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Application of the "Climafor" Baseline to Determine Leakage: The Case of Scolel Té.

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Abstract. The acceptance of forestry-based project activities to mitigate greenhouse gases emissions has been subjected to a number of methodological questions to be answered, of which the most challenging are baseline establishment and identification of and measuring leakage. Here we pose hypotheses for and quantify leakage of the Scolel Té project in Chiapas, Mexico. In this project small-scale farmers are implementing forestry, agroforestry, and forest conservation activities, with carbon sequestration as one of the goals.

The main leakage monitoring domain is defined as the area owned by the participating farmers or communities outside the area where the specific project activities take place. The null-hypothesis (no leakage) is that non-project land owned by the farmer or community will experience the same carbon stock changes as predicted by the regional baseline, specifically developed for the project.

First we assessed the most likely causes and sources of leakage that may occur in the project. From this analysis, one type of leakage seems to be important, i.e., activity shifting. Second we estimated the leakage of a sample of participating farmers and communities. Actual land use was then compared with expected land use derived from the baseline. The Plan Vivo of each participant, complemented with readily available tools to identify the main sources and drivers of leakage are used to develop simple leakage assessment procedures, as demonstrated in this paper. Negative leakage was estimated to be negligible in this study. Incorporating these procedures already in the project planning stage will reduce the uncertainties related to the actual carbon mitigation potential of any forestry project.

Keywords. leakage assessment, Plan Vivo, regional baseline.

1 Introduction

The acceptance of forestry-based project activities to mitigate the effect of greenhouse gases on climate has been subjected to a number of methodological questions to be answered before such measures are universally admitted. This is particularly evident for projects that are directed towards avoiding greenhouse gas (GHG) emissions through reduced deforestation and forest management, where criticism relating to environmental integrity has led to the exclusion of these activities from the Clean Development Mechanism (CDM) of the Kyoto Protocol, at least for the first commitment period (Aukland et al., 2003). Among the key technical issues, the most challenging are the methodologies for baseline establishment and identification and monitoring of leakage. Leakage is defined as "the indirect impact of a targeted land use, land-use change and forestry activity in a certain place at a certain time on carbon storage at another place or time" (Brown et al 2000, § 2.3.5.2, p. 71).

There are very few papers that empirically estimate leakage from an established carbon sequestration project in the forestry sector (Sohngen and Brown, 2004). The existing literature relevant for leakage assessment establishes definitions and typologies and a framework for analysis (Schwarze et al, 2002; Aukland et al, 2003), multi-region, multi-sector examination of adopting GHG abatement measures (Murray and McCarl, 2002), or general assessments of region-specific leakage sources (Barker, 1999). Multi-sector, multi-region leakage estimates range from negligible (Barker, 1999) to substantial (Felder and Rutherford, 1993), but typically are in the range of 10-20 percent of targeted country emission reductions. Lee et al. (2004) predict leakage in the form of reduced US exports and increased production in non-U.S. Annex B and non-Annex B countries of up to 2.66% and 12.22% respectively (at US$ 100 /tCO_2) if the US adopts the Kyoto Protocol production

Although project experience to date is limited, it is expected that prevailing landscape dynamics may provide a signal as to whether the project has either a none-to-low or a moderate-to-high risk potential for leakage. Projects implemented on land that have few or no competing uses are unlikely to impact areas outside the project boundary, and thus the leakage potential will be minimal. Where land has competing uses or is set in a dynamic environment where factors such as population growth, logging or agricultural production for export, subsistence agriculture, fuelwood needs, and concerns about deforestation interact, a project's impact may extend beyond the area of direct project activities (Brown, 1998).

While the potential for leakage does not necessarily make a project unattractive, strategies need to be developed to either mitigate and/or account for it (Sohngen & Brown 2004). Brown et al (2000) point out that to date two approaches have been used and proposed to monitor leakage: project-level and regional level. The regional approach involves defining a regional baseline, in which leakage can be internalized, the project-level approach involves identifying key indicators of leakage on the basis of demand that drives land-use change and management upfront that allows incorporating additional activities if the project appears vulnerable to leakage.

A few studies estimating potential leakage in current carbon projects are beginning to emerge.

The goal of our project is to pose hypotheses for and to assess and quantify leakage from an ongoing forestry carbon sequestration project. Such a study will: increase the ability to identify possible sources of leakage, and provide analytical methods for assessing leakage. The study is based on the 6-year experience of the Scolel Té project in Chiapas, Mexico, where small-scale farmers are implementing forestry, agroforestry, and forest conservation activities, with carbon sequestration as one of the goals.

2 The Scolel Té Project.

The project is located in Chiapas, where tropical rain forests, pine-oak forests, and montane rain forests are among the important vegetation types. The majority of the rural communities consist of subsistence or semi-subsistence farmers, who rely heavily on forest resources for fuel wood, construction materials, and food supplements. Traditional land-use includes slash-and-burn agriculture, extensive pasture and perennial cash crops, such as coffee, cacao, and fruits. Large areas are subject to processes of deforestation and land degradation due to increasing population pressure without economic alternatives to increase sustainable production. Estimated deforestation rates are among the highest of Mexico (De Jong et al, 1999; 2000). About 80% of the territory is under a communal form of tenure known as ejido. Within the ejido, families – members of the ejido – hold agricultural land in private usufruct, whereas forestland and barren areas are often kept and managed as common resources. Farmers are given usufruct of land varying in size between about 10-50 ha, depending on type of land and land use, land availability, etc. Traditionally the farmers maintained parcels of land with mature and secondary forest, but as his or her family is continuously growing, the remaining farmers´ forests are disappearing rapidly. Additionally the slash-and-burn systems is rapidly converting from long fallow with short cropping systems to short fallow and long cropping systems, also contributing to the deforestation trend. The 1992 change in the Mexican Land Tenure Law (Article 27) gives legal title to the rural communities for the land they manage as an ejido or community. The new Law allows rural farmers legal status to establish join ventures with investors, so that capital can be invested in alternative land-use systems. To ensure mutually profitable and just partnerships, farmers´ organizations are playing an important role in the negotiations between the farmers they represent and interested investors (De Jong et al, 1997).

Since 1997, the Scolel Té project is selling voluntary carbon credits to national and international institutions interested in off-setting their emissions. The funds obtained are used to provide financial incentives and technical assistance to farmers interested to participate in the project (De Jong et al, 2004). Currently about 900 farmers of 8 ethnical groups located in 43 communities spread out over a large area of Chiapas and four communities (one in Chiapas and three in Oaxaca) are participating in the project. Currently about 1000 ha have been reforested (predominantly shade trees for coffee, fallow enrichment planting and Taungya) and almost 4000 has are registered as community conservation plots. Farmers or communities voluntarily submit a proposal to a local trust fund Fondo Bioclimático (FBC) in which they present a “working plan” known as Plan Vivo. The Plan Vivo System (www.planvivo.org) is used to register and monitor carbon sequestration activities implemented by farmers and communities. Local promoters help farmers design their Plan Vivo, which is constructed around the needs and resources of the producer’s family or community. The main component of the Plan Vivo is an annotated map of the entire producer’s land showing the different fields that he/she/they own and the land use or vegetation type of each plot. On this map, the producer or community marks, which plot will be incorporated in the project and what activity will be implemented. The remainder of his land where no project activities will take place can then be used for leakage assessment (Figure 1).

Place figure 1 here

Figure 1. Example of a plan vivo and area used for the leakage assessment.

From the information provided in the Plan Vivo, the FBC subsequently determines whether the proposal does or does not compete with other land-use activities on the rest of his land, if there is potential for leakage of carbon and if so, how this can be avoided, how much carbon will be sequestered by the proposed activity, and what will be the implementation cost, based on the technical specifications of each system. Viable plans are registered with the FBC and are eligible to generate carbon services. A 20 to 25-year contract will be established for reforestation activities, and a 5-year contract for conservation projects.

In the case of Scolel Té, the main leakage monitoring domain is defined as the area owned by the participating farmers or communities outside the area where the specific project activities take place. They are considered as the key baseline agents that may cause leakage (*sensu* Aukland et al, 2003). The null-hypothesis (no leakage) can thus be formulated as follows: uses of the land owned by the project participants, but not incorporated in the project, will be such as to have the same carbon stock or stock changes as (no leakage) or better than (positive leakage) the baseline of the project. That is, non-project land owned by the farmer or community will experience the same carbon stock changes as predicted by the regional baseline, specifically developed for the project (Castillo-Santiago *et al*, in press, De Jong *et al*, 2005). The project will not account for positive leakage, in other words less emissions from land-use change on non-project land of project participants compared to the regional baseline estimation. The expected emissions of the baseline has been set at the lower boundary of the calculated 95% confidence interval, to have the most conservative estimate, taking into account all important factors of uncertainties (De Jong et al, 2004). Thus if the hypothesis is accepted, we will have a high degree of certainty that no negative leakage has occurred from this non-project area during the first six years of the project.

3 Regional baseline.

The leakage assessment is based on the “Climafor” baseline approach that was developed specifically for the project. Since communities participating in the project are scattered over a large heterogeneous landscape a regional baseline approach was selected (Castillo *et al*, 2006; De Jong *et al*, 2005). The following is the basic approach of the baseline, that in turn will be the basis for the leakage analysis. The baseline was put in place to estimate the expected land-use change and related carbon stock changes for any community or farmer that wishes to enter the program and is based on the spatial relationships between historical deforestation and carbon emissions and possible causal factors, which were grouped as:

a) ‘Predisposing or accessibility ’ factors that determine the susceptibility of a particular area of forest to change (e.g. slope, distance to agriculture and roads and land tenure) and

b) ‘Driving or pressure’ factors representing the pressures for change (e.g. population density, poverty).

Each factor was categorized into a series of discrete classes and spatially distributed in the form of GIS-layers. The maps generated for each factor were superimposed over the land-use change map to calculate the rate of deforestation in each class of the factor, spatially represented as homogeneous polygons. Factors that showed a significant correlation coefficient were then reclassified into 3 to 4 ranked categories. Various combinations of categories were tested for each factor to produce the most significant, unidirectional trend in deforestation. The rate of deforestation and its 95% confidence interval was then calculated for each of the combinations of predisposing and driving factor classes.

Based on the results of the analysis, two risk matrices were constructed, using population density as the driving factor and distance to roads and distance to agriculture as the predisposing factors. Each matrix is composed of 12 combinations of predisposing and driving factors and each cell value in the matrix represents the average percentage of deforestation observed between 1975 and 1996 for this particular category and its 95% confidence interval (Table 1).

TABLE 1.

Annual deforestation rates in relation to the combinations of one driving factor (Population density, PopDens) with two predisposing factors (Distance to Agriculture, DistAg; and Distance to Roads, DistRd), adapted from De Jong et al (2005).

Place table 1 here

The matrices show two clear linear trends: 1) deforestation increases as one shift from low to high population density, and 2) deforestation also increases as one move nearer to roads or agricultural land. The deforestation rates of the Distance to Roads-Population Density (DistRd-PopDens) matrix were found to be in general slightly lower than the rates of the Distance to Agriculture-Population Density (DistAg-PopDens) matrix, which means that we can expect more conservative deforestation rates with DistRd-PopDens compared to DistAg-PopDens (De Jong et al., 2005). For each farmer or community, the expected deforestation over time can be calculated superimposing the community map over the deforestation risk map (See Castillo-Santiago *et al*, this issue). Subsequent carbon emissions can be estimated by applying the baseline deforestation rate to the forest cover of the farmer or community at the start of their project activity (Plan Vivo) and calculating expected carbon losses due to the deforestation, applying the most conservative measured vulnerable carbon density to the forest[1]. All estimations are derived from empirical data that are subject to improvements and adjustments when new data become available, such as changes in population densities (national census data), road construction, agricultural land (land-use maps), and carbon densities (ongoing inventories, project monitoring). The first improvements were implemented in 2000, when the regional baseline was developed. The next adjustments are expected in 2005, when new land-cover land/use data and biomass densities will be available. Carbon emissions due to degradation processes are not considered yet in the baseline as not enough data are available at present. The effect of this omission is a more conservative baseline, in accordance with the Scolel Té project goals.

4 Leakage domain of the Scolel Té project

To assess possible categories of leakage, we follow the procedures of leakage proposed by Schwarze et al (2002) and Aukland et al (2003). The first step to assess leakage is to determine the most likely causes and sources of leakage that may occur in the project. We first applied the decision tree approach of Aukland et al (2003) to define which types of leakage most likely affect the Scolel Té project (Figure 2).

Place figure 2 here

Figure 2. Decision tree to identify types and importance of leakage for the Scolel Té project, Chiapas, Mexico.

From this analysis, one type of leakage seems to be important, i.e., activity shifting

Applying the definitions and procedures proposed by Schwarze et al (2002), we first defined two tenure classes: individual (agroforestry and small-scale reforestation) and communal (forest conservation and restoration) activities. For each action, we identified the most important driver that could cause leakage and the type and direction of leakage to be expected.

TABLE 2.

Activity classes for each tenure class carried out in the Scolel Té project, main leakage drivers, and expected effect on each leakage mechanism, after Schwarze et al (2002). In bold the most significant leakage mechanism.

Place table 2 Here

Subsequently in both classes we grouped the main land-use activities into two types: small-scale reforestation and agroforestry activities implemented by the individual farmers, and forest conservation and forest restoration implemented by the communities. For each land-use activity we identified the most likely leakage driver, and which mechanism and direction of leakage caused by the leakage driver will be the most important to take into account (Table 2).

Next we provide a short description of each activity.

5 Agroforestry by individual farmers:

The agroforestry systems that are currently implemented by the individual farmers include taungya, improved fallow, coffee with shade trees, and to a lesser extend living fences. The taungya system combines crop production (mainly corn) and tree planting on the same land for a couple of years, until the trees compete too much with the crop. The improved fallow system involves the management of secondary vegetation for the production of timber, fuelwood and other products through enrichment planting. Both taungya and improved fallow systems replace slash-and-burn agriculture and both depend to a large extent on the availability of land: care has thus to be taken to avoid activity-shifting leakage, such as reduced slash-and-burn cycles and deforestation of remaining forested parcels.

Farmers are encouraged to implement permanent agriculture combining the production of corn with green manuring. This has maintained corn production for at least 10 years, thus avoiding incorporation of new forest land into the agricultural cycle. Coffee with shade trees involves low-density enrichment planting of timber trees to provide shade in coffee plantations and aims to buffer coffee price fluctuations through diversifying marketable products. Small-holder cultivation in Mexico generally involves planting coffee under sparse canopy of small shade trees sometimes intercropped with bananas or citrus trees. Because most farmers use more traditional coffee varieties that maintain production with varying shade, no negative effect on coffee production is expected. Live fences consist of planting trees around the edge of arable fields or areas of pasture. The trees produce timber and other products and if correctly managed, crop yields will not be affected by competition for light or water. This is an attractive system where land is scarce, as crops are not displaced and therefore does not encourage activity shifting.

6 Small-scale reforestation by individual farmers:

Predominantly reforestation with timber trees of privately-owned or communally managed degraded pasture land in the tropical lower montane region (mainly with Pine species). Cattle grazing on the reforested lands are controlled through fencing. Farmers are encouraged to change the induced (low productive) pasture with high productive pasture, and where possible to plant protein-rich leguminous tree species in either fodder banks or living fences. These latter measures are intended to reduce possible leakage of displacing cattle to other forested plots.

7 Community-based forest conservation:

A small number of communities have voluntarily set aside a forested area for conservation purposes. The activities involved to guarantee the conservation of the forest include the establishment and maintenance of fire-controlling strips, and control measures to prevent illegal logging, among others. The conservation contract is revised and renewed every 3-5 years. Possible leakages include degradation in remaining forests through increased harvesting. Each community has established a surveillance committee to check on illegal harvesting within each community boundary.

8 Community-based forest restoration:

One community has reforested a communally-managed degraded pasture land with predominantly pine trees. The community has agreed to ban any grazing activities to avoid damage to the pine reforestation. Successful trials with nitrogen-fixing alder trees (*Alnus acuminata*) have aroused a lot of interest in the community to diversify the restoration activities with other species (Ramírez-Marcial, ECOSUR, pers. comm., 2003). Possible sources of leakage include displacing cattle to other forested areas; the community has agreed in principle to establish improved pasture land for those farmers who want to keep their cattle.

All land-use activities carried out by the project participants can give rise to activity shifting leakage, and furthermore the direction of the leakage cannot be predicted beforehand. Additionally, a small but positive ecological and life cycle leakage (Schwarze et al, 2002) may be expected for some of the land-use activities.

Although the project activities will generate timber products that eventually will be put into the market stream, the effect on the market is expected to be negligible. As pointed out by Tipper et al (1998), a significant impact on the market is only likely if the project grows way beyond the plausible limits. On the other hand, because most timber production currently is obtained from forest exploitation with very little management directed towards maintaining or increasing natural regeneration of the timber trees, we actually may expect a positive impact due to a decrease in unsustainable timber production. A decrease in unsustainable timber production has already been observed in various timber producing communities in the state of Quintana Roo.

9 Leakage assessment.

The possible sources and extent of leakage was assessed by combining the Plan-Vivo system with the regional baseline. The land reported in the Plan Vivo where no project activities will take place is used for this purpose. Current land use of the plots not included in the project but owned by the participating farmers and communities were compared with original Plan-Vivo data. The baseline emission quota for this non-project land from the time he/she entered the program until the survey of the selected farmers and communities was calculated, based on the location of the community in relation to the regional baseline (See for details Castillo-Santiago *et al* 2006 and de Jong *et al* 2005). The total sum of expected deforestation of all farmers is compared to the observed deforestation, obtained from structured interviews combined with field visits.

Structured interviews were developed as a tool to obtain the land-use data from the farmers and tested on a small number of farmers (not included in the final survey). A stratified sample of around 10% of the participating individual farmers and two out of five participating communities was selected. The communities were chosen on the basis of available detailed land-use and land-use change data, whereas the individual farmers were randomly selected from the stratified database, with agroforestry systems and eco-regions as the stratification parameters. Each selected farmer was individually interviewed, whereas data collection in the communities was carried out through workshops with all community members. The following data were collected through the interviews and workshops:

1. Farmers´ knowledge of his original Plan-Vivo.
2. Current land use and/or cover of all their plots, including plot size.

3. If changes in land use and/or plot size had occurred between the original Plan Vivo and current land use data, the farmer was asked why the changes had occurred.

Plots that are reported with forest are considered as forest plots, all other plots, including plots that are reported with forest fallow, are considered agricultural plots, in accordance with our baseline approach, where only deforestation is accounted for in the future baseline emissions.

Comparing the land-use data of the original Plan Vivo with the currently reported land use, the farmers are allocated to one or more of the following categories:

1. Farmers with net positive change of land within the agricultural land-use sector: from low-biomass land use to higher-biomass land use (e.g., from agriculture to forest fallow): AsL1.
2. Farmers with net negative change within the agricultural land-use sector: from high-biomass land use to low-biomass land use (e.g., from forest fallow to agriculture): AsL2.
3. Farmers with net neutral change within the agricultural land-use sector: land-use change occurs between classes which are either low-biomass or high-biomass land uses (e.g., from corn to bean agriculture): AsL3.
4. Farmers with no land-use change within the agricultural sector
5. Farmers that changed forest to agriculture: D1.
6. Farmers that have more or less land currently compared to the Plan Vivo: OS1

Activity-shifting leakage within the agricultural land-use categories can be positive, negative or negligible.

- It is positive when the sum of the land surface (in ha) in each class results in:

$$AsL1 > 0 \text{ and } AsL2 = 0, \text{ or}$$

$$AsL1 > AsL2$$

- It is negative (and thus has to be taken into account) when:

$$AsL2 > 0 \text{ and } AsL1 = 0 \text{ or}$$

$$AsL1 < AsL2$$

- And negligible if no changes in AsL1 or AsL2 occur, or when:

$$AsL1 = AsL2$$

Changes of the type AsL3 have no effect on leakage.

Changes of the type D1 can also cause negative, positive or neutral leakage.

- Positive when: *D1 < expected deforestation* (according to the baseline),
- Negative when: *D1 > expected deforestation*,
- And is neutral when: *D1 = expected deforestation*

10 Results

We will present the results first from the individual farmers and next from the community plan vivos.

11 Individual farmers:

The total area reported by the farmers interviewed varied slightly between the time the Plan Vivo was developed and the leakage survey (Table 3).

TABLE 3.

Land surface reported in the Plan Vivo compared to land surface currently reported with number of farmers reporting an increase or decrease in area.

Place Table 3 Here

The number of farmers reporting a different area was rather high (42%). However, most of these farmers (16 out of 20) reported a difference of less than or equal to 1 ha (around 5% or less of their land area) between the Plan Vivo and current land surface, which probably is due to error in surface estimation. Of the remaining four farmers reporting a difference of more than 1 ha, three farmers reported a larger current area, whereas one farmer reported a decrease of 8.5 ha, originally in his Plan Vivo used as fallow land. As the farmer reported no change in his property, this difference may be due to an error in his original Plan Vivo. None of the farmers interviewed traded the land with the carbon obligations.

Only one farmer reported a conversion of forest to agricultural land, whereas 14 farmers changed land from low-biomass to high-biomass land use (AsL1), 11 farmers from high to low biomass (AsL2), four farmers changed land use that had no apparent impact on carbon density, and 18 farmers reported no change in land use (Table 4).

TABLE 4.

Number of reports (and % of total) and corresponding land surface.

Place table 4 here

Agricultural land-use change tends to be toward an increase in high-biomass land cover (AsL1 > AsL2), from which we conclude that:

- **AsL1 > AsL2 → positive activity-shifting leakage within the agricultural land-use category**

Because D1 > 0 we need to compare the actual deforestation with the expected baseline deforestation of all the farmers, according to the pre-established regional baseline.

12 Baseline deforestation assessment:

Each plot of the farmers interviewed was geo-referenced, so that we could superimpose each plot over the baseline deforestation risk map. The corresponding lower boundary of the 95% confidence interval of the yearly deforestation rate was assigned to the plot of the farmer, according to the category of the risk map. This is the most conservative rate for each farmer, in accordance with the Plan Vivo principles. Expected total deforestation rate of each farmer from the time he entered the program until the leakage survey was calculated with the following formula:

$Dt_i = ((1-Dy_i)^n - 1)*100\%$

Where $\mathbf{Dt_i}$ total expected deforestation of farmer *I* in percentage of his forested area;

$\mathbf{Dy_i}$ is the yearly expected deforestation rate of farmer *i*, according to the risk map

n is the number of years the farmer *i* is participating in the project until the survey.

The expected total deforestation for each farmer was calculated, multiplying Dt_i of each farmer *i*, with the amount of forest he owned at the time he presented his Plan Vivo. The total sum of the expected deforestation of all farmers resulted in 1.69 ha. Only one farmer changed one ha of forest to agriculture, none of the other farmers converted their forest land. Because the expected deforestation is higher than the actual deforestation, we conclude that:

- **$D1 < \Sigma Dt_i \rightarrow$ a slight positive activity-shifting leakage of deforestation.**

13 Communities:

Because a part of the community land has been allocated to individual farmers and the remaining part is managed communally, a slightly different procedure was followed for the community leakage assessment. First we assessed the land-use changes of the farmer's managed land, using responses to the survey of each farmer of the two communities. Additionally a survey was held to identify changes in the land use of the communal land through community workshops. Joining the two databases gave insight into the land-use dynamics from the time the community submitted their Plan Vivo until the date of the leakage survey. The most important changes observed in both communities were shifts from low-biomass shrub fallow to low-biomass agriculture or pasture, all in line with the original Plan Vivo, where it was stated that this land would eventually be converted to more permanent agriculture or pasture. In Reforma Agraria, 18 ha were converted to ecological agriculture, where traditional corn production is replaced by production of corn with green manuring, without burning (Table 5).

In both communities, farmers converted some of their forests into agriculture, in Reforma Agraria 5 ha were deforested in one year, whereas farmers in La Corona converted 27 ha of forest in three years (Table 5). Total deforestation was thus 9 ha per year for the two communities. None of the community forests had been converted.

To compare the estimated emissions with the expected baseline emissions, we converted the deforestation in each community to carbon emissions, using the vulnerable carbon densities of each land use as published by De Jong et al (2005). The expected baseline of La Corona was also taken from De Jong et al

(2005), whereas the expected baseline for Reforma Agraria was calculated for this study using the same procedures as reported for La Corona. Only deforestation is considered in the baseline, because other changes are difficult to detect. This will result in a conservative baseline, as land use in areas not considered as forest, still tends to move from higher-biomass land uses (such as slash-and-burn with long fallow periods) to lower-biomass land uses (such as short rotation slash- and –burn or permanent agriculture.

No land was transferred between the community members.

TABLE 5.

Land use and land-use change of La Corona and Reforma Agraria at the start of their project (Plan Vivo) and at the time of the leakage survey.

Place table 5 here

The total expected emissions from both La Corona and Reforma Agraria were higher than the estimated actual emissions (Table 6).

TABLE 6.

Expected and estimated emissions from La Corona and Reforma Agraria.

Place Table 6 here

For both communities the outcome demonstrates that:

- **$D1 < \Sigma Dt_i$ → positive activity-shifting leakage of deforestation.**
- **AsL1 and AsL2 = 0 → no activity-shifting leakage within the agricultural land-use category**

No negative leakage could be detected in the Scolel Té project. Some slight positive sources of leakage were observed in the rate of deforestation and related carbon emissions, both for the individual farmers and the two communities.

14 Discussion.

This leakage assessment was highly facilitated by the Mexican land tenure system. Because almost all the land available to farmers has either a private or community tenure status or is protected, activity-shifting leakage due to displacement of farmers to other areas is most unlikely. In countries where at least part of the public land is available to farmers, the potential spatial displacement of farmers may have to be taken into consideration. The application of the leakage flow chart may indicate if this type of leakage may be a problem. If it turns out to be a possible source of leakage, this could make the assessment of a project more complicated and costly because not only the land-use dynamics within the project domain needs to be monitored but also changes outside the borders of the domain, up to areas where displacement is most likely going to occur, may have to be monitored too.

The positive activity-shifting leakage that we observed in the Scolel Té project may be caused by at least three factors:

1. Although we established a very conservative baseline, according to the lowest boundary of the 95% confidence interval of all data sources, the baseline may still be too high in terms of expected baseline emissions, due to factors such as local variance outside the range of the confidence interval, incorrect procedures, etc.
2. The conditions have changed since the baseline was established. For instance, the forest policy of the government might have convinced the farmers to conserve their forests.
3. The farmers and communities participating in the Scolel Té project are more conservative in terms of biomass-related land management than the non-participating farmers and communities.

The first case is related to an incorrectly defined baseline, the second case requires more dynamic baselines (shorter periods), whereas the third case can be considered as positive leakage, especially if the farmers or communities have changed their attitude due to project participation.

To determine which of these factors are valid, the baseline needs to be validated for the whole region. Currently a new land-use map of the region is being developed with which we can validate the baseline map.

If conversion of forest to agricultural land is halted but agricultural productivity is not increased or guaranteed on existing land, the project is likely to result in leakage. For land under shifting cultivation used for the production of corn and beans for subsistence, this means that the same agricultural production has to be obtained on less land, which means in practice less land under fallow and which in turn requires a shift to more sustainable agriculture practices, such as green manuring, no-tillage and no-burn agriculture, among others. The Scolel Té project has been consistently promoting ecological measures from the beginning to reduce leakage, such as permanent sustainable agriculture as a measure to avoid activity-shifting leakage. The results of this survey indicate that these measures have been successfully applied by the farmers that were surveyed.

The Scolel Té project show that leakage in forestry projects can be dealt with effectively if efforts are undertaken to identify the possible sources of leakage and the main drivers expected to cause these. Various papers and manuals are available that could serve as tools to help project managers to deal with this issue. Other contentious issues related to forest mitigation projects are effectively dealt with in various papers that have been published or upcoming, such as the baselines issue (e.g. the Scolel Té baseline model as applied in this paper, the application of GEOMOD in various project cases (Brown et al 2006).

In the case of the Scolel Té project, the well-documented Plan Vivo complemented with readily available tools to identify the main sources and drivers of leakage are in place to develop simple but effective leakage assessment procedures, as demonstrated in this paper. Incorporating these procedures already in the project planning stage will reduce the uncertainties related to the actual carbon mitigation potential of any forestry project.

Notes

[1] The vulnerable carbon is here defined as the fraction of biomass that is susceptible to disappear rapidly as a result of human interference; see De Jong et al, 2004 for a detailed description of the calculation procedure

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Table 1. Annual deforestation rates in relation to the combinations of one driving factor (Population density, PopDens) with two predisposing factors (Distance to Agriculture, DistAg; and Distance to Roads, DistRd), adapted from De Jong et al (2005).

PopDens (hab/km2)	**DistAg (m)** **0 - 500**	**500 - 1000**	**>1000**
>30	4.88% ± 0.12%	3.63% ± 0.14%	3.34% ± 0.15%
>15 - 30	4.05% ± 0.11%	3.16% ± 0.12%	2.64% ± 0.13%
>0 - 15	3.83% ± 0.12%	2.98% ± 0.14%	2.40% ± 0.17%
0	3.34% ± 0.23%	2.25% ± 0.25%	1.68% ± 0.21%

PopDens (hab/km2)	**DistRd (m)** **0 - 1000**	**1000 - 2000**	**>2000**
>30	4.24% ± 0.15%	3.39% ± 0.14%	2.62% ± 0.50%
>15 - 30	3.54% ± 0.11%	2.90% ± 0.12%	2.46% ± 0.29%
>0 - 15	3.12% ± 0.13%	2.26% ± 0.12%	1.64% ± 0.16%
0	2.31% ± 0.19%	1.57% ± 0.15%	1.40% ± 0.22%

Table 2. Activity classes for each tenure class carried out in the Scolel Té project, main leakage drivers, and expected effect on each leakage mechanism, after Schwarze et al (2002). In bold the most significant leakage mechanism.

Tenure	**Activity**	**Driver**	**Mechanism**	**Expected Effect**
Individual	Agroforestry	Subsistence needs (+/-) Land availability (-)	**Activity shifting** Market Life-Cycle Ecological	+ / N / **-** N/+ N N /+
Individual	Small-scale reforestation	Land availability(-) Timber supply (+/-)	**Activity shifting** Market Life-Cycle Ecological	+ / N / **-** N N N / +
Communal	Forest conservation	Resource and land availability (-)	**Activity shifting** Market Life-Cycle Ecological	+ / N / **-** N N / + N / +
Communal	Forest restoration	Resource and land availability (-) Timber supply (+/-)	**Activity shifting** Market Life-Cycle Ecological	+ / N / **-** N/+ N N / +

Definitions Schwarze et al (2002):

Activity shifting: A project or policy can displace an activity or change the likelihood of an activity outside the project's boundaries. In the case of the Scolel Té project, we expect possible activity-shifting leakage within the boundaries of the farmer's or community´s land. Since almost all land has either a private or community tenure status or protective status (National monument, biosphere reserve), so there is no other land freely available to either group to shift their activities.

+ = positive leakage; - = negative leakage; N = negligible leakage

Table 3. Land surface reported in the Plan Vivo compared to land surface currently reported with number of farmers reporting an increase or decrease in area.

	Area reported	Increasing	Decreasing
Land in Plan Vivo	496.75 ha	8 (17%)	12 (25%)
Current land	513.25 ha		

Table 4. Number of reports (and % of total) and corresponding land surface.

Category	**No. of reports**	**(% of farmers)**	**Ha**
AsL1	14	(29%)	17.05
AsL2	11	(23%)	15.75
AsL3	4	(8%)	4.50
No change	18	(38%)	474.95
D1	1	(2%)	1.00
Total	48	(100%)	513.25

Table 5. Land use and land-use change of La Corona and Reforma Agraria at the start of their project (Plan Vivo) and at the time of the leakage survey.

	Reforma Agraria					
	Plan Vivo (2000)		***Current (2003)***		***Change***	***Vuln-C***
Individually managed	**N**	**ha**	**N**	**ha**	**ha**	**tC/ha**
Forest	18	108.0	18	103.0	-5.0	222.2
Low shrub fallow	36	201.2	30	151.7	-49.5	0
Pasture	37	580.0	38	600.0	20.0	0
Agriculture	13	32.5	18	49.0	16.5	0
Reforestation	3	3.0	3	3.0	0.0	0
Ecol. Agriculture	0	0.0	5	18.0	18.0	0
Total	**42**	**924.7**		**924.7**	**0.0**	
Community managed						
Forest	1	1350.0	1	1350.0	0.0	222.2

	La Corona					
	Plan Vivo (2002)		***Current (2003)***		***Change***	***Vuln-C***
Individually managed	**N**	**ha**	**N**	**ha**	**ha**	**tC/ha**
Forest	24	235.0	23	208.0	-27.0	222.2
Low shrub fallow	41	590.0	40	492.0	-98.0	0
Pasture	20	99.0	34	180.5	81.5	0
Agriculture	1	2.0	21	45.5	43.5	0
Total	**49**	**926.0**	**49**	**926.0**	**0.0**	
Community managed						
Forest	1	1538.3	1	1538.3	0.0	222.2

The total expected emissions from both La Corona and Reforma Agraria were higher than the estimated actual emissions (Table 6).

Table 6

Table 6. Expected and estimated emissions from La Corona and Reforma Agraria.

Carbon emission of communities		tC
Reforma Agraria		
Expected emission derived from regional baseline (Ambio, Unpubl data)		3,764
Real emissions, based on this leakage assessment (5 ha * 222.2 tC/ha)		1,111
	Difference (leakage)	2,653
La Corona		
Expected emission derived from regional baseline (De Jong et al, 2004)		4,565
Real emissions, based on this leakage assessment (27 ha * 222.2 tC/ha)		2,000
	Difference (leakage)	2,566

Figure 1: Example of a plan vivo and area used for the leakage assessment.

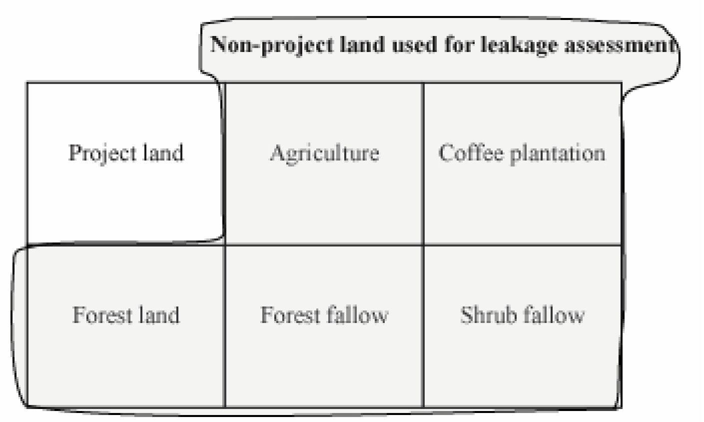

Figure 2: Decision tree to identify types and importance of leakage for the Scolel Té project, Chiapas, Mexico.