need results from all member countries to cover full program area.
Market models				
• *Fixed rate from previous study*	2	5	2	Timber leakage rate ready to use; applying to all projects means ignoring differences b/w commodities and countries
• *Market Leakage equation*	4	4	4	Ready to use; more flexible parametric approach incorporates commodity and country-specific data and carbon stock differences
• *New Models*	3	2	3	Hard to assess credibility of model not done yet; time and experts required for development; could be tailored to AFCP-specific countries and commodities; international scale not desirable.
Connectedness rating	1	3	3	Potentially straightforward and inexpensive. But no study empirically linking market connectedness and leakage currently available. Simple way to estimate international leakage, if desirable.
Simple adjustment/ Project location	2	4	2	Simple procedure to account for carbon stock differences across program area, though needs assumption about leakage rate. Could be combined with connectedness ratings or econometric modeling results to better estimate leakage rate.
Leakage prevention activities				
Leakage prevention activities	2	2	3	Well intentioned, though implementation could involve much time and cost. Questionable efficacy at slowing leakage. Perhaps simpler to apply leakage deductions. Check-list developed by socio-economic team may address this issue.

Assigning a value for activity-shifting leakage generated through predictive models could prove simpler and less expensive than the project monitoring options under the reconcile approach (e.g., CDM precedent). Using predictive models will require the contracting of experts by AFCP and may mean potentially high up-front costs. But if data collection is standardized and model adjustment is not too

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frequent, it is likely to be more cost-effective overall than project monitoring options. Moreover, costs and responsibility for generating leakage estimates would be conducted at the program level and managed by the program administrator. This would save the project proponents considerable effort and cost as well as reduce the burden on reviewers. Otherwise, there may be less project development than desired. As the size of the AFCP program increases, per project or per ton carbon avoided costs may decrease as well as may the potential for leakage. Lastly, predictive modeling for activity-shifting leakage could build off of or overlap with baseline estimation modeling effort. Developing a modeling package for both ends would save time and resources.

4.4.1.3. Acceptability

It will be important to voluntary credit buyers or compliance regimes that some type of systematic approach to monitoring and/or estimating leakage is in place. Whether leakage belt and/or activity monitoring options will be considered acceptable is unclear, although several disadvantages of those options have been highlighted above. Since CDM has been much criticized, there could be concerns about acceptability with using a leakage methodology (e.g., activity monitoring) patterned on CDM.

Potential producers and buyers of RED carbon credits may prefer to see an upfront leakage discount on a project's credits rather than a reconcile-after-monitoring approach because the former offers greater certainty. Greater certainty would translate to less risk for investors. Of course, the discount could also change when the estimates from the predictive model are updated (which could occur annually or after each crediting period or synced with baseline re-estimation). But this new discount rate could be limited in application, being only applicable to new projects and/or new crediting periods rather than requiring forfeiture of previously earned credits by the project.

If respected experts are commissioned to develop the predictive models and they go through a peer-review process, this may be more acceptable to buyers than the complicated methodologies requiring significant reviewer discretion for the leakage belt and activity monitoring options.

4.4.1.4. Recommendation

A model predicting local leakage based on region- and project-level factors and generating standard activity-shifting leakage discount values would be ideal, though such a model, to our knowledge, has not been developed yet. Nevertheless, using a fixed leakage discount value or values has distinct advantages over the monitoring options. Unlike monitor and reconcile, there would be no question about consistency in application of the discount values. Credit buyers would likely prefer having the certainty of a leakage discount, fixed for at least each crediting period, versus the uncertainty of the reconcile-after-monitoring system. For these reasons, and despite an admittedly thin empirical foundation at this point, we recommend that a small discount (e.g., 10%) for activity-shifting leakage be assessed on all projects. To date, the best empirical findings for activity-shifting leakage in the AFCP region suggest no local spillover effects from previous forest protection initiatives, suggesting a local leakage effect of 0% might be appropriate. However, using a modest discount would be more conservative in the absence of the preponderance of evidence. In the meantime, AFCP could commission studies to be conducted at project sites to evaluate directly whether activity-shifting leakage is occurring and could gather data that could be used to improve a discount factor for local leakage or parameterize a predictive model for it that could be applied in different settings. The leakage belt and/or activity monitoring methods used by other standards could be employed to do so. The predictive modeling for local leakage could be developed in conjunction with the baseline estimation modeling efforts, saving time and resources. Once developed, a predictive model of local leakage could be readily updated and adjusted as conditions change and new data become available.

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4.4.2. Market-effects leakage

4.4.2.1. Credibility

National reconciliation by all AFCP countries would be the most creditable approach to capture both regional and intranational market leakage and activity shifting since it would provide nation-wide, sector-wide coverage across the region. That said, technological limitations may constrain the ability to disentangle changes in carbon stock due to natural variation from those due to a forest carbon program.

Regarding econometric market modeling, the range of leakage rates estimated by these efforts to date has been broad (0% to 90%). This gives the impression that it is difficult to come up with accurate measures of market leakage and that there is no consensus has been reached on leakage magnitude in the scientific community. Individual studies also present ranges of leakage estimates (e.g., 2% to 38% in Bolivia study). These ranges depend on the assumptions and inputs (e.g., demand elasticity, extent of market) used in the modeling. The program administrator and/or experts would have to select the set of assumptions that would be most conservative or appropriate for program area. It is questionable if the extent of international leakage could be estimated with sufficient accuracy to inform development of a standard discount rate or other compensatory measure. Moreover, using international market leakage would be an attempt to make projects accountable for basically everything and therefore not very creditable. For these reasons, modeling at the national- or perhaps basin-level would be most defensible.

Applying the fixed rate taken from the Bolivian timber study to all projects would ignore potentially significant differences between commodities and AFCP countries, and would lack credibility because of that. The market leakage equation employs a parametric approach that will be more flexible, enabling the generation of leakage estimates for specific commodities, countries, and the AFCP program area itself. The equation also incorporates differences in carbon stock across the landscape.

The connectedness rating option is attractive for its intuitiveness—the larger the scale of the market associated with the displaced commodity production, the greater the potential for leakage. To our knowledge, however, a study has not yet been conducted that determines these ratings among a basket of products, so it is unclear how accurate they could be for estimating leakage for those various products. Thus, for now, we would have to consider this a non-credible option.

The simple adjustment based on project location modeling option provides a straightforward procedure for accounting for carbon stock differences between the project area and potential receiving areas of displaced activities. The distribution of carbon stocks across the Amazonian landscape is well understood (STAT report), though this option involves using mean carbon stock numbers and would potentially yield fairly crude estimates. Also, because this option depends on base leakage assumption, it is only as good as this assumption. If the assumption used was not based on empirical evidence, this option would not seem very creditable. Lastly, since carbon stocks are integrated into three market model options, the project location method does not seem to bring much to the table.

4.4.2.2. Practicability

National reconciliation would be ideal for capturing all leakage within country by observation, but could be very expensive and a national responsibility, not AFCPs per se. AFCP would need results from all five member countries to cover the entire program area. Although it appears to be the direction international policy is going, national monitoring infrastructure may not be ready in near term for all AFCP countries. It would be possible to consider a hybrid system in which national or state monitoring was done for one or more countries/states that had the capability and modeling used for the others. But that could expose AFCP to variable coverage across its program area, perhaps leading to projects from different countries and states being treated differently.

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Connectedness ratings and leakage estimates from market modeling or the project location modeling would be very user-friendly once determined. Drawing from previous research, a market leakage estimate for timber and a generalized market leakage equation for any commodity are already ready to use, thus being very practical. Project proponents would be aware of the standard leakage discount values from the beginning, enabling them to integrate those numbers into their financial due diligence. Using these estimates would also make the job easy for verifiers. Similar to predictive modeling for activity-shifting leakage, the program administrator would manage the development of the leakage estimates (or the elasticities for the default equation) at the program level through contracting with experts and project proponents would be saved time and cost. These leakage estimates could be updated on a timely basis to account for changing conditions in the AFCP area, though not at the fine resolution that might be required by a national reconciliation process.

Computing regional-, national- or international-scale leakage would generally not be feasible (or relevant) for individual projects (unless encompassing a vast area) since one project's marginal impact on broader supply would be very small. Conducting the market leakage analysis at the program level and then assigning leakage factors to projects within the program would be more reasonable and appropriate. Market modeling should take place at either country level, AFCP program level, or at scale of all five AFCP countries. Access to or availability of data will inform this decision, as data quality and quantity will vary across AFCP countries. The data and assumptions necessary to model international leakage make it impractical.

4.4.2.3. Acceptability

Under the evolving Copenhagen Accord, there is a clear focus on national reconciliation for RED programs. Nevertheless, since the AFCP is private and not a governmental entity, it can potentially define its own "program area." As national monitoring and reconciliation becomes the norm, AFCP can adapt accordingly.

Market modeling is in many cases the best tool we have, but it has limitations. For example, GDP estimates produced by large macroeconomic models can miss large shifts in economic activity and, at best, are always revised to some degree, often multiple times. Overall though, leakage estimates based on market models should have moderate degree of acceptance given the familiarity with economic modeling results and respect for market modeling rigor. Given that estimates of international leakage could be politically sensitive as well as come with high uncertainty around them, it makes sense to exclude it from AFCP consideration and leave that to the international negotiation process. Excluding international leakage is consistent with international carbon accounting norms—neither Annex I nor non-Annex I countries are required to account for international leakage under Kyoto reporting or compliance. Lastly, trying to determine to what extent Amazon is a receptor of leaked activities and emissions from other countries would be politically unattractive, in addition to being technically challenging.

Connectedness ratings are intuitive and thus could be readily understood by the market. However, the fact that there is no strong empirical basis for the quantitative relationship between the ratings and the corresponding leakage rates weakens acceptability.

The idea that forest carbon stocks may vary across the program area is fairly intuitive and buyers may expect leakage estimates to reflect that. Thus, some form of the project location option should be included in calculating leakage estimates—which is the case for the market model options.

4.4.2.4. Recommendation

National monitoring and reconciliation would be the ideal way to detect all leakage, but that option is still years out for the whole AFCP program area. Market models are really the only credible option for estimating market-effects leakage that can be implemented now. Given that commodity production is a

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main driver of the Amazonian deforestation, not accounting for market leakage would mean missing a substantial portion of the potential leakage.

Values from a market leakage equation derived from Murray et al. (2004) are available for immediate use. Using commodity market share data and elasticity estimates drawn from international secondary data sources and the economics literature, both country-specific (i.e., the extent of market leakage within country) and AFCP-wide (the extent of market leakage within all five AFCP countries) estimates for market leakage have been produced for the commodities most pertinent to deforestation—soybeans, cattle, timber, and sugarcane. The commodity list could be lengthened if needed. We recommend using an AFCP-wide market leakage factor for all projects because it is simpler and ensures consistent treatment across AFCP countries. In Table 4.4, we present draft proposed default leakage parameters, which will be refined as needed during the standards development process.

Table 4.4. AFCP-wide market leakage estimates.[23]

	Leakage estimate
Soybeans	30.9%
Cattle	20.2%
Timber	8.7%
Sugarcane	21.7%

One factor to consider when evaluating the leakage values in Table 4.4 is that these capture leakage that occurs within and across all AFCP countries. So the leakage estimate for a project in Bolivia captures displacement not only within Bolivia, but to the other AFCP countries. We recommend this because it treats projects consistently across all countries in the AFCP basin. We also have estimates for the market leakage contained within each individual country for each commodity, which could be used instead of the AFCP-wide estimates if the AFCP so chooses. The implication of using the country-specific measure for each commodity is that while there is ample opportunity for leakage within a large country like Brazil, there is very limited opportunity for it within a small country like Ecuador, where most leakage would be extramural. This would mean that Brazil's leakage estimate would be substantially higher than Ecuador's and projects in Brazil would be discounted more substantially merely because they are in a larger country.

One of the key parameters needed to develop the leakage estimates in Table 4.4 is the carbon displacement ratio associated with the forests or other land uses to which new commodity production may be shifted. It is the product of two components: land displacement ratio and the carbon density ratio. The land ratio accounts for any change in acreage, whether up or down, required to meet the foregone output level of the RED project area. The carbon density ratio reflects the differential carbon stock values across the landscape, so that the carbon loss from deforesting a new hectare may be greater or lesser than if a hectare of the RED project area were cleared. The yield potential and carbon density of the hypothetical leakage-receiving area could be estimated by using the distribution of growing areas and their corresponding market shares for the commodity of interest across regions in the AFCP countries to create weighted averages of those factors. This will require coordination with the STAT team.

AFCP should consider developing new econometric market models to replace the default values in Table 4.4 over time. This would require more data and expert time, though would be more rigorous overall and most tailored to the AFCP program area. The appropriate scale of modeling efforts should either be at the

[23] The AFCP-wide estimates are based on commodity market shares aggregated across all five member countries. For lack of data, we make the assumption that the supply elasticities facing each country are equivalent. Also, it is assumed here that the productivity and carbon stocks in locations receiving market leakage are equivalent to those in the RED project area. This can be adjusted by computing and applying the carbon displacement ratio, discussed in more detail in Section 4.5.

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country-level or the Amazon basin-level. Global models can be used to estimate international leakage if that is desired; however, we have been operating under the assumption that AFCP is primarily interested in capturing leakage within its own member countries.

4.4.3. Leakage prevention activities

4.4.3.1. Credibility

It is not clear that these activities would have a high certainty of stanching leakage and actually could result in greater levels of leakage. In the history of Integrated Conservation and Development Programs (ICDPs), reportedly many projects unintentionally attracted more people to park edges and people used new income streams to increase their extraction/clearing activities rather than direct new income towards "alternative livelihood strategies." If the precedent of ICDPs applies, then there would be ample possibility that GHG benefits produced by the projects could be undermined by these well-intentioned prevention activities (Ferraro and Kiss 2002).

In addition, separating emitting activities related to leakage prevention efforts from those associated with other economic forces could be difficult. This would be necessary because these activities may produce additional GHG emissions, so the leakage due to the leakage prevention activities would have to be accounted for.

4.4.3.2. Practicability

The idea of project proponents establishing these activities and then tracking their adoption, both by local deforestation agents and by others, seems onerous and complicated and unlikely to be practicable. It could substantially impact monitoring and transaction costs. Moreover, these leakage mitigation activities would increase the amount of work, perhaps substantially, required from reviewers to assess RED projects.

Also, it is not clear where leakage prevention activities, such as agroforestry and woodlots, would take place; would these be inside or outside the boundaries of the project? While the implementation of such leakage prevention activities could make RED projects more financially feasible, it may raise questions about double-dipping.

4.4.3.3. Acceptability

International buyers of avoided deforestation credits may be sensitive to the possibility of social costs to forest-dwelling communities associated with RED projects and therefore may expect AFCP projects to be socially neutral at worst. Although leakage prevention activities may evince a veneer of acceptability, the problems with credibility and practicability overshadow the social benefits these activities may offer. However, ensuring community buy-in not only is fair, but could help guard against activity-shifting leakage. Requirements in CCBS, such as obtaining local peoples' consent for projects and their participation in project design, could work to support this and should be considered as part of the overall standard.

4.4.3.4. Recommendation

These activities, while well-intentioned, would divert scarce time and resources to establishing and monitoring activities with questionable efficacy at mitigating leakage. Moreover, they actually carry the potential of creating additional leakage. It may be best to avoid these, at least as part of the leakage protocol. It should be noted that the Climate, Community, and Biodiversity Standard (CCBS) requires local peoples' consent for projects' existence and participation in project design and that these measures could help guard against activity-shifting leakage by ensuring community buy-in. These issues are addressed in the Socio-economic Team report, for which checklists are being developed to cover key issues pertinent to fair and informed community participation.

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4.5. Leakage assessment steps

In light of the above assessment of the available options, we provide a stepwise method intended to be a practical guide to estimating project leakage. It combines estimates for activity-shifting and market-effects leakage, which are additive. A numerical example for estimating total leakage is provided at the end of this section. This method has the four following steps:

1. Weighting local and market leakage effects – Assign weights to each type of leakage based either on an independent assessment of deforestation drivers in the project area or on a submission identifying deforestation drivers by the project proponent that is reviewed by AFCP.
    - **a.** S_L = share of potential displaced activity that is local in nature
    - **b.** S_M = share of potential displaced activity that will affect commodity markets. This can be further share-weighted by commodity group, so that $S_M = \sum S_{Mi}$ where i represents the relevant commodity
    - **c.** $S_L + \sum S_{Mi} = 1.0$
2. Estimate local leakage (L_L) using method described below
3. Estimate market leakage (L_{Mi}) for each commodity using method described below
4. Estimate total leakage using, $L = L_L * S_L + \sum L_{Mi} * S_{Mi}$

Local activity-shifting leakage (L_L).
As discussed above, we suggest that a small discount (e.g., 10%) for activity-shifting leakage be assessed on all projects to begin with. Because this type of leakage tends to occur near the RED project area (thus, local), we assume that the amount of carbon per hectare of the area receiving the leakage is equivalent to that of the project area. This may not always be the case, however, so a method to calculate the carbon displacement ratio is detailed below in the market leakage discussion (as it is a more pertinent issue for market leakage).

Market leakage for each commodity (L_{Mi}).
Starting with the general market leakage equation from Murray et al. (2004) described in Section 4.3.2.2.1.2, we distinguish between domestic and global markets in order to isolate the intranational leakage from the international leakage. This is elaborated in Appendix A**Error! Reference source not found.**. Using commodity market share data from a variety of secondary data sources and elasticity estimates drawn from the economics literature, both country-specific and AFCP-wide estimates for market leakage are calculated for the commodities most pertinent to deforestation—soybeans, cattle, timber, and sugarcane. In Table 4.5, we show the core elasticities, for the demand and supply side, used in the equation. These price elasticities represent the aggregate responses of consumers and producers (in quantity demanded or supplied) to a percent change in the commodity price. They were drawn from the Food and Agricultural Policy Research Institute (FAPRI) elasticity database as well as from specific studies in the literature. Where possible, long-run supply elasticities (vs. short-run) were selected since the assumption is that shifts in production supplies due to RED projects will induce structural adjustments over a longer time horizon. The issue of time is not as applicable to changes in demand because they tend to occur over the short-run.

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Table 4.5. Core elasticities used to generate market leakage estimates.

	Core elasticities	
	Demand (E)	Supply (e)
Soybeans	-0.24	1.08
Cattle	-0.27	0.59
Timber	-0.98	0.57
Sugarcane	-0.1	0.13

Source: FAPRI database and other economics literature.

Appendix A shows us that a country or region's global market share is a key element in estimating the elasticity of demand facing that country/region's producers of the commodity. Commodity market share data for soybeans, cattle, and sugarcane were taken from the Food and Agriculture Organization's (FAO) online database. Data for the tropical timber market was obtained from the International Tropical Timber Organization's (ITTO) 2009 Annual Review. The proportion of the world market share for each of the four commodities is presented in Table 4.6 for the AFCP countries and for the AFCP in aggregate (i.e., the market shares of the AFCP countries summed). Relative to the other countries, Brazil plays a substantial role in the world markets for all of the focal commodities.

Table 4.6. Global market share and market leakage estimates for AFCP countries and AFCP in aggregate.

	Soybeans		Cattle		Timber (tropical)		Sugarcane	
	Share	Leakage*	Share	Leakage	Share	Leakage	Share	Leakage
Bolivia	0.0069	2.9%	0.0027	0.6%	0.0067	0.4%	0.0037	0.5%
Brazil	0.2505	30.8%	0.1447	18.6%	0.1758	8.3%	0.3723	21.3%
Colombia	0.0003	0.1%	0.0147	3.0%	0.0088	0.5%	0.0221	2.7%
Ecuador	0.0003	0.1%	0.0040	0.8%	0.0018	0.1%	0.0054	0.7%
Peru	0.0000	0.0%	0.0026	0.6%	0.0175	1.0%	0.0047	0.6%
AFCP	0.2579	30.9%	0.1687	20.2%	0.1863	8.6%	0.4081	21.7%

Source: FAOSTAT; ITTO.
* See Appendix A for leakage calculation.

Table 4.5 provides draft default leakage estimates, which can be refined as needed during the standards development process. We recommend using AFCP-wide market leakage factors for all projects because it is simpler and ensures consistent treatment across all five AFCP countries. These factors range from 8.6% for tropical timber to 31% for soybeans. The reasoning is that these estimates capture leakage that occurs within and across all AFCP countries. Thus, the leakage estimate for a project in Ecuador captures production displacement not only within Ecuador, but to the other AFCP countries as well. The implication of using the country-specific measure for each commodity is that while there is ample opportunity for leakage within a large country like Brazil, there is very limited opportunity for it within a small country like Ecuador, where most leakage would be displaced across its borders to AFCP neighbors. This would mean that Brazil's leakage estimate would be considerably higher than Ecuador's and that projects in Brazil would be discounted more substantially merely because they are in a larger country with greater market share.

Another essential parameter for determining leakage estimates is the carbon displacement ratio associated with the locations to which new commodity production may be shifted. It is the product of two factors: the land displacement ratio and the carbon density ratio. The land displacement ratio accounts for any change in acreage, whether up or down, required to meet the foregone output level of the RED project area. For example, the leakage receiving area may have a greater yield (200 kg/ha) for a given commodity

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than the project area (150 kg/ha) and therefore 25% fewer hectares would need to go into production to compensate for the curtailed production due to the project. The carbon density ratio reflects the differential carbon stock values across the landscape, so that the carbon loss from deforesting a new hectare may be greater or lesser than if a hectare of the RED project area were cleared. For example, the leakage receiving area and the RED project area may have carbon densities of 250 tCO_2e/ha and 500 tCO_2e/ha respectively, which means that 50% less carbon is released per hectare converted to new production in the receiving area.

The yield potential and carbon density of the hypothetical leakage-receiving area could be estimated by using the distribution of growing areas and their corresponding market shares for the commodity of interest across regions in the AFCP countries to create weighted averages of those factors. Regional productivity for each commodity could be found in secondary data (e.g., FAOSTAT) and the STAT team could provide the carbon stock distribution across the landscape. Table 4.7 illustrates a simple approach to finding a weighted average yield for the AFCP program area. The basic concept is that areas in which the commodity of interest, soybeans in this example, is already grown have a greater probability of receiving leakage. Thus, the soybean production shares for each country are multiplied by the corresponding yields and then those products are summed to arrive at the AFCP weighted average yield of 2.545 tons of soy per hectare. If a RED project were to take place at a location in Bolivia that has the same average yield as the country, then the land displacement ratio would be 0.652 (1.660/2.545). This means that the leakage estimate for soybeans (30.9%) would by adjusted by this ratio so that it drops to 20.2%. Since the AFCP weighted average yield is much greater than Bolivia's, this implies that less land would be needed to compensate for the displaced soybean production outside of the project area and consequently leakage will be lower. This basic example is for illustrative purposes, as one would want to divide up the AFCP area more finely into growing regions so that differences in market share and yield would be better represented and thus the weighted average yield more accurate. The growing regions would potentially differ by commodity type and each country would probably have more than one growing region.

Table 4.7. Weighted average yield and weighted average carbon stock for soybean production across AFCP program area.

	Soybean Production (t)	AFCP share	Yield (t/ha)	Wtd Avg Yield	Carbon stock* (CO_2e/ha)	Wtd Avg Carbon Stock
Bolivia	1,533,410	0.027	1.660	0.045	350	9.384
Brazil	55,541,425	0.971	2.571	2.496	400	388.433
Colombia	56,940	0.001	2.071	0.002	450	0.448
Ecuador	60,530	0.001	1.967	0.002	350	0.370
Peru	3,052	0.000	1.613	0.000	300	0.016
AFCP	57,195,358			2.545		398.651

Source for soybean data: FAOSTAT.
*These values are hypothetical, pending actual carbon stock data from the STAT team.

The carbon density ratio would be computed through the same procedure, except that, in this case, we deal with carbon stocks instead of yields in the growing areas. The places in which soybeans are grown in the AFCP area will vary by land use type and carbon density, with humid forests having more carbon than scrublands (e.g., cerrado in Brazil) and grasslands. In Table 4.7, the AFCP weighted average carbon stock appears in the far right column, calculated with *hypothetical* carbon stock numbers. Again assuming that the RED project location contains the same average carbon stock as Bolivia, we find that its average carbon stock is higher than the weighted average for the AFCP area and so the carbon density ratio is greater than one (398/350 = 1.139). This indicates that since the carbon stock in the project area is lower than the AFCP weighted average stock, displaced production causing land use change will be releasing

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more carbon per hectare than would have happened in Bolivia. In other words, this ratio would be multiplied by the 20.2% leakage rate from above to arrive at a leakage estimate of 23.0% for a hectare of soybean production displaced by a project in Bolivia. Though in this example we use faux stock numbers, the STAT team should be able to provide a map of carbon stocks across the landscape to operationalize this process. The carbon displacement ratio, the product of the two ratios just calculated, would be 0.743 (0.652*1.139).

Table 4.8. Calculation of total leakage.

		Share	Leakage factor	Unadjusted Leakage rate	Carbon Displacement Ratio	Total Leakage
Local leakage		0.5	0.1	0.05	1	0.050
Market leakage		0.5				
Soybeans	0.6	0.3	0.309	0.0927	0.743	0.069
Cattle	0.3	0.15	0.202	0.0303	0.525	0.016
Timber	0.1	0.05	0.086	0.0043	0.546	0.002
Sugarcane	0	0	0	0	0.441	0.000
Total Leakage adjustment						**0.137**

This final example brings everything together to estimate the total leakage of a hypothetical RED project. An analysis of deforestation drivers for the area shows that 50% of the anticipated forest clearing would have gone into production for local end use (local leakage) and 50% would have gone into commodity production (market leakage). Of the potentially displaced commodity production, 60% would be soybeans, 30% cattle, and 10% timber. The leakage factor for activity-shifting leakage is 10%, which translates to 5% leakage given local leakage drivers' 50% share. It is assumed that local leakage occurs on lands with the same productivity and carbon density as the project area and so a carbon displacement ratio of one is employed. For the different commodities, the market leakage factors from Table 4.6 are multiplied by the share to find the unadjusted leakage rates for each. The figure for soy is adjusted by 0.743, which was derived above. Hypothetical carbon displacement ratios are used for the other commodities. Finally, the leakage rates for the various drivers are summed to calculate the total leakage adjustment (L). In sum, 13.7% would be the leakage discount applied to AFCP RED projects fitting this description.

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APPENDIX A

The objective of this appendix is to demonstrate how the general leakage equation in Murray et al. (2004) (see Section 4.3.2.2.1.2) can be used to estimate market leakage, both international and intranational, stemming from RED actions.

The equation can be re-expressed as follows:

$$L_{ij} = [e_{ij}/(e_{ij}-E_{ij}(1+\Phi_{ij})]*c_{ij} \quad [A.1]$$

Where

e_{ij} = elasticity of supply for commodity i in country j

E_{ij} = elasticity of demand for commodity i in country j

$\Phi_{ij} = s_{ij}/(1-s_{ij})$, where s is the size of the supply shock caused by the RED project or program (i.e., the share of commodity production withdrawn by the RED action]

$C_{ij} = C^{N}_{ij}/C^{R}_{ij}$ = Carbon ratio of the leakage "receiving area" to the area protected by RED

Global leakage from a RED action in Country j

We are interested in associating leakage with specific commodity i produced in country j. We assume a global commodity market for i, which is a homogeneous good, that is perfectly substitutable and tradeable across all supply and demand sources.

For illustrative purposes, let the following parameters represent "global" values for supply and demand elasticities for commodity i. These values are averages of the price elasticities of supply and demand for soybeans across multiple countries (FAPRI elasticity database). We will refine these values later.

$$e_{ij} = e_i = 0.33 \quad [A.2a]$$

$$E_{ij} = E_i = -0.24 \quad [A.2b]$$

These values indicate that a given 1% change in price would induce a 0.33% positive supply response and a 0.24% negative demand response. These are fairly inelastic (i.e., small response) values.

If we assume that the RED action in Country j is significant enough to withdraw s=1% of the supply of globally traded commodity i, this yields a supply shock value of

$$\Phi_{ij} = 0.01/(1-0.01) = 0.0101 \quad [A.3]$$

For now, we assume that the leakage ratio CN/CR = 1.0, meaning that the carbon stocks in the RED project area and leakage receiving area are equal.

With these values, we would expect leakage to be:

$$L_{ij} = [0.33/(0.33- -0.24(1+.01)]*[1.0] = 0.5765 \quad [A.4]$$

Meaning that for every ton of emissions reduced by a RED action taken in Country j, 0.5765 tons are emitted somewhere else in the world. This occurs because suppliers all over the world respond to the induced shortage of commodity i by increasing their supply quantity of i. Increasing quantity supplied in other locations implies a concomitant increase in GHG emissions in those locations. If policy indicates

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that leakage estimates must capture any displaced emissions globally, this would be the appropriate measure.

Intranational or intra-regional leakage

Policy decisions may indicate that leakage only needs to be accounted for within the country (or region) in which the RED activity occurs. So if RED activity reduces soybean production in one part of Brazil (or AFCP region), it is only the displaced production and emissions within Brazil (or AFCP region) that are counted. This is a critically important distinction.

Murray et al. (2004) show how the general leakage equation is derived from market equilibrium. The general equation in [A.1] does not distinguish between global markets and domestic markets, but we must do so here to separate intranational leakage from international leakage. To capture this, we must specify the underlying equilibrium for the global commodity market, which equates global demand to the two sources of supply:

$$Q^D_i\,(P) = Q^S_{ij}\,(P) + Q^S_{i\text{-}j}\,(P) \qquad [A.5]$$

where Q^D_i (P) is the global demand function, Q^S_{ij} (P) is the supply function from Country j, and $Q^S_{i\text{-}j}$ (P) is the supply function from all other countries. The equilibrium can be expressed in terms of equating the net demand for Country j's output with its supply

$$Q^{DR}_{ij} = [Q^D_i - Q^S_{i\text{-}j}] = Q^S_{ij} \qquad [A.6]$$

The first equality represents the *residual demand function* facing a country's producers. This is equal to the global demand function for the commodity (Q^Di) minus the amount supplied by the rest of the world ($Q^S_{i\text{-}j}$). The second equality equates the country's residual demand to its supply, which is relevant for separating how much demand shifting occurs within country versus shifting outside the country.

The leakage equation in [1] remains essentially unchanged, except that the demand elasticity should reflect the country's residual demand function rather than the global demand function. The residual demand elasticity can be expressed:

$$E^R_{ij} = E_i(1/S_{ij}) – e_i(1/S_{i\text{-}j}) \qquad [A.7]$$

where S_{ij} is country j's total share of world production of commodity i and $S_{i\text{-}j}$ is the rest of the world's share of production ($S_{ij} + S_{i\text{-}j} = 1.0$)[24], and E_i and e_i are the global demand and supply elasticities referenced previously. In addition, the supply shock, s_{ij}, should reflect how much Country j's supply is initially reduced by the RED activity.

We extend our earlier example to look at leakage within Brazil from a RED project/program that avoids forest being cleared for soybean production. Brazil produces about 25% of the world's soybeans (5-year average [2005-2009] from FAOSTAT). Therefore, the residual demand elasticity facing Brazilian soybean producers is:

$$E^R(\text{soybeans, Brazil}) = -0.24(1/0.25) - 0.33(1/0.75) = -1.4 \qquad [A.8]$$

Which is about five times the magnitude of the global demand elasticity for soybeans (assumed = -0.3). Now, suppose that this is a very large RED activity causing a 1% shift (reduction) in Brazilian soybean

[24] Note that this is the country's total share of global production, not its share of exports.

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supply (s_{ij} = 0.01). Placing these values in the leakage equation and keeping all other market parameters the same, we get a leakage estimate of

L (soybeans, Brazil) = [0.33/(0.33- -1.4(1+.1010)]*[1.0] = 0.189 [A.9]

So leakage within Brazil is estimated to be almost 19%. The remainder of the 57.65% leakage estimated above occurs in other countries.

We should recognize that even though intranational leakage within Brazil is much smaller than the global leakage estimate, it is actually a fairly large number, given that Brazil is the world's second largest producer of soybeans and has one-quarter of the market. If Brazil only had 1% of the market, the elasticity of residual demand would be very high (-24.3), and intranational leakage would be very low (0.013) – i.e., virtually all of the leakage would be international rather than within Brazil. We will find this latter case to be the exception rather than the rule for most commodities in most tropical forest countries. For example, in Table A.1 we provide data on the share of each of the 5 Amazonian country's on global tropical timber production, the residual demand elasticity for each country, the residual demand facing the entire five country region (AFCP), and the equivalent leakage estimate from a 1% shift in each country's supply or in the entire AFCP's supply.[25] In addition to tropical timber, we also include the same information for soybeans, cattle, and sugarcane.

Implications

Focusing on the Amazon region, we note that for soybeans, Brazil is the only significant market player so leakage from soybeans would presumably only apply there. Other AFCP countries will have negligible leakage potential. Using AFCP-wide leakage would provide consistent treatment across countries, so that a large country with considerable commodity market share would not get a heavy leakage discount while other countries had small ones. Further adjustment may also be necessary for the relative carbon ratio for land receiving the leakage within the country. These values assume the ratio is 1.0. See the main text for possible variations on this scenario.

Further refinements may include treating the commodities as imperfect substitutes (again, See Murray et al. 2004), but this probably will not be necessary if we are looking at substitution within, rather than across countries.

[25] We provide a separate elasticity estimate and intra-regional leakage effect for the AFCP countries together in case there is interest in confining the leakage estimate to within those 5 countries.

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Table A1. Residual demand elasticities and intranational leakage estimates for timber and cattle in five Amazonian countries.

Timber (tropical				
	Core elasticities			
	Demand (E_i)	***Supply (e_i)***		
	-0.98	***0.57***		
	Production share	**Rest of world**	**Residual demand elasticity**	**Leakage estimate**
Bolivia	0.0067	0.9933	-146.8838	**0.0038**
Brazil	0.1758	0.8242	-6.2672	**0.0826**
Colombia	0.0088	0.9912	-112.2554	**0.0050**
Ecuador	0.0018	0.9982	-555.6882	**0.0010**
Peru	0.0175	0.9825	-56.6573	**0.0099**
AFCP	0.1863	0.8137	-5.9607	**0.0865**
Source: http://www.itto.int/en/annual_review/; economics literature				

Soybeans				
	Core elasticities			
	Demand (E_i)	***Supply (e_i)***		
	-0.24	***1.08***		
	Production share	**Rest of world**	**Residual demand elasticity**	**Leakage estimate**
Bolivia	0.0069	0.9931	-36.0414	**0.0288**
Brazil	0.2505	0.7495	-2.4059	**0.3077**
Colombia	0.0003	0.9997	-942.3982	**0.0011**
Ecuador	0.0003	0.9997	-886.5691	**0.0012**
Peru	0.0000	1.0000	-17560.5873	**0.0001**
AFCP	0.2579	0.7421	-2.3925	**0.3089**
Source: FAOstat				

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Table A.1 (continued)

Cattle				
	Core elasticities			
	Demand (E_i)	*Supply (e_i)*		
	-0.27	***0.59***		
	Production share	**Rest of world**	**Residual demand elasticity**	**Leakage estimate**
Bolivia	0.0027	0.9973	-99.6392	**0.0058**
Brazil	0.1447	0.8553	-2.5557	**0.1860**
Colombia	0.0147	0.9853	-18.9536	**0.0299**
Ecuador	0.0040	0.9960	-68.4742	**0.0085**
Peru	0.0026	0.9974	-103.7440	**0.0056**
AFCP	0.1687	0.8313	-2.3099	**0.2018**
Source: http://faostat.fao.org/site/569/DesktopDefault.aspx?PageID=569 - ancor				

Sugarcane				
	Core elasticities			
	Demand (E_i)	*Supply (e_i)*		
	-0.1	***0.13***		
	Production share	**Rest of world**	**Residual demand elasticity**	**Leakage estimate**
Bolivia	0.0037	0.9963	-27.2844	**0.0047**
Brazil	0.3723	0.6277	-0.4757	**0.2129**
Colombia	0.0221	0.9779	-4.6605	**0.0269**
Ecuador	0.0054	0.9946	-18.7912	**0.0068**
Peru	0.0047	0.9953	-21.3139	**0.0060**
AFCP	0.4081	0.5919	-0.4647	**0.2169**
Source: FAOstat				