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CARBON COUNTS: ESTIMATING CLIMATE CHANGE MITIGATION IN FORESTRY PROJECTS

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I. Introduction

As the scientific evidence for greenhouse warming continues to mount both in terms of sophistication and confidence, so too does the urgency of exploring strategies to help stabilize the global climate This urgency is underscored by the Intergovernmental Panel on Climate Change, which in 1995 concluded that human activities are having a "discernible" impact on global climate (1)

One climate stabilization strategy is to continue using forests to store carbon, which in turn reduces atmospheric carbon dioxide, the predominant greenhouse gas Unlike controlled scientific experiments, evaluations of carbon storage projects hinge on uncertain estimates of future human activity in the face of changed circumstances Understanding and anticipating how people are likely to respond to such changes can diminish uncertainty about the long-term benefits of carbon sequestration projects This report continues the work of the World Resources Institute (WRI) and others on the use of forests for carbon sequestration as a response to global warming See *Box I* (2) It particularly looks at improving the reliability of net carbon savings estimates by anticipating and avoiding leakage--that is, unexpected carbon losses Fortunately, it appears that in many cases leakage can be either avoided or reduced to acceptable levels

Using the analyses of five recent case studies, that are briefly described in Box 2, as well as other case studies and past WRI research as references, this paper offers guidance on correctly estimating carbon sequestration benefits and on designing and implementing projects that will deliver these promised benefits

Box 1 Carbon Sequestration History and Context

More than 2,400 scientists and 2 600 economists 8 Nobel Prize winners among them signed statements supporting the 1995 Intergovernmental Panel on Climate Change report (1) These experts conclude that the potential risks of climate change justify preventative steps If concentrations of greenhouse gases continue to rise mean global temperatures could rise raising sea levels and increasing the variability of hydrologic events and risks to human health

Can anything be done to avert these events? The 1992 climate change convention commits signatory nations to set targets to lower greenhouse emissions in the next century These targets will have to be met primarily by increasing reliance on energy sources that emit comparatively lower levels of greenhouse gases Forests and forest soils can also be a part of the solution as they sequester carbon thus keeping it from the atmosphere Planting trees or encouraging agroforestry can store "new' carbon saving existing forests can prevent the release of stored carbon

WRI s interest in carbon sequestration projects dates back to 1988 when Applied Energy Services, Inc a U S based independent electric power producer asked the Institute to identify and evaluate forestry projects that could offset the carbon dioxide emissions of a new AES coal fired power plant in Connecticut The new plant was expected to emit about 14 1 million metric tons of carbon (52 1 million tons of CO_2) during its 40 year life

The most attractive proposal submitted, was located in Guatemala and proposed by CARE, a well-known international development and relief organization The project had several components including creating community woodlots implementing agroforestry practices terracing vulnerable slopes, and providing training for community forest fire brigades

WRI calculated that the project would sequester an estimated 16 3 million metric tons of carbon over 40 years through net addition to the standing inventory of biomass carbon retention of standing forests as a result of demand displacement via woodlots and agroforestry projects protection of some carbon in soils and retention of some standing forests because of community fire brigades

The opportunity to improve the evaluation process occurred soon thereafter, again in response to an AES plan to offer $5 million for projects that would offset emissions through forest management For this effort, WRI attempted to develop a more sophisticated methodological approach The carbon sequestration potential of the projects was evaluated using project site data and a simple land-use model The model was designed to assess changes in the landscape over the life of the power plant and to provide insight into how the different trends and interventions could affect the landscape during future decades The model was also designed to capture essential physical interactions between people and forests, to be relatively simple and to be suitable for a wide variety of situations and management schemes

Box 3 presents additional information on the LUCS model The model and a manual describing its assumptions methods and limitations as well as projects and results are available from WRI

Note 1 Intergovernmental Panel on Climate Change Working Group I *Climate Change 1995 The Science of Climate Change Summary for Policy Makers*, (Cambridge University Press 1995) Scientist s Statement on Global Climate Disruption June 18 1997 Ozone Action Washington D C Economists Statement on Climate Change ' June 18, 1997 Redefining Progress San Francisco California

Box 2. Five New Cases

This study draws on five recent carbon sequestration projects which are described briefly here

CASE 1 Reduced Impact Logging Sabah, Malaysia

The reduced-impact logging pilot project began in August 1992 when New England Electric Systems of Massachusetts (NEES) a coal burning utility, decided to provide funds to Innoprise Corp of Sabah, Malaysia a timber concession holder to implement reduced impact logging guidelines for 1 400 hectares of Innoprise's 1 million hectare concession The project emphasizes staff training to use existing technology and machinery in an environmentally sensitive way and to increase supervision of harvesting operations

The harvesting guidelines include specifications for creating buffer zones for streams and roads developing a formal harvesting plan cutting climber vines before harvesting, planning and marking skid trails, marking trees for future harvests, and undertaking directional felling of marked trees to reduce residual damage to surrounding forest

The project's potential benefits include reduced damage to the residual forest, decreased erosion carbon emissions and land degradation increased capacity for future timber production, increased biodiversity decreased incidence of fire reduced weed infestations, and increased long term ecological and economic productivity

CASE 2 Krkonose National Park Czech Republic

The Krkonose project is designed to restore 15 000 hectares of damaged and dead forest in Krkonose National Park, which is located northeast of Prague in a mountainous area between Poland and the Czech Republic The mountain range is endowed with unique vegetation and is the only Norway spruce forest in Europe that is adapted to a harsh montane climate Because of its unusual florae 38,500 hectares on the Czech side were designated as a national park in 1963

The *Norway spruce* (Picea abies) stands are heavily degraded by air pollution and increasing acidification By 1992 one-half of the existing forest in 1963 had been seriously damaged or had died About 7 000 hectares of land was so acidic that natural regeneration was impossible This area was completely reforested On the remaining 8 000 hectares, trees were planted in gaps in the forest landscape

Long-term prospects for success depend on reducing the acidity of rainfall in the area the source of the problem is thought to be sulfur emissions at nearby coal burning power plants in Poland The Electricity Generating Board (SEP) of the Netherlands has provided funds for two flue gas desulfurization units for the largest power station in Poland

The project is sponsored by Forests Absorbing Carbon Emissions (FACE) a financing mechanism created by SEP FACE supports projects that will offset some of the CO_2 emitted from the use of fossil fuel for electricity generation in the Netherlands

CASE 3 The Olafo Project-Peten, Guatemala

The Olafo project area is in a part of the Maya Biosphere Reserve in the Peten region of northern Guatemala that permits multiple land uses Under the current system of shifting subsistence agriculture land can be cultivated for 2 years, but then must lie fallow for 8 years Permanent agriculture is not possible because of high weed infestation and low soil fertility

Residents are primarily migrants For each new arrival about one hectare of new land must be cleared After the land has been cultivated for 2 years additional forest must be converted to agriculture Because of population pressures the shifting cultivation cycle is unsustainable and deforestation continues

The project is attempting both to promote the sustainable management of natural forests and to extend the cultivation time of shifting agricultural lands through the use of green cover crops Specifically, it aims to extend the cropping period from 2 years to 8-10 years New forest management practices include sustainable timber harvests, harvesting of *Desmoncus* vines for rattan type furniture and ornamental plant extraction The project is intended to help boost income for local families recuperate forest areas and reduce the deforestation rate

The Olafo Project is being developed by the Tropical Agriculture Research and Education Center (CATIE) a regional nonprofit scientific and educational institution based in Turrialba, Costa Rica. The project is supported by three Scandinavian aid agencies DANIDA (Denmark) NORAD (Norway) and SIDA (Sweden)

CASE 4 Rusafor Afforestation Project Saratov, Russia

The biological operational and institutional opportunities to manage a Russian forest as a carbon sink will be evaluated in the Saratov oblast region 700 kilometers southeast of Moscow Representatives from the Russian Federal Forest Service (RFFS) and Oregon State University (OSU) working under a Cooperative Agreement with the U S Environmental Protection Agency (EPA) negotiated this pilot project in Russia The RUSAFOR project will explore how such projects can be organized and managed and how the sequestered carbon can be credited

The project has many goals including assessing the value of forest management projects as greenhouse gas mitigation projects identifying barriers to private investment in Russian forestry and ways of overcoming them assisting Russian partners to establish forest plantations and sharing information that quantifies the project's biological economic and institutional benefits

The project is being coordinated by EPA and implemented through cooperative agreements with the Environmental Defense Fund (EDF) and Oregon State University

The project would afforest 420 hectares of agricultural wasteland The land currently has an average biomass of 8 tons per hectare, with the project however average biomass will peak at about 269 tons per hectare

CASE 5 Carfix Costa Rica

The CARFIX project is located in the Central Volcanic Mountain Range Conservation Area It is being implemented by the Fundacion para el Desarrollo de la Cordillera Volcanica Central (FUNDECOR) a nongovernmental organization

The region is characterized by agricultural production (primarily cattle) for export. Deforestation is occurring at a rate of about 5 percent per year Once logged the land is converted to agricultural use

The pressure on the closed forest and open woodland is primarily to expand the agricultural land base with some income from logging The key to slowing deforestation therefore is to provide alternative sources of income that are competitive with agricultural exports

FUNDECOR's primary activities are natural forest management (NFM) and development of tree plantations on grazed or degraded lands The project addresses the grazing land demand by substituting income from NFM for cattle production To ensure the practice of sustainable logging, the project will provide income to the local population during the interim between timber harvests

The potential role of forests in slowing global warming is still being debated At an April 1995 meeting in Berlin, the Conference of Parties to the Framework Convention on Climate Change agreed to begin a pilot phase exploration of the efficacy of "activities implemented jointly" to reduce greenhouse gas emissions or sequester carbon (3) The international community is using this pilot phase exploration to decide if such projects are a valid way to reduce atmospheric concentrations of greenhouse gas emissions Climate-convention signatory nations may approve Joint Implementation as a formal mechanism for achieving greenhouse emission reductions if the projects are shown to offer real benefits to developed and developing countries

The current convention defines "joint implementation" agreements as "efforts undertaken voluntarily and cooperatively between at least two parties in two or more countries that reduce, avoid, or sequester" greenhouse gas emissions The parties could include the private sector, governments, non-governmental organizations (NGOs), or academic institutions (4)

Under a joint implementation framework, forestry projects are potentially an attractive sequestration option, because they may be a relatively inexpensive way to offset greenhouse gas emissions However, the cost-effectiveness of forestry projects for carbon sequestration remains uncertain, particularly once transaction and monitoring costs are considered

Not everyone is convinced, however, that joint implementation is a valid option for reducing greenhouse gas concentrations Several NGOs, China, and a majority of the "G-77" group of developing nations have reservations about these agreements They argue that developed countries are responsible for the historical buildup of greenhouse gases and are ducking their commitments by using these forestry projects as a way to continue their profligate domestic energy consumption Thus far, the G-77 nations support only pilot projects or forestry agreements between developed countries (5) However, some developing nations, including Costa Rica, view such agreements as an opportunity to attract foreign investment capital and funding for rural development and conservation projects

Whether forestry and land-use projects have a place in a future Joint Implementation program depends on their ability to deliver verifiable carbon benefits Delivering the carbon reductions claimed is a key to the credibility, and hence the acceptance, of these projects for greenhouse gas mitigation and reduction

II. Leakage

Leakage is defined here as the unexpected loss of estimated net carbon sequestered In some cases leakage may be positive--that is, more net carbon reductions were achieved than was expected, but it is the loss of greenhouse gases that most concern us Leakage can be the result of incorrectly estimating the project's impact or of unexpected effects such as a population increase in the project region, during the course of a project Therefore, correctly estimating a project's impact and designing projects that avoid leakage are critical

Figure 1 illustrates the land-use dynamics and potential leakage over time in a project region characterized by subsistence agriculture, where population growth and demand for agricultural land drive deforestation As population grows, marginal upland is brought into agricultural production As this land eventually degrades into pasture, people cultivate increasingly higher, and more easily degraded slopes Each of the three scenarios depicted in Figure 1 features permanent agriculture on the lowland areas and a combination of cattle grazing and farming in the upland areas The project goals are to move from scenario 1 (the baseline) to scenario 3, and sequester carbon by relieving pressure on the forest through the introduction of higher productivity agroforestry and tree plantations, which would provide fuelwood However, as shown by scenario 2, leakage occurs Agroforestry is more productive than the pasture and agriculture it replaces, but the movement of cattle to upland areas results in forest conversion and degradation, albeit at a slower pace than indicated in the baseline Ideally, leakage can be anticipated, or mitigated, by the measures listed in scenario 3--halting encroachment allowing sustainable use of forests, and incorporating cattle into the woodlots via silvopastoral systems

In response in part to uncertainties regarding correct net carbon calculation, investors are focussing on simple afforestation projects, because their impacts appear to be easier to quantify than those of other types of forestry carbon sequestration projects In fact, tree planting is the only forestry activity the U S Department of Energy defines as a "standard" rather than "reporter-designed" project, meaning that enough credible data has been assembled to estimate the project's carbon benefits (6) Of the greenhouse gas mitigation projects reported to the Department of Energy, tree planting projects are the most popular (7) The carbon storage portfolio sponsored by the Netherlands' state utility consists entirely of tree planting on degraded lands (8)

The popularity of tree planting may also be explained in part by the notion that growing biomass accumulates carbon while mature forests are merely stable However, these "stable", mature forests have usually accumulated much more carbon in biomass than tree plantations are likely to, as Table 1 illustrates The biomass accumulation of the mature forests in the northwestern United States, Malaysia's Sabah region, and Cameroon represents only carbon in living biomass, the total carbon of tree plantations with rotations varying by species, represents projected accumulations of carbon in living biomass and forest products after 300 years (9)

Table 1 compellingly illustrates that tree plantations are less effective than natural forests at storing carbon, even when carbon storage in wood products are included in the estimate Furthermore, a recent study of a tropical rain forest in Brazil indicates that undisturbed forests are continually sequestering carbon The study estimated that the forest sequestered one metric ton of carbon per hectare per year (10) This finding underscores the greenhouse gas benefits of projects that prevent deforestation

It is important to note that when the authors in this publication refer to projects that prevent deforestation, they are not necessarily referring to forest preservation projects that set aside forestland in a park or protected area, which can have significant leakage problems Rather they are referring to those projects that successfully prevent deforestation by addressing underlying land-use dynamics and demands on resources in and around the project site Satisfying demands for these resources can, and often does, involve tree planting, as noted later in the case studies

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Figure 1 Expanding Agricultural Frontier

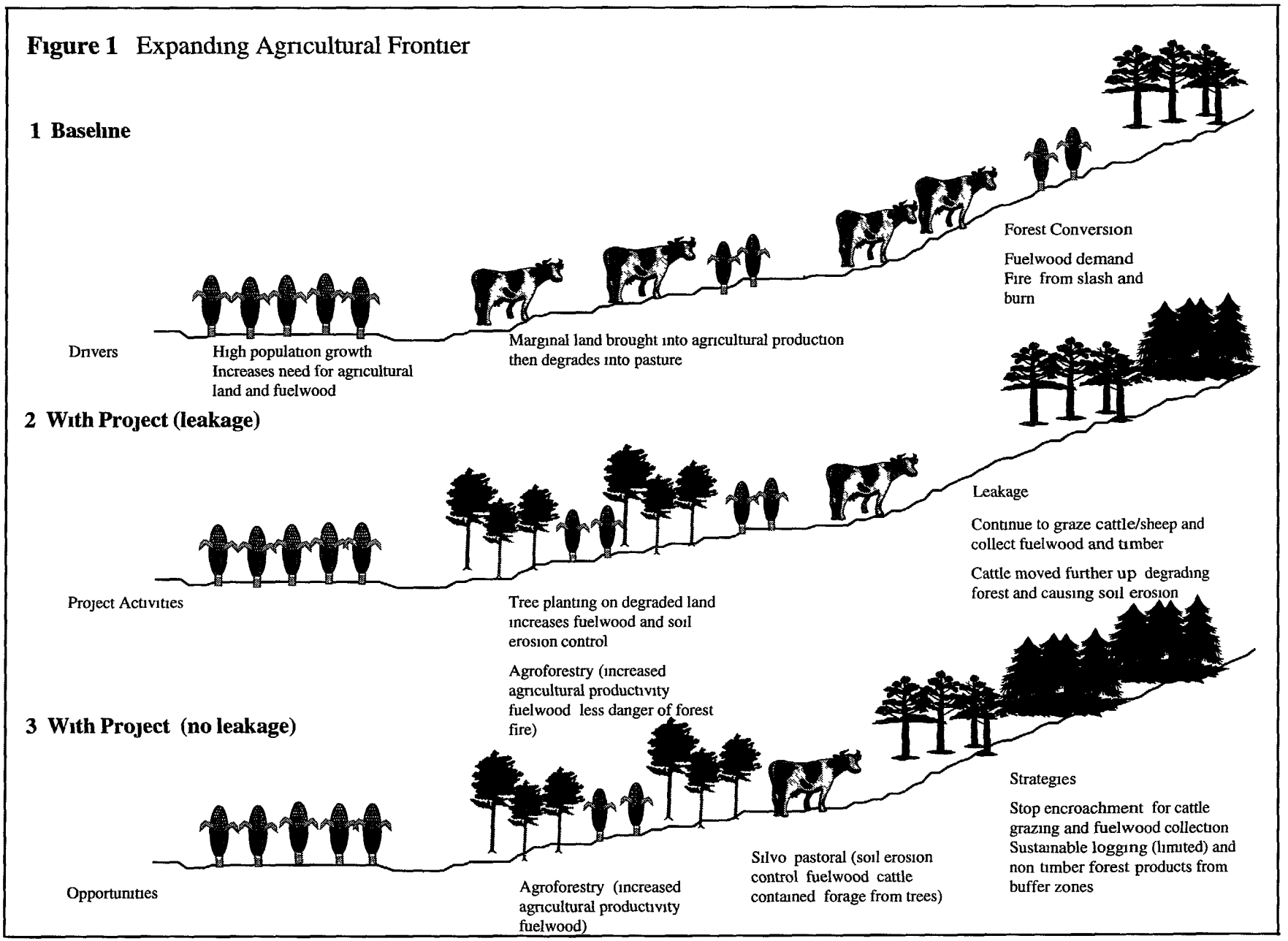


Table 1 Comparison of Potential Biomass

Forest Type	Tons of Carbon per Hectare
Mature Douglas Fir Northwestern United States	611 (1)
Mature Closed Forest Sabah Malaysia	348 (2)
Mature Primary Moist Forest Cameroon	279 (3)
Industrial Black Locust Plantation Europe	195
Industrial Slash Pine Plantation Brazil	191
Afforestation of Tropical Wasteland Borneo	188
Industrial Poplar Plantation Europe	137

1 Mark E Harmon William K Ferrell and Jerry F Franklin Effects on Carbon Storage of Conversion of Old Growth Forests to Young Forests *Science* 9 February 1990 699
2 Francis E Putz and Michelle Pinard Reduced Impact Logging as a Carbon Offset Method *Conservation Biology* vol 7 no 4 December 1993 755 757
3 Sandra Brown Andrew J R Gillespie and Ariel E Lugo Biomass Estimation Methods for Tropical Forests with Applications to Forest Inventory Data *Forest Science* vol 35 no 4 December 1989 895

The urge to pursue simple projects in an effort to avoid difficult issues is understandable but unnecessary It is possible to evaluate projects, identify conditions likely to result in leakage, determine factors contributing to this problem, and recommend actions to avoid or at a minimum account for it

The analysis of specific carbon sequestration projects indicates that leakage can and should be incorporated into project design and that projects addressing the drivers of land use-change will maximize project benefits reduce risks and costs and minimize the potential for leakage

Causes of Leakage

A project may fail to meet its carbon sequestration target because of unforeseen circumstances that are beyond the control of project participants, improperly defined key parameters, such as time horizon, project boundaries, or baselines, or inappropriate project design and activities in light of the land-use patterns in and around the project site

Unforeseen Circumstances

Extreme weather, political instability, climate change, pests disease, or fire are unforeseen circumstances that project designers and implementors cannot control Such circumstances can be dealt with at two levels the individual project level and a broader multi-project, national or international level Project failure at the macro level can be guarded against in at least three ways creating a diverse portfolio of projects that hedge against individual project failures, pinning carbon reduction credits to national baselines, or creating insurance funds that would provide funding for a replacement project should one fail (11) Each of these options would mitigate the consequences of an individual project failure

Of the three options, the portfolio strategy is the only one currently being used To sequester nearly 100 million tons of carbon, FACE, (the financing arm of the Netherlands' state utility), has set up projects in seven countries FACE has sufficiently diversified so that the failure of one project will not seriously hamper its carbon mitigation effort Utilities that do not have the resources to invest in more than one forestry project can still reduce the risks of an individual project failure by working in concert In the United States, for example, 40 utilities have jointly invested in the nonprofit UtiliTree Carbon Company to provide more than $2 million for five or six forestry-based projects (12)

The portfolio concept can be applied not just to the number but also to the types of projects Because natural forests are usually adapted to naturally occurring events typical to their region, projects that maintain these forests may therefore be more resilient than projects focussing solely on tree plantations, which tend to be more susceptible to drought, fire, and disease (13)

Our project review indicated some guidelines for dealing with these and other unforeseen circumstances at the individual project level One guideline is to provide benefits to the people living in the project area. Projects that fail to provide local benefits can solidify political opposition and increase the projects' risk of failure

Conversely, projects that provide such benefits can create incentives for local people to overcome risks and even expand projects' impacts

The CARE/Guatemala project, which increased fuelwood availability and agricultural productivity by providing trees through CARE-sponsored tree nurseries, has persisted during years of political strife and uncertainty because it involved local people as stakeholders in its success Moreover, these people have adopted the project's techniques in areas beyond its boundaries by setting up their own tree nurseries, thereby potentially increasing the amount of carbon sequestered (sometimes called positive leakage) and providing other ancillary benefits

Other projects have used different methods to enhance their success The RUSAFOR project, for example, contains both a stick and a carrot RUSAFOR has built loss provisions into its contract with the Russian Forest Service, stipulating that the Service will replant trees if the original ones do not survive Also, the project splits any future carbon credits evenly between the United States and Russia

In conclusion, the mere existence of risk from unforeseen circumstances is not a sufficiently compelling reason to exclude forestry and land-use projects from a joint implementation program The strategies outlined above can reduce the risk of a project's failure to an acceptable level Furthermore, risk is not endemic to forestry projects, but is also a concern for energy-based, greenhouse gas offset projects To date, no forestry or land-use projects to sequester carbon have failed

Improperly Defined Key Parameters

One of the challenges of avoiding leakage is to correctly define a project's three key parameters One is the baseline--what would happen in the project's absence It is the foundation for estimating the project's net carbon sequestration benefits The second parameter is the appropriate project lifetime And the third parameter is the project's boundaries which may differ from the project's physical boundaries, the area where carbon sequestration activities are directly implemented The impact of these activities may extend beyond the physical boundaries The Leakage Index, presented in a later section, describes the various drivers of land-use change and project components that help to define a project s boundaries These three parameters are particularly important in helping project designers more accurately estimate carbon benefits, discover potential sources of leakage, and design projects to minimize or eliminate this problem.(14)

Baseline

Net carbon sequestration is difficult to estimate, in part because of the conjectural nature of baseline projections The case studies suggest a few guidelines for constructing reasonable projections

First, estimates of what would happen in the project's absence should be based on existing forest trends and an identifiable cause In the Krkonose project, in the Czech Republic, such estimates were aided by the existence of historic data on the Krkonose forest's decline and a clear understanding of the decline's cause --acid rain resulting from emissions from nearby power plants The CARFIX project in Costa Rica used LANDSAT data collected during a 5-year interval to refine its baseline projections

Second, barriers to positive change should be analyzed to strengthen the case for a likely baseline scenario The point of this action is to determine if the social benefits offered by forestry projects could be realized without outside intervention Although agroforestry or sustainable forestry projects generally provide environmental and social benefits, small landowners, who typically have little access to capital, may be unable to wait for these benefits because they need to support themselves today (15) Both the original CARE/Guatemala and CARFIX projects provided interim income until the projects' benefits could be realized Furthermore, without such external funding, there would be no incentives to produce nonmarket goods such as sequestered carbon

Third, reforestation projects should include evidence of barriers to natural forest regeneration such as intensive cropping, pollution, soil degradation, perverse forest policies, pests, or fire Because forests eventually rebound from disruption, project planners must make a compelling case that the area would not regenerate naturally Baseline assumptions remain a thorny issue for reforestation and afforestation projects

Project Lifetime

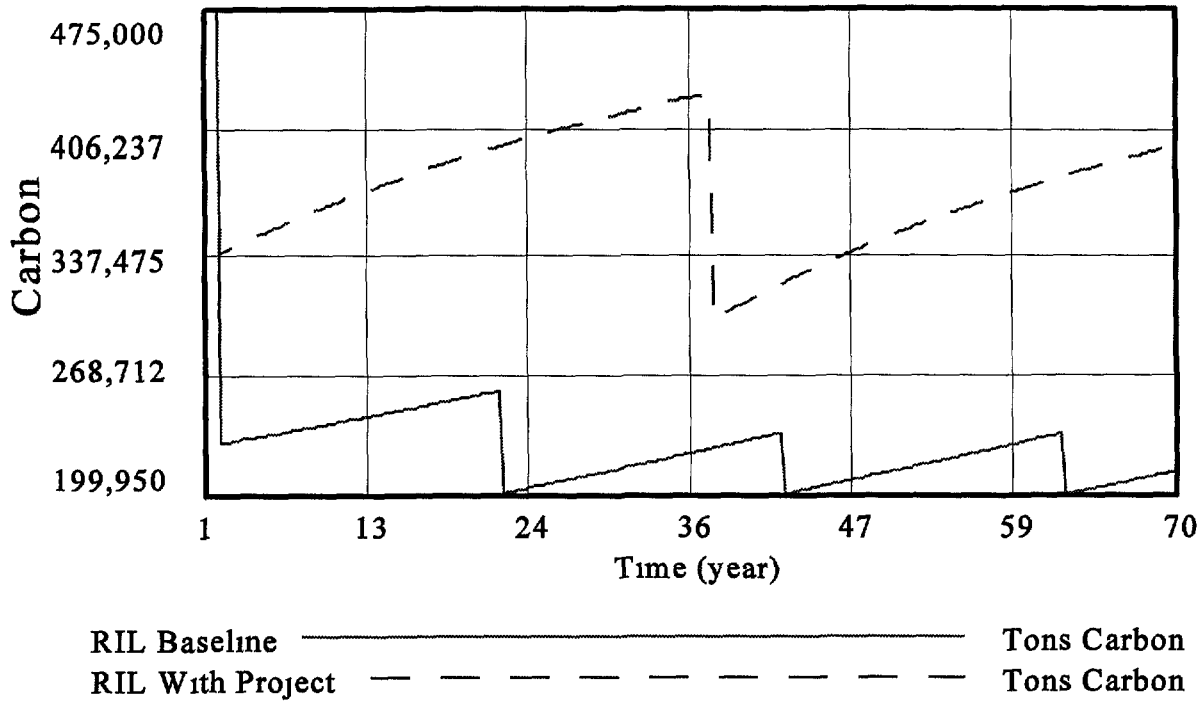
Picking an appropriate lifetime for a project is also an important parameter in developing an accurate estimate of expected future net carbon benefits Two issues are associated with choosing an appropriate time horizon The first is deciding which time horizon most accurately measures the effects of project activities, and therefore most accurately estimates the net reduction of greenhouse gases Different time horizons will yield different net estimates The second is ensuring that the project continues long enough to mitigate the global warming potential of greenhouse gas emissions but not so long that the project becomes unreasonable in terms of risk and monitoring The following three options address each of the above issues to varying degrees

Under the first option, referred to as "lifetime of an emitting activity," the project would be linked to the lifetime of a power plant's operations or other emitting activities that the project was designed to mitigate The CARE/Guatemala project, for example was linked to the 35-year lifetime of the AES-power plant it was offsetting However, a 35-year time horizon may be surpassed in duration by the entire lifetime of certain carbon forestry projects, such as RUSAFOR, which is situated in a slow-growing boreal zone (16) One advantage of such a time horizon is that the carbon emitter, who is typically the project investor, can play a monitoring role, as is the case with CARE/Guatemala

Under the second option, referred to as "lifetime of a project" only the carbon sequestered for the exact duration of project activities would be estimated In this case the time horizon would vary significantly from project to project as, for example, from 3 years for the logging project in Malaysia to 60 years for RUSAFOR However, only counting carbon for the duration of project activities, which do not include monitoring, carries the risk of miscalculating project impacts As Figure 2 illustrates, the potential differences in net carbon sequestration estimates can be large, depending on the time period used for calculation If estimates are calculated only for the first 5 years, the difference between the estimate for conventionally logged land and that for reduced-impact logged land will be greater than under a longer time frame Also, if the conventionally logged land regenerates, this difference will decrease

Under the third option, referred to as, "lifetime of carbon dioxide in the atmosphere,' the project's lifetime is estimated to be 50-200 years, the length of time that carbon dioxide persists in the atmosphere (17) However, assuming continued carbon sequestration over a time horizon reaching the upper end of this range is unreasonable given the impossibility of accounting for uncertainties about events and activities that far into the future

Figure 2 Reduced Impact Logging (RIL) Carbon



For the purpose of estimating a project's net carbon mitigation, the time frame should neither mask future land-use trends nor render parameter estimates meaningless It is necessary to balance a reasonable time frame for future projections against the need to sequester greenhouse gas emissions that persist for hundreds of years Given a changing landscape, using too long a time horizon renders parameter estimates undependable, reducing the reliability of a project's carbon estimates

In terms of tracking carbon, a project's lifetime should last until the time at which the carbon dioxide could have cycled out of the atmosphere, a minimum of 50 years In this way, the project is most likely to have reduced the atmospheric concentration of greenhouse gases Ideally, the project will be designed to provide local benefits that will ensure the continuation of project activities

Boundaries

Properly defining project boundaries is absolutely critical to avoid leakage Choosing an appropriate project boundary for making carbon sequestration estimates requires determining the spatial relationship between the demand causing land-use change, and the supply source Project activities can have impacts at a project level, a local/regional level, or a global level

Small pilot projects on land with little or no competing uses need only consider the area of direct project activities because the project's impact is unlikely to extend beyond its immediate boundaries Projects in Russia and the Czech Republic fall into this category Krkonose is situated in a national park, where there is no danger of encroachment, so there are no alternate land uses to displace FACE is funding efforts on 15,000 hectares, and only the dynamics of those hectares need to be considered

More often, competing land uses will mean that a project's impact extends beyond its own borders to the local area or region The Olafo and CARE projects in Guatemala, and CARFIX are in this category In dynamic settings where factors such as population growth, agricultural productivity, fuelwood needs, and concerns about deforestation interact, the project's impacts will extend beyond the areas of direct intervention Developing an agroforestry project in a region of subsistence agriculture, requires more than planting X number of trees on X number of hectares and calculating the carbon sequestered A project developer must also consider what type of land is converted to agroforestry If it is agricultural land, will agroforestry increase productivity? If not, will farmers need to clear more land than was previously thought necessary?

For some projects, notably those involving logging or agricultural production for export markets, the demand and supply dynamic will be essentially global in that the projects cannot control demand and cannot affect the quantity consumed If the Malaysia logging project reduces output, the world market will consume the same amount of timber, it just won't come from the Malaysian project site

Inappropriate Project Design

The spatial relationship between supply and demand not only determines the appropriate project boundaries but also structures the process of identifying and avoiding leakage during the project design and evaluation phase Potential types of leakage are activity shifting, market effects, and project construction effects (18) Unlike unforeseen circumstances, these manifestations can largely be anticipated and avoided Some or all are listed in the guidelines issued by the U S Initiative on Joint Implementation and by the U S Department of Energy for reporting greenhouse gas offset projects

Activity shifting occurs when the activity causing carbon loss in the project area is displaced to another location As an example, consider a project that buys out farmers and preserves the former agricultural land and surrounding forest In response, farmers may resume agricultural activities in a neighboring forest rather than move to a city or take up another occupation If farmers resume such activities elsewhere, the project has merely displaced the source of carbon emissions Similarly, the Malaysia logging project which reduced damage from logging, may increase timber harvests elsewhere by decreasing the project site's short-term timber output

Market effects occur when demand is unmet because a project reduces supply or because it unexpectedly increases demand A United Nations Development Programme proposal for a carbon sequestration and biodiversity project in an arid area of the Sudan refers to such effects According to the proposal, increased fuelwood and other resulting improvements might encourage immigration, increasing pressure on the new fuelwood source and undercutting net carbon savings (19)

The case of Carton de Colombia, a pulpwood producer, provides a useful example of market effects, even though it was not a carbon storage project, but resembles such a project Carton de Colombia, aimed to maintain a sustained yield through natural regeneration and by minimizing damage to residual trees in a lowland tropical forest on Colombia's Pacific Coast (20) However, the job opportunities created by the pulpwood producer triggered an influx of colonists, who could not all be absorbed and employed As a result, timber poaching and conversion of recently harvested areas to agriculture nullified potential project gains

Construction effects occur when a project increases the energy-intensiveness of an activity by, for example, mechanizing agriculture, or introducing new emissions-producing activities by requiring major infrastructural developments such as large dam construction With the exception of biomass projects for energy production, it is unlikely that a forestry project requiring such a large construction effort would be cost-effective enough to implement for carbon sequestration benefits alone This study did not examine any such projects

Of the three potential types of leakage, thus far only two--activity shifting and market effects--have emerged from our case studies as a concern They are both related to unmet demand Activity shifting will only occur if project boundaries are not configured to include relevant demands Market effects are associated with a demand shift in which the project itself provokes an

increase in demand and upsets original assumptions and hence carbon sequestration estimates

The next two sections present a conceptual framework, the Leakage Index, that helps determine when leakage is likely to be an issue and uses case studies to illustrate the index

Leakage Index

A rough guide to leakage potential is shown in Table 2, the Leakage Index Estimates of leakage potential were based primarily on an analysis of the type of demand for a resource (for example, agricultural land, fuel, or timber for either local or export consumption), market boundaries (local, regional, national, or global), and the extent to which the project satisfies the demand for a resource

Column one of the Leakage Index presents the main drivers of land-use change and the deforestation resulting from demand for agricultural land, fuelwood, and timber The underlying concept is that decreasing output or access to needed resources prevents a project from meeting its carbon sequestration goals The extent of the unmet demand determines the magnitude of leakage caused by project activities

Figure 1 depicts an example of this dynamic If upland forest had been strictly protected and no agricultural extension and tree planting had been undertaken, demand for agricultural land and fuelwood would be unmet This unmet demand would result in leakage as people attempted to intensify production on pasture land, further degrading the central, sloped areas, as they encroached on the protected area for fuel, or as they moved out of the area to cultivate unprotected forest

Determining the primary drivers of land-use change requires an understanding of the project area and the human activities there, which in turn determine the extent of project boundaries Although CARFIX proponents used GIS estimates indicating a 5 percent rate of deforestation, they needed to determine whether the deforestation was driven by demand for timber or for agricultural land In this case, timber demand proved to be a secondary issue

The second column of the Leakage Index further delineates the nature of demand, which could be either for local use, subsistence use, or export This delineation will help define the project boundary and the amount of leverage the project can exert on demand If demand for a resource is local or regional, the project can possibly offer substitute resources However, the project will have little or no leverage if the demand is for a large regional area or a global market

Column three of the Leakage Index lists likely project components based on those employed in carbon sequestration projects to date, and column four lists conditions under which these components become vulnerable to leakage As these columns indicate, a project that reduces access to resources without offering alternatives will likely result in leakage, as people within the project area will move elsewhere to find other sources

For a project to successfully sequester carbon, it must either expand or have a neutral impact on output of a resource Alternatively, the project could provide a substitute resource CARFIX, for example, addressed agricultural land demand by substituting income from sustainable forestry and carbon sequestration

Column 5 of the Leakage Index offers an assessment of a project's potential for leakage moderate or high, during the short or long term Because the Index is qualitative, there is no strict interpretation for these designations These designations are based on the availability of strategies to avoid leakage and the likely magnitude of leakage A moderate designation means that the amount of leakage as well as its presence or absence, is dependent on individual site conditions A high designation means that, unless there are mitigation strategies, leakage will occur Where timber is the primary resource demanded, leakage may be of short- or long-term duration, as proponents of sustainable forestry projects argue that in the long term project sites are more productive than their conventionally logged counterparts

The final column lists possible strategies for avoiding leakage Each of these strategies has been implemented in ongoing carbon sequestration projects or proposed for such projects In most cases, determination of appropriate strategies will depend on examination of forces leading to land-use change, which will be addressed through the project's key activities However, in some cases, redesigning a project and adding activities may be too costly, or may not be feasible because of the project's location If redesigning a project is impossible, potential carbon sequestration benefits must be recalculated to reveal the project's soundness An example of refiguring carbon estimates for a timber project is offered in the Timber Demand section following the Leakage Index

In summary, carbon projects must carefully consider impacts on surrounding areas Does the project help meet local needs for income, fuel, and food, or does it lock up resources? If a project preserves a forest for its carbon sequestration benefits without regard to local needs, it will either shift demand for land or fuelwood to adjacent areas or will deprive the local population, ultimately engendering local opposition to the project and others like it in the future

Table 2 Leakage Index

Primary Drivers	Market Boundaries	Project Components	Conditions Signaling Leakage	Potential Net Effect	Strategies
Agricultural Land	Subsistence for local use	Increased agricultural productivity through green cover crop cultivation agroforestry soil conservation practices or other measures	Increase output but free resources for development on adjacent lands	Moderate leakage	Protect adjacent forests Implement sustainable forestry Introduce ecotourism
		Forest preservation	Decrease agricultural output	High leakage	Create alternative income source Add agricultural productivity component
	Local regional or global export	Increased agricultural productivity	Free resources for development on adjacent lands	Moderate leakage	Protect adjacent forests Implement sustainable forestry Introduce ecotourism
		Forest preservation	Decrease agricultural output	High leakage depending on where activity shifts	Create alternative income source such as sustainable forestry
Fuelwood	Local use or regional market	Agroforestry Re/afforestation Windbreaks	Common property resource Offsite market demand	Moderate leakage potential	Employ transferable technology
		Fuelstoves	N/A	N/A	N/A
Timber	Local use	Sustainable forestry (Reduced impact logging Natural forest management)	Decrease short term timber output	Short term leakage	Reestimate project impacts over short term Develop alternative timber sources such as plantations on marginal land
			Decrease long term timber output	Leakage through out project life (High)	Reestimate project impacts Develop alternative timber sources such as plantations on marginal land
		Forest preservation	Decrease or halt timber output	High degree of leakage	Develop alternative timber sources such as plantations on marginal land Introduce sustainable harvest in buffer areas
	Export	Sustainable forestry (Reduced impact logging Natural forest management)	Decrease short term timber output	Short term leakage	Reestimate project impacts over short term
			Decrease long term timber output	Long term leakage	Reestimate long term project impacts
		Forest preservation	Decrease or halt timber output	Leakage	Develop alternative timber sources such as plantations on marginal land

Application of the Index

The case studies below illustrate how the drivers of land-use change have (or have not) been addressed Successes and failures are compared in the following sections to show how project evaluators and designers can avoid leakage by project design, or identify those projects in which leakage appears to be unavoidable

Agricultural Land Demand

The Olafo and CARFIX projects are likely to stabilize the agricultural frontier and minimize or avoid leakage Both projects satisfy demands causing land-use change

The boundary of the Olafo project is regional/local In the project area, land-use change is driven by the conversion of forest to agricultural land for subsistence (21) Because the project decreases the amount of land required for agriculture it appears to have low or no leakage potential

Figures 3 and 4 illustrate the difference in agricultural land required with and without the project Figure 3 shows the "With Project" scenario, which reduces the number of hectares required for agricultural production by decreasing the amount of fallow time required Because less agricultural land is required, the pressure to convert the forest to agricultural uses diminishes Concurrently, natural forest management gives standing forests value, thus creating incentives for local people to protect them

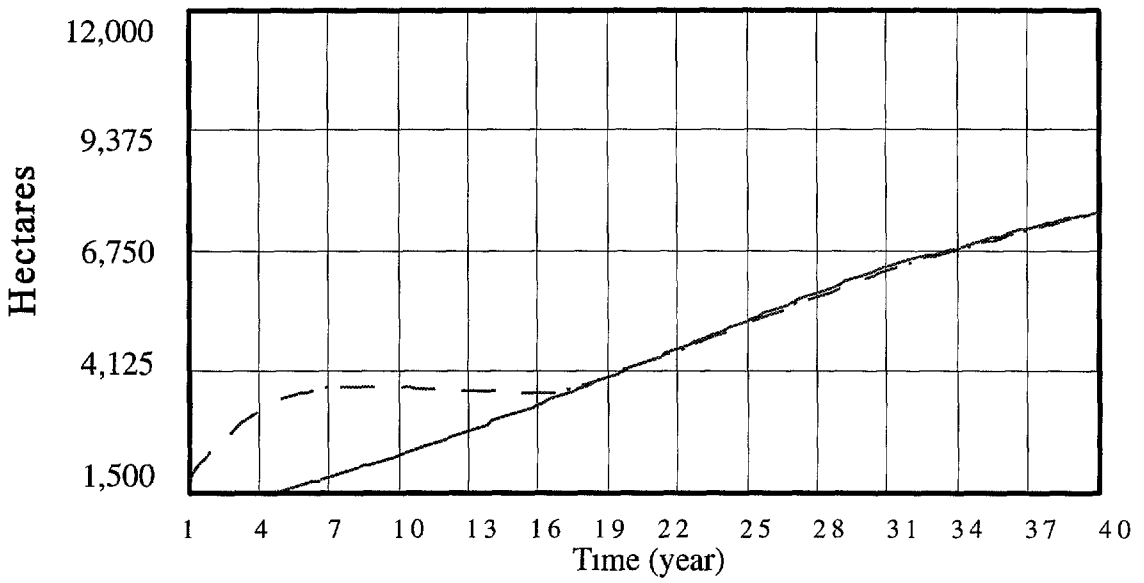
The use of green cover crops and other techniques of the Olafo project are easily adaptable in other areas Therefore, the project will not shift resource demand elsewhere or cause immigration Market effects and activity shifting will be avoided because the project benefits are not concentrated but instead can be applied where they are needed The analysis may understate these benefits

Figure 4 shows a potential shortage of agricultural land without the project because available agricultural land is scarcer than required agricultural land This shortage indicates that farmers may move beyond the project area in search of new agricultural land, thus increasing carbon emissions outside the project area under the baseline scenario

Both the shortage and the resulting increase in carbon emissions elsewhere can be approximated By year 40, for example, the difference between required and available agricultural land is about 500 hectares If the project region is surrounded by forest, the analyst may reasonably assume that an additional 500 hectares of this forest would have been converted to agricultural uses in the absence of the project At an average biomass of 400 tons per hectare, an additional 200,000 tons of carbon would have been sequestered by the project The same calculation can be made if an agricultural land shortage exists either under the "With" or "Without Project" scenarios

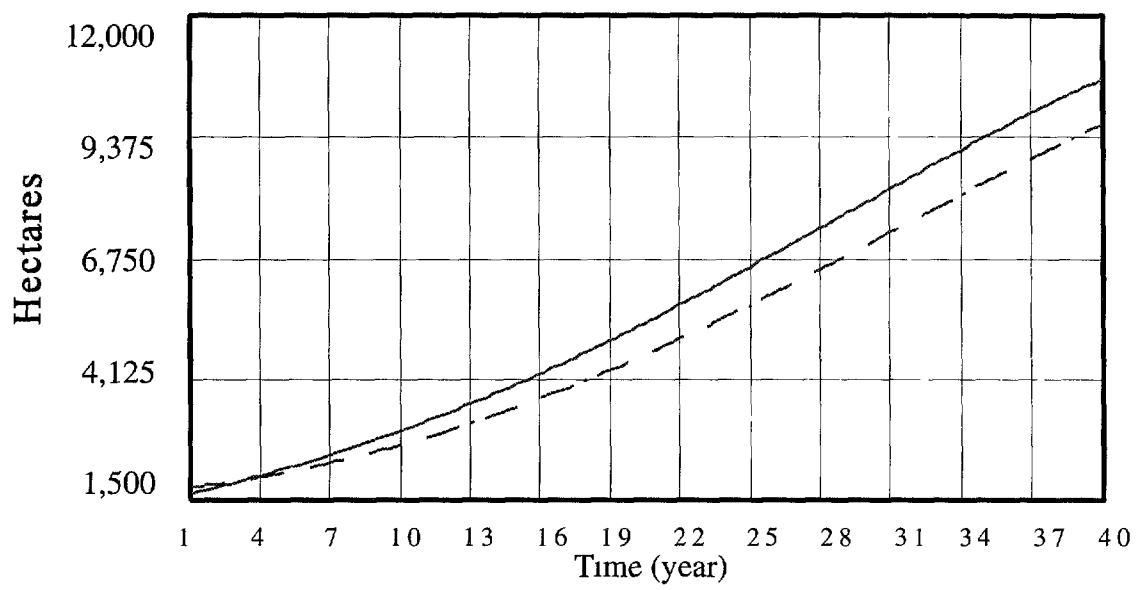
Logging and the subsequent expansion of the agricultural frontier for cattle production drives deforestation in the CARFIX region The key to slowing deforestation and avoiding leakage, therefore, is to provide an alternative income source to cattle production

Figure 3 Olafo Required and Available Agricultural Land



Olafo Project Required Ag Land ——— hectares
Olafo Project Available Land — — — — — — — — hectares

Figure 4 Olafo Required and Available Agricultural Land



Olafo Baseline Required Ag Land ——— hectares
Olafo Baseline Available Land — — — — — — — - hectares

CARFIX proposes to generate income from selling carbon offsets and sustainably harvested timber Annual payments will be advanced to the landowners in the years preceding harvests Income substitution should be successful because landowners are voluntary participants in the project and have thus presumably decided that timber and the supplementary income provided by CARFIX can replace income from cattle production

FUNDECOR, the agency implementing CARFIX, contends that conversion to cattle grazing produces little marketable timber Because the project will increase timber output, there will be no unmet timber demand (22) However, some activity shifting could result from reducing cattle production Whether cattle production is for export or for local or subsistence consumption is unclear, so fully assessing the leakage from decreasing such production is difficult The low leakage scenario would reflect essentially subsistence consumption, as increasing farmers' income would offset the need for raising cattle If the cattle are for export, leakage would depend on the location of the alternative production region and whether cattle operations can be intensified, or if additional land must be cleared to accommodate them

Some activity shifting could also occur Although CARFIX does not displace farmers as landowners, the project does call for silviculture which may be less labor intensive than cattle production The danger is that between harvests farmers will cultivate additional land or otherwise expand their activities in ways that increase carbon emissions

Carbon projects dealing with demand for agricultural land on the edges of standing forests must find a way to give those forests value In these areas agriculture and forestry can be used as substitute income sources and alternate land uses The trick is to stabilize the agricultural frontier, encourage sustainable forestry as a way to earn income and avoid a one-shot mining' operation and conversion to agricultural land

Fuelwood Demand

The Sudanese and CARE/Guatemala carbon sequestration projects illustrate both the problems associated with meeting fuelwood demand and their solutions The Sudanese project shows high potential for leakage, whereas the CARE/Guatemala project indicates a low potential for leakage

The Sudanese project aims to ease a serious fuelwood shortage in an area where fuelwood collection is resulting in deforestation and rangeland degradation The project's goals are to increase agricultural productivity by irrigating gardens, and improving fuelwood resources by planting windbreaks and woodlots But these improvements, that are concentrated in a small area may encourage settling of nomadic people or livestock herders Such a population influx, as noted above, would deplete fuelwood resources and erode carbon sequestration gains as a result of market effects Leakage will be avoided if the project is able to expand its scale, either by enlarging its boundaries and areas of activities or by employing transferable technologies

To reach the relevant areas, CARE/Guatemala expanded its scale to include most of the upland regions Like the Sudanese project region, the CARE/Guatemala project region was facing probable fuelwood shortages, which the project sought to address through woodlots and agroforestry Baseline projections showed that the initial conversion of forest land to agriculture would provide ample fuelwood However, once land conversion slows, fuelwood collection begins to degrade the remaining forest CARE/Guatemala's conversion of degraded land to woodlots and permanent agriculture to agroforestry increased fuelwood supply thus meeting most fuelwood needs Moreover CARE established tree nurseries run by local farmers which later became self-sufficient

In this case, the methods of increasing fuelwood availability and agricultural productivity were widely reproducible, and the project sponsor had the mobility to work at the country level, ensuring that project benefits could be diffused where needed

Timber Demand

In general, projects that constrain the supply of timber will not reduce net carbon emissions as much as anticipated, because they will lead to activity shifting A model of world timber supply indicates that restrictions on timber supply in one region will likely lead to timber harvests in a different region (23) Because timber is internationally traded and can be supplied by many parts of the world, reductions in output in one place can be replaced by increases in another area

However, the model's finding is based on decreasing output in North America, where there may be fewer market imperfections The response to reduced output may be different in areas where government subsidies and poorly negotiated timber concessions result in incentives to over harvest (24) In these areas, projects that constrain timber supply will not shift harvests elsewhere Because the harvests are induced through government policies, logging companies will not necessarily be able to find such profitable opportunities in other areas

The Malaysia logging project aimed to reduce damage from logging while maintaining the same timber output as conventionally logged areas Because harvests are not the result of gross market imperfections and because the extracted timber was for a global market, maintaining timber output was the key to avoiding leakage However, output from the project site reportedly has been less than conventionally logged areas The shortfall will likely be made up by harvests elsewhere in the region, another part of the concession, or possibly from another part of the world, thus signaling leakage

Evidence of leakage indicates that carbon should be recalculated but does not necessarily mean that the project is without merit That determination depends on whether the project's net carbon savings and other benefits make it competitive with similar projects

To recalculate the original net carbon estimate, the project evaluator needs to determine approximately how much area would have to be logged to compensate for the decrease in output The Malaysian project decreased timber output by 49 cubic meters per hectare on 450 hectares, making the total shortfall 22 050 cubic meters Logging approximately 145 hectares conventionally (at 152 cubic meters per hectare) or 214 hectares using reduced-impact methods (at 103 cubic meters per hectare) would make up for the reduction (25)

Because reduced-impact logging techniques reduce biomass loss by 50 percent per hectare, as long as the number of hectares logged to compensate for the timber shortfall is less than 50 percent of total hectares, the project still results in net carbon savings, although at a greater cost per ton (26) In addition, reduced-impact and sustainable harvesting techniques increase long-term forest productivity by protecting young trees The timber concessionaire may need to compensate for lower yields in the near term but will be rewarded with higher yields in the future while avoiding costs associated with enrichment plantings (27)

If timber demand is the primary driver of carbon loss and the timber is for an export market, maintaining output is imperative If timber is for a local market, the project may have an opportunity to provide an alternate timber source, or an alternate income source from nontimber products, increased environmental services, or, in the future-added value from sustainably harvested timber

III. Recommendations

This section gleans specific and practical recommendations for reducing the uncertainty associated with forestry and land-use projects to sequester carbon Drawing on these recommendations, it provides conclusions concerning the selection and evaluation of such projects

Carbon Sequestration Gains

To protect carbon sequestration gains, there are two recommendations concerning single projects versus portfolios of projects and ways to minimize risk at the project level

Recommendation 1

Joint Implementation pilot initiatives, such as those being developed by the United States, Canada, Costa Rica, Guatemala, Panama, Japan, and Australia, should *encourage the use of and provide incentives for the development of broad and diverse portfolios of carbon sequestration projects* Such portfolios will both provide a better knowledge base from which to judge the efficacy of projects and will reduce the impact of individual project failures, which is magnified by investor-contractor bilateral relationships

Several power companies, such as Applied Energy Services and New England Electric in the United States, have begun exploring isolated carbon sequestration pilot projects implemented on a bilateral basis under an investor-contractor type of relationship Such projects are inherently riskier than portfolios of diverse projects supported by multiple investors If a single power plant funds a single carbon offset project, as in the AES-CARE/Guatemala case a project failure causes the investor to lose all carbon offsets By contrast, a diversified portfolio offers a hedge against the risks of a single project failure

Recommendation 2

To minimize risk at the project level, project sponsors should ensure that local people are stakeholders, that the project is rooted in local institutions and that project managers have the appropriate experience and capacity to effectively implement the project at the scale proposed These recommendations derive from previous WRI work on carbon sequestration projects and have been further reinforced by current case studies (28) These studies indicate that successful and cost-effective projects link forestry with rural development and local needs

Key Parameters

To appropriately define key project parameters, there are two recommendations concerning the need for project interventions and the length of project duration

Recommendation 3

Baseline assumptions about the obstacles to positive changes in the absence of project interventions must be convincingly substantiated Baseline assumptions generally fall into two categories they assume loss of biomass or an absence of growth of biomass In all cases the baseline should be defined on the basis of the root cause of forest loss or the inability of the land to naturally regenerate The two examples at either extreme are preservation projects, which assume deforestation, and tree planting projects, which assume little or no regeneration

As the Leakage Index showed, forest preservation projects risk leakage if they contain no other project components However, carbon sequestration will be incorrectly estimated if care is not taken with baseline assumptions Identification of causes and trends of deforestation should be based on regional, not national trends

Similarly, tree planting projects risk erroneously assuming a lack of regeneration They often take for granted that the trees planted and their associated growth can be fully claimed as biomass that would not otherwise have existed They often do not subtract the biomass that would have accumulated naturally in the absence of the project Except in the most extreme cases, the alternative would never be zero vegetation

Recommendation 4

The project s time horizon should be tied to the minimum plausible amount of time required for carbon to begin cycling out of the atmosphere Following this recommendation would help ensure that the project truly minimizes the potential for global warming

Involving a local institution in project development and monitoring will give the project credibility and create incentives that ensure its longevity Alternatively, a governmental agency (such as the forestry or environment ministry) within the host country could monitor and guarantee the viability of a group of projects, thus further reducing the risk through the portfolio approach However, such an arrangement would be subject to the institutional constraints and weaknesses that may exist within governmental agencies

Project Design and Boundaries

Recommendation 5

Projects should be designed to satisfy the primary demands driving land use change Addressing demands leading to land-use change will avoid leakage and result in greater carbon sequestration gains Projects that have identified and dealt with the root causes of land-use change had credible baselines and therefore avoided leakage attributable to erroneous baseline assumptions

Recommendation 6

Projects should use transferable technologies so as not to restrict social benefits to a limited area The Olafo and CARE/Guatemala projects introduced green cover crops and agroforestry, respectively, to address the causes of land-use change These technologies have ensured that the projects' benefits could be duplicated elsewhere, thus avoiding leakage from market effects, potentially increasing carbon storage and creating local incentives that help guarantee project success

Recommendation 7

The determination of project boundaries should be based not on the area of project activities but on the spatial relationship between the demand driving land use change and the supply source The use of this relationship to help identify project boundaries will help avoid activity shifting because it accounts for a project's complete sphere of influence The Leakage Index provides a useful guide for determining a project's spatial boundaries to correctly estimate net carbon sequestered Thinking in terms of supply and demand will also help identify residual demand, which must either be incorporated into the net carbon calculation or if possible, the project design

Recommendation 8

Conditions resulting in leakage should be anticipated at the front-end of project design to avoid leakage effects Use of a logical framework such as the Leakage Index, may help to systematically address the potential for leakage As the index indicates unmet demand will result in leakage, and will not sequester as much carbon as estimated Project designers must be sure to remember the fundamental rule of economics markets will adjust to changes in supply and demand If projects restrict supplies, other sources of supply will be found and potentially nullify the carbon gains claimed by an individual project

IV. Conclusions

A successful project that satisfies the demands leading to land-use change, and offers social benefits can effectively confront deforestation Such projects are more successful in terms of estimating carbon sequestration and providing significant ancillary benefits The case studies and the Leakage Index described above provide useful tools for selecting carbon sequestration projects And the eight recommendations can greatly reduce the danger of leakage

The increase in tree planting projects relative to other types of projects is unfortunate This trend, which will reduce options for experimentation, appears to be based on the erroneous assumption that tree planting projects are easier to measure and less prone to leakage Tree planting projects will have a greater impact when they are employed as an alternative to the destruction of primary forests for timber or fuelwood use

Box 3 LUCS Model

LUCS is a carbon accounting device that compares project interventions to a baseline scenario The model estimates the amount of carbon sequestered by approximating land use and relative biomass changes on the landscape over time with and without the project These changes are driven by key variables such as population growth and the accompanying food and fuel needs agricultural productivity technological change, wood use, and harvesting practices Typically the project will seek to alter these interactions, thus changing carbon flows

Table 3 summarizes net carbon estimates using LUCS as well as the results of a simple cost benefit analysis Project costs for FACE and Olafo were discounted at 4 percent the rate for the investing countries, whereas the U S -funded projects were discounted at 5 percent The carbon was not discounted

Cost benefit analysis is generally a useful tool for highlighting choices and making each project s assumptions transparent It can lead to more informed decision making Estimates of the cost per ton of carbon sequestered can be useful in comparing dissimilar projects However such comparisons can also be misleading A single number often masks a host of assumptions, each with its own effects and underlying value judgments By contrast, cost-benefit analysis is sensitive to assumptions about discount rates the price of carbon, and the time horizon used to analyze the project

Because of the data difficulties and theoretical uncertainties involved, cost-benefit analysis should not be the final word on sequestration projects In particular, the choice of a discount rate carries a heavy analytical burden it represents equity intergenerational effects (which will be particularly acute with regard to global warming) risk aversion, and net social welfare In addition, cost-benefit analysis cannot fully incorporate nonmarket social and environmental benefits, such as biodiversity increases in the quality of life, or watershed protection which are often crucial elements in carbon sequestration projects

Table 3 Case Study Summaries

Project	Size (hectares)	Total Cost	Total Carbon Sequestered (tons)	Cost per Ton Carbon Sequestered ($)
CARE/Guatemala	3 000,000	$8,800 000	39,000,000	$0 23
Innoprise/ Malaysia	1 400	$189 000	197,000	$0 95
FACE/Czech Republic	15 000	$5,865 000	1,624 000	$4 37
OLAFO/ Guatemala	57,800	$1 060 000	4,920,000	$0 28
RUSAFOR/Russia	420	$50,000	29,000	$1 79
CARFIX/Costa Rica	290,187	$12,500,000	7,630 000	$1 46

Protecting existing carbon sinks by preventing deforestation is more cost-effective than creating new sinks The cost-per-ton comparisons in Box 3 show in every instance that tree planting is more expensive than preventing deforestation The Olafo project and CARFIX, both of which focus on the latter activity, cost 28 cents and $1 46 per ton, respectively In contrast, the Krkonose project and RUSAFOR, in Russia, both of which focus on tree planting, were estimated to cost $4 37 and $1 79, respectively The finding that the costs for forestation projects are greater than the costs of retarding deforestation is supported by a recent Harvard study (29)

Projects designed to satisfy the demands driving land-use change, thus preventing deforestation, provide benefits to a wide range of communities These benefits include goods, such as timber, and services such as watershed revitalization, biodiversity habitat, homes and sustenance to indigenous peoples, and, of course, climate regulation Many of these services are not quantified in the marketplace As a result, standing forests are often undervalued Furthermore countries with high rates of deforestation--such as Brazil, Indonesia, Suriname, and Russia--most need to capture the full value of forests (30)

Carbon storage benefits are a potentially important element in the valuation of forests (31) The industrialized world can help encourage the sustainable use of forest resources by paying for the benefits it receives Forestry and land-use projects aimed at capturing these benefits will provide only a small portion of the total needed greenhouse gas reductions, but preliminary evaluations of their worth and potential are encouraging (32) Properly designed projects offer low-cost greenhouse gas mitigation and provide reliable carbon sequestration estimates Their risk of failure is also reduced Experimentation with a broad range of land-use projects should be encouraged, especially under the pilot phase, to determine which projects are most reliable and promising

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In all of its policy research and work with institutions, WRI tries to build bridges between ideas and action, meshing the insights of scientific research, economic and institutional analyses, and practical experience with the need for open and participatory decision-making