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The leaky sink: persistent obstacles to a forest carbon sequestration program based on individual projects

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Abstract

One strategy for mitigating the increase in atmospheric carbon dioxide is to expand the size of the terrestrial carbon sink, particularly forests, essentially using trees as biological scrubbers. Within relevant ranges of carbon abatement targets, augmenting carbon sequestration by protecting and expanding biomass sinks can potentially make large contributions at costs that are comparable or lower than for emission source controls. The Kyoto protocol to the framework convention on climate change includes many provisions for forest and land use carbon sequestration projects and activities in its signatories' overall greenhouse gas mitigation plans. In particular, the protocol provides a joint implementation provision and a clean development mechanism that would allow nations to claim credit for carbon sequestration projects undertaken in cooperation with other countries. However, there are many obstacles for implementing an effective program of land use change and forestry carbon credits, especially measurement challenges. This paper explains the difficulty that even impartial analysts have in assessing the carbon offset benefits of projects. When these measurement challenges are combined with self-interest, asymmetries of information, and large numbers, it prevents to a project-based forest and land use carbon credit program may be insurmountable.

Keywords: Carbon sequestration projects; Clean development mechanism; Kyoto protocol

1. Introduction

As concern over climate change has grown and the discussion of mitigation options progressed, the potential role of forest carbon sequestration has received increasing attention. Within relevant ranges of carbon abatement targets, augmenting carbon sequestration by protecting and expanding biomass sinks, and particularly forests, can potentially make large contributions at costs that are comparable or lower than for emission source controls (IPCC, 1996; Richards and Stokes, 1999).

The enthusiasm for carbon sequestration has found practical expression in the form of both active and proposed forest carbon sink projects. For example, the Noel Kempf climate action project, designed

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to conserve forest from land use change in Bolivia, is being implemented by the nature conservancy, the forest action network and the Government of Bolivia, with funding from American Electric Power, British Petroleum US, and Pacificorp (Percy, 1997, p. 3; Brown, 1999, pp. 7, 8). A power company (Applied Energy Systems) undertook one of the earliest projects to offset carbon emissions in the United States. Their Guatemalan project was designed to reduce deforestation and to sequester carbon in newly planted trees (Hodas, 1995, p. 93). And it is not only American companies that have initiated major forest carbon sequestration projects — Tokyo Electric Power Co., in cooperation with the New South Wales Government, has invested A$ 2.6 million in Australia to establish new plantations for carbon sequestration (Millett, 2000). In 1999, the Governments of Canada and Honduras agreed on a 'debt-for-carbon-swap' by which Canada wrote off US$ 600 million (C$ 1 billion) of Honduras' foreign debt in return for future carbon dioxide emission credits (Financial Times, 2000). The Norwegian Government and Norwegian private parties have agreed to invest US$ 2.0 million to establish plantations and promote sustainable use of forests in Costa Rica (1999) (p. 10).

To explore the potential for carbon abatement projects that cost-effectively reduce net emissions, the United States founded the US initiative on joint implementation (USIJI).[1] Under this program, parties in the United States submit proposals for pilot projects that are reviewed by a panel of experts (Hodas, 1995, p. 89). To be certified by the USIJI, a proposal must demonstrate that the project involves specific measures to reduce or sequester greenhouse gas emissions, provides sufficient data and measurement methods to establish both a baseline and an estimate of future emissions, and plans for independent verification of the results. Many of the projects that were certified under the USIJI program were carbon sequestration activities in the forestry sector.

If the USIJI program contributes to a donor country 'push' of sequestration projects, Costa Rica has developed an active host country 'pull'. The Costa Rica 'national report on activities implemented jointly during the pilot phase' (Costa Rica, 1999) describes several bilateral agreements; the government signed with the United States, Norway, Switzerland, Mexico and Finland to explore joint implementation projects and to transfer greenhouse gas mitigation certificates (Costa Rica, 1999, p. 4). That national report lists four sequestration projects currently planned or underway: the ECOLAND, Klinki forestry, and PAP projects, primarily with United States and Costa Rican participants, and the private forestry project in cooperation with Norway. By the end of 1999, after 5 years of efforts trying to attract foreign investors into their joint implementation forestry projects, Costa Rica reported the total value of the bilateral agreements for carbon sequestration projects amounts to US$ 158.4 million (Costa Rica, 1999, p. 10).

Implicit in all of these projects and programs is the underlying assumption (or hope) that sometime in the future sequestration projects will earn emissions reduction credits that will offset carbon source emissions in a carbon allowance trading scheme. The Kyoto protocol includes many provisions for carbon sequestration projects and activities in its signatories' overall greenhouse gas mitigation plans. In particular, the protocol provides a joint implementation program and a clean development mechanism that would allow nations to claim credit for forest carbon sequestration projects undertaken in cooperation with other countries.

[1] In the interest of full disclosure, it should be noted that the first author was integrally involved in establishing the operating parameters for the USIJI pilot program in 1995–1996 and in evaluating the project proposals submitted in the first years of that program. He also managed development of the US guidelines for the voluntary reporting of greenhouse gas emissions and emission reductions known as the 1605(b) program, which serves as the reporting mechanism for the USIJI.

While there are many studies of carbon trading mechanisms extolling the cost-effectiveness of broadening the scope of greenhouse gas abatement practices, all appear to have ignored, or treated only tangentially, the particular challenges presented by carbon sinks. In fact, there is a striking disconnect between the enthusiasm for forest carbon sequestration projects, and the lack of serious consideration of what it would take to implement a trading program in which forest carbon sinks played a major role.

There is reason to be concerned. The forthcoming 'special report on land use, land use change, and forestry' from the intergovernmental panel on climate change examines a large number of issues associated with implementing the land use and forestry provisions of the Kyoto protocol (IPCC, 2000). The report is deferential in its treatment of the protocol, but a clear message emerges — it is difficult to interpret what the protocol intends for carbon sinks, and under any interpretation, actual implementation is going to be even more difficult. A recent report from the United Nations conference on trade and development warns that trading systems based on certification of credits have not fared well in practice (Tietenberg et al., 1999). It specifically points out that the monitoring problems associated with biotic carbon sources 'may limit the ability of some of these sources to participate in a cap and trade model' (Tietenberg et al., 1999, p. 38). Commodification [2] of environmental offsets is challenging under the best of circumstances (Salzman and Ruhl, 2000), and carbon sink offsets do not present favorable circumstances.

The purpose of this paper is to describe some of the specific concerns about implementing a carbon sequestration program based on a project-by-project approach. The first major concern is that the carbon sequestration accomplishments of individual projects cannot be easily measured, even under the best of circumstances. The second major concern is that even if it were possible to estimate the effects of individual projects, it would not be feasible to establish a forest carbon sequestration program based on the project-by-project approach because of inherent implementation obstacles. We conclude that the project-based approach, which seems to be favored for an international forest carbon sequestration program, is unlikely to succeed.

2. Measurement issues

2.1. Accounting for net effects of carbon sequestration projects

Advocates for including carbon sinks in an international greenhouse gas mitigation program argue that sequestration provides another set of potentially low-cost abatement options. To be consistent with that purpose, however, including sinks must not compromise the environmental integrity of the overall mitigation goal. Moreover, to reach its goal of decreasing the cost of achieving a given level of abatement, the additional costs of administering a forestry sinks program must not exceed the additional savings of including the carbon sequestration option in the larger abatement program. [3]

[2] Commodification, as discussed by Salzman and Ruhl, is defined as a strategy to address environmental problems through the establishment of environmental trading markets. Salzman and Ruhl (2000) note that it is an increasingly popular approach by which you 'commodify environmental impacts by creating markets for their sale'.

[3] This paper focuses specifically on forestry carbon offset projects. Many of the issues raised here are also applicable to energy (fossil fuel and alternative energy) projects. While we concentrate on forestry issues to provide focus and tractability in the discussion, an important broader question is whether any project-based offset provisions should be included in an international trading program.

If carbon sequestration offset projects are included in a carbon trading scheme, it will of course be necessary to determine the amount of credit to assign to each project (Brown, 1999, p. 2). The credit, in turn, must be at least roughly proportional to the effects of the projects. This raises the question of whether it is possible to estimate with confidence and at reasonable cost, the effects of individual projects. This is similar to the challenge faced in cost–benefit analysis, environmental impact statements, and economic development project assessments.

In this section we examine whether impartial experts can estimate the full effects of carbon sequestration projects at reasonable costs. If project effects are not measurable, it is entirely possible that expanding a carbon trading program to include carbon sinks could consume substantial resources and simultaneously lead to a decrease in environmental protection. The primary concern is not that individual projects will not have some positive effects. The problem is that if projects are awarded offset credits equal to their estimated effects, and those estimates tend to overstate project impacts, inclusion of forest carbon offset provisions in a larger carbon abatement program could lead to higher net emissions with relatively little cost savings.

To address measurability we first examine (in abstract) issues related to impacts that occur within the project boundary, i.e. on-site effects. We then turn to the more difficult challenge of off-site effects, raising the issue known as leakage. The discussion raises serious questions about whether it is reasonable to expect that analyses will estimate the full effects of individual projects. To demonstrate that the concern is warranted we examine an actual carbon sequestration project analysis by a recognized expert.

2.2. *On-site effects*

Typically forest carbon sequestration project evaluations define a land area in which forestry practices will be modified to increase carbon capture and storage. While it is not costless to measure how on-site carbon content changes on a specific plot over time, it is certainly feasible to do so. Fig. 1a shows how carbon stock Trajectory A for a hypothetical project could be mapped out over time.

Evaluating the effects of projects, programs, or policies require answering the question ‘effects relative to what?’ There is always a counterfactual (i.e. without-project) state-of the world to which the actual (i.e. with-project) state-of-the-world described by Trajectory A is compared. The most fundamental step in project analysis is determining a reference case and baseline carbon stock to which the project case is compared. In this article the reference case describes a scenario — those human actions and physical results that would have existed ‘but for’ the project. The baseline is the quantitative estimate of the carbon stock in the reference case.

2.2.1. *Difficulties with isolating and quantifying causes and effects in projects*

Developing the baseline then requires making informed assumptions in two areas (Table 1). First, how would human activity on the site have changed over time if the project had not occurred? Would land use on the site have remained the same, or would there have been changes in land use patterns? For example, in a project to convert agricultural land to forest plantations, it might be reasonable to assume that land has long been in field crops would remain that way, if not for the intervention of the carbon sequestration project. With respect to human activity, this is a static case. In contrast, for a forest preservation project, the very motivation of the project is that a forest is under imminent

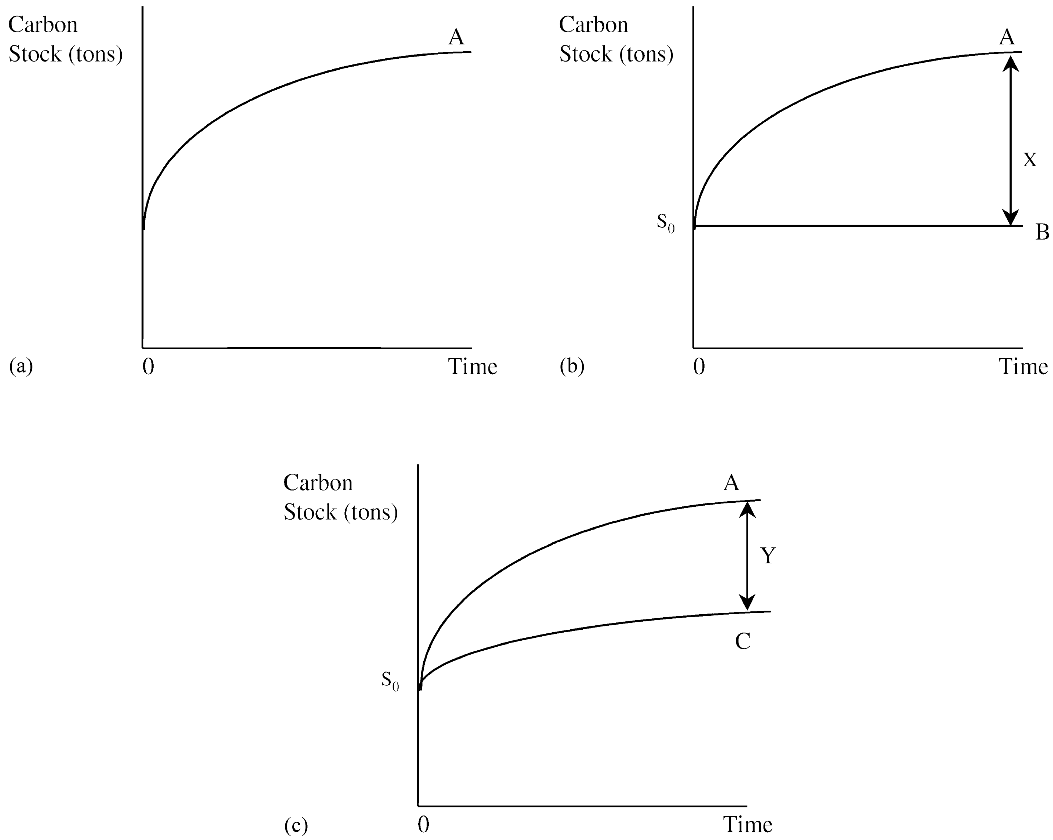

Fig. 1. Evaluation of carbon stock changes in a carbon sequestration project. (a) Changes in actual stock, with the project, Trajectory A can be measured through direct field measurement. Forecasts of those changes require modeling. (b) If it is assumed that the stock of on-site carbon would have remained constant in the reference case (Type 1 projects in Fig. 1b), the historical level, S_0, measured at time $t = 0$, fully defines the baseline, Trajectory B. (c) Estimating the baseline requires biological modeling/control plots in the case of Type 2 projects, where the carbon stocks would have changed due to natural processes and biological modeling and conjecture about human activities for Type 3 projects, where human activities would have changed stocks.

Table 1
Methods for estimating the baseline in the reference case[a]

Assumptions about carbon stock in the reference case	Static human activity	Dynamic human activity
Static carbon stock	Type 1: field measurement or biological models	Not applicable
Dynamic carbon stock	Type 2: control plots or biological models	Type 3: conjecture and biological model

[a] Assumptions about human activity in the reference case.

threat of logging or degradation. The threatened harvesting activity represents a dynamic reference case.

The second assumption relates to what would have happened to forest systems, and in particular carbon stocks, given the assumed human activity. Again, both static and dynamic scenarios are possible. If on-site carbon stocks would have remained the same, as is often assumed in the case of agriculture-to-forest conversion projects, then the reference case is static. But if the carbon stock in the pre-existing ecosystem was increasing or decreasing, the reference case is dynamic.

The nature of the reference case has important implications for the methods required to estimate the baseline carbon stocks (Table 1). There are three basic types of projects. In Type 1 projects, where it is reasonable to assume that both human and natural activity would have been static, a projection based purely on a field measurement of on-site carbon stocks, taken at a single point in time, fully defines the baseline B (Fig. 1b). The difference between A and B at any given time is a measure of the cumulative net carbon accumulation attributable to the project up to that point in time. In Type 2 projects, where it is reasonable to assume that human activity would have remained the same, but that the on-site carbon stocks would have changed over time, it is necessary to use biological models to estimate the baseline C (Fig. 1c). This situation would arise, for example, in the case of a project to accelerate forest growth beyond natural regeneration rates. This introduces an added element of uncertainty relative to Case 1 where direct field measurement suffices.

In Type 3 projects in Table 1, it is assumed that changes in human activity at the project site would have affected the carbon sequestering capacity of the biological system in the reference case. This significantly complicates the analysis of project effects, requiring first, conjecture as to how human activity would have changed over time, and second, biological modeling of how the on-site carbon stocks would have responded to the assumed changes in human activity.[4]

Developing the conjectural reference case for human activity on a specific site is difficult at best. Analysts generally look to historic trends on the site, in the region, and in similar settings. They often incorporate site-specific knowledge, such as the plans and proclivities of the owner of the land. Developing a reference case often involves forecasting economic regional activities related to logging and harvesting, conversion from one land use to another, and the effects of possible changes in national laws and programs. It could require using remote sensing data to monitor '(t)rends in plantation or agroforestry establishment at the sub-national or national scale' (Brown, 1999). It is problematic, however, to use these observations of regional or national trends to forecast what would have happened on a specific site. Making assumptions about human behavior and anticipated land use change in the absence of the project often requires a great deal of judgment.

One method for reducing the uncertainty from using biological models in Types 2 and 3 projects is to establish control plots that have essentially the same characteristics as the project site before the project begins. When using control plots, physical measurement of a site that is analogous to the reference case of the project site substitutes for the biological model. Control plots are most useful in Type 2 projects where it is assumed that human activity would have been static on the project site. To use control plots for Type 3 projects it would be necessary to assume that human activity on the project site would have changed identically to what actually happens on the control plot.

[4] In Table 1, the entry corresponding to assumptions of dynamic human activity and static natural activity is empty because, by definition, changes in on-site human activity are significant only if they affect the on-site carbon stocks.

2.2.2. The additionality criterion

Another criterion, in the form of additionality, repeatedly appears in discussions of project evaluation. For a project to meet the additionality criteria it must have been motivated by the carbon credit program itself. This adds yet another type of conjecture to the analysis and will lead to even higher estimation costs and hurdles as well as greater uncertainty (Tietenberg et al., 1999, p. 7). With the additionality criteria, it is not enough to ask what would have happened in the absence of the project; now the analysis must address whether the project would have happened in the absence of the offset program.

2.2.3. On-site effects in projects

In practice, there may be some Type 1 projects where it is reasonable to assume that both human activity and carbon stocks are static. As mentioned above, a project to convert agricultural land to forest plantation may fall in this category. In that case, measuring the on-site carbon stock at the beginning the project would provide all the data that is necessary for the baseline. Modified forest management projects may fall in the second category — those with static human systems and dynamic natural systems. For example, an analyst of a project to intensely manage a naturally regenerating forest might reasonably assume that humans would not intervene on the site, and that carbon would slowly accumulate in the unmanaged forest. Having defined this reference case, the analyst could estimate the baseline using models or control plots.

The majority of projects, however, involve conjecture about how humans would have changed the site if the sequestration project developers had not intervened. The difficulty, of course, is that land use decisions are made in a larger economic, social, and legal context. Thus prediction of the reference case requires predicting changes in complex systems. In practice, this exercise generally involves significant guesswork and conjecture on the part of the analyst.

2.3. Off-site leakage effects

The value of a carbon sequestration project is not its effect in a specific geographic area, but rather its contribution to a global reduction in net carbon emissions. Thus it is important to remember that biological carbon offset projects do not take place in a vacuum. Just as it is necessary to consider how changes in the economy will cause shifts in likely land use on a specific site, it is also necessary to consider how changes on the site will cause shifts in off-site emissions. In the context of carbon sequestration, leakage works through (1) shifting activities from the project site to areas outside the boundary and (2) through market prices.[5] Leakage in this context does not refer to physical leakage of carbon from the site. Rather it refers to secondary effects that occur through changes in human behavior and prices.

To use the economics analog, on-site project analysis is like partial equilibrium analysis. Partial equilibrium analysis captures only the most immediate effects of a change in the economy or government policy. Complete accounting requires general equilibrium analysis that often reveals very different results than partial equilibrium analysis.

Consider one important example from project analysis, forest preservation. Let us assume that most deforestation results from human demand for wood products and agricultural land. A project to preserve the forest on a particular site does not fundamentally change the demand for these services. Logging is a mobile activity, if it is prohibited on one site, it can be shifted to another. The price of harvestable

[5] For a discussion of leakage in the context of fossil fuel-based carbon emissions (see Stavins, 1997, p. 318).

forest land may rise marginally, decreasing the overall level of logging activity marginally, but the final demand for wood products will be met in part by an increase in harvest outside the project site. Similarly, if forest conversion to agricultural land is prevented within a project site, it may simply shift to outside the defined boundaries. The homeostasis of the economic system could largely eliminate the positive effects of isolated projects.

To estimate the off-site effects of individual carbon sequestration projects is difficult at best. It requires broadening the scope of analysis to include the shifts in supply functions for forest products, agricultural land, and agricultural products. None of the published project analyses appear to have undertaken this onerous task.

It might be argued that leakage is not such a substantial problem. It is after all, an empirical question. If the extent of off-site effects is quite small, then it may not be necessary to estimate them. While we do not know how severe the problem is, it is possibly quite large. In one indicative study (Alig et al., 1998) found that the carbon mitigation effects of a large scale carbon sequestration program to convert agricultural land to tree plantations in the United States eventually would be completely dissipated. In that model landowners responded to the sequestration program by harvesting existing forests, converting unsubsidized forest land back to agriculture, and decreasing the replanting of forests following harvest.

2.4. A project analysis example

Sandra Brown, a highly qualified and respected forest scientist, provided a detailed description of a carbon sequestration project evaluation that illustrates the steps and the difficulties described above (Brown, 1999). The project, designed to prevent forest land from being logged and converted to agricultural uses, is located in Santa Cruz, Bolivia on a 634,000 ha site adjacent to the Noel Kempf Mercado National Park. The monitoring program consisted of 625 sample plots designed to provide estimates of aboveground, belowground, and understory biomass, litter, and soil carbon inventories with a 95% confidence level. This information was used to estimate the carbon stock at the beginning of the 'with-project' case. Of course, it also provides an estimate of the carbon stock at the beginning of the reference case. [6]

To estimate the reference case or 'without-project' carbon stock the biological modeling was conducted in two parts, one for averted logging and another for averted conversion to agriculture. In that model the carbon savings attributable to averted logging resulted from changes in live biomass, dead biomass, and the wood product pool. Similarly, the gains from decreased conversion of forests to agriculture were due to a combination of increased biomass and soil carbon. Brown derived the estimates for these figures, on a per hectare basis, using direct measurement of pre-project carbon, control plots for estimating live biomass on logged and unlogged sites, and data derived from literature. [7]

Brown's description of the process by which she derived an estimate of the number of hectares of averted logging and conversion to agricultural land within the site is a bit more sketchy. She used information

[6] It is not clear from Brown's description whether the actual trajectory of carbon stock, corresponding to A in Fig. 1, was based solely on the initial carbon stock estimate, or if there was ongoing periodic sampling to assess changes in the carbon stock.

[7] Note that although the Noel Kempf project is a Type 3 project (Table 1), Brown used control plots to estimate the reference case. That is because in her analysis of averted logging there are only two types of human activity: 'logging' and 'not logging'. She can find off-site examples of logging sufficient to serve as control plots for the logging effects, per hectare, in the reference case. However the control plots provide no information on the number of hectares of logging that would have occurred in the reference case.

from a recent Bolivian forestry law that regulates diameter classes and frequency of harvesting to 'predict how much forest area in the project area would be harvested in a given year for each year over the length of the project'. She combined that with data from logging operations and practitioners to predict the likely quantity of wood that would have been extracted annually from the project area.[8]

The estimate of the number of hectares of forest land preserved from conversion to agriculture 'was established using projected human demographics in the areas adjacent to the project area'. The estimate, then, is based on the assumptions that: (1) the projections of demographics are accurate; (2) that whatever demographic trends occur on adjacent areas would have been mirrored on the project site and (3) that there is a stable relation over time between demographic trends and land use changes.

What is most noticeable about the analysis is that it makes no attempt to estimate the effects of leakage, nor does the project design appear to control it. This is important, given that earlier in the article Brown acknowledged the problem of leakage and stated that '(l)eakage can often be anticipated and prevented as part of the project design by addressing the demands (e.g. agricultural land, timber, fuel wood) contributing to the land use change'. There is no evidence in that report, that this project has addressed the underlying social force that drives logging and land use conversion.

The analysis of the Noel Kempf project in Bolivia is typical of reports and studies of carbon sequestration projects. It has highly detailed analysis of the observable carbon stocks, conjecture about the extent of change in human activity within the physical boundaries of the project, and no analysis or discussion of the dissipation of carbon sequestration effects due to human and market responses outside the project. Where the estimate of changes in human activities on-site may have error bars of ±50%, and where leakage may be as much as 100% (or even more in some cases, see Alig et al., 1998), highly precise estimates of the physical parameters are not enough.

2.5. Broader examples of problems in impact analysis

Certainly the problems of project impact analysis and estimation of cause-and-effect in large systems are not unique to the problems of carbon sequestration. In this section we review two examples from the literature on the analysis of economic development projects that are pertinent to the problem of carbon sequestration. The first relates to how ex ante analysis of expected project impacts can be foiled by the simplest, and yet often unpredictable, social and scientific realities. The second illustrates that even dispassionate, independent researchers can view the same evidence on land use change trends and arrive at quite different conclusions.

2.5.1. The problem of ex ante analysis

In a study of a nationwide, foreign-funded reforestation program in the Philippines, Frances Korten analyzed some of the difficulties in large scale forestry interventions.[9] In 1988 the Asian Development Bank (ADB) approved a forestry sector program loan of US$ 277 million. The program's objective was to reforest 358,000 ha over 5 years. The design of the program incorporated NGOs and local communities in the reforestation activities, granted local people long-term use rights to land and planted forest, used performance-based criteria for payments, and employed outside parties to assess results. In other words, this was a program that had been developed 'by the book'. But despite its efforts to incorporate all the

[8] It appears that the estimate is based on the assumption that the area would have been harvested as fast as legally permitted.

[9] This paragraph is essentially a summary of the main findings of the study appear in Asia–Pacific Issues #7, September 1993.

modern concepts and ideas of development project design, the program failed. An evaluation carried out after just 1 year of program operations reported the following results:

- sapling survival rates were dropping below 50%;
- soil erosion, which had been the principal raison d'être of the program, unexpectedly increased because of planting the fast growing *Gmelina arborea* species in grasslands; [10]
- increased levels of corruption were believed to be associated with the large sums of money involved in the program;
- workload on the implementing agency was overwhelming and as a result the quality of their work suffered.

Korten, along with three other independent program evaluators, all arrived at the same basic conclusion. The program was unable to establish an effective relationship with local communities. Very few communities exhibited the high level commitment that is required to guarantee the survival of reforested trees. The negative results can all be attributed, at least in part, to the fact that 'the program's demands exceeded the capacity of the agency' (Korten, 1993, p. 5). She finds that the eloquent and attractive state-of-the-art ideas described in the program document were often distorted or simply ignored by the parties responsible for the actual implementation.

The case illustrates how difficult it is to create successful forestry programs in developing countries through foreign investment. The problem with initiatives such as the JI and CDM that rely at least in part on ex ante analysis for the certification process is that they generally do not account for these difficulties. Instead they seem to assume that if sufficient money is pumped into the forestry sectors of developing countries, the century long trend of forest degradation in poor countries will come to an end. There is little evidence from the last 50 years of development cooperation to support that assumption.

2.5.2. Model specification problem: expert disagreement on determinants

To show that a particular project's emission credits meet the additionality criteria, it is necessary to predict what would have happened if the project had not been carried out in the first place. A common strategy to construct this hypothetical scenario has been to use dynamic ecological models that predict land use changes based on past human behavior (Brown, 1999; WRI, 1999). While this is a useful approach for understanding general landscape dynamics, it has proven to be problematic for accurate predictions of vegetative land cover changes (Fearnside, 1996). Part of the problem is the widespread uncertainty about what the driving factors of land use change are in different regions of the world.

In an effort to model the dynamics of carbon stocks in the Brazilian Amazon, Fearnside (1996) notes the difficulty in quantifying probabilities of particular human-induced land cover changes. Ideally, such probabilities are calculated from existing empirical evidence from the area of study. The problem is that such location-specific studies are often lacking and in the cases where they exist, one study often contradicts another. Fearnside, for example found that the empirical evidence provided by one study was 'so at odds with more general information about land use patterns in the region that it was judged more reliable to use (a completely different description of) the typical behavior' (Fearnside, 1996).

When faced with contradictory empirical evidence, the modeler is forced to weigh one piece of evidence against another and decide what probability would be most representative for the particular process that is being studied. This observation should trigger warning alarms for social scientists concerned with the

[10] One of the characteristics of this species is that it tends to inhibit undergrowth which has proven to drastically reduce its preventive effects on soil erosion.

implementation of the Kyoto protocol. If actors who have no financial stake in the results of ecological models come up with inconsistent evidence, what will happen when modelers face substantial economic incentives to exaggerate the positive effects of carbon sequestration projects?

2.6. Challenge to the climate policy community: a modest proposal

One measure of the feasibility of estimating the effects of carbon offset projects is whether the results are independently reproducible. Given that so much rides on the future of a large scale carbon sequestration program, it might be reasonable to check this attribute. One way to do that would be to assemble, for example, three teams of acknowledged experts in the field of carbon project evaluation, develop a portfolio of five to eight different carbon sequestration projects of various types, and have each of the teams evaluate the portfolio independently. The results would be informative. They would indicate which types of projects are subject to the greatest variance in evaluation. Comparison of the analyses would provide insight into which types of effects led to the most variance in methods. And it would illustrate how different groups of analysts dealt with different types of uncertainty. To our knowledge, no such exercise has been conducted.

3. Implementation issues

As discussed above, it is difficult to measure carbon sequestration project effects, even in a setting of academic or scientific study. In the context of program implementation, the problem becomes much more severe due to asymmetric information, opportunistic behavior, high transaction costs, and the reversibility of project benefits.

From the economic and administrative perspective, a carbon sink program should exhibit transparency as well as low monitoring and transaction costs (Tietenberg et al., 1999). Transparency is necessary both for enforcement and public acceptance. Monitoring and transaction costs include the public and private costs of applying for and granting certification, evaluating projects, verifying performance, tracking emissions reduction credits, distributing the risk of project failure, and dealing with the uncertainty at each step of the process.

3.1. Information asymmetries and opportunistic behavior

It is an inevitable case that project developers will have more project-specific information, if not more expertise, than the implementing agency. Typically, reviewing agencies have relied heavily on data, analysis, and estimates provided by the proposing party. When the project developer stands to benefit from exaggeration and obfuscation, the agency's evaluation and monitoring tasks are much more difficult. There are several issues that arise in the context of asymmetric information and opportunistic behavior.

3.1.1. Adverse selection

Project developers will be competing for funders or purchasers of offset credits. The larger the credited offset of a given program, the more credits the developer will have to offer, and the lower the unit cost of credits. In that setting, project developers will choose projects on two criteria: the unit cost of accomplishing real carbon sequestration and the ease of exaggerating estimates of the accomplishment. All other things being equal, projects whose accomplishments are easiest to exaggerate will be chosen by developers. Brokers and developers who are most gifted at obfuscation will out-compete the more scrupulous competitors. The penalties for exaggeration cannot be severe, because it is at least plausible to claim sincere mistake even in the most ludicrous cases.

3.1.2. Moral hazard

Carbon sequestration projects are generally long-lived, complex activities. They require continuous care to reach full potential. If an implementation program is designed to provide rewards at the outset of the project, as most proposals seem to imply, then a situation of moral hazard develops. Having reaped the reward of predicted carbon sequestration, the developer has little incentive to take optimal care of the project to assure long-term success. Only monitoring on the part of the agency can overcome this problem.

3.1.3. Perverse incentives for host countries

In some contexts, for example in the case of energy service companies whose compensation is proportional to estimated energy savings, the potential for the project developers to exaggerate their accomplishments is held in check by the scrutiny of their trading partners. In the case of carbon-offset projects, both the host country and the project developer have incentives to exaggerate their accomplishments (Stavins, 1997, p. 312). This leaves the regulatory agency as the sole police for the estimates of all projects. Moreover, countries will have incentives to block laws and programs that would lead to broadly improved forest management practices, lest they erode the reference case losses they can claim in specific projects.

3.2. Administrative and enforcement capacity

3.2.1. Large numbers

The problems associated with asymmetries of information might be overcome by careful scrutiny of each proposal and monitoring of each ongoing project (though the previous discussion of measurement issues casts doubt on the possibility). However, any program with enough projects to have a substantial effect on net emissions will involve thousands or even tens of thousands of projects. This makes it more likely that the agency will not be able to carefully analyze each proposal.

3.2.2. Variety of projects

If all the projects were of a similar type where estimation methods could be easily standardized, the difficulties of asymmetric information, opportunistic behavior, and large numbers might be managed through procedural rules and standard certification criteria (Tietenberg et al., 1999, pp. 11, 71). The problem is that there are a multitude of project types, each set in its own legal, cultural and economic context. As with so many types of project analysis, carbon offset estimation will inevitably remain idiosyncratic.

3.2.3. Verification

One suggestion that frequently surfaces to address the problem of opportunistic behavior is to arrange for third party auditors to verify that a project has actually delivered on its promise for carbon sequestration. This approach is based on a model of the certified public accountant who verifies the books of publicly held companies. There are at least two difficulties with relying on third party verification in the context of offset projects. First, the analysis that is required for offset projects is more like cost–benefit analysis than the financial analysis that accountants do. Financial analysis is limited to the resource flows into and out of a firm or organization. The effects that the firm has outside its own walls are not important in financial accounting. In contrast, cost–benefit analysis requires examination of the broader impacts of projects or policies, including those that act through shifts in market equilibrium. Analogously, project analysis requires looking beyond simple on-site effects to include off-site effects occurring through market shifts and physical adjustments in response to the project. This moves the verification process into the realm of economics and policy analysis where standard procedures may be impossible to develop.

Second, ex post verification may be able to confirm the actual carbon on-site at the project. However, as discussed above, the greatest uncertainty for estimation is not in the area of on-site carbon, but rather in off-site carbon and in the levels of various human activities in the reference case. These uncertainties are not reduced by ex post monitoring.

4. Discussion of findings and conclusions

These factors taken together suggest that either the reliability of project analysis will be low or the costs of analysis will be high, and quite possibly both. In addition to the direct costs of estimates, there will be additional transactions costs associated with the uncertainty facing project developers who will not know if their projects will be certified until after they invest considerable time and money in the process.

The analysis of Tietenberg et al. (1999) (p. 38) casts doubt on whether the offset approach can work. Their United Nations study demonstrates that emissions allowance trading programs that define an aggregate cap on emissions or harvest, such as the regional clean air incentives market in Los Angeles, the national acid rain program in the United States, and the New Zealand fisheries license trading system, have substantially succeeded in lowering costs of abatement. At the same time programs designed around emissions reduction credits, which do not define caps but reward reductions, 'have generally performed poorly, principally because of their high transaction costs and the uncertainty and risk involved in obtaining government approval of credit trades'.

The difficulty of arriving at reliable estimates of the isolated quantities of carbon uptake resulting from specific projects in the forestry sector presents a challenge to policy analysts concerned with the implementation of the Kyoto protocol. The problem of accurate measurements is particularly prevalent in the project-by-project approach because its narrow, fine-scaled focus prevents it from measuring overall net effects. Project leakage and the consequences of trying to apply the additionality criterion to projects pose particularly severe constraints for accurate estimates.

Inaccurate measurements may not only lead to erroneous calculation of emission credits issued to mitigation projects, but more seriously, it may cause insurmountable enforcement problems for the Kyoto protocol. Contrary to much of the conventional wisdom about the design of the Kyoto protocol's flexible mechanisms for land use change and forestry activities, as reflected by the mainstream climate change debate and the forthcoming IPCC report, this paper argues that the project-based trading approach may be detrimental to the overall mitigation goals of the protocol.

Does this imply that carbon sequestration has no role in an international carbon allowance trading program? Probably not, but it does imply that inclusion of carbon sinks must be thoughtfully implemented with a careful eye to the potential pitfalls. In particularly, it is important to attend to the technical difficulties of the prevailing approach and consider a wider range of possible strategies. A viable alternative to the project-based approach must define its key parameters and scale of operations based on the measurability of results and prospects for effective implementation. One such alternative would be an international trading program that uses as the basis for emission credits the periodic change in signatory countries' carbon stocks as measured by their national forest inventories. This type of program, as discussed by Andersson and Richards (2000), seems better suited to capture the net effects of anthropogenic activities on the build-up of carbon dioxide in the atmosphere.

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