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Alternative Approaches to Addressing the Risk of Non-Permanence in Afforestation and Reforestation Projects under the Clean Development Mechanism

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Executive Summary

Afforestation and reforestation (A/R) projects can generate greenhouse gas (GHG) reduction credits by removing carbon dioxide (CO₂) from the atmosphere through biophysical processes and storing it in terrestrial carbon stocks such as biomass, litter, and soils. One feature of these A/R activities is the possibility of *non-permanence*, whereby the stored carbon is subsequently lost through natural disturbances such as fire and wind or anthropogenic disturbances such as harvesting. These disturbances cause the stored carbon to be released back into the atmosphere as CO₂, thus providing a temporary climate mitigation benefit.

Adequately accounting for non-permanence under land use, land-use change, and forestry (LULUCF) activity such as A/R has been a point of ongoing discussion at the United Nations Framework Convention on Climate Change's (UNFCCC) Conference of the Parties (COP). Specifically, the 17th Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP) in Durban, South Africa, requested the UNFCCC's Subsidiary Body on Scientific and Technological Advice (SBSTA) to initiate a work program to consider modalities and procedures to address "the risk of non-permanence" (which this report refers to throughout as the risk of a carbon *reversal*) in A/R activities, starting with activities covered under the Clean Development Mechanism (CDM).

Regulatory and voluntary program precedents exist for addressing reversals in LULUCF activities, including A/R, forest management, and reducing emissions from deforestation and forest degradation (REDD+). Reversal risk in A/R CDM projects is currently handled by issuing temporary credits for carbon storage which expire at some date in the future, requiring replacement at that time. The CMP decision focuses on consideration of alternative approaches to address the risk of reversals. Yet there has been limited analysis to show how different approaches perform in protecting the integrity of the offset mechanisms in which they operate and their cost-effectiveness. This report examines alternative approaches for addressing reversals to inform ongoing UNFCCC discussions on (1) the effectiveness of various approaches in handling real-world reversal scenarios in ways that ensure net carbon balance and integrity of the A/R offsets; and (2) the economic and practical feasibility of various approaches, taking into account the costs and returns of A/R projects.

This report provides a conceptual basis for viewing the non-permanence issue, evaluating current approaches to address reversals and highlighting implications for policy and investment decisions. The key policy issues include:

- Risk screening requirements for A/R projects.
- Whether to issue credits incrementally over time (rather than all at the time of initial verification).
- If credits are issued up front, whether to classify them as temporary or permanent in nature.
- If permanent credits are issued, what replacement requirements should be considered when reversals occur? Should these requirements differ for unintentional reversals (caused by natural disturbances) and intentional reversals caused on purpose by project participants?
- What risk management mechanisms should be put in place (if any) to ensure that projects can meet replacement requirements?

Toward this last issue, the report conducts analysis using forest carbon risk data and models in settings relevant to A/R projects. The analysis draws from modeling of multiple policy and accounting mechanisms for handling reversal risks using observational data on natural disturbances (e.g., fire and wind). It also explores reversals that could arise from intentional actions to clear a forest before a project is slated to end. Finally, the risk of unintentional and intentional reversals is explored together. Within each scenario, we quantitatively and qualitatively assess the impact of several different risk management mechanisms, including categorical exclusions or exceptions for risk management requirements; temporary credits, as now used for A/R projects under the CDM; “tonne year” approaches, where permanent credits are issued incrementally over time as carbon is retained; credit reserve buffers, a common method for addressing reversals in the voluntary market wherein a share of permanent credits issued at the time of verification are set aside in an account and accessed in case of a reversal; commercial insurance, in which a third party contracts to cover credit replacement risk for a fee; host country guarantees, wherein the country hosting the A/R project agrees to satisfy otherwise uncovered reversals at the subnational scale; and combinations of these approaches.

The report’s analysis does not seek to recommend a specific approach for A/R mitigation projects or specific parameters for different approaches (e.g., set-aside percentage for credit buffers, insurance premium levels), which are best informed by careful examination of the risk factors affecting each country or project. Instead, the report outlines the options available and their relative strengths and shortcomings, thus providing insight to inform the UNFCCC/CMP with regard to decisions addressing reversals in A/R activities.

Key messages from the analysis include:

- **The concept of permanence has biophysical, political, and practical foundations.** Any subsequent release of stored carbon ultimately negates the original benefits of storage from an atmospheric standpoint. But practical realities dictate that policy and contract commitment are typically for finite periods of time. Policymakers may therefore opt to make “permanence” achievable within a fixed time period rather than at the elusive “end of time.”
- **Empirical analysis of unintentional risks from natural disturbances finds the following determinants of risk management performance:**
 - **Location matters.** Ground data can reveal where projects are more (or less) likely to confront reversals.
 - **Scale matters.** Over time, large projects have less relative risk of catastrophic loss from reversal than do small projects. More area in a project means that some part of the project may experience reversal, but it is less likely that the reversal is catastrophically large.
 - **System dynamics matter.** We model a representative forest system under likely A/R project conditions, but the selection of different species or types of operation in a different disturbance regime may yield different conclusions. In the system modeled here, forest growth dynamics and disturbance characteristics combine to make longer projects more susceptible to reversals than shorter ones.
 - **There is power in risk diversification.** Building on scale effects, pooling together risks from small projects into a larger portfolio of projects can reduce the relative risk of reversal for an A/R activity.
- **The risk management mechanisms examined have a range of features and tradeoffs among risk conservatism, economic returns, and other factors.** Some approaches deal with risk very

conservatively, but tend to have lower financial returns; some approaches are less conservative, thus yielding higher returns but requiring risk back-up mechanisms to ensure integrity.

- **The mechanisms vary in their ability to effectively address both intentional and unintentional reversals.** Projects may face both kinds of risk over the life of the project, and both should be assessed at the initial risk assessment stage to inform the risk management process. Virtually all crediting mechanisms examined are designed to deal with unintentional risks from natural disturbances such as fire and wind, but some mechanisms may be less effective in addressing intentional risks from a project holder's decisions to pursue other objectives. Key findings on this issue across the risk management mechanisms include:
 - **Temporary crediting in the form of tCERs**, such as those used in the CDM to date, may provide both intentional and unintentional reversal risk protection to the atmosphere by requiring credits to expire and be replaced periodically; this conservatism comes at a cost, however, and may not be able to adequately incentivize A/R projects.
 - **A tonne year approach to carbon crediting**, which issues credits incrementally over time as carbon storage is retained, avoids the need to reclaim credits after they are issued and reversed (either intentionally or unintentionally) to protect system integrity. Our analysis suggests that this approach can be more attractive financially than the temporary crediting approach (since the credits issued are deemed permanent, for which the market will pay more), but this depends on the specific parameters (e.g., the length of the assumed permanence period and the corresponding rate at which permanent credits are incrementally issued for carbon storage).
 - **Permanent credit issuance up front, backed by a buffer mechanism**, can provide a practical alternative to temporary crediting and can work to protect against reversals if the buffers are adequately built, and managed. A buffer is one of several mechanisms evaluated that allows permanent credits to be issued once storage is verified, which improves financial performance (assuming that permanent credits command a price premium relative to their temporary credit counterparts). In the case of buffers, effective protection against reversals requires a robust and location-specific risk assessment to determine the appropriate size of the buffer withholding requirement and other operating procedures on a case-by-case basis. Buffers may be ineffective against intentional reversals, which are inherently difficult to model at a system level. A high prevalence of intentional reversals could cause a system-wide buffer to collapse and put the entire system at risk, requiring further back-up mechanisms (such as those discussed below).
 - **Permanent credit issuance up front, backed by commercial insurance**, could be an effective and more actuarially refined mechanism than a buffer to address unintentional reversals of the issued permanent credits. Although products to insure forest carbon are still in their formative stages, insurers can draw from their experience insuring timber and other properties affected by natural risks to develop products that protect a project against extreme risks at a cost comparable to or less than alternative approaches, depending on project length. Commercial insurance, however, is not well-suited to cover against intentional actions.
 - **Host country guarantees** can provide a further backstop against reversal risk mechanisms established for projects within the country.
 - **Modalities established for carbon capture and storage (CCS) projects under the CDM**, wherein a mix of a buffer, minimum permanence period, and host country guarantees could create a workable analog for A/R, would need to be refined to capture the risk characteristics of forest carbon storage vis-à-vis the geological storage of CO₂ in CCS

projects. For example, CCS reversal risks may diminish over time as below-ground CO₂ stabilizes, whereas A/R reversal risk may increase as the biomass in above-ground pools increases. Intentional reversal factors differ between A/R and CCS projects; these should be taken into account as well.

Further Policy Issues

A major issue is the ease by which projects can address intentional reversals if permanent credits have been issued in advance. Screening criteria, enforceable guarantees, and opt-out provisions need to ensure that any deemed-permanent carbon credits issued are replaced, but questions remain as to the implementation of such provisions in the context of CDM activities. In the event of intentional reversal, buyers or sellers could be made liable to replace the credits issued thus far. Commercial insurance is not well-suited to cover against these intentional actions, and a system-wide buffer could put the entire system at risk if the prevalence of intentional reversals is high relative to the size of the buffer. Alternatively, temporary crediting and tonne year approaches could accommodate this form of reversal without bringing the system down; however, due to the potential lack of economic viability, the success of such projects is uncertain.

Flexibility is key. It is advantageous to consider a flexible system where project investors and credit buyers have a menu of approaches for dealing with reversals, as long as safeguards are put in place to ensure environmental integrity in the most cost-efficient way. One of the advantages of a flexible menu-driven system is that it can provide incentives for innovative insurance and financing mechanisms to evolve and provide near-term and long-term options for project investors. From the perspective of project participants, choice among approaches to dealing with reversals may also be advantageous. The choice of approaches can create opportunities for project participants to pick and choose their approach. From the perspective of the project participants, it is also important that that approaches are cost-effective to apply and lead to fungible credits. From the perspective of a regulatory agency, clear guidelines need to be put in place to support the implementation of different approaches (and combinations of approaches) to ensure that each is verifiable, ensures the environmental integrity of the project, and is practicable to apply.

By anticipating reversal risk and pooling such risk across projects, it remains feasible to create a mechanism that protects against net carbon loss without sacrificing the financial viability of A/R projects. Indeed, the analysis herein shows that a certain level of buffering and aggregation lowers both the chance of an offset system going negative and the extent of loss experienced should this actually occur. While the analysis focuses on A/R projects, similar conclusions may be surmised for other types of forest carbon projects (such as REDD+) and other terrestrial mitigation activities (such as wetland restoration and agriculture). The emphasis rests not on the project type but on the proper analysis of risk coupled with modeling of reversal scenarios to enhance the likelihood of the offset system remaining a net carbon sink.

The analysis in this report reflects on issues that the UNFCCC Parties may wish to consider in deciding how to address non-permanence with A/R and, potentially, with other LULUCF activities under the CDM: risk screening requirements, incremental versus full issuance up front, replacement requirements, risk management options, opt-out provisions, and the like. As indicated here, Parties may want to consider allowing flexibility given the voluntary nature of the CDM; however, provisions must be established for determining which actions require credit replacement and, if so, by whom.

1. Introduction: Carbon Sinks, Permanence, and Reversals in Climate Change Mitigation Policy

Land use, land-use change, and forestry (LULUCF) comprise about 30 percent of global greenhouse gas (GHG) emissions (IPCC 2007). A substantial part of this flow is tied to the absorption, storage, and release of carbon dioxide (CO₂) in soils, biomass, and other organic pools referred to as “carbon sinks.” Sinks can accumulate carbon through both the maintenance of preexisting stocks (e.g., reduced deforestation, degradation, or other forms of land clearing) or through the creation of new stocks (afforestation, reforestation, improved management, and other forms of restoration). As such, terrestrial carbon sequestration projects are part of the GHG mitigation strategy set, typically identified as a potential “offset” for emissions from other sources.¹ In principle, using a tonne of terrestrially stored carbon (or CO₂ equivalent, tCO₂e) as an offset is an equivalent credit against an (allowed or capped) emission if it completely negates the climatic impact of that emission.²

Recognizing the importance of terrestrial carbon sinks in climate mitigation; policies have been designed and implemented to expand carbon sinks. However, these terrestrial ecosystems are susceptible to disturbances that cause the stored carbon to be released back into the atmosphere. Problems can arise when stored carbon that has been credited as part of a climate change mitigation effort returns to the atmosphere via these disturbances, a phenomenon known as “reversal.” Reversals, when they occur, can nullify emissions reductions and undermine *the permanence* of these climate mitigation actions; they must be addressed through policies and accounting procedures. The distinction between reversal and non-permanence is at times a subtle one, but critically important to devising workable approaches for dealing with carbon loss. As used herein, a “reversal” is a reduction in carbon storage relative to some previously credited amount (e.g., a net loss of carbon credits), whereas “non-permanence” refers only to the inherent vulnerability of a carbon stock to reversal. See also Box 1 and Section 1.2.

Box 1: Non-Permanence v. Reversal v. Non-Performance

It is important to distinguish between the concepts of non-permanence, reversal, and non-performance in the context of terrestrial carbon sequestration projects. The inherent susceptibility of terrestrial carbon projects to rerelease of stored carbon is described as *non-permanence*; it is impossible to guarantee that a given tonne of carbon stored in a given terrestrial carbon pool will remain sequestered forever. Sequestration credits are generated during a time period if there is a net increase in carbon storage relative to the crediting baseline during that period. Should an unanticipated release of carbon subsequently occur, the loss may be termed a reversal if it causes the carbon stock to drop relative to the baseline. If prior generation of carbon gains produces a project credit, then a reversal that creates a net carbon loss can be viewed equivalently as a project debit – and some sort of accounting adjustment is necessary to balance the books. However, if the disturbance event causes a loss of carbon that is less than the total amount gained elsewhere onsite over the same time period, the end result is not a debit or reversal *per se* but a diminishment in the number of credits that are generated during that period. The project on balance still gains carbon, but not as much as would have been expected in the absence of the disturbance event, a phenomenon that may be referred to as *non-performance* or under-performance. Note that there may be other forms of non-performance unrelated to disturbances, such as the failure of an afforestation and reforestation (A/R) project to physically yield as much carbon as initially projected or the failure of certain actions to as effectively reduce emissions from deforestation.

¹ Terrestrial carbon storage may also be directly regulated as part of larger emission reduction obligations, as in the case of New Zealand’s Emissions Trading Scheme.

² The term “tonne” throughout the document will refer to a metric tonne, or megagram (Mg), of CO₂ equivalent.

1.1. Climate Change Mitigation Policies and Projects under the UNFCCC

Carbon sink mechanisms operate at two different scales, national and project, under the UN Framework Convention on Climate Change (UNFCCC). National incentives for carbon sinks have until recently focused on the inclusion of LULUCF activity in the national accounting of Annex I (developed) countries under the 1997 Kyoto Protocol (KP). Carbon stock enhancement and emissions avoidance can help Annex I countries meet their KP emission reduction obligations. Under the KP's Clean Development Mechanism (CDM), developing countries can host carbon sink projects that generate certified emission reduction credits. These credits can be sold to Annex I countries to help them meet their emissions reduction obligations. Joint Implementation (JI) guidelines also provide for the opportunity for LULUCF activities (JISC, 2009) at the project level within Annex I countries, coordinated with national accounting.

The focus of this report is on the CDM in developing countries.³ Afforestation and reforestation (A/R) are eligible project activities under the CDM in the second commitment period (per the 2/CMP.7 decision by parties to the Protocol). Although the UNFCCC is now considering the inclusion of additional land use, land-use change, and forestry activities under the CDM, the focus of this report is A/R.

Currently, CDM sinks projects address reversals by issuing expiring (temporary) credits. Upon expiration, these credits must be replaced. This replacement requirement raises the cost to the buyer of using them (relative to a full-price permanent credit), thereby reducing the monetary value of the credit and the net revenue flow to the project. As A/R projects have not been widely adopted thus far – they account for less than one percent of all CDM projects to date (UNEP, 2012) – the question is whether other approaches for dealing with reversals are needed. Toward that end, the seventh session of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP7) in its recent decision on LULUCF under the KP requests:

the Subsidiary Body for Scientific and Technological Advice to initiate a work programme to consider and, as appropriate, develop and recommend modalities and procedures for alternative approaches to addressing the risk of non-permanence under the clean development mechanism with a view to forwarding a draft decision on this matter to the Conference of the Parties ... (UNFCCC, 2011a)

In light of this request, the focus of this report is on approaches to address the risk of reversal in A/R project-level activities under the CDM, with broader implications drawn for programmatic or system-level approaches beyond individual projects.

1.2. Sinks, Permanence, Reversals, and Crediting at the Project Level: Concepts and Examples

LULUCF activities are subject to both natural and anthropogenic disturbances. Relevant natural disturbances include fire, wind, flood, drought, ice/snow, pest infestations, disease, landslides, earthquakes, and volcanic activity (see, Galik and Jackson, 2009, for a review). Human-induced disturbances include the legal or illegal harvesting of trees, land clearing, and incidental mortality

³ JI projects for LULUCF activity within Annex I countries can generate credits that Annex I countries can use to meet obligations under the Kyoto Protocol. However, their use has been almost non-existent because of EU ETS limitations on the use of forestry credits from either the JI or CDM.

occurring as a result of other activities (e.g., war). The intensity and extent of disturbance can vary for both human-caused and natural events, ranging from slight damage to complete loss and from individual trees to thousands of hectares. This section describes disturbance types for A/R activity.

Afforestation and reforestation both entail the establishment of forests on land that is currently non-forested. For the purposes of the CDM, afforestation and reforestation are defined by the Marrakech Accords:

“Afforestation” is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources; “reforestation” is the direct human-induced conversion of non-forested land to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989 [FCCC/CP/2001/13/Add.1].

Although there are semantic and legal reasons for treating them separately, the mechanics of carbon sequestration and reversal are similar between the two. The rate of sequestration will depend on a variety of site- and project-specific factors, but the sequestration trajectory generally follows a logistic-like curve (see Figure 1). Carbon accumulates slowly as the stand is established. The sequestration rate then generally increases for a time, and then slows as the stand reaches maturity. Figure 1 depicts the carbon profile for a hypothetical 40-year project using data derived from the quantitative analysis described below. In the absence of disturbance, the area under the “Live Tree, Undisturbed” line reflects the per-hectare carbon sequestration benefits generated in the live tree carbon pool over that time. Note the general profile, where early year storage occurs slowly, building over time before finally plateauing or even declining. Under the simplifying assumption that the alternative land use to an A/R project would accumulate no carbon, these cumulative carbon stock benefits provide the starting point for project crediting.

The effects of unexpected natural disturbances on the live tree pool are shown in Figure 1 by the “Live Tree, Subject to Disturbance” line. The amount of carbon lost and the rate of future carbon storage are both functions of disturbance timing, intensity, and extent. In the early years of project implementation, less carbon has been accumulated and therefore less is at risk. While the ratio of sequestered carbon to potentially lost carbon may not change over time, loss magnitude will increase; larger losses are inherently more expensive to address. Early-year disturbances are also more likely to be masked by rapid growth occurring elsewhere on the stand; this is seen in Figure 1, “Live Tree, Subject to Disturbance,” as the rare and minor early year reversals as compared to the large, recurring later-year ones. Including additional carbon pools in the project (e.g., lying dead wood, standing dead wood, and litter) can also act as an implicit hedge against disturbance. Because disturbance does not result in the instantaneous loss of carbon onsite, but rather involves a transfer between pools (e.g., “live tree” to “dead tree”), the carbon consequences of a disturbance are somewhat muted at the stand level when more pools are included (the “All pools, Subject to Disturbance” line).⁴ The interrelated dynamics of

⁴ Harvested wood products (HWP) represent another potential hedge against carbon loss. This analysis does not include planned harvests or post-disturbance salvage operations, and therefore does not assess contributions of the HWP pool to total forest carbon.

growth, timing, and carbon pool choice are therefore all important to consider when weighing mechanisms to address reversals in this particular activity type.

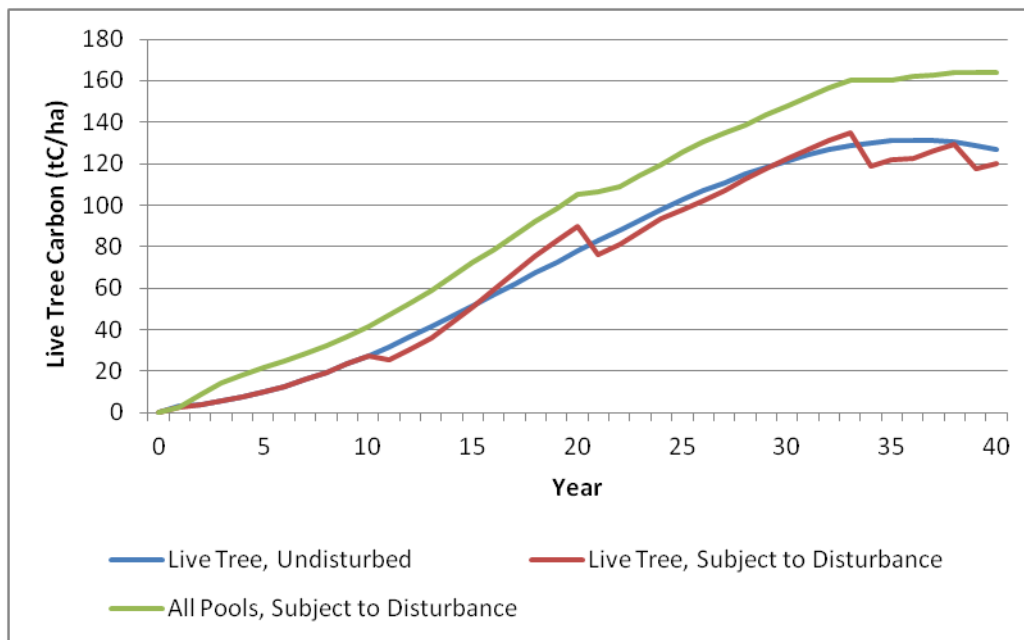


Figure 1. A/R carbon stock accumulation, with and without natural disturbance.

1.2.1. Permanence Period: How Long Must Carbon be Stored?

If the carbon stored in the terrestrial pool remains there forever, then it has served its offsetting function. If the stored carbon is released at any time in the future, however, a key question is whether that offset has effectively negated the emission allowed. To that end, the permanence of biologically sequestered carbon can be defined as the point in time when the stored carbon has essentially fulfilled its role in offsetting the global warming potential of the original emission that it is offsetting. Determining the equivalence of a unit emitted and sequestered in the same year is complicated by the issue of how long and at what rate CO₂ and other GHGs reside in the atmosphere. The original emission that created the offset opportunity does not itself remain in the atmosphere forever. It decays over time, as would have the CO₂ that was removed from the atmosphere and stored in a terrestrial carbon reservoir via carbon sequestration. The “permanence equivalence” nature of the problem stems from the relative patterns of atmospheric CO₂ residency from these two events.

The operative question is whether the carbon returned to the atmosphere completely negates the climate benefit of the offset or whether the timing of the subsequent release matters. In other words, is permanence absolute or relative? The answer depends on the residency time of CO₂ in the atmosphere *and the time horizon over which CO₂ concentrations are being targeted*. The relevant time horizon relies as much or more on policy judgments as on atmospheric science, as we shall now discuss.

1.2.1.1. Permanence in the Context of Atmospheric Chemistry⁵

Greenhouse gases are stock pollutants, in that it is the accumulated level in the atmosphere that matters rather than the amount introduced in any one year. Accumulated increases in GHG concentrations alter the radiative balance of the atmosphere by enhancing the absorption of outgoing long-wave radiation, which raises global temperatures. The time profile of atmospheric residency for a unit of CO₂ emitted into the atmosphere is a critical consideration. From an atmospheric chemistry perspective, a pulse of “excess” CO₂ released into the atmosphere decays over time (Figure 2).

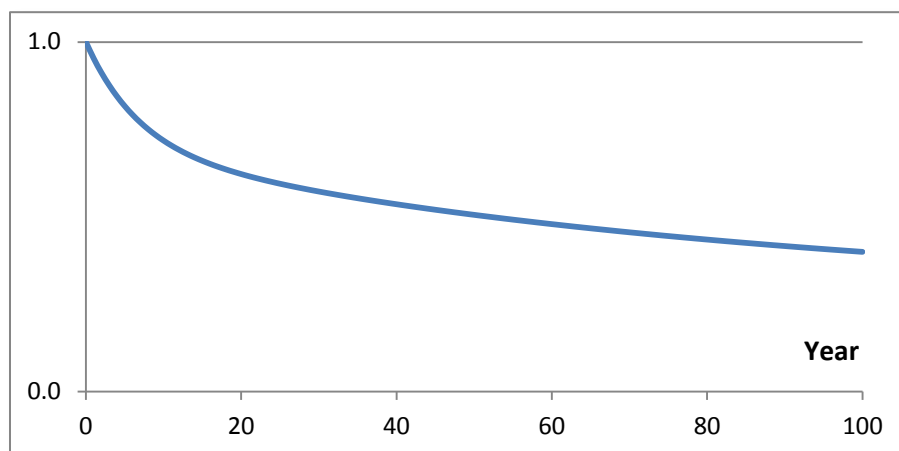


Figure 2. Representative decay function for CO₂ in the atmosphere following emission. The horizontal axis displays time and the vertical axis represents the portion of the initial CO₂ remaining in the atmosphere.

One can approximate the fraction of excess CO₂ that remains in the atmosphere at some point in time following a release, and some portion of it remains in the atmosphere indefinitely. Therefore, from a long-run atmospheric perspective, any reservoir created by a carbon sink to offset the excess CO₂ pulse is equivalent only if the carbon it contains remains stored indefinitely.⁶ This is because the release of CO₂ from the offset reservoir back into the atmosphere will have the same cumulative effect on the atmosphere (called the “integrated climate forcing”) as the original emission; the only effect would be a delay in when the climate-forcing effect would start (which may have some economic implications in terms of the cost of climate damages, but in the long run the climate consequences are essentially the same). This infinite horizon view of CO₂ residency implicitly underlies the carbon-accounting approaches discussed below, that require any rerelease (reversal) of terrestrial stored CO₂ to fully cancel any offset credits generated by the project no matter when they occur. Other approaches discussed below, meanwhile, consider the possibility of at least crediting for storage of carbon over a finite horizon.

“Permanence” in a Finite Policy Horizon

The warming potential created over a specific time period is often the relevant horizon for policy purposes. While the goal may be permanent reductions in atmospheric GHG concentrations, the policy itself often involves fixed emissions targets for finite periods (e.g., to 2020, to 2050), presumably adjustable by future policy decisions.

⁵ Much of the work in this section is based on collaboration between one of the co-authors, Brian Murray, and Duke colleague Professor Prasad Kasibhatla. That work will be released in a more extended form in a forthcoming manuscript (Murray and Kasibhatla, forthcoming).

⁶ Here we follow the IPCC convention of referring to a carbon *sink* as the flow of CO₂ removed from the atmosphere and stored in a terrestrial carbon stock reservoir or pool such as biomass or soil. We clarify this point as it is not uncommon to elsewhere see the carbon sink referred to as a stock, rather than a flow.

1.2.1.1.1. Permanence at the End of the Policy Period

The Kyoto Protocol's CDM addresses permanence at the end of the policy period by establishing that temporary credits for A/R projects are only valid until a certain date, at which point they expire and must either be re-verified or replaced with permanent credits from another source. As a result there is, in essence, no real permanent equivalence for storage – just deferred replacement. In this case, the policy-related time horizons are more like checkpoints on the way to full replacement rather than milestones on the way to achievement of permanence. In this regard, the temporary credits are essentially a form of deferred obligation to replace A/R credits with “permanent” credits rather than an indication of cumulative progress of A/R carbon storage toward some long-term notion of permanence.

The voluntary market, however, has taken a more flexible view of permanence. It issues permanent (rather than temporary) credits, typically with finite contract periods under which the landholder commits to keeping the carbon in place. Perhaps the clearest statement of the relationship (or lack thereof) between finite contract length and permanence was made by the American Carbon Registry (ACR), which in explaining its 40-year contract period, stated:

AFOLU [Agriculture, Forestry, and Land Use] carbon protocols sometimes confuse permanence with the length of time for which a Project Proponent or landowner must commit to maintain, monitor, and verify the project activity. In fact, minimum project duration and the assurance of permanence are unrelated. No length of time short of perpetual is truly permanent, nor is there a sound scientific basis or accepted international standard around any particular number of years... ACR requires Project Proponents to commit to a Minimum Project Term of forty (40) years for project continuance, monitoring, and verification. ACR views forest and other AFOLU activities as a “bridge” strategy to achieve near-term reductions cost-effectively over the period from now through 2050 – the timeframe over which U.S. legislative frameworks and international negotiations propose effective de-carbonization of major emitting sectors, with reductions of around 80 [percent] below current GHG emissions. Requiring Project Proponents to commit to 40 years ensures these activities will continue over the relevant timeframe, or if they or their landowners choose to discontinue activities, that any credited [Emission Reduction Tonne] will be replaced. (American Carbon Registry, 2010, p.30)

In other words, ACR sees the contract length as a means to keep sequestered carbon aligned with time commitments tied to the underlying climate policy process, at least in the context of U.S. federal policy proposals that were in place at the time the statement was written in 2010. There is not a single cap-and-trade program for carbon that establishes a cap into infinity.

1.2.1.1.2. Reversals During the Policy Period

The ACR approach, and others in the voluntary market, require full replacement of credits that are reversed before the end of the time period. A possible modification of this approach is to partially credit for storage that accrues during the project and then reverses before the project is over. One such approach is the *tonne year approach* (Moura-Costa and Wilson, 2000; Noble et al., 2000), which is similar in some ways to the rental approach described by Sohngen (2003) in which credits accrue the longer the carbon is stored. In this approach, tonnes stored early on in a project receive small payments that progressively accumulate as the project continues and achieves storage over a longer period. Since payments are contingent on permanence, there is no “up-front” payment for permanent credits once initial storage is verified. Rather, a reversal simply reduces the basis for subsequent payments.

As an example, the atmospheric effects of a sink reversal under a finite time horizon of 100 years are displayed in Figure 3. The creation of the sink tonne in Year 0 produces an atmospheric credit value of -1. At the same time, the emission that is allowed by generating a sink offset credit produces a debit value of +1. As discussed above, the emission tonne allowed by the offset decays over time (depicted by the red line). The total radiative forcing – the amount of warming potential – of the allowed emission is captured by the area A+B. The tonne of CO₂ that is removed from the atmosphere during sink creation (the blue line, which is the inverse mirror image of the red line) would have the equivalent negative forcing effect (C=B+A) if the sink tonne stays intact for the full 100 years, and thus will have offset the atmospheric effects of the corresponding emitted tonne in Year 0. For the purposes of this 100-year time horizon, the sink will have met the permanence requirement.

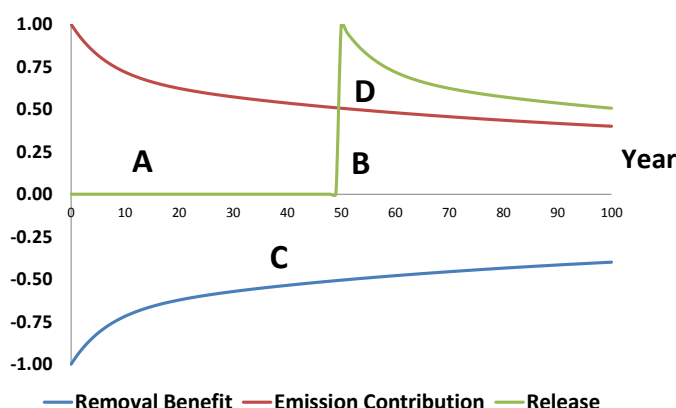


Figure 3. Net radiative forcing effect of a sink (removal) created in Year 0, followed by a release in year 50. Area B+D are the cumulative effect on atmospheric CO₂ concentrations. The initial emission offset by the sink has a cumulative effect of A+B. The atmospheric effect of the reversal scenario within the 100-year horizon is smaller (D<A), so some climate benefit accrues even when reversal occurs.

The possibility that the tonne sequestered in Year 0 is released before 100 years, however, raises the more nuanced issue of partial or equivalent permanence. In Figure 3, this situation is depicted by the green line showing the effects of a sink reversal in Year 50. For 50 years, the tonne of carbon has been kept out of the atmosphere, but a disturbance in Year 50 leads to a release of the sequestered tonne.⁷ This automatically creates an atmospheric debt of +1, which declines over time as the CO₂ decays in the atmosphere. Because, in this case, the stipulated policy target is the net warming potential (or radiative forcing) over the 100-year time horizon, the reversal negates some, *but not all*, of the sink removal

⁷ Note that the radiative forcing (global warming potential) is the indirect consequence of the emission residency depicted here. The common assumption is that an X-percent increase in GHG concentrations leads to an X-percent increase in radiative forcing, so we use emissions residence as a proxy for radiative forcing and warming potential.

benefit that occurred over the first 50 years. The difference in radiative forcing between the sink followed by reversal and the initial emission allowed equals $(D+B) - (A+B) = D-A$. In this case, the area D will always be smaller than A, so the radiative forcing over that time period will always be smaller; thus, at least some atmospheric benefit will be deemed to have been achieved during this time period.

Using a CO₂ residency decay function of Moura-Costa and Wilson, we can calculate the relative permanence of the Year 50 reversal and the 100-year time horizon in Figure 3 as $-D/(A+B)$, which gives a proportion between 0 and 1. The closer to 1.0, the “more permanent” the reduction. This is reported in Table 1, along with other combinations of time horizons and reversal timing.

Table 1. Equivalent Permanence Achieved by Reversal Year and Accounting Time Horizon.

Reversal Year	100-year Horizon	40-year Horizon
20	0.15	0.42
30	0.23	0.66
50	0.41	--

The main implication of this approach is it introduces the possibility that credits can be issued incrementally over time based on the amount of permanence achieved within the relevant accounting period. This means that credits would be issued based on permanence already achieved and future replacement need not be necessary should a reversal occur. The approach also sets a strong incentive to continue with project implementation as the full benefits materialize only in the long run and reduces the financial risk of having to replace credits in the future. Note that this is just one example using one atmospheric decay function. As discussed more below, other functions (e.g., linear approximations) can be used to capture this form of partial permanence via the tonne year approach.

1.2.1.1.3. Additional Comments on Permanence and Finite Policy Horizons

Clearly, the intention of policies today, even if specified for finite time periods, is to permanently reduce atmospheric GHGs and thereby permanently reduce climate change risks. These intentions, however, operate within the reality of policy processes that are staggered in time. Terrestrial carbon is often seen as a bridge to a new regime when low carbon alternatives are more abundant and, perhaps, cap levels adjusted. Of course, this implicitly creates a societal obligation to deal with the accumulated terrestrial carbon reservoirs whenever the current policy period ends. Again, temporary crediting addresses this by requiring full replacement at such time. For alternative approaches that issue permanent credits and require maintenance for a fixed period (e.g., ACR’s 40 years), future policy decisions will presumably need to address whether to pay for continued carbon storage, impose obligations on landowners to continue carbon storage, or make up any subsequent reversals with further de-carbonization efforts (replacement). Thus, the issue is deferred rather than avoided altogether.

2. Reversal Risk: Types, Characteristics, and Liability

Risks from LULUCF activity are conventionally classified into two types: (1) unintentional reversals due to natural disturbances outside of the project holder’s control (such as wildfires, wind, and flooding) and (2) intentional risks caused by purposeful actions of the project participants (such as harvesting, land clearing, and intentionally set fires). A conceptual overview of these different reversal risks can be seen in Table 2. The causes and consequences of these two types of risks are different and thus the empirical

analysis here considers them separately. This section describes how these risks are quantified in the analysis.

Table 2. Overview of Reversal Risks (sources and losses adapted from VCS, 2012). The general sources of threats are indicated, as are the mechanisms or vectors of potential loss and the location along a spectrum of risk category as used in this analysis. Some losses may be seen as purely intentional, others unintentional, and still others a combination of both.

Source of Threat	Risk of Loss Due To	Risk Category
Internal to the Project	High Opportunity Cost Change in Financial Viability Inadequate Project Management	
Institutional	Inadequate Community Engagement Inadequate Land and Resource Tenure Political Uncertainty and Conflict	
Natural Disturbances	Fire Pest and Disease Extreme Weather Geological Risk	

2.1. Unintentional (Natural) Reversals

Forests are inherently vulnerable to natural disturbances. Wildfire and wind are common causes of loss, but a great deal of variation exists both within and between each with regard to disturbance frequency, intensity, and area affected. Low-intensity fires may affect large areas but consume only litter and ground vegetation, resulting in negligible carbon consequences for an A/R project. Conversely, high-intensity fires can reach into the forest crown and be utterly destructive, with catastrophic results for both previously stored carbon and future sequestration potential. Wind, meanwhile, tends to affect small areas but with great intensity. While the blow-down that results from severe wind events may kill or damage individual trees, stored carbon may not be lost immediately but rather transferred from live tree to dead tree pools where it is lost slowly over time.

Both wind and fire are repeatedly mentioned in A/R project design documents (PDDs) as possible threats, with fire appearing in nearly all of the documents listed in the CDM project database.⁸ Wind is mentioned in far fewer PDDs, but is still referenced as a potential threat in at least two other projects.⁹ Questions remain, however, as to the aggregate effects of these varied disturbance regimes on carbon losses in A/R projects. To help answer these questions, we quantitatively assess the relative and absolute performance of multiple policy approaches on hypothetical projects under the threat of both wildfire and wind disturbance.¹⁰

⁸ <http://cdm.unfccc.int/Projects/projsearch.html> (last accessed August 6, 2012).

⁹ Other threats mentioned in A/R PDDs include grazing and pest outbreaks; these are not modeled here.

¹⁰ Two methods are used to assess the performance of various policy approaches in the presence of natural disturbance events. The first, used in the majority of the analysis, makes use of the LANDCARB ecosystem simulation model. The second, used in examples where analysis calls for observation of historical events and geographic variation in the risk of reversal, makes use of empirical fire data from Chile. Both assume that all lands are afforested in the first year of the project. No harvests are conducted during the project, meaning that we do not track harvested wood products (HWP) nor do we assess potential long-term carbon storage in the HWP pool.

Our modeled projects take place in a hypothetical subtropical country representative of A/R project experience under the CDM. Biophysical parameters for the modeled projects are informed by PDDs contained in the CDM project database, while implementation costs were based on expert opinion, project experience, and the available literature.¹¹ To model forest growth, we based our forest stands on growth-yield curves established for high management, high productivity softwood plantation species (*Pinus taeda*, *P. echinata*) stands as described in Smith et al. (2006). We believe this to be a reasonable assumption, as multiple existing A/R projects make use of these or similar conifer species.

We considered the effects of wildfire and wind natural disturbance regimes on our hypothetical projects using an ecosystem simulation model, LANDCARB (Harmon, 2012), customized for this study. We evaluated the probabilistic nature of wind and fire disturbance by making multiple runs (or iterations) of forest stand development and carbon consequences under empirically based random disturbance shocks. For each run, we created two project sizes to gauge the scale dependence of disturbance effects. The entire output for each run was 20,250 hectares (though for simplicity, this area is rounded down to 20,000 ha when discussed in the text). From each 20,250 ha output, we randomly selected a smaller project area of 1,000 ha (contiguous) to compare scale effects.

Figure 4 illustrates the relative impact of our modeled natural disturbance reversals over the first 40 years of an A/R project. The figure shows the relative level of reversal loss (total cumulative reversals divided by total carbon sequestered) over time across 50 simulations of a 20,000 ha project. We see that in most cases, the reversal effect is small – less than one percent – relative to total carbon sequestered (the gross basis for crediting), but occasionally the losses can spike. This is a representative case that we deployed for our assessment of reversal risk mechanisms; actual project risks will vary by the ecological, climatological, and institutional conditions applicable to it.

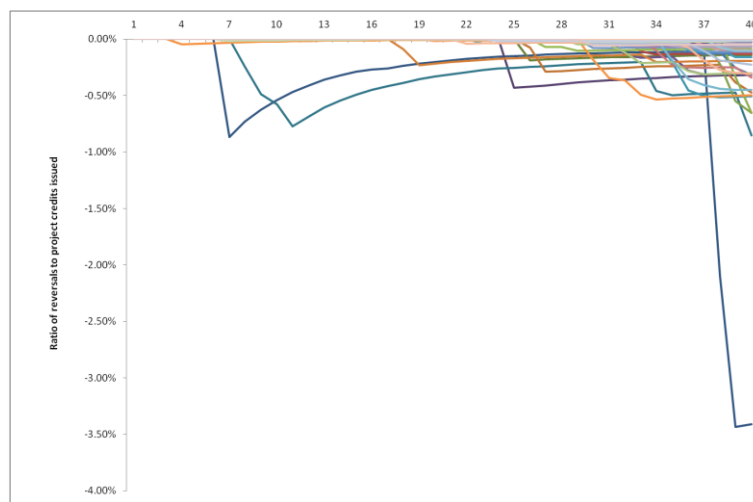


Figure 4. Ratio of reversals to project credits issued across 50 model iterations over time. This assumes a 40-year project, 20,000 ha in size, with no reversal protection mechanism. Each line represents the ratio of reversal losses to credits issued. Negative ratios indicate that a reversal has occurred and that more credits have been issued than remain stored on the site.

See “Appendix B: Unintentional Reversal Assessment Methodology” for a greater discussion of methods and assumptions in our analysis.

¹¹ See “Appendix E: Project Cost Data and Assumptions” for an overview of cost data.

We note at the outset that our model results provide an indication of possible losses under a specific set of parameters and assumptions. For example, use of a different forest type or different disturbance regime is likely to generate different output data on both carbon storage and the susceptibility of that storage to subsequent loss. Slow-growing hardwoods in fire-prone tropical and subtropical broadleaf forest ecosystems would encounter wildfire and be affected by fire differently than, say, a temperate softwood plantation. Nonetheless, the data presented here are still informative and provide the beginnings of a comprehensive quantitative analysis of different approaches to addressing non-permanence.

2.2. Intentional Reversals

A landholder may opt to purposely deplete stored carbon. In some cases, for instance from a planned harvest or a prescribed management fire or thinning, this may be part of the approved project plan and crediting is handled accordingly. In other cases, the intentional reversal may not be part of the approved plan. This could occur if the project is abandoned or the project proponent deviates from the plan to seek other objectives (e.g., increased timber revenue).

Suppose a party chooses to abandon an A/R project before the expiration of any permanence obligation. There are a variety of reasons why they would choose to do this (see “Internal to the Project” sources in Table 2). For example, the landholder could divest a project upon determining that it is no longer economically viable. If this occurs, the project would forego the opportunity to generate future carbon returns if it is still operating within a valid crediting period. More to the point of this report, the carbon that the project had accumulated to date would now be subject to reversal that must be accounted for.

The economic viability of a project may diminish because of higher costs, lower revenues, or a change in market conditions that makes alternative land uses more attractive. One possible outcome under these conditions is that the landholder converts the land to another use (e.g., trees are cleared for agricultural cultivation). Appendix C provides a detailed example of how such a land-use conversion could be driven by simultaneous changes in the carbon and commodity markets. The findings and implications of intentional reversals such as those highlighted in the soybean case study in Appendix C are discussed qualitatively below. A more robust quantitative modeling of intentional reversals at the project level would require an assessment of all relevant commodity (agricultural, forestry/timber, carbon) price change distributions, along with landowner behavioral data to discern the incidence of A/R project adoption and abandonment. This is beyond the scope of the present analysis.¹²

A key policy question that emerges from this analysis is that, if intentional A/R project reversals can be anticipated, how will corresponding carbon losses be handled in the accounting framework? This is the question to which we turn in Section 3.

3. Risk Management Approaches

Reversal risk management occurs in two stages – screening and accounting (see Figure 5). Screening involves an initial assessment of the reversal risk characteristics of a project, and is the focus of this section. Such risk quantification can be done in the accounting stage to assess the type and specification

¹² Another factor to consider is the possibility that a project participant initiates an action that is meant to look as if it occurred naturally (e.g., a set fire or intentional flooding). They may do this, for instance, if they will be held accountable for intentional reversals but held harmless for “natural disturbance” reversals. Later in the report, we discuss accountability for reversal losses by type and the possibly perverse incentives this can create.

of measures to handle reversals – or even whether reversals need to be handled. The accounting stage, discussed in greater detail in Section 3.3, includes the initial crediting that occurs when carbon is stored and adjustments to that accounting (including credit replacement, if necessary) to ensure system integrity.

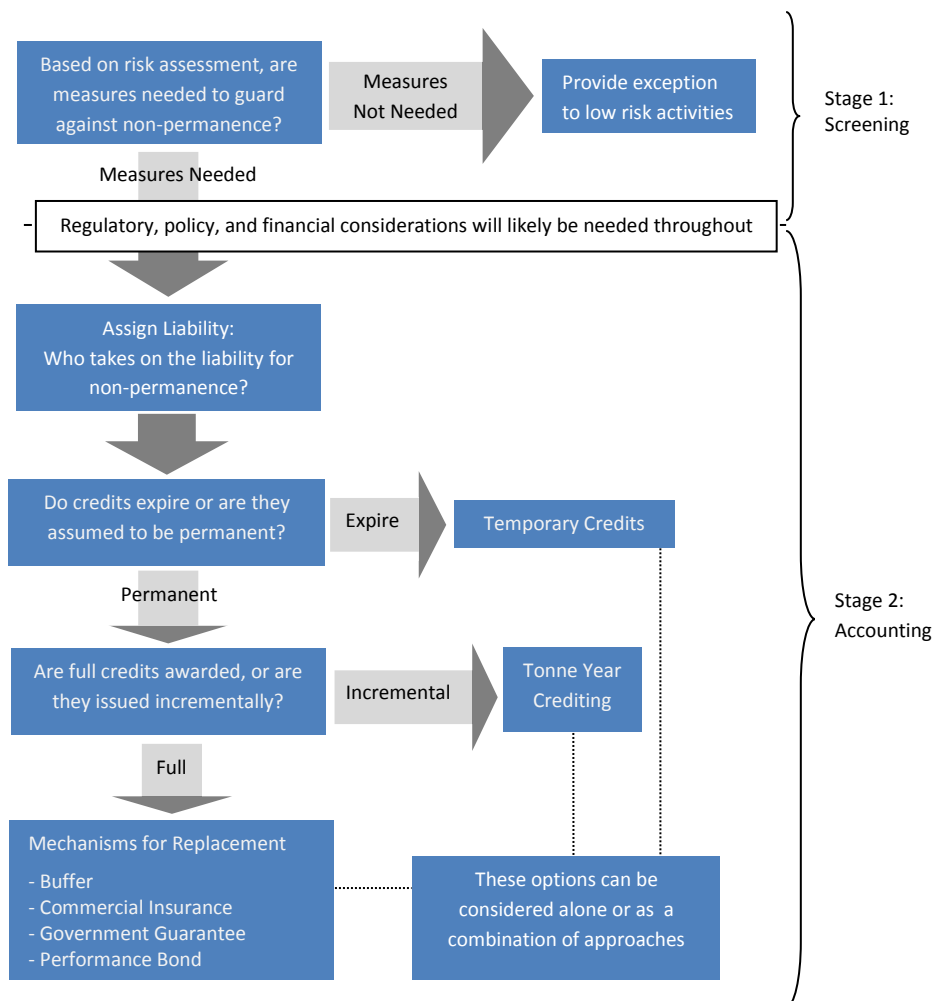


Figure 5. Conceptual diagram of permanence considerations and choice of risk management approach at the project level.

3.1. Screening for Reversal Risk: Concepts and Criteria

As illustrated in Table 2, there are a number of factors – natural, institutional, and internal – that can contribute to the threat of reversals. The risk screening stage may require an initial assessment of these risks to guide decisions about categorical exceptions or risk management requirements. It may be possible to incorporate an *exception* principle for certain projects or project types. Categorical exceptions have traditionally referred to the process of deeming carbon credits originating from certain low risk projects as permanent (e.g., A/R activities in adequately enforced protected areas).¹³

¹³ See, for example, Addressing Non-permanence and Reversal Risks of Afforestation and Reforestation (A/R) Activities under the Clean Development Mechanism (CDM). Prepared on behalf of the World Bank Carbon Finance Unit (BioCarbon Fund) by the Nicholas Institute for Environmental Policy Solutions, Duke University. http://siteresources.worldbank.org/INTCARBONFINANCE/Resources/WEB_Addressig_Non-permanence_in_CDM_AR_Activities_Information_Note.pdf (last accessed August 31, 2012).

Alternatively, risk assessment results could simply be applied to the accounting and adjusting requirements discussed below (e.g., eliminate any buffer requirement for such projects).

3.1.1. Screening for Unintentional Reversals from Natural Disturbances

Key Results

- Categorical exceptions are a potential way to limit the replacement or monitoring obligations of certain low-risk projects.
- It is possible to conduct preliminary risk analyses using historical data.
- Some areas will show higher losses than others, with losses exacerbated by project length.
- Any screen or exception must be site- and project-specific and confirmed by an independent auditor, possibly facilitated through a screening tool or other formally established process or instrument.

One possible way to assess natural disturbance risk is to use the ecological processing model approach used to demonstrate natural reversal risks.¹⁴ This can simulate likely risks from a project over time. The example illustrated in Figure 4 shows a relatively low risk profile for an A/R investment, but different parametric assumptions could yield higher risks specific to the circumstances. Process modeling is, however, a specialized skill and may not be applicable in all cases. Another approach is to make use of historical risk data (where available). For example, some countries (such as Chile) have extensive historical fire activity data which can be used as a rough proxy for reversals. These data provide a rough proxy because they do not by themselves capture the spatial and temporal dynamics of fire disturbance within a forest stand, nor do they provide any indication of intensity – all potentially important factors for A/R projects. Given the multiple assumptions needed to apply historical data to an individual A/R project, these data provide at best a first-cut assessment of the implications of simply deeming all carbon credits permanent upon generation.¹⁵ Increased temporal and spatial resolution would be needed to adequately characterize the actual risks faced by a given project.

Figure 6 and Figure 7 show the difference between credits issued at the time of generation and standing carbon at the end of the project for three different areas, using fire risk data from Chile instead of the process model output seen in Figure 4. Comparing the total amount of carbon claimed by the project to the total amount of carbon in the project in each year indicates whether or not a project experienced a reversal. Note in particular the difference between lower risk areas (A and B) and higher risk areas (C).¹⁶

¹⁴ Natural risks are unique in that they can be assumed to be probabilistic, occurring randomly along some known or estimated distribution. Other types of unintentional risk, such as political instability and conflict, are not, and therefore cannot be modeled in similar ways. The relative likelihood of their occurrence may still be weighed, however, and factored into the conclusion of a project's total reversal risk (see, for example, VCS, 2012).

¹⁵ See "Appendix B: Unintentional Reversal Assessment Methodology, Empirical Disturbance Analysis - Chilean Historical Fire Data Overview" for a greater discussion of methods and assumptions in our analysis.

¹⁶ Again, the data only indicate that a given area has been affected. For the purposes of this example, we assume that each fire results in an equal proportion of carbon loss. In reality, frequent fire could result in lower carbon emissions as fuel loads are likely to be lower and burns are likely to be less intense than an infrequently burned area.

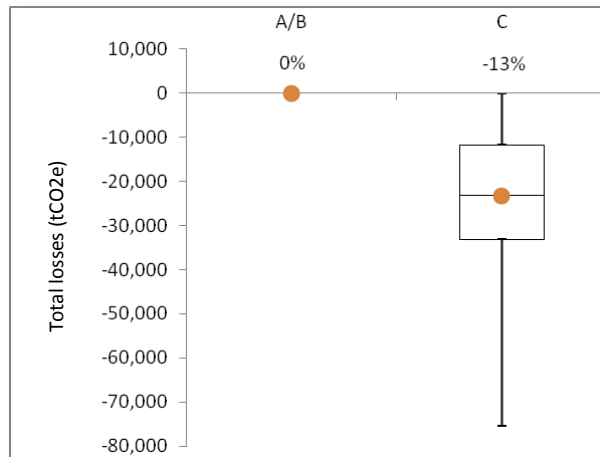


Figure 6. Distribution of total losses (tCO₂e) at the end of 20 years for two low risk areas (A and B) and one high risk area (C). Error bars represent the minimum and maximum value recorded across 1,000 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean. A value of “0” represents no unaccounted loss, whereas a negative number represents a project scenario in which losses occurred. Percentages indicate size of mean loss relative to total credits earned by the project.

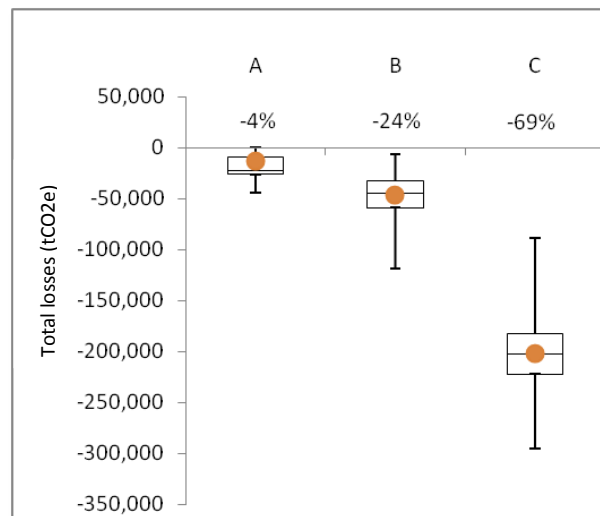


Figure 7. Distribution of total losses (tCO₂e) at the end of 40 years for a very low risk area (A), a moderately low risk area (B) and a high risk area (C). Error bars represent the minimum and maximum value recorded across 1,000 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean. A value of “0” represents no unaccounted loss, whereas a negative number represents a project scenario in which losses occurred. Percentages indicate size of mean loss relative to total credits earned by the project.

All areas are similarly-sized and assume identical project crediting and financial parameters; the only difference is the underlying risk distribution for each. The high risk area (C) shows significant losses even in short project periods of 20 years (Figure 6), whereas the lower risk areas only show losses when project periods are extended to 40 years (Figure 7). The increase in losses with project length is attributable to a slowdown in growth of the modeled forest. In early years, losses in one part of a project are generally compensated for or outpaced by forest growth on other portions of the project. As forest growth slows over time, however, year-over-year losses become more commonplace. These simulations suggest that exceptions could be more feasible in some areas than in others. The difficulty is in determining appropriate thresholds and acquiring the necessary data to assess whether these

thresholds are met in the field. An independent auditor will also likely be needed to ensure that the proper conclusions have been reached.

3.1.2. Screening for Intentional Reversals

The voluntary market addresses intentional reversals (those from internal factors) by requiring project proponents to complete a risk assessment that objectively rates risks from a number of sub-categories. For example, the Verified Carbon Standard (VCS) requires project proponents to develop a scored assessment of internal project risks, to include the following categories of factors (VCS, 2012):

- Project management (e.g., management experience, asset protection capability).
- Financial viability (e.g., payback period, sustained financing).
- Opportunity costs (relative value of competing land use).
- Project longevity (e.g., legal requirement to continue the practice).

The VCS and others use this information (and similar information on natural risks) to establish the level of credits that must be set aside in a buffer and their system for replacing reversed credits (see below for more details). Thus the initial screening forms the basis for the risk management system put in place. A similar approach could be followed for A/R projects under the CDM, regardless of the approach put in place to address reversal. This type of approach could also be used to determine whether a categorical exception can be made to avoid certain reversal risk requirements.

3.2. Liability Determination and Assignment¹⁷

If the screening process results in a determination that exceptions are inappropriate or infeasible, liability for reversals must be assigned. From an accounting perspective, a reversal occurs once it is detected, quantified, and reported. Standard practice would cancel credits equivalent to the size of the reversal. Since canceled credits mean that the use of the credits for offsetting emissions has been compromised, some replacement of the canceled credits with valid credits would be necessary to restore balance to the system. The issue comes down to who is liable for replacing the credits. We consider four options for the party assigned the liability: (1) the producer; (2) the buyer; (3) negotiated liability; or (4) the “system.” Each is discussed below, and the advantages and disadvantages of the options are summarized in Table 3.

3.2.1. Producer Liability

If the producer of the A/R offset credits (the project’s controlling interest) assumes liability, they are responsible for any credit loss and repayment terms imposed. A common way to resolve this liability would be to replace the reversed credits with other verified credits to settle any default balance. The advantage of the producer liability approach is that it provides strong incentive for the project party, who is in the best position to manage risk, to take preemptive action and reduce the risk. Whatever residual risk remains, however, would carry a liability that would cut into the project’s net return. In the case of a catastrophic loss of previously credited carbon, the financial impact could be quite severe for an individual project. Mechanisms for managing this liability are further discussed below.

¹⁷ The description of liability options here draws heavily from the Duke authors’ background technical reports prepared for the development of the Rainforest Standard. Available at http://cees.columbia.edu/files_cees/imce_shared/RFS_2_0_-_June_2012_tm_.pdf; last accessed October 30, 2012.

3.2.2. Buyer Liability

An alternative to producer liability is to have the liability transfer with the ownership of the credit. This can take several forms, depending on whether the credit is being banked or has already been used for compliance. If a reversal were to occur, any credits being banked for future use would not be useable for future compliance and would thus be retired. Under buyer liability, any credits already used to meet regulatory obligations must be replaced by the user. With buyer liability, risk will presumably be priced into the value of the credit, much like default risk is factored into the price of a bond. Like bonds, this means that different credits could trade at different prices to reflect different levels of risk. For example, credits from A/R projects with higher risk of fire, disease, and human intervention might trade at a discount to those with lower risk.

Keohane and Raustiala (2009) argue that, under the buyer liability approach, buyers have a strong financial interest in buying high-quality offsets – thus enforcing quality on producers. So while producers may not face the risks of reversals directly, they will still have a strong incentive to mitigate risks if it means they can sell their offsets at a higher price on the market. The producer incentive to keep reversals low is driven by the ability to receive a higher price for all credits in the class. Whether this is a stronger incentive than individual producers directly bearing the liability themselves is up for debate (Morris and Fell, 2012). Conversely, buyers of temporary credits have to bear the liability of loss and have not shown a strong interest in temporary credits. California, which imparts buyer liability on the purchasers of offsets to replace invalidated offsets (though notably, in the case of forest offsets invalidation does not include reversals, which is covered separately with a buffer approach), is expected to yield empirical data on the willingness of the market to accept such arrangements.

3.2.3. Customized Contracts Between Buyers and Producers

Instruments such as long-term contracts between buyers and producers or direct investment by buyers into an A/R project could involve negotiated agreements between buyers and producers about reversal liability. Suppose, for example, that an industrial facility enters into a long-term contract with an A/R project. The industrial firm may advance the money to the producer and obtain rights to the stream of credits generated. The contract between the two parties could thus address what happens in the case of reversal. The standardized contract could be set up with default specification of liability for one party or the other, but liability assignment could be modified in the contract if the parties agree to do so. For example, the buyer/investor might bear the risk of unintentional reversals faced by the project (e.g., wildfire), while the producer might bear responsibility for intentional or neglectful actions that cause reversal.

3.2.4. System Liability

System liability refers to an approach under which the program (e.g., the CDM) assumes the liability on behalf of buyers and producers. This could occur at the local, national, or international level. The system assumes the liability by putting a mechanism in place that pools the risk across the participants. Sometimes the risk is shared; for instance, where the producer is liable up to a point and the system is liable beyond that. The underlying premise is that risks are more manageable when diversified across a portfolio, as discussed further below. Typical approaches for dealing with system liability include imposing holding requirements on individual projects, establishing a system-wide buffer to pool risks across all projects, and combinations thereof. These options are discussed in the risk management section.

Table 3. Liability Options Summary.

Liable Party	Description	Advantages	Disadvantages	Examples
Producer	Originator or forest landowner responsible for replacing reversed credits.	Tied directly to location. Avoids chain of custody complications from producer to buyer. Strongest reversal prevention incentive.	Small producers may not be able to bear risk or may be required to have a large risk premium to do so.	New Zealand ETS.
Buyer	Liability travels with the credit holder – like default risk for bondholder.	Natural extension of compliance performance – need to provide only “good” credits to meet requirements.	Complicates transaction by keeping unresolved liability on the books for buyers. Monitoring and chain of custody requirements.	CDM through expired temporary crediting (see below). California AB32 in some offset categories.
Customized Contracts	Liability can be negotiated between buyers and producers on a case-by-case basis, using standardized contracts and modifications thereof.	Flexibility to specific circumstances of the project.	Transaction costs of negotiating explicit contract terms.	Common practice in over the counter transactions.
System	The program manages liability on behalf of the buyers and producers by setting up mechanisms to pool risks and replace credits as needed after reversals occur.	Pooling risk reduces exposure for individual market participants.	Risk of underestimating risk leading to system failure. Moral hazard and adverse selection possible.	Voluntary markets. California AB32 for forest carbon credits.

3.3. Accounting Mechanisms for Addressing Reversals as They Occur

The incidence of reversal can be automatically incorporated into the crediting system in a number of ways. Historically, many of the considerations for addressing reversals have evolved from a project-level perspective and emerged from the modalities and procedures developed for A/R under the CDM and from the voluntary market. Appendix A provides a summary of how key forest carbon offset programs in regulatory compliance settings, as well as the voluntary carbon market; address the risks of non-permanence and reversals.

Although often lumped together as ways to collectively address non-permanence, these approaches are fundamentally different in the questions they seek to answer and the function they seek to provide. We review multiple approaches below, grouping them into incremental and full permanence approaches. Within the latter, we further distinguish between temporary and permanent crediting approaches (see also Figure 5).

3.3.1. Incremental Crediting Over Time (“Tonne Year” Approach)

Key Results

- The tonne year approach carries no residual liability for reversed carbon.
- Absolute effects of reversals on atmospheric integrity rely on the assumptions of CO₂ residence time.
- Project length has a strong influence on the number of credits earned.
- The permanence period has a strong influence on both credits and net present value (NPV).
- The approach generates lower NPVs than other approaches (e.g., buffer).

One could assign more permanent credits for projects that store carbon for longer periods of time, a concept called “tonne year accounting.” Referring back to the above discussion of permanence and

policy periods, the basic notion of tonne year accounting is that even if a tonne stored today is emitted in the future, it has provided at least a temporary carbon removal function that has kept atmospheric concentrations down for a policy-relevant period of time. In essence, carbon storage can be viewed as a series of payments over time, with a greater service provided the longer the carbon is stored. Because the tonne year value goes down when stock goes down, it provides an economic incentive to maintain or enhance the forest carbon stock. But because the stock is essentially being paid on an incremental basis, reversals do not cause a loss of previously issued credits that must then be replaced.

Building on the conceptual overview provided in Figure 3 and Table 1, Table 4 provides an example of how tonne year may be applied to a project that stores 1,000 new tonnes of carbon each year for 100 years. The 1,000 tonnes stored in Year 1 produces 1,000 tonne years of storage. The next year, if the same 1,000 tonnes stored in Year 1 is successfully maintained, this counts for another 1,000 tonne years worth of savings in Year 2. Meanwhile, a new 1,000 tonnes is also stored (saved) by the project that period, say from more reduced deforestation or more growth on a reforested stand. So the total tonne years produced in Year 2 is 2,000 and the cumulative tonne years produced by the project in Years 1 and 2 is 3,000 tonnes. Drawing from the 100-year permanence period discussed above, one can assign an average value of 0.01 permanent tonnes generated for each tonne year produced; the project then produces 10 tonnes of credits in the first year, 20 more in the second year, 30 more in the third year, and so forth. Once these tonnes are deemed permanent, they have no residual reversal liability as they have achieved partial measures of permanence.¹⁸

Table 4. Assigning “Permanent” Reductions Over Time Using the Tonne Year Equivalence Approach (one tonne year = 0.01 permanent tonnes).

Period	Annual Carbon Stored (tonnes)	Cumulative Storage (tonnes)	Cumulative Tonne Years of Storage (year 1 cumulative storage + year 2 + year n)	Permanent Tonnes Earned @ 0.01	% Reductions Permanent (permanent tonnes / cumulative storage)
1	1,000	1,000	1,000	10	1.0%
10	1,000	10,000	55,000	550	5.5%
20	1,000	20,000	210,000	2,100	10.5%
30	1,000	30,000	465,000	4,650	15.5%
40	1,000	40,000	820,000	8,200	20.5%
50	1,000	50,000	1,275,000	12,750	25.5%
60	1,000	60,000	1,830,000	18,300	30.5%
70	1,000	70,000	2,485,000	24,850	35.5%
80	1,000	80,000	3,240,000	32,400	40.5%
90	1,000	90,000	4,095,000	40,950	45.5%
100	1,000	100,000	5,050,000	50,500	50.5%

¹⁸ The annual average rate for achieved permanence (0.01) is used here, but the actual rate consistent with the tonne year approach would vary over time, with annual rates being lower in the earlier years of the permanence period and higher in the later years.

3.3.1.1. Unintentional Reversals

Viewing the outcome of the tonne year analysis, several themes are quickly evident. First, project length has a strong influence on the number of credits earned (Figure 8). The reason for this is twofold. The first is simply that a growing forest will generate a larger number of credits over time. The second has to do with the nature of the tonne year approach. Since only a fraction of credits are earned in each year, more credits are accumulated as time goes on. Also note the strong role of the assumed permanence period on project crediting. The permanence period defines the fraction of the credit earned in each year; a longer permanence period equates to a smaller portion of a credit being earned in each year. For example, a 40-year permanence period means that 2.5 percent (100 percent/40) of a credit will be earned in any given year. A 100-year permanence period meanwhile only yields a one-percent credit each year (100 percent/100), 400 years would yield a credit of 0.25 percent per year, and so forth.¹⁹ Clearly the longer the relevant time period to achieve permanence, the more diminished is the annual tonne year value.

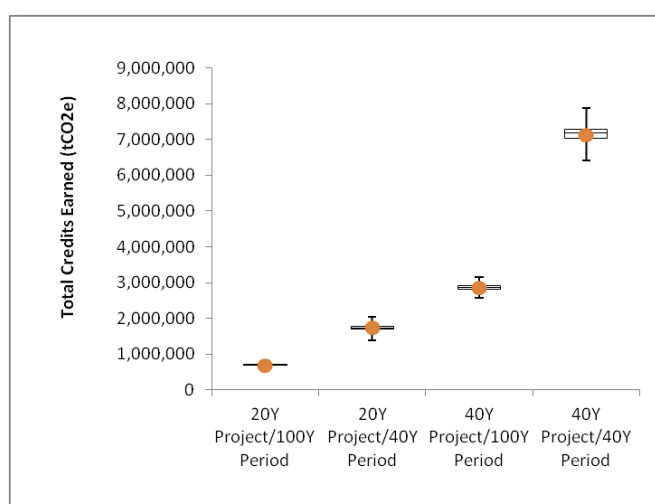


Figure 8. Total credits generated in a 20,000 ha project assuming a tonne year approach, both 40- and 100-year permanence periods and 20- and 40-year project lives. Error bars represent the minimum and maximum value recorded across 50 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean.

The number and timing of credits generated in turn has a strong influence on project net present value (Figure 9). Not surprisingly, we see that project length and permanence period again figure strongly in project financial outcomes. From this analysis, it appears as though project length has a stronger influence on project finances than the permanence period assumption – the improvement between 20- and 40-year projects is greater than between the 40- and 100-year permanence periods (crediting rates of 0.25 and .01, respectively), holding all else constant.²⁰

¹⁹ Note that this is a linear approximation of the examples described in Table 1.

²⁰ Similar trends are likewise seen in the 1,000 ha example, though the projects tend to perform poorer financially due in part to economies of scale with regard to transaction and implementation costs. The relative risk of catastrophic loss is also greater in smaller projects, as disturbance events tend to affect larger portions of the smaller project, which in turn affects income under a tonne year approach. See "Appendix F: Expanded Output and Sensitivity Analysis, Tonne Year."

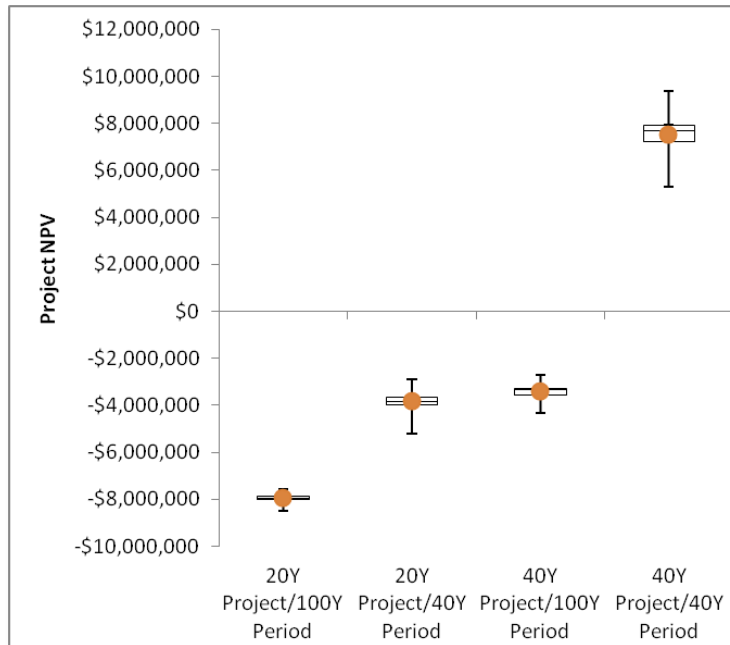


Figure 9. Project NPV for a 20,000 ha project assuming a tonne year approach, both 40- and 100-year permanence periods and 20- and 40-year project lives. Error bars represent the minimum and maximum value recorded across 50 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean.

3.3.1.2. Intentional Reversals

A tonne year approach implicitly protects against intentional reversals as crediting is based on the incremental assignment of permanent credits over time – after permanence is “earned.” In other words, the credits are not issued before an equivalent level of permanence is established. Once issued, therefore, these credits need not be replaced upon an intentional reversal to correct for early reversal. In summary, reversals (intentional or unintentional) do not introduce integrity risks to the system because credits are not issued before permanence is achieved.

3.3.2. Full Crediting Upon Verification

Rather than awarding credits incrementally, credits could be fully awarded upon verification. Doing so, however, requires that mechanisms be in place to ensure that any carbon that is subsequently lost to reversal is accounted for or replaced. These mechanisms can take many forms. As discussed in Section 3.1 (“Screening for Reversal Risk: Concepts and Criteria”), it is technically possible to estimate the range of losses expected in a particular project operating in a particular area, but risk remains that actual losses could undermine system integrity. One option to address potential losses is to assume that credits are temporary and that they expire after a short period of time. Alternatively, permanent credits may be issued, but only so long as their replacement following a reversal is guaranteed. Beginning with an assumption that all projects are legally required to replace credits lost to reversal, additional policy approaches may be employed to facilitate replacement. A portion of credits could be set aside in a buffer account or requirements put in place to ensure that lost carbon be backstopped. Losses could be guaranteed by a third-party private insurer or host country. Or the legal obligation to replace may be left entirely to the project to navigate by itself, with only a performance bond or other similar test applied at the beginning to ensure sufficient means. These are the mechanisms we now discuss.

3.3.2.1. Temporary Crediting (tCERS)

Key Results

- As with tonne year, tCERs create no interim liability (additional replacement requirement) for reversals, thereby reducing the accounting burden should reversals occur.
- From an atmospheric integrity perspective, the intentional reversal situation is no different than the unintentional reversal case as there is no need to replace lost sequestration.
- Analysis indicates that tCERs may be a means to address reversals, at least in the short term.
- Financial performance of tCERs is highly dependent on credit price assumptions. Performance lags behind other approaches when prices are calculated according to their theoretical value. With higher prices, however, tCERs could generate significant revenue over time.

There are two temporary crediting approaches currently available under the CDM. Under the temporary certified emission reduction (tCER) approach, all credits that were issued for a project expire at the end of the (Kyoto) commitment period after they were issued. Crediting periods can be much longer for long-term certified emission reductions (ICERs), which are valid for 20 years, renewable twice (for up to 60 years) or for a single, 30-year crediting period. Simple economics suggests that the difference in credit life will translate into a difference in price between the two types of credits. Under a system that mandates replacement at the end of the contracts, short contracts will have heavily discounted credits, since the replacement requirement will be near at hand (Kim et al., 2008; Murray et al., 2007). ICERs would therefore command a higher price than tCERs due to the greater amount of time before replacement is required, while themselves trading for less than a comparable “permanent” credit.²¹

The two types of temporary credits also differ in the way that carbon is accounted for. While tCERs are only valid for a single commitment period, the underlying carbon can be rolled over into new credits. ICERs are valid for much longer, but new credits can only be issued for incremental gains in carbon since the last certification. Stated another way, tCERs allow for the same tonnes to be sold over and over but at a heavy discount; ICERs allow for the same tonne to be sold only once, but that tonne commands a higher price. ICERs also require repayment of credits should a reversal occur prior to the end of the crediting period.

In light of the extremely limited market for ICERs at the present time, we focus our analysis on tCERs. Empirically, ICERs also behave much as permanent credits in terms of how reversals are accounted for within a given crediting period. The key difference is, of course, the ultimate obligation to replace the credit at the end of the crediting period, and the effect that this obligation has on both credit price and atmospheric integrity. But given similarities to the intra-period dynamics of permanent credits, we feel that our focus on the unique temporal issues created by tCERs is warranted. For the purposes of our modeling exercise, we specifically consider the example of repeatedly verified tCERs issued every five years for projects that are 20 and 40 years long.

3.3.2.1.1. Unintentional Reversals

One feature of the tCER is that there is no residual liability upon expiration – the expiring credit must be replaced by the buyer, but no further expectation exists that the associated carbon remains intact. The

²¹ Longer contracts should have lower discounts, but this depends on the expectation of future prices of replacement credits; if the price of securing replacement credits is expected to be much higher in the future than it is today, then temporary credits may have little value. There is, however, no transaction data upon which to confirm this. See “Appendix E: Project Cost Data and Assumptions, Calculation of tCER Pricing” for a more detailed description of the approach for calculating the price of a temporary credit.

atmospheric integrity story is therefore quite straightforward – the default assumption is that carbon storage is a temporary phenomenon; any continued sequestration therefore generates an implicit climate benefit. tCERs are also characterized by interesting intra-period dynamics. Assuming that there are no obligations to address unintentional reversals with a crediting period, tCERs can mask either increased or decreased atmospheric benefit in the interim.²² In a situation where a forest stand keeps accumulating carbon after verification, the carbon stored onsite between the first verification and the next represents an unreported increase in sequestration. Conversely, forest losses would also be masked under such a situation, meaning that less sequestration is ultimately delivered in the intervening years. Forest growth and disturbance will influence the direction of any differential between reported and actual stored carbon in any given year. In the forest system modeled here, early years will be more likely to experience more carbon storage than credited, whereas later years are more likely to experience lower levels. Regardless of the direction, verification allows the system to be “trued-up,” resetting the differential between credited and actual carbon stocks and limiting the magnitude of any discrepancy.

The tCER financial story is likewise complicated. Because there is not a robust market for tCERs at this time, and because of the complexity of the role that credit expiration plays, we must calculate (rather than observe) an expected selling price for tCERs based on the expected price of permanent CERs and the time rate of discount (see Appendix E for the methodology). At assumed carbon price increase rates and global discount rates (assumed in this analysis to both be 6 percent), the theoretical price of tCERs go to \$0. There is no market transaction history, however, to confirm the relevance of the theoretical value of tCERs to actual trades. The only trades in tCERs of which we are aware are recent purchases by the BioCarbon Fund for approximately \$4-5/tCO₂e. As these purchases are better viewed as an attempt to seed a nascent market, the question remains as to the true value of a tCER. A price \$0 is obviously too low a price to fairly assess the net present value (NPV) of a tCER approach – but \$4 is likely too high.

Rather than rely on observed prices emerging from the BioCarbon Fund’s purchase of tCERs or calculating the expected tCER value per the economics literature, we instead rely on general relationships noted in Bird et al. (2004). In situations where the discount rate and “inflation rate” (assumed to be the rate of carbon price increase) are similar in value, 5-year tCERs will trade at approximately 10% of the price of full permanent credits. Under these pricing assumptions, we yield a highly negative project NPV in our 20-year project example (Figure 10). In time, this deficit is largely overcome, with some model runs yielding positive NPVs in the 40-year project example. We note that our analysis of tCER NPV, especially for the 40-year projects, is largely driven by assumptions in carbon price. In the presence of a higher carbon price and positive carbon price growth rate, tCERs could prove to be quite attractive, financially. This is due to the “rolling” nature of tCERs, in which carbon storage may be repeatedly credited in subsequent verification periods, yielding large pools of potential credits in the later, higher-carbon-price years of the project.

²² Although not discussed at length here, there are several options to address intra-period risk should there be a desire to do so. One would be to use shorter crediting periods, so that the opportunity to experience either gains or losses relative to previously-issued credit totals is minimized. This, however, comes at the risk of increasing verification and other transaction costs. Decreasing the length of time that a credit is valid also further depresses its value relative to “permanent” credits. Alternatively, intra-period losses could be backstopped by many of the same mechanisms discussed in “Permanent Crediting” (see Section 3.3.2.2). We do not assess the performance of these approaches in the context of temporary crediting, but lessons learned in the context of permanent credits are nonetheless relevant. Specifically, layering these different approaches is likely to impose additional costs on projects, for example by reducing the credits available for sale (e.g., required buffer contributions) or by increasing out-of-pocket expenditures (e.g., required commercial insurance coverage).

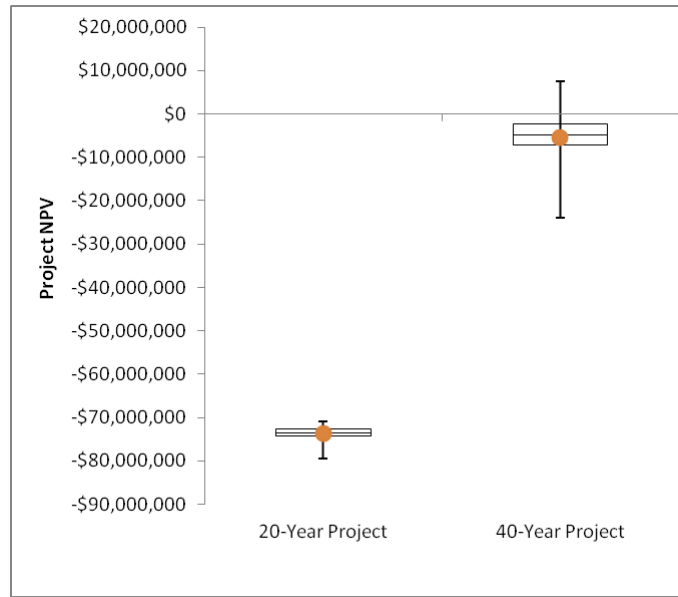


Figure 10. Project NPV for a 20,000 ha project using tCERs and operating for both 20 and 40 years. Both assume that tCERs trade at 10 percent of the value of a full permanent credit. Error bars represent the minimum and maximum value recorded across 50 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean.

3.3.2.1.2. Intentional Reversals

If the A/R project is intentionally terminated after 10 years (as in the case study example presented in Appendix C), it will have only earned 10 years worth of credits – presumably less than planned at project inception – but would not face any replacement requirements other than that required by the designated credit expiry at the end of the commitment or credit period. The project would not, for instance, be required to retroactively cancel the credits earned to date, as they were temporary to begin with and set to expire in Year 10.²³ If the temporary credits are expiring tCERs, the credits are time limited; when that time expires, no further liability for future provision is assumed.

3.3.2.2. Permanent Crediting

Voluntary and nascent compliance markets tend to issue fungible “permanent” credits once carbon storage is verified, typically requiring replacement of credits previously issued for carbon that has been deemed to have been reversed before the end of the period stipulated to fulfill a permanence obligation. These credits can be sold as soon as the carbon is sequestered and credits are issued. But as the credit is issued prior to fully serving its offsetting function, and with no preset expectation of expiration as in the case of temporary credits, legal obligations to replace lost storage and/or specific accounting procedures to facilitate such replacement must be put in place to ensure that system integrity is not affected in the event of reversal. The sections below detail several of the approaches used to address reversals under the issuance of permanent credits.

²³ For simplicity, we assume that the tCERs were set to expire at the end of a five-year commitment period also ending in Year 10.

3.3.2.2.1. Buffer Set Aside

Key Results

- Buffers are generally effective at addressing the unintentional reversals modeled here.
- Project length and withholding rates affect both project net present value and buffer integrity.
- Pooling the buffer through project aggregation can serve to reduce the risk of buffer failure.
- Performance of the buffer in the presence of intentional reversal is dependent on repayment requirements.

The buffer concept is common in the voluntary market. It has also caught hold in the UNFCCC process, as evidenced by recent CMP7 approved modalities and procedures for geological carbon capture and storage (CCS) projects under the CDM (UNFCCC, 2011b). We discuss the applicability of the CCS example to A/R projects in Section 4.

A buffer approach requires that some portion of earned credits be set aside or held in escrow to address non-permanence.²⁴ If a reversal occurs in the context of a buffer approach, credits from the buffer are used to compensate for the credibility of carbon storage relative to the losses. The size of the set aside may vary depending on the inherent riskiness of the activity and the length of time over which the risk is evaluated. For example, an A/R project generating 100 tCO₂e of carbon storage and operating under a 20-percent buffer requirement would receive 80 tCO₂e in credits and place 20 tCO₂e into reserve. A project operating under a higher risk of reversal might face a 40-percent set-aside requirement and place 40 tCO₂e into reserve.²⁵

A primary concern in the use of a buffer system is that the number of pooled credits be large enough to adequately compensate for the reversals that actually occur (e.g., Cooley et al., 2012). Setting the appropriate withholding rate is therefore critically important. If the amount set aside is too small, pooled credits may be insufficient to cover catastrophic losses. The risk assessment stage described above can be an important step in establishing the proper buffer size. Buffers should also be continually replenished or they run the risk of being overdrawn and unable to satisfy subsequent replacement requirements. Simply setting a high set-aside rate is likely to be counterproductive, however, as it raises the effective cost of generating a credit and could discourage program participation. In the end, system-wide rules or guidelines will likely be required to ensure that withholding rates are set at an appropriate level and the resulting buffers are sufficiently capitalized on a consistent basis.

There are several different approaches to buffer pool management. It is possible to establish project-specific buffers, in which individual project activities contribute to their own reserve pool. Alternatively,

²⁴ Conceptually similar to the buffer is discounting; we do not separately assess its performance here. As opposed to a buffer, discount factors permanently eliminate credits from sale. But similar to buffers, discounts do not necessarily guarantee that resolution of the reversals will occur at the system level (for example, if the actual reversals were higher in percentage terms than the discount). This would cast doubt on the integrity of the program if it were allowed to persist. To address this concern, programmatic discounts could change over time as greater certainty enters the market (Schwarze et al., 2002). Buffer withholding rates could likewise change, though decisions would be necessary on the fate of already reserved credits (e.g., are they to be refunded or do reduced rates apply only to new contributions).

²⁵ These buffer rates are similar to what would be expected for a “medium risk class” AR project operating under the VCS. “Voluntary Carbon Standard - Tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination (VCS 2007.1, 2008).” VCS Association. Available at: www.v-c-s.org. Alternatively, a higher risk project could be disallowed entirely, depending on if/how exceptions or exclusions are applied (See Section 3.1, Screening for Reversal Risk: Concepts and Criteria).

program- or system-wide buffers may be established, with all project activities contributing to a common pool. Some portion of reserve credits may be returned to projects that have not experienced a reversal over some period of time, or they may be forfeited at the time of escrow. Should an activity experience a reversal and tap into the reserve buffer, it may or may not be required that used buffer credits be replaced. In the analysis below, we assume that no unused credits are returned to the project, and that projects are not required to replace used buffer credits.

3.3.2.2.1.1. *Unintentional Reversals*

The ability of a buffer system to perform effectively depends on its ability to be appropriately capitalized to cover potential liability from replacing reversed credits. In other words, the buffer should maintain a non-negative balance. Our analysis of unintentional reversals from fire and wind shows that 20-year projects tend to achieve this coverage using a 10-percent withholding rate, yielding positive buffer balances at the conclusion of the project (Figure 11). Over 40 years, the buffer is positive in most iterations; occasionally, however, it ends in deficit. We attribute this to two general causes. The first is that forest growth in these modeled forest stands begins to slow over time. In the early years of the project, forest growth is quite aggressive and losses encountered on one part of the project are compensated for or even outpaced by continued growth elsewhere. Although the project may generate fewer credits as a result of the event, fewer credits are actually lost. A second cause pertains to fuel buildup in forested stands over time. As fuel accumulates on the stand in the form of downed material and dead wood, there is a larger risk of more intense events occurring. The example is therefore illustrative, but one could expect different assumptions regarding forest growth and disturbance regimes to yield different results.

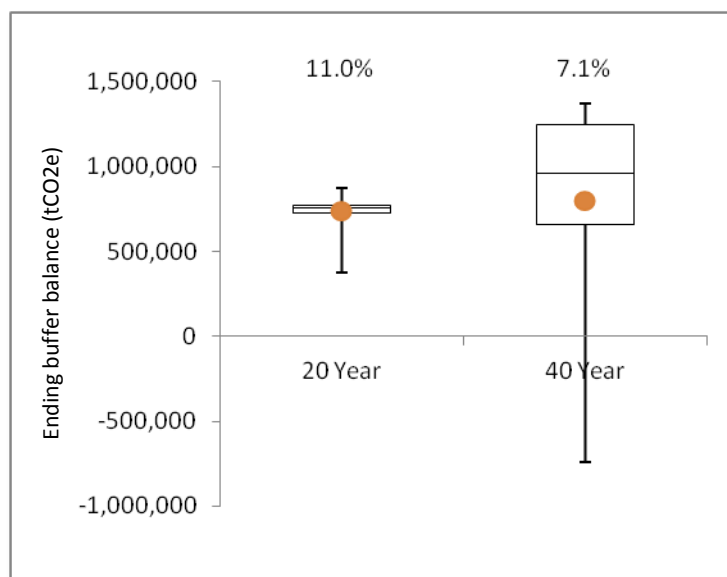


Figure 11. Ending buffer balance, assuming a 10-percent withholding rate in 20,000 ha projects at the conclusion of 20-year and 40-year projects. Mean buffer balance as a percentage of total credits earned is indicated above in each example. Error bars represent the minimum and maximum value recorded across 50 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean.

Our analysis produces results that show a greater likelihood of more intense events later in the project. If an event does occur, carbon losses are less likely to be compensated for by growth elsewhere on the project, thereby resulting in a net carbon reduction (which defines a reversal). As a result, longer project periods tend to have more scenarios end in negative buffer balances, even though the mean buffer balance across project lengths is roughly the same. This means that there is a greater spread between

the best and worst performing projects over time. Increasing buffer withholding rates can reduce or eliminate instances of negative buffers in the scenarios modeled here, but this comes at a financial cost to the project and fails to address the increasing spread between project outcomes (See “Appendix F: Expanded Output and Sensitivity Analysis, Buffer Set Aside”).

Assuming a 10-percent buffer, project NPVs are positive for both the 20- and 40-year 20,000 ha project examples (Figure 12). As would be expected, longer projects tend to have higher NPVs, as more credits are earned and sold over time. Manipulation of buffer withholding rates does affect project NPV – higher withholding rates result in lower NPVs because fewer credits are available for sale by the project.²⁶

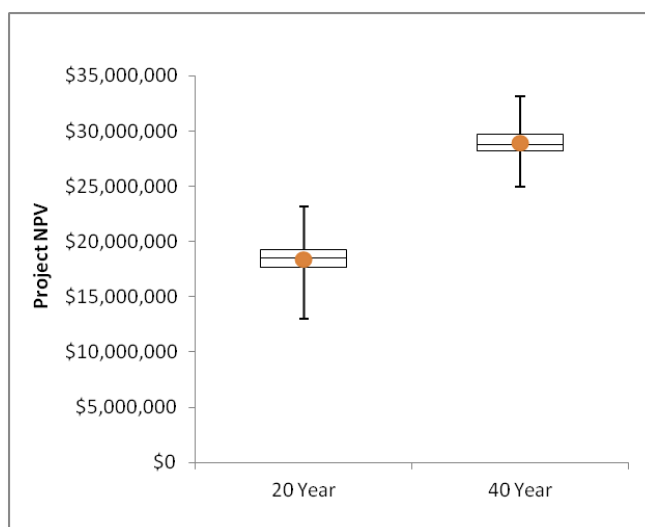


Figure 12. Project NPV for a 10-percent buffer in 20,000 ha projects at the conclusion of 20-year and 40-year projects. Error bars represent the minimum and maximum value recorded across 50 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean.

The buffer requirements described above can also be imposed on all projects and the retained credits deposited in a master buffer account pooled across all projects. This means that the replacement requirements of individual projects due to reversal can be covered by the buffer holdings of the broader pool of projects, most of which will experience no reversal during that period. This can be seen, for example, in Figure 13, where one can follow the balance of a 10-percent buffer in 20 different 1,000 ha projects that commence over a 10-year period of time.²⁷ While some buffers collapse due to significant reversals, others continue to increase throughout the project life. As a whole, the vast majority of times the buffer remains positive.

²⁶ Though the magnitudes are obviously different between results generated by 1,000 ha and 20,000 ha project sizes, the trends are similar. 1,000 ha projects tend to perform poorer financially due in part to economies of scale with regard to transaction and implementation costs. See “Appendix F: Expanded Output and Sensitivity Analysis, Buffer Set Aside.”

²⁷ Note the staggered start, as not all projects begin simultaneously. Rather, project starting year is randomly assigned between year 1 and 10 for each project within our portfolio analysis. This is done to approximate what would likely be experienced in reality – that a given portfolio would include a mix of new and established projects.

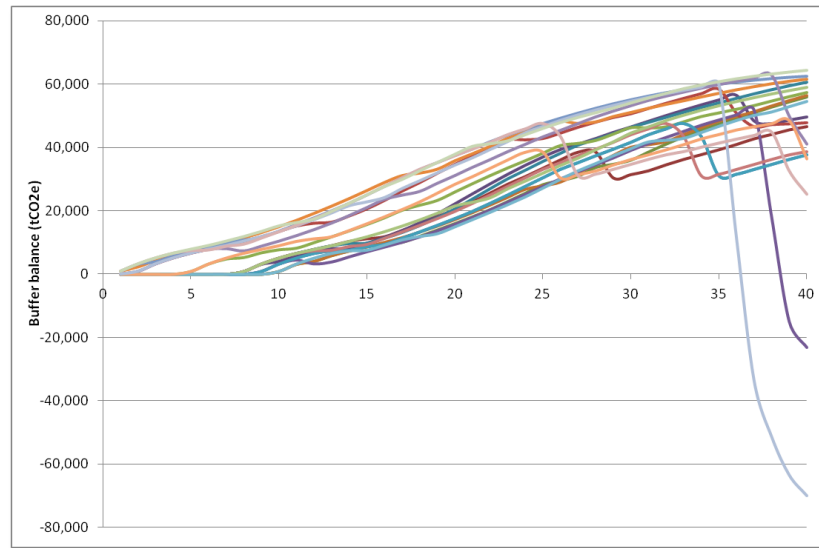


Figure 13. Balance of a 10-percent buffer in 20 randomly selected 1,000 ha project iterations. Project starting year, from 1 to 10, is randomly assigned.

Buffer robustness can also be enhanced through risk pooling. Assuming that the same 20 different project iterations were part of a single portfolio, one can compare the outcome to single project examples to assess whether such aggregation helps to reduce exposure to the catastrophic loss experienced in the purple and lavender lines in Figure 13. This comparison is seen in Figure 14, which shows the ending buffer balance for a 10-percent buffer after 40 years for both 50 iterations of a 20,000 ha project and 50 different portfolio configurations made up of 20 randomly selected 1,000 ha projects.²⁸ While the individual projects sometimes experience negative buffers, no portfolios do. The key to making such a system work is ensuring that the collective buffer withholdings are sufficient in size to cover the aggregate risk of the pool. This is more likely to occur if the pooled buffer system is large relative to the individual projects within and is geographically diversified to minimize common risks across the pool (e.g., extremely widespread wildfires, wind damage, or pest outbreaks).

²⁸ Note that the projects comprising the portfolio are not contiguous. Rather, one 1,000 ha parcel is selected at random from within a larger 20,000 ha run.

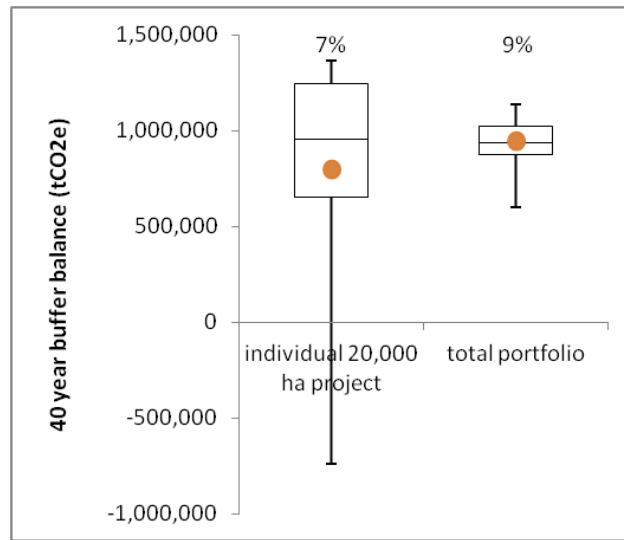


Figure 14. Buffer balance for single 20,000 ha projects and the 20,000 ha portfolio comprising 20 1,000 ha projects. Percentage in above figure indicates the mean loss as compared to total credits earned by the project. Error bars represent the minimum and maximum value recorded across 50 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean.

3.3.2.2.1.2. Intentional Reversals

The performance of buffers in the presence of intentional reversals depends entirely on whether the buffer is called upon to supply the intentionally reversed credits. Figure 15 illustrates some options for handling intentional reversals under a buffer approach and the implications for the integrity of offsets under different outcomes. The figure illustrates two policy options for handling intentional reversals with a buffer:

1. Do the rules allow the buffer to replace credits from intentional reversals? If not,
2. Do the rules require the project to replace the credits?

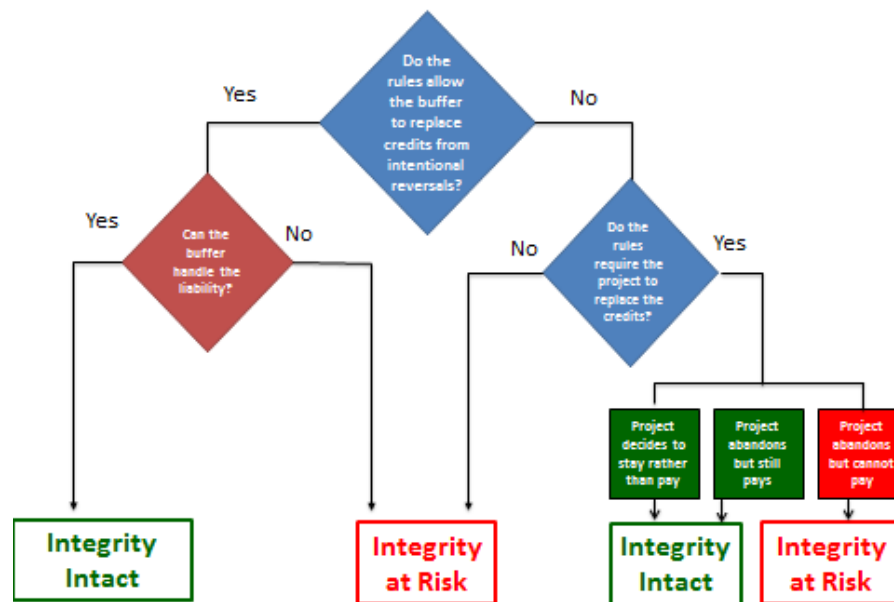


Figure 15. Options for buffer handling intentional reversals, potential outcomes, and consequences for offset integrity.

The success of the first option depends in large part on whether the buffer can cover the risk imposed on it by replacing reversals from intentional actions.

Figure 16 shows the cumulative distribution of results for the ending buffer balance for 1,000 random draws from a risk distribution calculated from historical fire data in Chile under a scenario in which no intentional reversal occurs and one in which one-third of the projects are assumed to be abandoned over the course of the project.²⁹ We assume for these purposes that abandonment means all previously credited carbon is reversed. In this context, “cumulative” means we rank-ordered ending buffer size for each scenario from smallest to largest. The vertical axis indicates the percentage of the draws that are at or below the value indicated on the horizontal axis. This allowed us, for example, to assess the probability that the ending buffer goes negative (overdrawn) over 1,000 random observations of the two scenarios. Here, the red line shows the performance of a buffer operating in the absence of intentional reversal. The blue line shows the scenario in which one-third of the projects are intentionally abandoned and all affected project lands cleared after 10 years. Together, they show that a significant incidence of project abandonment can in itself compromise the integrity of an otherwise robust buffer. In other words, the buffer would fail to protect against offset integrity in cases where there is a voluntary “run” on the buffer, much like a commercial bank’s finite reserves could not withstand a run on the bank.

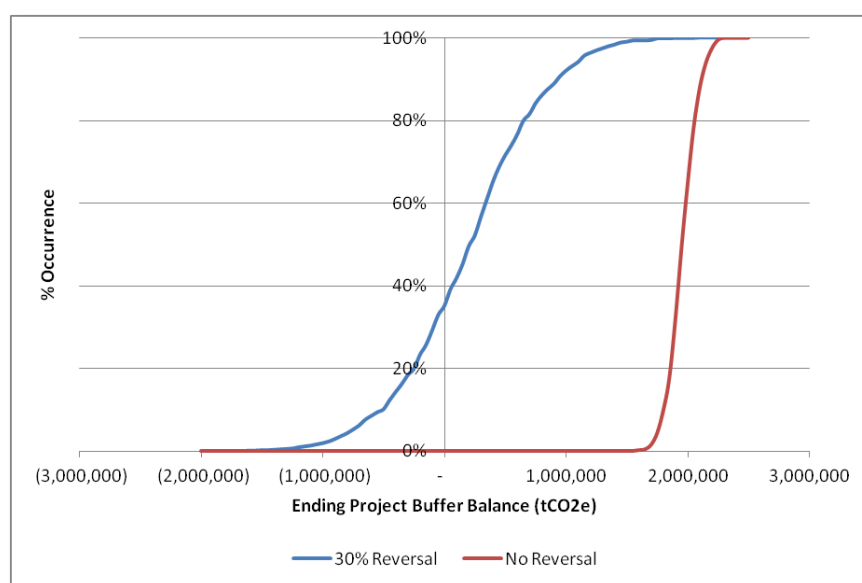


Figure 16. Ending buffer balance for two 20-project portfolio configurations under threat of intentional reversal and natural disturbance. Natural disturbance is based on distributions calculated from historical fire data in Chile. “30-Percent Reversal” assumes that roughly one-third of the projects available to the portfolio are abandoned after 10 years. “No Reversal” still subjects the project to random fire events, but assumes that all projects last the full project length. The figure is expressed as a cumulative distribution, meaning that results are rank-ordered from smallest to largest. The vertical axis indicates the percentage of the model runs that are at or below the value indicated on the horizontal axis.

Note that the example in Figure 16 treats abandonment as exogenous. Rules that would allow projects to abandon the carbon and shift the replacement requirement on the buffer, however, would induce very strong incentives for abandonment, particularly toward the end of the project when carbon growth

²⁹ See “Appendix B: Unintentional Reversal Assessment Methodology, Empirical Disturbance Analysis - Chilean Historical Fire Data Overview” for more discussion of data and methods.

and further crediting potential slows. Thus one should consider the possibility of rules that do not allow the buffer to handle intentional reversals. One possibility is that the rules not establish any further liability beyond the buffer; in this case, the offset integrity problem remains. Rules could be established, however, so that the intentional reversals become the full responsibility of the project party, who must replace them upon the decision to abandon the project. Under these rules, one can envision three possible outcomes:

- i. The party opts not to abandon the project because the liability associated with doing so outweighs any financial advantages. The carbon and offset integrity remains intact.
- ii. The party opts to abandon the project because the financial advantage of doing so still outweighs the replacement liability. The carbon is lost, but is replaced with other credits, maintaining the integrity of the offset system.
- iii. The party is unable to continue the project or pay to replace the reversed carbon. Without any further recourse for replacement, the carbon is at risk – as is the offset system integrity.

In order to avoid the last scenario and the corresponding loss of offset integrity, rules could be established at the outset of the project that require parties to establish a financial guarantee, performance bond, or some other form of collateral to ensure that replacement credits can be purchased in the event of project abandonment. This is not dissimilar to the way that financial markets handle default risks; the same principles could be applied here. We do recognize, however, that imposing strict liability at the project level may be difficult in CDM settings, so other parties (e.g., insurance companies, host country governments) may need to further back these risks. One could also consider the possibility that the buffer be used to cover the third scenario, so long as the project is abandoned purely by its inability to continue financially and the project holder's demonstrated inability to pay (e.g., insolvency), rather than simply a preference not to continue. Some buffers such as those in the CAR and VCS systems are structured this way. We have not, however, explicitly considered the random risks of insolvent default here, only an aggregate loss from what could be assumed to be a variety of causes.

3.3.2.2.2. Private Insurance

Key Results

- Insurance transfers liability for loss to a third-party; as such, it is unlikely to cover intentional reversals.
- Analysis of sample full value coverage options shows positive net present values for all projects assessed.
- Insurance products are available to address specific types and magnitudes of losses, with financial and GHG performance varying under each.

Another way to address the potential loss of permanent credits is through commercial insurance. Private insurance for carbon markets and policy regimes functions in much the same as it does in personal and commodity markets. Regular payments, or premiums, are paid to some insuring entity, which in turn guarantees the permanence of credits generated by the covered activity (e.g., by replacing reversed credits). In the event of loss, the project will likely be required to first pay a deductible. As opposed to buffers, which require that some number of credits be set aside up front, the deductible is an “if and when” call that is only required upon reversal.

Carbon insurance products are presently rare, but analogs exist in other forest and agriculture applications. When it is available, a primary benefit of insurance is that it is simple and straightforward

to implement. So long as the insured pays its premiums and complies with the terms of its policy, the value of any credits lost to non-permanence should be covered. In order for the insurance to be effective, the insuring entity must be appropriately capitalized to withstand catastrophic loss.

The pooled buffering system described above is a form of collective insurance, which might be handled more effectively by specialized insurance firms that assess the underlying risks and charge customer premiums. Voluntary programs such as VCS will allow project proponents to forgo the buffering requirement if they procure an approved commercial insurance product for the individual project or program. While such commercial products are still rare, insurance may conceivably be used as a supplemental approach to address reversals.³⁰

In the case of individual projects, insurance can be used to supplement a buffer system; it is especially useful in the early years of project establishment. In this role, insurance can act as a backstop against early-year reversals that would otherwise overwhelm a poorly capitalized buffer pool. Insurance can also be used to augment the buffer in more mature projects, thus allowing for a lower level of buffer contributions to be made by the project developer. At the system level, insurance can be used to provide additional protection to a pooled buffer by “topping off” the buffer in situations of extreme loss.

We explore three insurance options below: project full value replacement, catastrophic loss limit, and buffer insurance. Project full value guarantees replacement of all losses from a project due to a variety of disturbances. Catastrophic loss limit covers up to the amount expected to be lost in a rare, catastrophic disturbance event (e.g., a 1-in-250 year event). Buffer insurance, meanwhile, guarantees capitalization up to a certain threshold of a given buffer (e.g., 85 percent of initial buffer volume), providing a commercial insurance backstop against excessive buffer depletion.

Premiums and deductibles for project full value and buffer insurance are estimated from the mean annual loss for each of the 40 years across the 50 reiterations of the 20,000 ha project example. In this respect, the data and assumptions represent a simplified midpoint analysis. There is a strong likelihood that single policies would not be written for the duration of a project. Rather, policies would likely be written for much shorter durations (e.g., annually), with new premiums and deductibles estimated upon renewal.

3.3.2.2.2.1. Insuring Unintentional Reversals

We begin our assessment with a detailed look at full value insurance. Figure 17 shows the NPV of two 20,000 ha projects, one 20 years in length, the other 40 years long. Both projects generate positive NPVs and, as with other approaches, the longer project performs better financially.³¹ Performance of insurance, however, declines relative to other approaches over longer periods of time. The reason for this is twofold. One is that, as discussed above, reversals become more common as project length increases—and increased reversals require additional out-of-pocket expenditures to cover deductibles. A second reason is that carbon price continues to increase over time, and that both deductibles and

³⁰ See “Appendix D: Insurance for Forestry Projects - Approach and Key Terms” for further information on commercial forest carbon insurance products. Although functionally different than traditional insurance products, ACR presently offers a risk mitigation tool that attempts to fill a similar role (<http://www.carbonreductioncorporation.com/>; last accessed October 31, 2012).

³¹ Similar trends are seen in 1,000 ha project examples. See “Appendix F: Expanded Output and Sensitivity Analysis, Commercial Insurance.”

premiums are calculated and expressed in units of tCO₂e.³² The cash value of the tonnes therefore increases as the carbon price increases, meaning that late-year premiums and deductibles will be more expensive relative to early-year ones. Our use of a project midpoint to assess insurance pricing obviously influences these findings, but the extent to which it drives the results is unclear. Although the magnitude of the results may change under different assumptions, we expect the relative performance of 20- and 40-year projects to be similar if not more pronounced; basing payments on mean storage “penalizes” early, low-carbon storage years and “subsidizes” later ones.

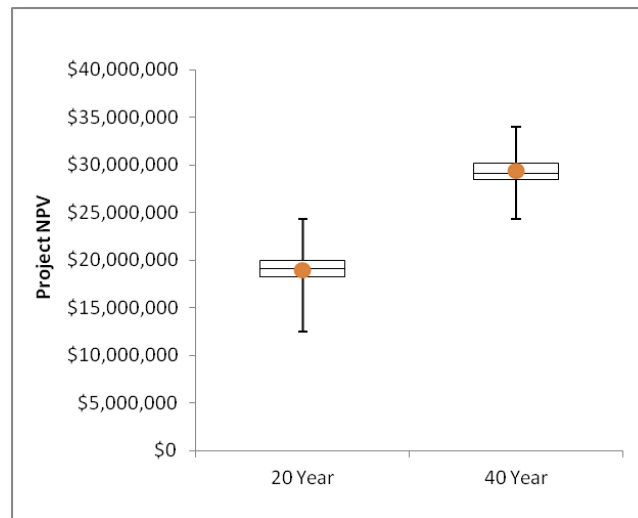


Figure 17. Project NPV for a 20,000 ha project assuming full value option insurance coverage, over 20- and 40-year project lives. Error bars represent the minimum and maximum value recorded across 50 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean.

Comparing full value insurance with other insurance products, we see a great deal of variation with regard to both project financial performance and net GHG reduction (Figure 18). Buffer insurance is modeled on the far left, and shows the effect of a 10-percent buffer supplemented by an insurance product which prevents the buffer from falling below 85 percent of its starting value in any given year. Such a product is perhaps better characterized as a buffer “top-off” rather than insurance against buffer failure. Although a “top-off” implicitly insures that a buffer never fails, it may overprotect or overcapitalize a buffer.³³ Our modeling resulted in so few years of buffer failure that pricing a product that simply insures against collapse was not possible using standard techniques. So, while conservative, it provides a rough indication of the expected effects of using such a combined approach.

³² We calculate project NPV based on the cash equivalent of the premium and deductible, but it is also possible to trade in tonnes themselves. The latter approach would also serve as a hedge against carbon price increases.

³³ Alternatively, such an approach could represent a situation in which the buffer is not intended to address natural disturbance loss, but rather other “uninsurable” losses due to intentional reversals. In this case, insurance would seek only to address the incremental natural disturbance events that would otherwise deplete the buffer over time.

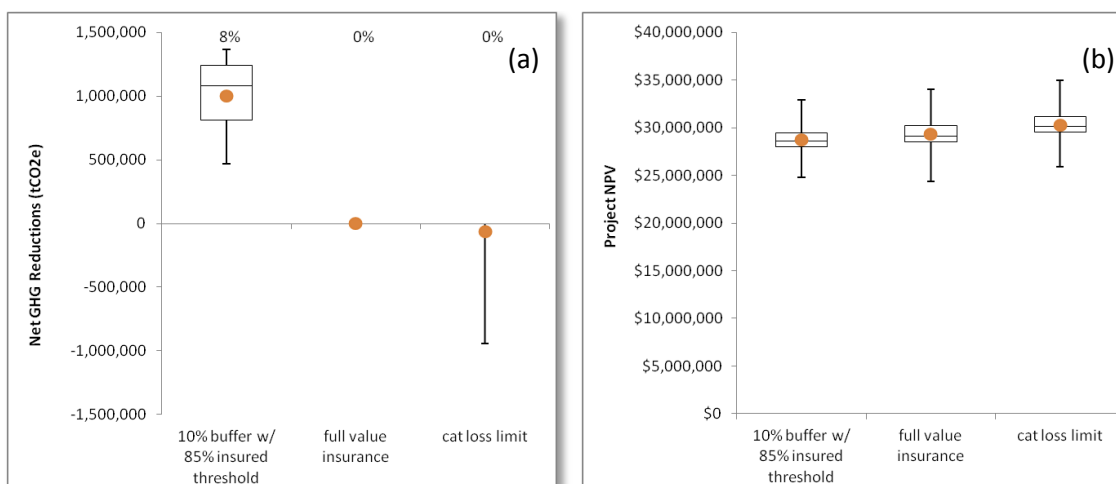


Figure 18. Comparison of multiple insurance product effects on (a) net GHG reduction and atmospheric integrity and (b) project financial performance. All projects are 40 years in length and 20,000 ha in size. Percentages above the GHG reduction figures indicate net reductions relative to total credits earned. Error bars represent the minimum and maximum value recorded across 50 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean.

Full value insurance performs somewhat better financially than the buffer+insurance approach. As all losses are covered as they incur, there is no residual storage or loss associated with this approach. Compare this to the catastrophic loss limit (“cat loss”) example on the right, in which only losses below some threshold are covered (e.g., those encountered in a 1-in-250 year event). In this situation, there are some losses associated with the scenario as a handful of disturbance events modeled here actually exceeded the mean calculated loss limit. We modeled these as losses recorded by the system (i.e., no one is responsible for picking up the residual loss). In reality, it is likely that some individual or entity would be responsible for backstopping the loss (e.g., a host country). But as the catastrophic loss product covers fewer losses, it is a less-expensive product than the full value option and therefore results in a marginally higher project NPV.

3.3.2.2.2. *Insuring Intentional Reversals*

Insurance is generally unavailable to cover intentional reversals by the insured party due to the voluntary nature of the underlying cause of loss. Thus, one of the other mechanisms for covering loss from intentional reversals discussed in this report would need to supplement any insurance that handles unintentional risks.

3.3.2.2.3. *Host Government Guarantee*

An alternative strategy for addressing reversals is to enlist the assistance of a host country entity or other third party to guarantee or otherwise backstop project performance. The host country guarantee approach builds off recent proposals to address residual liability for CCS activities under the CDM (UNFCCC, 2011b), in which the host country acts as a fiduciary backstop to address reversals unresolved at the project or sub-national level.³⁴ Under this model, a given country (or their designated third party) can choose to assume liability for any losses over and above the provisions made for covering losses (such as a buffer) at the project or sub-national program levels. The economic viability of such an approach depends on the relationship between the monetary value of expected losses and host country or third-party willingness and ability to devote the necessary resources to cover them.

³⁴ Precedent also exists under the Joint Implementation (JI) mechanism, in which project losses must be balanced against a given country’s national account.

This approach is similar to loan guarantee programs issued by governments.³⁵ Current products offered by the World Bank could likewise facilitate host country guarantees for sequestered carbon or provide a model for how they could work. The International Finance Corporation within the World Bank currently offers a carbon delivery guarantee. Other products, traditionally targeted to infrastructure development, could be made to work in a carbon context as well.³⁶ For example, Partial Risk Guarantees (PRG) protects private-sector actors against government non-performance of contracts. By reducing risk to private parties, the PRG serves to facilitate investment. In a carbon context, one could envision such a product being directly applicable to reversal losses and buffer underperformance; rather than the PRG applying to infrastructure or other development projects as it traditionally would, a carbon-focused product could augment a host country's ability to backstop carbon losses. A Partial Credit Guarantee (PCG), meanwhile, could support borrowing and investment by reducing risks to commercial lenders, thus facilitating the use of commercial debt for development (e.g., budgetary, infrastructure) purposes. PCG products would help to facilitate carbon project development at the front end by helping to reduce barriers to commercial financing. In particular, they could facilitate host country backstop capabilities by expanding the financing options available to fully capitalize against catastrophic losses.

Host country guarantees allow otherwise nonmarketable projects to be marketed at lower risk to the buyer, thereby increasing the volume of carbon credits for sale. The host country could realize actuarial benefits by holding a diverse array of projects, thus minimizing risk as a whole while maximizing its sovereign carbon mitigation potential. Abuse of the guarantee system, however, could lead to unrealized carbon benefits. For example, one country may have an incentive to guarantee an excessive amount of high-risk projects. If those projects fail, and the country had not anticipated the financial implications of a systemic failure, a lack of funds could prevent the country from realizing its guarantee. To prevent such abuse, terms and conditions could be developed and incorporated into guidance or regulation that clearly defines the structure of permissible guarantees.

3.3.2.2.4. Performance Bond

We assume that each of the approaches assessed above is accompanied by a legal obligation to replace credits lost to reversal. It is also possible to have a replacement obligation in the absence of any formal mechanism (i.e., no buffer contribution/commercial insurance coverage requirement). With no mechanism facilitating credit payback, however, protections must be put into place to ensure that affected projects have the financial resources to compensate for lost storage. One potential way to do this is to require a project to establish a performance bond or some other form of collateral.

3.3.3. Comparing Approaches

This section briefly compares the accounting approaches in terms of their ability to deal with unintentional and intentional reversals.

3.3.3.1. Unintentional Reversals

It is difficult to directly compare the ability of the various approaches to guard against unintentional reversals because each approach is doing something different to achieve a similar goal, ensuring that offset integrity holds. For example, tonne year guards against impermanence by incrementally awarding credits in line with the atmospheric benefit they achieve. Temporary credits award full quantity, but

³⁵ Or, more basically, a co-signer on a contract.

³⁶ Summarized from World Bank Guarantee Program for the Consultation of "Modernizing the World Bank's Operational Policy on Guarantees." January 2012.

assume that credits expire sometime in the near future. Buffers work by requiring that projects set aside some portion of full-quantity credits into an escrow account. Insurance, meanwhile, works by transferring the liability to a third-party entity which agrees to replace lost credits in exchange for regularly paid premiums and upon-loss deductibles.

Different approaches can be compared from a financial perspective (Figure 19). Under our chosen set of price assumptions, tCERs perform poorly relative to other approaches, but tend to improve performance over longer periods of time. Buffer and insurance are comparable for both project lengths, whereas tonne year performs substantially better in a longer project. Note that each approach will affect a project's bottom line in a different way or through a different mechanism. Tonne year awards only a fraction of credits to a project in any given year. Temporary credits must be replaced in time, and so trade at a heavy price discount. Buffers require that a portion of credits be held back from sale. Insurance requires payment of a premium and a deductible, but the latter is only required in the event of an actual loss. Regardless of the mechanism, the effect of each approach is ultimately reflected in a project's NPV, allowing for comparison among them.

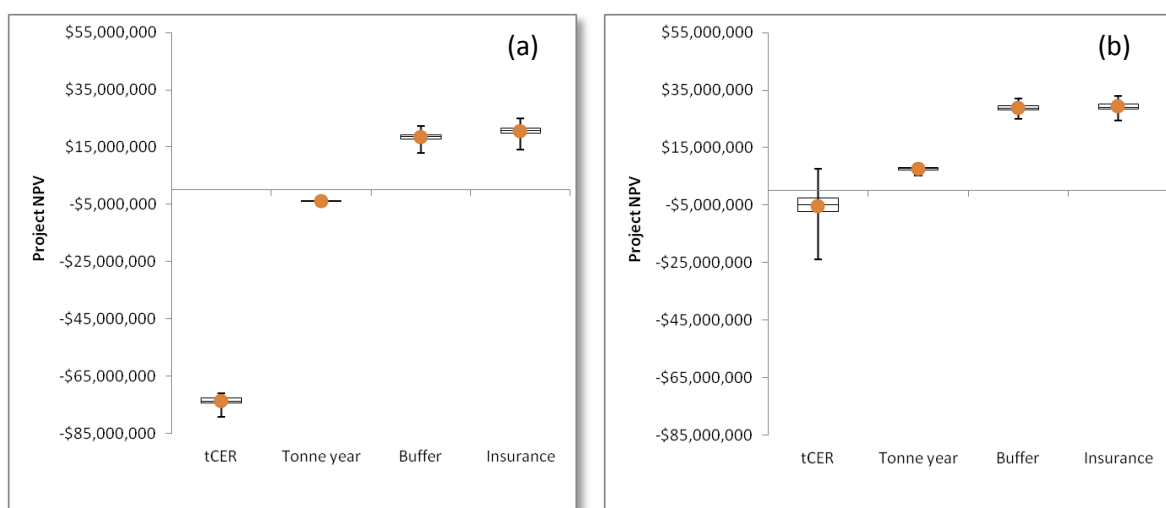


Figure 19. Comparison of financial performance of four permanence approaches, tCER, Tonne Year, Buffer, and Commercial Insurance for (a) 20-year and (b) 40-year projects. tCER assumes that tCERs trade at 10 percent of the value of a full permanent credit. Tonne year assumes a 40 year permanence period, Buffer assumes a 10-percent buffer, and Insurance assumes full value coverage. Error bars represent the minimum and maximum value recorded across 50 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean.

3.3.3.2. Intentional Reversals

Table 5 compares various approaches and how they address intentional reversals. Depending on how they are structured, temporary credits or approaches that incrementally defer issuance of permanent credits until permanence has been demonstrated (tonne year) can be protective of offset integrity – but achieve this at a cost of lower returns. Higher returns are possible (though not guaranteed) when permanent credits are issued upon verification and set aside provisionally in a buffer; how the buffer performs depends on whether it actually covers intentional reversals (the pros and cons of which are discussed above). The buffer could, in principle, cover intentional reversals and thereby maintain offset integrity, but this creates incentive problems that could undermine the buffer's ability to cover losses. These problems include *moral hazard*, wherein project parties are not sufficiently dissuaded from creating intentional reversals due to lack of financial penalty, and *adverse selection*, wherein parties who are more inclined to engage in intentional reversals are the parties more drawn to a buffer approach (if many options are available, as discussed elsewhere), thereby imposing risk costs on others less inclined

to creating the risk and undermining the stability of the buffer. These two incentive problems are the main reason why commercial insurance parties will not cover intentional reversals in products they offer. A similar argument could be made persuasively in the case of buffers, which would suggest disallowing any truly intentional reversal from systematic coverage in a buffer – with the possible exception of cases of project default, where projects operating in good faith nonetheless become insolvent or otherwise financially unable to continue with the project. An adequately capitalized buffer and some further back-up of the buffer (e.g., through host country guarantees) could be considered in these cases, with some precedent to draw upon.

Table 5. Comparing Accounting Approaches on Addressing Intentional Reversals.

	Effectiveness in Addressing Intentional Reversals	Relative Effect on Project Financial Returns
Temporary Crediting	Effective for addressing reversals after credits expire; less so for reversals within verification period and before expiry (for tCERs); requires repayment for intra-period loss (for ICERs)	Low
Tonne Year	Potentially effective, depending on frequency of verification and the tonne year crediting rate's reflection of permanent storage	Low-medium, depending on stipulated permanence period
Buffer		
• Covers intentional reversals	Variable, depends on degree of abandonment and project default risk and extent of coverage.	High/Variable, depends on size of buffer
• Does not cover intentional reversals (projects pay)	High, unless abandoned projects cannot pay to replace (default) and no back-up replacement plan exists	Variable, depends on size of reversal that must be paid by project party and whether there is further backing in case party cannot pay replacement credits
Commercial Insurance	Will generally not cover intentional risks (see row above)	Will generally not cover intentional risks (see row above)

In reality, A/R projects face simultaneous threats from both intentional and unintentional reversals. The practical effect of both can be seen in Figure 20. Here we see the net GHG consequences of intentional reversal in the presence of unintentional wildfire and wind losses. Specifically considered are buffers of different sizes and full value insurance. In the case of full value insurance, losses stemming from A/R project abandonment are completely uncovered. Losses in the buffer examples are net of any buffer set-aside. In each case, the project party is assumed *not to be liable for intentional loss*. This is done for the express purpose of highlighting the ability of each mechanism to handle combined intentional and unintentional losses in and of themselves.³⁷

³⁷ Recall that our quantitative analysis of permanent crediting approaches above specifically assumes a legal obligation to replace lost credits.

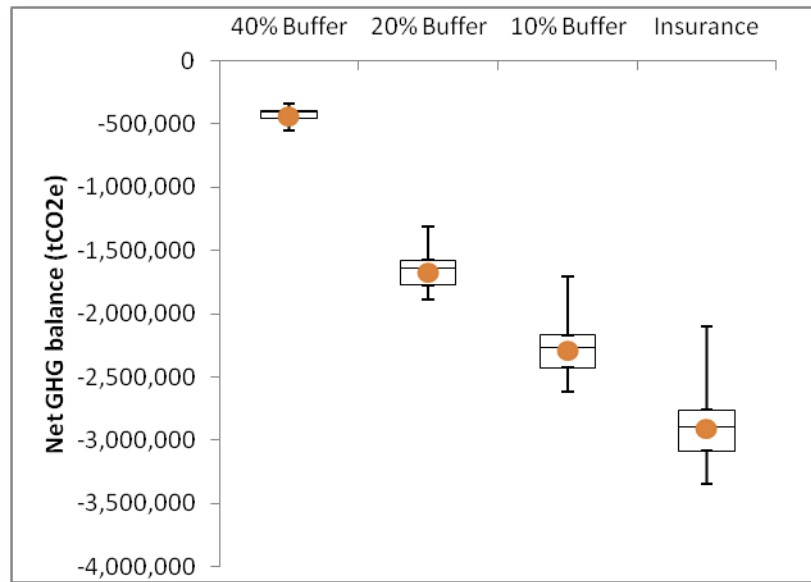


Figure 20. Net GHG balance under multiple policy approaches in the presence of unintentional fire and wind loss and following 20,000 ha project price-shock induced abandonment in year 10 with no credit payback required. Error bars represent the minimum and maximum value recorded across 50 model iterations. The box plot indicates 3rd quartile, median, and 1st quartile values, while the orange circle represents the mean.

As should quickly become apparent, significant risks to atmospheric integrity exist in the absence of payback requirements. This implies that, in the failure or inability to guarantee that the project holder replaces all proceeds in the event of intentional reversal, some other provision (e.g., performance bonds or other guarantees) may be necessary. This, however, creates risks for the program if the incidence of reversal is high (see Figure 16). The absolute effects of such reversal at the national or programmatic level will depend on the rate of project failure due to both types of reversals. Our analysis includes estimates of fire and wind loss, but the rate of intentional reversal remains unknown and is itself directly affected by the rules established to govern situations of project abandonment. The example in Figure 20 shows that, if and when intentional reversals do occur, significant project-level losses can occur unless properly addressed and accounted for.

In closing this discussion, we must not confuse the issue of offset integrity with the issue of recourse. Integrity deals with the issue of whether the rules have been set to best ensure that the atmospheric objectives are met. The rules may include requiring parties to replace any intentional reversals. Recourse is tied to the consequences of generating these intentional reversals (e.g., the party must pay (or not) to replace). Strong recourse terms can bolster system integrity, but will depend on the extent to which these rules can actually be enforced. Recourse and its enforcement is an important factor in risk assessment and countries with weak legal systems will need to compensate by setting up different mechanisms to address the risk that they cannot enforce their laws.

3.3.3.3. Combination of Approaches

Program rules could be set up in to combine features of the different accounting approaches discussed above into one system. Options could include:

- Temporary crediting with only partial replacement at expiry, based on interim permanence achieved via the tonne year principles.

- Programmatic buffer backed by commercial insurance should the buffer fail (example provided above).
- Programmatic buffer backed by host country guarantee (see example below).

Alternatively, a menu-based system could be set up to allow entities the flexibility to choose among approaches; the menu-based approach could also be useful given different country's capacities for guarantees. Owing to unique project circumstances, some projects could choose to generate temporary credits; others may opt for a tonne year crediting approach. Some of these options have lower initial financial returns, but they reduce obligations for long-term commitment and thus might suit some project participants better as such provisions would allow them to more easily opt out should circumstances warrant. Other project participants may be more willing to commit to longer time periods and opt to generate permanent credits upon verification, but also accept the responsibilities associated with replacement under different options presented to them – system buffer or commercial insurance (if available), possibly backed up by a financial guarantee on the part of the project participants or some other third party. In allowing entities to choose their preferred approach, however, care must be taken to avoid issues of adverse selection. This could occur, for example, if high-risk projects, unable to secure coverage or competitive rates for private insurance, turn instead to a managed buffer system. In such a case, the composition of the resulting buffer would be skewed by contributions from these higher-risk projects, making it more likely to be drawn upon and, therefore, more prone to failure.

4. Application of Modalities for Reversal Risks for Geological Carbon Capture and Storage (CCS) under the CDM in the Context of A/R

CCS projects also run the risk of non-permanence, through seepage or pulse release of CO₂ stored in geological formations by the project. The modalities and procedures for geological CCS projects under the CDM addresses this reversal risk through a monitoring period, buffer mechanism, supplanted by provisions for a government guarantee either by the host country or, in lieu of a host country guarantee, buyer (Annex I) country replacement liability (UNFCCC 2011b). This might be a model for A/R CDM as well, although further analysis is required. Table 6 highlights the key features of the CCS modalities and assesses their potential applicability to A/R.

The CCS modalities propose a universal buffer withholding rate of 5%. It needs to be assessed if this would be applicable for A/R CDM or if A/R may require buffer withholding rates customized to the risk profile of the projects. The empirical analysis in this report suggests that the appropriate buffer size necessary to handle reversals likely depends on the local risk factors, rather than a single universal size proposed for CCS. A key difference between CCS and A/R in this regard is the role of intentional reversal. With CCS, it is hard to envision incentives that would drive one to intentionally release stored CO₂, whereas A/R projects face potentially significant opportunity costs in the form of revenues from timber harvest, agricultural production, etc., that could vary both spatially and temporally. In light of these variable risks, guidelines could be developed to advise necessary buffer thresholds, perhaps taking into account the project-level risk assessment process currently in place under existing standards or other similar procedures.

Table 6. CCS Reversal Management Modalities Under CDM and Potential Applicability to A/R.

CCS Reversal Management Modalities Under CDM	Potential Applicability to A/R
Place 5% of credits in a reserve account (buffer)	Risks with A/R may require buffer withholding rates, customized to the risk profile of A/R projects.
Permanence attained after 20-year monitoring period	While CCS reversal risks may diminish over time as below-ground CO ₂ stabilizes. For A/R projects, terrestrial reversal risks may increase as the biomass of above-ground pool increases. Monitoring periods for forests are typically longer than 20 years.
Host country guarantee of reversals in excess of the reserve (optional) or Annex I country responsibility for reversals if host country does not guarantee	Host or Annex I country guarantee may be feasible if countries assess risks, their capacity for backing risks, and determine type of guarantee to back the project. Credits sold from non-guaranteed countries may trade at a risk-adjusted discount.
Pool reserve across multiple projects (under consideration)	Risk analysis above suggests that the risk diversification by pooling credit reserves of projects may make them collectively more resilient than managing them separately.

The modalities and procedures for CCS also note that permanence is attained after a 20-year monitoring period. This may make more sense for below-ground geological storage of CO₂, if the deposits stabilize over time, a matter of some scientific uncertainty. But it is not necessarily the case that above-ground forest carbon becomes less risk-prone over time. Monitoring periods for forests are typically longer than 20 years as the biomass of above-ground pool still increases and remains at risk. Indeed the analysis above suggests that risks typically grow with age.

A Host or Annex I country guarantee may be feasible if countries assess risks and determine the type of guarantee required to back the project. Moreover, there are several institutional support arrangements to help countries address project risk within countries that may provide a foundation for these host country guarantees.

5. Policy Decisions for Parties and Stakeholder Implications

This report was motivated by *the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol, (CMP)* calling for:

the Subsidiary Body for Scientific and Technological Advice to initiate a work programme to consider and, as appropriate, develop and recommend modalities and procedures for alternative approaches to addressing the risk of non-permanence under the Clean Development Mechanism with a view to forwarding a draft decision on this matter to the Conference of the Parties ... (UNFCCC, 2011a)

The report introduces several issues the Parties and SBSTA might consider in developing its draft decision. The issues raised for consideration are presented below. The analysis in the report provides some insights into the relative merits of different approaches. This section delineates the issues Parties may wish to consider in their deliberations on alternative approaches to addressing non-permanence.

5.1. Issues for Consideration

The analysis in this report highlights a number of policy issues for consideration.

5.1.1. Risk Screening

The requirement for risk screening (by projects or, perhaps, buyers if they are liable for replacement) has the advantage of providing a systematic view of both natural and anthropogenic risks faced by projects and allows for separation into categories that can handle risk differently. This does, however, impose additional time and expense on the process.

If risk screening is adopted, the outcome of the risk assessment needs to be considered. Possible options include:

- Whether to make an exception and allow certain projects to proceed without further permanence considerations (tonne-year crediting, buffers, insurance, and so forth).
- Whether to disallow certain projects whose risks are deemed extreme.
- Establishment of the terms of risk mechanisms under consideration (liability assignment, type and length of obligation, requirements for risk management, and/or parameters for risk management approaches, such as buffers, insurance, or host country guarantees).

The guidance for implementing risk assessment needs to be considered.

5.1.2. Timing of the Issuance of Credits

In principle, credits can be issued in full once the carbon storage has been quantified (i.e., at the end of the verification period), or they can be issued incrementally using a tonne year approach, in which permanent credits are issued over time as storage is demonstrated. To assess the proportion of annual credits to be issued under the tonne year approach, permanence period needs to be adopted that takes into account scientific and policy aspects of mitigation.

If credits are to be issued in full at the time of verification, another set of considerations becomes relevant. These are discussed below.

5.1.3. Issuance of Credits

If credits are issued in full at the time of verification, this leads to the issue of whether or not those credits are *temporary credits* with an expiry date, as is currently the case with CDM A/R credits. The considerations relevant for issuance of *permanent credits*, on par with credits from other sectors under the CDM, other compliance, and voluntary markets are discussed below.

5.1.3.1. Considerations for Temporary Crediting

Under temporary crediting, the status quo requires replacement of credits after each commitment period for tCERs or crediting period for ICERs, with the possibility of postponing the replacement liability by reissuances of tCERs or ICERs for longer crediting periods. The requirement for full replacement of credits at defined points in time is a disincentive for projects. A possible remedy is to permit the transformation temporary credits into permanent credits at the end of a crediting period, thereby removing the replacement liability. Parties may also consider modifying the length of a credit period so that projects successfully renewing their crediting periods can receive waiver from the requirements of credit replacement.

5.1.3.2. Considerations for Permanent Credits

For permanent credits issued upon verification, there is a contingent liability for credit replacement upon reversal, which requires clarification of liability and mechanisms for handling the liability:

- **Replacement liability.** The modalities and procedures need to clarify legal liability for replacing reversed credits (project/seller or buyer). Additional mechanisms could allow for the liability to be transferred via contracts, a managed buffer, commercial insurance, a performance bond, or a demonstration of financial standing required to ensure that the liable party has the means to cover reversal losses. Other considerations may be whether liability differs between unintentional and intentional reversals and the role that opt-out provisions could play in liability determination. The period at which point storage has reached an acceptable level of permanence must also be clarified in order to assess replacement liability, particularly in the case of a tonne year approach.
- **Replacement risk mechanism requirements.** This addresses whether to require project participants to employ some reversal risk management to protect the system from widespread uncontained reversals. Options include:
 - **Buffer system,** operating at the project, sub-national, national, or international scale. Specific rules and modalities (e.g., approaches to determining the share of credits set aside in the buffer) would have to be established based on assessment of relevant risks.
 - **Commercial insurance,** which could be used by participants in lieu of a buffer or perhaps as a reinsurance mechanism to back the buffer from overdraft.
 - **Host country guarantee** of any remaining liability for reversal not covered by the participants, buffers, or insurance policies. The recent decision to establish host country guarantees, coupled with a buffer for carbon capture and storage projects under the CDM provides a precedent for an extension to A/R projects.
 - **Menu of options,** whereby participants are required to choose among approved options based on their circumstances. Special care should be taken to avoid adverse selection (e.g., only the high risk projects, unable to get private insurance, opt into managed buffer systems).

5.2. Implications for Countries

The decisions on approaches adopted have implications for host countries of A/R projects and Annex I “buyer” countries of credits from those projects.

5.2.1. Implications for A/R CDM Host Countries

Certain CMP decisions, if made, *could increase* the responsibilities of host countries, relative to the status quo system of temporary crediting. These may include decision outcomes that:

- Require reversal risk screening, if it were to be a national responsibility.
- Establish and manage a credit buffer at the sub-national or national level.
- Create the option for host country guarantees, backstopping reversals of projects within the country.

Decision outcomes that *could decrease* host country obligations relative to the status quo might be if the Parties were to set default liability for reversals with buyer countries or allow market participants the flexibility to work out the liability among them.

5.2.2. Implications for Annex I Buyer Countries

Decision outcomes that *increase* buyer country obligations relative to the status quo include those that, in lieu of temporary credits that expire at the end of commitment or crediting period, assign full liability

to replace permanent credits issued at the time of verification. Given that the status quo requires buyer countries to cancel out temporary credits from their national accounting and replace when they expire, this is not an entirely new responsibility. However, it differs in that it would require tracking of credits once they have been deemed “reversed” and in need of replacement.

Decisions that *could* decrease Annex I country obligations relative to the status quo were if default liability was established on the producers of the credits (projects), or host countries guaranteed delivery of non-reversible credits to buyers. In these instances, there would be no additional responsibilities for the buyer country, or entities therein, to replace reversals when they occur.

5.3. Implications for Project Participants

The choices for A/R project participants are currently limited. They can choose between temporary credit categories of tCERs and ICERs – although to date they almost always have chosen tCERs – but they cannot generate permanent credits. If projects are permitted to generate permanent credits, they will have more options – including making A/R projects viable for climate change mitigation, while requiring more responsibilities for risk management. The modalities and procedures could prescribe approaches for addressing non-permanence risk or allow flexibility among the approaches. The latter may provide some impetus for innovation in risk management as participants navigate their options and markets evolve to serve their needs.

6. References

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Appendix A. Comparison of Reversal Approaches in Existing Standards

Standard	Intentional v. Unintentional Reversals	Types of Credits Issued for Forest Carbon	Replacement Liability	Reversal Mechanism Details	Minimum Contract Period
Compliance Offset Markets					
CDM^A	No distinction	Temporary	Buyers liable at time of credit expiry	A/R projects are issued either temporary certified emission reductions (tCER) or long-term CERs (ICERs). tCERs expire each subsequent commitment period (e.g., after 5 years) and must be replaced. National registries must contain a tCER replacement account. ICERs expire after a credit period of either 30 years or 60 years and require full replacement.	Credits expire after 5, 30-60 years (see mechanism details)
California (AB 32)^B	Distinction	Permanent	Unintentional: system liability Intentional: producer liability	Unintentional reversals are insured against by contributing a percentage of ARB offset credits to a Forest Buffer Account. The amount of the contribution is based on a project-specific risk evaluation. The regulatory obligation for all intentional reversals of GHG reductions and GHG removal enhancements to be compensated for through retirement of other Compliance instruments.	100 years
New Zealand ETS^C	No distinction	Permanent	Producers	New Zealand's ETS operates like a cap-and-trade system which includes forestry as a capped sector. Forest owners must use compliance credits for any net forest carbon loss over a compliance period. This applies to both intentional reversals and unintentional reversals. Forest owners can purchase commercial insurance to protect against reversal risk or can self-insure by setting aside previously issued credits. Participation is optional for owners of forests established after 1989, but, if these owners opt in, they are liable for replacing reversed carbon. Commercial is insurance available for producers.	Ongoing obligation
Australian Carbon Farming Initiative (CFI)^D	Distinction	Permanent	Producers	Australia's Carbon Farming Initiative operates as an offset system linked to Australia's carbon pricing scheme being used to meet the country's Kyoto commitments. The CFI has specific rules for permanence.	100 years
Voluntary Carbon Markets					
ACR^E	Distinction	Permanent	Unintentional: system liability Intentional: producer liability	Intentional reversals must all be replaced by the project entity. Unintentional reversals are covered by the buffer pool like an insurable risk, though project must reestablish buffer after conversion. Buffer percentages can be updated after risks are reassessed.	40 years, with opt-out allowed if credits replaced

Standard	Intentional v. Unintentional Reversals	Types of Credits Issued for Forest Carbon	Replacement Liability	Reversal Mechanism Details	Minimum Contract Period
CAR ^F	Distinction	Permanent	Unintentional: system liability Intentional: producer liability	Project Implementation Agreement requires Projects' CAR credits account debited to compensate for "avoidable" reversals (negligence, gross negligence, or willful intent). CAR Pooled Buffer Account established wherein projects are required to guard against "unavoidable" reversals (fire, pests) by withholding a certain percentage of their credits in a Pooled Buffer Account. The share of credits withheld is based on project-specific risk evaluation (determined prior to registration and recalculated every year the project undergoes a verification site visit); conservation easements lower a project's risk rating. In instances of "unavoidable" reversals, credits from buffer are used to replace the loss.	100 years
VCS ^G	No direct distinction Catastrophic vs non-catastrophic used instead with similar consequences	Permanent	See mechanism detail	Projects are required to guard against reversals by withholding a certain percentage of their credits in a Pooled Buffer Account. The share of credits withheld is based on project-specific risk evaluation. For reversals, credits from the buffer are used to replace the loss. The risk rating is based on a variety of project-specific risk factors (e.g., clarity of land tenure, local deforestation pressure, and financial viability). Depending on a project's risk rating, between 10–40 percent of credits could be withheld in a buffer for afforestation, reforestation and revegetation projects. The registry retains ownership of buffer credits and retires buffer credits in case of actual reversal. Possibility of returning buffer credits to projects for sale if long-term performance demonstrated. Under some conditions, the project proponent is required to replace all reversed credits (over and above credits already set in a buffer) before new credits are issued. If the project proponent fails to monitor and report carbon within a fixed period of time after a reversal event, the carbon is assumed gone and all issued credits are replaced with buffer credits. Considers replacement of buffer with private insurance if available.	20–100 years

Acronym Key: CDM = Clean Development Mechanism of the Kyoto Protocol; VCS = Verified Carbon Standard; CAR = Climate Action Reserve; ACR = American Carbon Registry; AB32 = California Assembly Bill 32, California Global Warming Solutions Act; ETS = Emissions Trading System

Sources:

^A CDM Rulebook. Long-term certified emission reduction (ICER). <http://cdmrulebook.org/332> (last accessed October 31, 2012); CDM Rulebook. Temporary certified emission reduction (tCER). <http://cdmrulebook.org/380> (last accessed October 31, 2012).

^B California (2011).

^C New Zealand Ministry of Agriculture and Forestry (2011).

^D Australia CFI as described in Australia's submission under FCCC/SBSTA/2012/L.3 | September 2012.

^E American Carbon Registry (2010).

^F Climate Action Reserve (2010).

^G VCS: Verified Carbon Standard. Methodologies for Agriculture, Forestry and Land Use (various). <http://v-c-s.org/methodologies/find> (last accessed October 31, 2012).

Appendix B: Unintentional Reversal Assessment Methodology

Two methods are used to assess the performance of various approaches in the presence of natural disturbance events. The first, used in the majority of the analysis, makes use of the LANDCARB ecosystem simulation model. The second, used in examples where analysis calls for observation of historical events and geographic variation in the risk of reversal, makes use of empirical fire data from Chile. Both assume that all lands are afforested in the first year of the project. No harvests are conducted during the project, meaning that we do not track harvested wood products (HWP) nor do we assess potential long-term carbon storage in the HWP pool.

LANDCARB Overview

We simulated forest growth using a significantly updated version of the ecosystem simulation model LANDCARB (Harmon, 2012). LANDCARB is a landscape-level ecosystem process model. LANDCARB integrates climate-driven growth and decomposition processes with species-specific rates of senescence and mortality, while incorporating the dynamics of inter- and intra-specific competition that characterize forest gap dynamics. Inter- and intra-specific competition dynamics are accounted for by modeling species-specific responses to solar radiation as a function of each species' light compensation point and assuming light is delineated through foliage following a Beer-Lambert function. By incorporating these dynamics, the model simulates successional changes as one life-form replaces another, thereby representing the associated changes in ecosystem processes that result from species-specific rates of growth, senescence, mortality, and decomposition.

LANDCARB represents stands on a cell-by-cell basis, with the aggregated matrix of stand cells representing an entire landscape. Each cell in LANDCARB simulates a number of cohorts that represent different episodes of disturbance and colonization within a stand. Each cohort contains up to four layers of vegetation (upper tree layer, lower tree layer, shrub, and herb). For each of the 50 runs performed, we assessed a 45x45 matrix of 10 hectare cells, for a total project area of 20,250 ha. To assess forest growth and disturbance on the performance of smaller projects, we randomly selected a starting cell from each run of 45x45 cells and chose the adjacent 10 rows and columns, yielding a smaller project area of 1,000 ha.

Forest growth in our model runs is based on growth-yield curves established for high management, high productivity softwood plantation species (*Pinus taeda*, *P. echinata*) stands as described in Smith et al. (2006). These and other similar softwood species are featured in existing A/R projects. The sequestration profile of *P. taeda* also lies between faster growing shorter rotation species and slower growing longer rotation species used in A/R projects (Figure AB-1), thus providing for a rough mid-point analysis.

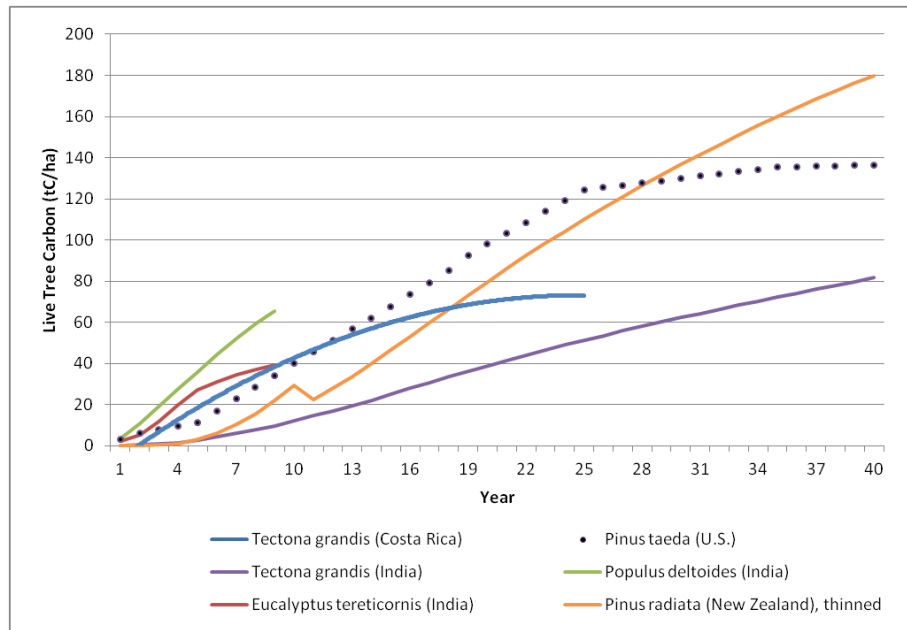


Figure AB-1. Sequestration profile for species used (or similar to those used) in CDM A/R projects. *Pinus taeda* (U.S.) shows the sequestration profile of the forest type assumed in the quantitative analysis performed in this paper. Source: Costa Rica *Tectona grandis* – Bermejo et al. (2004), site index 23, fit using simple polynomial trendline; *T. grandis*, *Eucalyptus tereticornis*, and *Populus deltoides* (India) – Kaul et al. (2010); *P. taeda* (U.S.) – adapted from Smith et al. (2006); *P. radiata* – Paul et al. (2008).

Our analysis incorporates wildfires in all simulations. In the LANDCARB model, fire severity controls the amount of live vegetation killed and the amount of combustion from the various C pools, and is influenced by the amount and type of fuel present. Fires can increase (or decrease) in severity depending on how much the weighted fuel index of a given cell exceeds (or falls short of) the fuel level thresholds for each fire severity class (T_{light} , T_{medium} , T_{high} , and T_{max}) and the probability values for the increase or decrease in fire severity (P_i and P_d). For example, a low-severity fire may increase to a medium-severity fire if the fuel index sufficiently exceeds the threshold for a medium-severity fire. Fuel-level thresholds were set by monitoring fuel levels in a large series of simulation runs where fires were set at very short intervals to see how low fuel levels needed to be to create a significant decrease in expected fire severity.

The modeled fire regime is intended to replicate fire behavior in subtropical loblolly pine stands. Not only does this fire regime conform to our choice of species to use in the A/R project, but it may also be representative of other subtropical locations that are home to a sizable portion of current A/R projects. Although data on low-frequency, high-severity fires is generally unavailable in the Southeastern U.S. due to a lack of primary forest on which fire reconstruction studies could be performed, we can nonetheless estimate reasonable fire return intervals through comparison with other forested systems. For example, longleaf pine stands are adapted to a low-severity, high-frequency (3-7 years) fire regime; loblolly pine stands burn with less frequency than longleaf pine stands, but this is, in part, due to fire suppression. A reasonable estimate for mean fire return interval (MFRI) could therefore be 16 years for a low-severity burn, a 100-year MFRI for a medium-severity fire, and a 300-year MFRI for a high-severity fire. Based on these, we generated exponential random variables to assign the years of fire occurrence (Van Wagner, 1978). The cumulative distribution for our negative exponential function is given in equation [A1] where X is a continuous random variable defined for all possible numbers x in the probability function P and λ represents the inverse of the expected time for a fire return interval given in equation [A2]:

$$P\{X \leq x\} = \int_0^x \lambda e^{-\lambda x} dx \quad [A1]$$

where

$$E[X] = \frac{1}{\lambda} \quad [A2]$$

Fire severities in each year generated by this function are cell-specific, as each cell is assigned a weighted fuel index calculated from fuel accumulation within that cell and the respective flammability of each fuel component, the latter of which is derived from estimates of wildfire-caused biomass consumption.

Wind loss is represented in the LANDCARB model as a “harvest” in which no timber is removed (i.e., all downed timber is left onsite). Lacking adequate data on the distribution of wind disturbance frequency and intensity in any of the countries currently hosting A/R projects, we used U.S. data as a proxy. The incidence and intensity of wind disturbance events were derived from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center Storm Events Database,³⁸ using the state of Georgia, USA, as a reference point. Area affected is not consistently included in the events database, so we instead used U.S. census data on housing density and housing value along with expected levels of damage at varying wind intensities as reported in the Fujita tornado damage scale, to generate estimates of windstorm area.³⁹ Next, we estimated likely loss to a forested stand and assumed that all events of a particular intensity resulted in a particular loss of forest overstory. Events above 45 meters per second (m/s, or approximately 100 mph) resulted in 100-percent loss, 35-45 m/s (approximately 78-100 mph) resulted in 75-percent loss, and 25-35 m/s (approximately 56-78 mph) resulted in 50-percent loss.⁴⁰ When this exercise was conducted for Clayton County, Georgia, an area slightly larger (37,037 ha) than our modeled landscape area (20,250 ha), we estimated that the average annual percent area affected is 0.3 percent, with an average weighted intensity of 50 percent loss. This average annual loss was applied to the modeled scenario each year, but its spatial occurrence was randomized. Put another way, 0.3 percent of the area will be affected each year, but where it occurs will be randomly assigned by the model.

Empirical Disturbance Analysis - Chilean Historical Fire Data Overview

A/R projects are assumed to consist of newly established, vigorously growing plantations. We used a growth rate of $10 \text{ m}^3 \text{ ha}^{-1} \text{ yr}^{-1}$, a low estimate but within values reported for tropical plantations (IPCC 2006). We assumed that plantations achieve a maximum volume of $165 \text{ m}^3 \text{ ha}^{-1}$. Volume was converted to tCO_2e using a biomass expansion factor of 2, a rough approximation of IPCC (2006) values for humid tropical forests greater than 40 cubic meters per hectare. This yielded an approximate annual growth rate of $20 \text{ tCO}_2\text{e ha}^{-1} \text{ yr}^{-1}$ and a maximum stand volume of $330 \text{ tCO}_2\text{e ha}^{-1} \text{ yr}^{-1}$. We assumed that plantations are established for the express purpose of accumulating on-site carbon and thus did not consider the carbon or financial implications of timber harvest.⁴¹

³⁸ <http://www.ncdc.noaa.gov/stormevents/ftp.jsp> (last accessed August 6, 2012).

³⁹ <http://www.spc.noaa.gov/faq/tornado/f-scale.html> (last accessed August 6, 2012).

⁴⁰ Thresholds are based on categories and descriptions of loss detailed on pp 350-1 in Mason (2002), though the assignment of loss percentages to each threshold is ours alone. Assessing the risk of wind damage is a complicated undertaking, and we acknowledge this treatment vastly oversimplifies the effect of wind disturbance on forest stands. See, e.g., Quine (1995), Moore and Quine (2000), and Mason (2002) for more information.

⁴¹ Collectively, these assumptions result in forest growth and yield somewhat similar to that modeled in LANDCARB. Although approximate, they are not identical. A key difference is the complexity of forest growth

Disturbance events and reversals modeled here are based on distributions calculated from observed fire activity in Chile.⁴² The data provide a detailed overview of the number of fire events and the annual total area affected at varying levels of spatial resolution.⁴³ At the national level, summary data is available as far back as the 1960s; the comuna⁴⁴-level data used as the basis for the analysis conducted here is available back to 1984-85. Prior to estimation of fire risk distributions, we examined the data for spatial and temporal correlation. A fixed effects panel regression estimation of fire loss on one-, two-, and three-year lagged losses suggested a great deal of correlation across comunas, but very little year-to-year correlation within individual comunas. Specifically regressing total fire loss for a given year on one-, two-, and three-year lagged losses within individual comunas further suggests minimal temporal correlation; no significant lagged effects were detected in the comuna data used herein.

The absence of strong temporal correlation allowed for a straightforward modeling of disturbance events. For each geographic unit assessed here, we first used observed fire loss data to calculate a distribution of annual percentage area affected. For any given year, a percentage area affected was pulled from this distribution using a random number generator and applied to the project. We made use of several such distributions, subjectively characterizing each as low, moderate, or high relative risk to draw distinctions between scenarios. We assumed a uniform rate of forest carbon loss for each event, regardless of fire size. Loss estimates were based on field research of fire effects in Peru (Román-Cuesta et al., 2011), and were assumed to cause a carbon loss equivalent to the amount stored in standing and lying dead wood, an aggregate loss of approximately 22 percent of total forest carbon for each fire event.

modeled in LANDCARB, resulting in gradually slowing growth over time and greater transfer of carbon between live tree and other forest carbon pools throughout the life of the stand.

⁴² Data for Chile acquired from Phil Cottle, ForestRe (pers. comm.; January 17, 18, 20, 2012). Additional data and description available at <http://www.conaf.cl/conaf/seccion-estadisticas-historicas.html> (last accessed February 13, 2012).

⁴³ Fire data include the total number of fires and the total area affected in any given year. The data do not specify the area affected in any one particular event.

⁴⁴ Comunas are the smallest geographic unit evaluated here, and range from a few hectares of forest area to over 60,000 hectares.

Appendix C: Intentional Reversals Case Study: Competition from Soybean Production

Here we provide a stylized example of competition for land between A/R projects and agricultural production (soybean) that could affect decisions about whether to terminate an A/R project in favor of agricultural conversion. In particular, we explore two aspects of this competition: where initial conditions favor A/R, and where conditions change to favor agriculture.

Initial Conditions Favoring A/R

Consider conditions at the beginning of a project that point to A/R investment. A decision rule reflecting this can be expressed:

$$\text{Invest in A/R, if } R_{AR} > R_A$$

Where R_{AR} represents A/R project returns, including all carbon credit payments less the cost of establishment and ongoing operating costs incurred (for measurement, monitoring, and verification), and R_A represents returns from alternative land use (agriculture). Both terms are further described below.

R_{AR} : Returns from an A/R Project

A/R project returns include all carbon credit payments less the ongoing operating costs incurred (for measurement, monitoring, and verification). Mathematically, this can be further specified as:

$$R_{AR} = \sum_0^T \frac{E[P_t^C] * Q_t^C - c_t^C}{(1+r)^t} - E_{AR} \quad [A3]$$

Where P^C is the carbon price, Q^C is the quantity of carbon credits generated, c^C is the annual operating cost, and r is the annual discount rate. T is the length of time of the project and the subscript t indicates the year of occurrence between project establishment ($t=0$) and project end point ($t=T$). E_{AR} is project establishment cost, which include the cost of planting the trees as well as the upfront costs of planning, registering, and implementing the project.

The use of the expectations operator $E[P_t^C]$ indicates that future carbon prices are unknown at the time of the investment, a point to which we will return below.⁴⁵

R_A : Returns from Alternative Land Use (Agriculture)

The returns from an alternative land use, such as agriculture can be specified as:

$$R_A = \sum_0^T \frac{E[P_t^A] * Q_t^A - c_t^A}{(1+r)^t} \quad [A4]$$

Where P^A is the alternate commodity (agriculture) price, Q^A is agricultural output, c^A is the annual agricultural production cost, and all other variables and subscripts are as defined above.

⁴⁵ We recognize that the other variables – yields and costs – are also uncertain, but we focus the discussion on uncertain prices as they tend to be subject to the external volatility of most concern.

In light of this decision rule, we consider the case of a 1,000-hectare tract of land that is arable and can be used for soybean (soya) production or can host an A/R project.⁴⁶ In this example, we assume the A/R project commitment is 40 years so that we can compare the present value of A/R returns with agricultural returns over that time period. We assume for now that carbon standing at the end of the 40-year period is deemed permanent for crediting purposes.

Figure AC-1 shows how sensitive this A/R investment decision is to different price assumptions. Under the efficient markets hypothesis (see, e.g., Malkiel, 1987), current prices provide the best expectation of future market prices; thus landholders will take these price levels, as well as their underlying variability and risk preferences, into account. The point where each line in the figure crosses over the horizontal axis (where the difference between A/R and soy returns is zero) represents the break-even CO₂ price. The break-even price for CO₂ and soybeans are positively correlated. At a low soybean price (\$250/tonne), any carbon price above \$2.50/tonne CO₂e favors A/R. At higher soybean prices (\$450/tonne), the CO₂ break-even price is above about \$17 for an A/R investment.

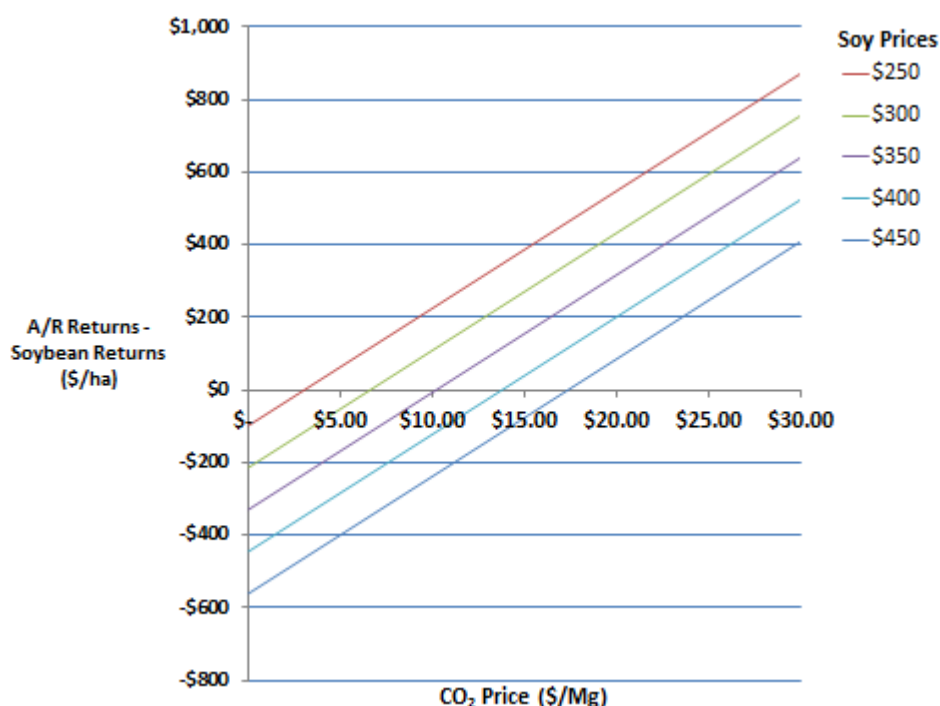


Figure AC-1. Relative returns at different price combinations: A/R vs. Soybeans, marginal land (annualized)

⁴⁶ As elsewhere in this report, we base our modeled scenarios on factors identified in existing A/R PDDs. Soy is mentioned as an alternative commodity in at least one PDD (“Reforestation of Grazing Lands in Santo Domingo, Argentina”). Other commodities (e.g., wheat, barley, rapeseed, rice, maize, sorghum, sugarcane, coconut, and cocoa) are likewise represented in one or more PDDs. The example presented here should therefore be seen as illustrative, not exhaustive. We used data from soya yields and costs from a South American country for illustrative purposes and do not imply that soy production is any more or less at risk of intentional reversal than any other commodity.

Land-Use Decisions on a Landscape of Varying Quality

Not all land is of equal quality for an A/R project or agriculture, and the relative returns will reflect this. Figure AC-2 illustrates a profile of land returns for A/R and agriculture along a continuum of land quality. “Quality” here reflects arability or suitability for agriculture (see Murray 2003). Higher quality land yields higher returns for both agriculture (R_A) and A/R (R_{AR}). Given an initial set of prices, P^A and P^C , agricultural returns are higher than A/R up to the point that the two lines cross – the land-use margin. Under these circumstances, we would expect the highest quality land up to the land-use margin to be allocated to agriculture, and the remainder to be allocated to A/R projects. Figure AC-2 reflects the initial allocation of land after A/R project opportunities are introduced, so that L_{AR} reflects the amount of land initially allocated to A/R; the rest of the land stays in agriculture. Any land incapable of generating positive returns for either agriculture or A/R is considered idle land.

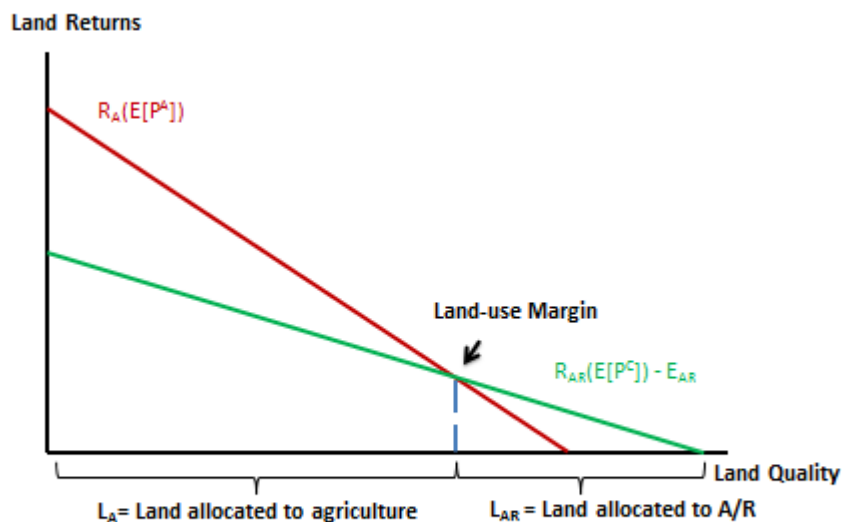


Figure AC-2. Land allocation between A/R projects and agriculture over a land quality continuum.

Following the logic described above, Table AC-1 compares soybean production on an average site (about 2.7 tonnes per ha per year) with an A/R project on an average site (ranging between 5-30 tonnes CO_2e per year over 40 years, following a standard S-shaped growth function), at soybean and CO_2 prices in the range of recent history (\$360/tonne and \$10/tonne, respectively). The returns for A/R are based on the net carbon price paid to the seller after any price adjustments for reversals referenced elsewhere in the report. (i.e., the price after a buffered amount has been set aside).

Table AC-1 shows that soybean production on land of average productivity out-competes A/R (it has a higher return). However, we find that an A/R investment will break even with a low yield soybean site (about 80 percent of average yield) at the indicated prices. We can think of this break-even condition as the land-use margin referenced in Figure AC-2. At these prices, we might expect land with higher soy

productivity than the low yield estimate to remain in soy production and land less productive than that to potentially be more profitable as an A/R project.

Table AC-1. Comparison of Returns to Soybean Production and A/R Project

	Note	Soybean Avg. Yield	A/R Project	Soybean Low Yield
Initial Yield (tonnes/ha/yr)	a	2.68	5-30	2.16
Initial Price (\$/tonne)	b	\$ 360	\$ 10	\$ 360
Revenue (annualized)	c	\$ 1,029	\$ 347	\$ 827
Operating Cost	c	\$ 302	\$ 22	\$ 302
Net Income Before Overhead		\$ 727	\$ 324	\$ 525
Overhead Costs	c	\$ 250	\$ 49	\$ 250
Land Return (annualized)		\$ 477	\$ 275	\$ 275
Notes:				
a. Soybean yield projected to increase 0.5%/yr; forest yields follow empirical yield function for subtropical softwoods over time				
b. CO ₂ price rises at the rate of discount following standard Hotelling price assumption for storable goods; soy price is constant				
c. Annualized over 40-year project period				

Data Sources:

- World Soybean Production: Area Harvested, Yield, and Long-Term Projections
http://ageconsearch.umn.edu/bitstream/92573/2/20091023_Formatted.pdf.
- Economic Research Service, U.S. Department of Agriculture, <http://www.ers.usda.gov/data/costsandreturns/testpick.htm>.
- Internal project A/R data (see above).

Change in Market Conditions Favoring Agriculture

The underlying uncertainty and periodic discrete shifts in commodity markets may create situations in which continuation of the project may seem unprofitable relative to an alternative land use. This can also happen if carbon yields are not as large as expected.⁴⁷ Just as the decision to initiate an A/R project will depend on future expectations of carbon and commodity prices, so might the decision to stay with the project. Note that in the case of an A/R project reverting to agriculture, the decision to terminate a project and switch to agriculture involves a one-time clearing cost to revert, effectively the reverse of initial establishment costs. Given the observed dynamics of commodity markets, this could be a critical factor affecting landholders' desire to maintain an A/R project after inception.

Suppose at the time an A/R project is being considered, carbon prices are \$12 per tonne of CO₂e and soybean prices are \$360 per tonne. Under these prices, as illustrated in Figure AC-1, the expected return from an A/R project exceeds the expected return from soybean production – and we assume the landholder undertakes the A/R project.⁴⁸ Suppose after 10 years, however, there is a distinct shift in the

⁴⁷ As commented on by one reviewer, landholders make these land-use decisions under uncertainty and thereby hold option value; they may wait until the uncertainty resolves before committing land to a use, such as forest, which involves a long-term commitment that is costly to reverse. This “wait and see” approach may weaken the response of landholders undertaking an A/R investment in the first place, but it may also reduce the incidence of post-investment regret and desire to switch back to agriculture (see Schaatzki, 2003).

⁴⁸ $R_{AR} (P^C=\$12) = \$5,089 / \text{ha} > R_A (P^A=\$360) = \$4,144 / \text{ha}$

carbon and commodity markets; namely the carbon price drops considerably and the soybean price rises considerably. This is not outside the realm of recent history (see Figures AC-3 and AC-4 for recent price history of CO₂ prices and agricultural commodity prices). The A/R project holder may now question whether the A/R project should continue if these prices hold. The following decision rule applies:

$$\text{Divest A/R project if } R'_{AR} < R'_A - [S_{ARA} + C_R]$$

Where R'_{AR} is the revised value of A/R returns over the remaining years of the project under the new prices, R'_A is the revised value of alternative land use (soybeans) over the same time under the new prices, S_{ARA} is the switching cost associated with clearing the trees to enable cultivation, and C_R is the cost of replacing the reversed carbon (if required).

Figure AC-3 and Figure AC-4 represent observed historical prices for carbon (CO₂e) and a suite of relevant agricultural commodities, respectively. Carbon prices are from the EU Emissions Trading System (EU ETS); they have a relatively short history because the carbon market has only been around for less than a decade.⁴⁹ But, even in that time, the prices have shown a propensity for both short-term volatility and occasional discrete shifts reflecting changes in market fundamentals (Maniloff and Murray, 2011). Three discrete shifts in the EU carbon market can be seen. One occurred in early 2006, reflecting the release of the initial national emissions data – the market had traded without this essential data in its first year. The second shift coincided with the end of the first ETS trading period in 2008 and the beginning of the global recession. The third discrete drop in price started in early 2011 as the European economy experienced its own distinct financial and fiscal crisis and global climate agreements continued to stall. Figure AC-4 shows 30-year price histories (nominal and real) for four of the most relevant agricultural commodities that may compete with A/R investment: soybeans (South America), palm oil (Southeast Asia), cocoa beans (Africa), and cattle (South and Central America). As with the carbon market, each of these commodities shows a propensity for high price volatility and periodic shifts.

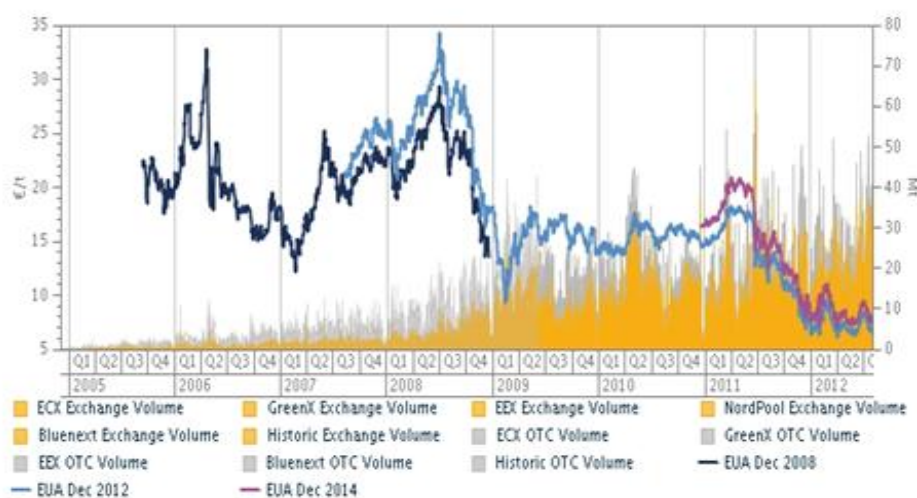
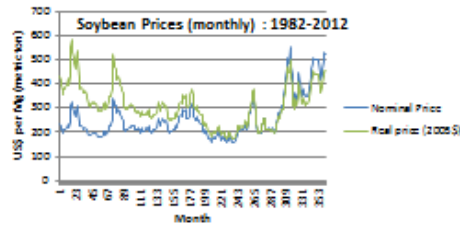
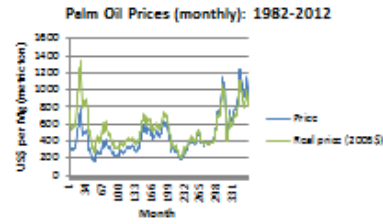


Figure AC-3. EU ETS emissions prices: 2005-2012. Source: Point Carbon (pointcarbon.com). Downloaded, Aug 1, 2012

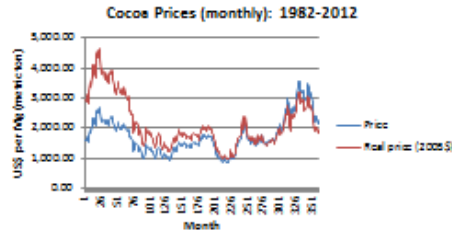
⁴⁹ Although forest carbon does not trade directly in the EU ETS, we use that time series as an indicator of the potential shifts and volatility in the carbon market.



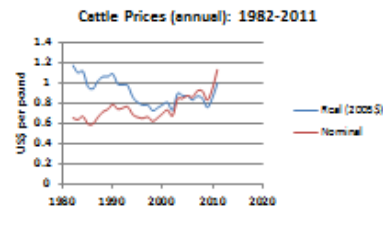
Source: indexmundi.com, downloaded on July 25, 2012.



Source: indexmundi.com, downloaded on July 30, 2012.



Source: indexmundi.com, downloaded on July 30, 2012.



Source: Elin, 2012, Iowa State U

Figure AC-4. Relevant Agricultural Commodity Prices for A/R Alternatives

Outcomes Under Price Shocks

Consider an example under the following price shifts in Year 10:

- Consistent with our initial assumption, the starting carbon price of \$12 rises at the real discount rate (6%) and at Year 10 holds the following value, $P_{10}^C = \$12(1.06)^{10} = \20.27 . But in year 10, the price drops 50%, $P_{10}^C = \$10.14$.⁵⁰
- The soybean price in year 10 is assumed to remain constant at its initial value of \$360, but in Year 10 it shifts up 25%, $P_{10}^A = \$450$.

Under these circumstances, and using the same yield and cost data referenced thus far, the returns from remaining in the A/R project for the remainder of the project period (30 more years) and switching to soybeans, respectively are:

$$\begin{aligned} R'_{AR} &= \$3,780 \\ R'_A &= \$7,330 \end{aligned}$$

If we estimate the cost of clearing the 10-year old A/R project of trees to be \$250 per hectare, then the net payoff of converting the A/R project to soybeans is \$3,300 per hectare $[(\$7,330 - \$250) - \$3,780]$ before considering whether or how to assign carbon repayment, an issue that is dealt with extensively in the main text.

⁵⁰ The real rate increase for carbon prices is consistent with standard assumptions about carbon markets that allow banking and borrowing of allowances between periods. In those situations, the price rises at the real rate of interest in equilibrium, as the holder of an allowance would be indifferent between using it in the current or future period.

Table AC-2 considers different combinations of price shocks in the carbon and soybean market (a 50-percent drop in carbon price, a 25 percent increase in soy prices) to consider the cases where only the carbon price shock occurs and soy price remains unaffected, and vice versa. Results in Table AC-2 focus on situations where (1) all replacement liability is covered by the project holder rather than a third party, or (2) the project pays the balance of what is owed after an initial (30 percent) of credits set aside in a buffer are used (see main text for description of the buffer approach).

Table AC-2. Returns to project abandonment with full credit replacement required. Values in the table are net returns to termination under different shocks to the soybean and carbon markets and different approaches to covering liability (no mechanism and buffer). For example, if the soy price rises 25 percent and the CO₂ price drops 50 percent, the landholder would gain \$1,877 by terminating A/R and converting to soybeans if they had to pay to replace all credits themselves. If the amount they pay into the buffer covered 30 percent of the replacement liability, then the return to conversion would be \$2,304. Note however that conversion is not profitable if either the CO₂ price stays the same or the soy price stays the same.

1. No Third-party Mechanism				2. 30% Buffer			
		Soy Price Shock (%)				Soy Price Shock (%)	
		0%	+25%			0%	+25%
CO ₂ Price Shock (%)	0%	--	\$ (3,636)	CO ₂ Price Shock (%)	0%	--	\$ (2,782)
	-50%	\$ (1,110)	\$ 1,877		-50%	\$ (683)	\$ 2,304

The results suggest that if the carbon price does not drop when the soy price goes up, the carbon liability is such that switching to soybeans is not profitable. Likewise, if the soy price does not go up when the carbon price plummets, then the return to abandoning the project may be negative. Thus it may take a swing in both directions for this type of project termination to be a threat. As would be expected, the buffer approach results in more favorable net returns in the form of lower net costs (in the presence of a carbon price drop *or* a soy price increase) and higher net returns (in the presence of both). This is because there are lower repayment requirements in the presence of a buffer; 30 percent of the credits were already set aside throughout the course of the project. In this respect, a buffer reduces the barrier to conversion. But if credit payback is required, there are no adverse carbon consequences to this as the atmosphere is “made whole” upon project exit.

The key message here is that, under realistic conditions, commodity prices could change to favor termination of the project and conversion of the trees to agricultural production, a form of intentional reversal. Imposing the requirement that the project replace the credits reversed can make the difference between whether or not it is profitable to do so. Even with the payback requirement, however, in some cases project developers may find it optimal to opt out. The critical issue is that they do so only after making the atmosphere “whole” by replacing the reversed credits.

Appendix D: Insurance for Forestry Projects - Approach and Key Terms

Contracts	Almost universally one year insurance contracts. Any loss event occurring in that insured year is covered, even if it takes some months (or years) to measure the loss and to pay the claim. This is important in carbon projects as loss events and certification of the loss of carbon may be several years apart. Insurers would rather prefer annual verification of carbon status in order to be able to close their books on that “underwriting year.”
Purpose	In natural hazard insurance (fire, wind, and so forth), 90 percent of commercial losses are caused by 2 percent of events. Forestry Insurance is normally designed as catastrophic coverage. That is to say, it protects the project from the infrequent but severe event (i.e., an event that would have an adverse effect on the net present value of the project). Insurance of common and frequent losses is termed “dollar-swapping” when a premium is paid to insurers and then claimed back after losses. This is expensive and unnecessary to the survival of the project as a business proposition.
Deductible	Insurance contracts oblige the project to retain risk as a deductible; this is often set by the insurer after discussion with the insured. The deductible in carbon projects is designed to remove small frequent “attritional” losses (see above), often 95-99 percent of loss events. It is usually applied “each and every event” (EEL). Carbon projects need to keep back the carbon required as the deductible only for one year; after that, it may be released as the old insurance contract terminates. New deductibles are required for new contracts. They may be expressed as absolute dollar amounts, tonnes C or as a percentage of the loss with minimum and maximum values, or as a percentage of the total sum insured with minimum and maximum values.
Total Sum Insured	(TSI) The total value of the project (Tonnes C x Price/tonne). The premium rate is conventionally applied to the TSI.
Annual Aggregate Loss Limit	(AAL) this is the liability of the insurer and is the maximum value paid out by the insurer. Often described as the “loss limit, EEL, & AAL.” The AAL will be based on the 1:100 year modeled event, or the 1:250 year event on the basis that more infrequent events will not in all probability occur. It may be set arbitrarily. Once exhausted, the insurer is no longer liable to pay claims. If doubt exists about the AAL required, a reinstatement may be arranged in exchange for an additional premium (example 150 percent of the original premium). This may not be a likely tool in carbon projects, as by the time the loss is measured the insurance cover may have already expired.

Insurable Perils	FLEXA (fire, lightning, explosion, and aircraft); wind, and tornadoes, flood, earthquakes, SRCCMD (strike riot civil commotion), ice storms, and drought.
Risk Pricing	Insurers price risk ideally on a pure risk basis (i.e., the price if no expenses or profits were required). Then they “gross up” for the last two items. This is done in a number of ways, according to the insurer. A simple example is that, if one needs a 50-percent margin for profit & expenses, then the pure risk price needs to be doubled.
Pricing Methodology	Traditionally, insurers do pricing methodology by inspecting loss data provided by the client. Where the probability of loss is very small, and this would lead to a technical pricing that is not commercial, insurers will rate on a rate-on-line basis (ROL). ROL is the percentage that the premium bears to the insurers’ liability: Liability (AAL) = \$100; Premium = \$4 => ROL 4%. 3% to 4% might be a typically acceptable ROL. If there is no risk, the ROL will still be at least 1 percent due to the opportunity cost of the insurer’s capital. Generally, each insured peril is rated separately. An exception is made when the rate of loss is due to <i>all</i> perils and it is not possible to separate out the effects of each one. Although rare in forestry, the present analysis yields only aggregate results of all perils – fire, wind, and ecological in-forest carbon fluxes.

Appendix E: Project Cost Data and Assumptions

Afforestation/Reforestation (A/R) Costs		
Parameter	Value	Comments
Site Preparation	\$50 ha ⁻¹	Costs will be highly variable. This is a moderate to low estimate, assuming some vegetation control or soil preparation using power equipment (power equipment cost is estimated at U.S. rates), and developing country wage rates.
Inventory	\$30,000 project ⁻¹	Assumes developing country field technician costs of \$15/day, and limited road access (e.g., relatively high amounts of time to travel to plots). Assumes enough plots to achieve +/- 10%-percent confidence interval at 95-percent statistical confidence. Assumes experienced staff compile inventory at developed country wage rates. Does not include major equipment purchases, such as multiple electronic data recorders. Occurs at project inception and again at 5-year intervals.
Management Plan Preparation	\$30,000 project ⁻¹	Assumes a basic management plan with maps, inventory, prescriptions, and general harvest and road plans. Does not include detailed surveys of sensitive species. Occurs at project inception and again at 10-year intervals.
Regeneration	\$500 ha ⁻¹	Assumed to be half of the cost of commercial forest regeneration in the U.S.
Project Development	\$30,000 project ⁻¹	A low-end estimate based on observation of about 20 projects. This cost covers some map development and writing a project document. It does not include methodology development or significant payments to consultants for modeling.
Pre-project Calculations	\$10,000 project ⁻¹	Assumes experienced staff that can quickly make calculations from inventory data.
Field Verification	\$35,000 project ⁻¹	Slightly higher than a mid-range estimate to allow extra travel costs to remote sites. Based on observation of verification contracts of the past few years. Occurs at project inception and again at 5-year intervals.
Validation	\$40,000 project ⁻¹	Cost is slightly higher than a mid-range estimate, based on observed validation contracts of the past few years.
Site Maintenance	\$1 ha ⁻¹	A low “placeholder” rate. Actual costs could be lower or much higher. If higher costs occur, the higher costs should only be for the first 1-3 years after planting. Higher costs could be needed for control of competing vegetation or protection of plantings from herbivores.
Field Sampling and Monitoring	\$40,000 project ⁻¹	Includes the cost of an inventory, plus a modest amount for staff to prepare monitoring reports for verification. Occurs at project inception and again at 5-year intervals.
Annual Verification Report	\$1,000 project ⁻¹	A desk review performed in years when field verification is not performed. Although the time involved is low, transaction costs of contracting and liability costs of verifiers will likely cause these fees to increase.
Registry Maintenance Fee	\$500 project ⁻¹ year ⁻¹	Estimated from the APX fee schedule for a VCS account. Offset issuance and transfers are sometimes denominated in U.S. dollars and sometimes denominated in Euros.
Issuance/Registration Fee	\$0.15 credit ⁻¹	Estimated from current registry fees.
Carbon Price Increase	6 percent	Increases at the discount rate, consistent with recent analysis of comprehensive climate policy initiatives (e.g., U.S. Environmental Protection Agency, 2009).
Discount Rate	10 percent for in-country project development expenses; 6 percent for international capital.	

Calculation of tCER Pricing

The value of a temporary credit stems from the deferred compliance the credit generates. An entity that purchases a tCER offsets full compliance by the number of years the tCER stands viable. Short contracts will have heavily discounted credits, since the replacement requirement will be near at hand (Kim et al., 2008; Murray et al., 2007). Longer contracts should have lower discounts, but this depends on the expectation of future prices for replacement credits; if the price of replacement credits is expected to be much higher in the future than it is today, then temporary credits may have little value. For tCERs to maintain any value, prices of permanent credit must grow at a rate lower than the discount rate (Olschewski and Benítez 2005; Maréchal and Hecq 2006; Bird et al. 2004; Subak 2003). This assumes that tCER credits follow the same risk and cost profiles as permanent credits. Following this logic, the equation for determining tCER prices is simply (Maréchal and Hecq 2006):

$$p_{tCER_0} = p_{CER_0} - \frac{p_{CER_T}}{(1+d)^T} \quad [A3]$$

Where p_{tCER_0} is the price of a temporary credit at the time of issuance, p_{CER_0} is the price of a permanent credit at the time of tCER issuance, p_{CER_T} is the price of a permanent credit at the time the tCER expires at year T, and d is the discount rate. If the price of a permanent credit grows at a set rate (say, α) then the equation translates to:

$$p_{tCER_0} = p_{CER_0} - \frac{p_{CER_0}(1+\alpha)^T}{(1+d)^T} \quad [A4]$$

For example, if the price of a permanent carbon credit trades for \$5, the discount rate is 6 percent, and carbon prices rise at 5 percent, the value of a tCER that defers compliance for five years would be:

$$p_{tCER_0} = \$5 - \frac{\$5(1 + .05)^5}{(1 + .06)^5} = \$0.23$$

Under this equation, if the rate of growth of permanent credits is equal to or greater than the discount rate, the value of a temporary credit becomes zero or negative. The only way to alter this situation would be to include nuances in the pricing determination of tCERs for individual actors. One nuance could deal with regulatory certainty for specific industry groups. If one sector of the economy will no longer be regulated by its carbon emissions but cannot sell its purchased permanent credits, temporary credits would be a logical purchase. Further, high transaction costs for the sale of permanent credits combined with a growth in self-compliance could incentivize the purchase of temporary credits for certain individuals. For example, if an energy company plans to shut down a coal plant but finds it difficult to dispose of excess permanent credits that will result, then the purchase of temporary credits would be ideal. On the credit supply side, host countries may show favor toward temporary credits as they retain a shorter span of liability as compared to permanent credits.

While some projects have traded on the delivery of future CDM A/R tCER credits, it is difficult to determine the precise price that tCERs will sell in the future. The World Bank's BioCarbon Fund has dominated the purchase of CDM A/R credits. The price paid for these projects hovers in the \$4-5 range,⁵¹ similar to the prevailing price of a permanent credit on the voluntary market (Diaz et al., 2011).

⁵¹ See the following CDM project descriptions: <http://cdm.unfccc.int/Projects/DB/JACO1260322827.04/view> and <http://cdm.unfccc.int/Projects/DB/JACO1245724331.7/view> (accessed 15 February 2012).

Appendix F: Expanded Output and Sensitivity Analysis

Tonne Year

We see that similar trends occur in the 1,000 ha projects as in the 20,000 ha, as discussed in the main body of this report. An important difference is that the smaller projects tend to perform poorer, financially, due in part to economies of scale with regard to transaction and implementation costs. The relative risk of catastrophic loss is also greater in smaller projects, as disturbance events tend to affect larger portions of the smaller project, which in turn affects income under a tonne year approach.

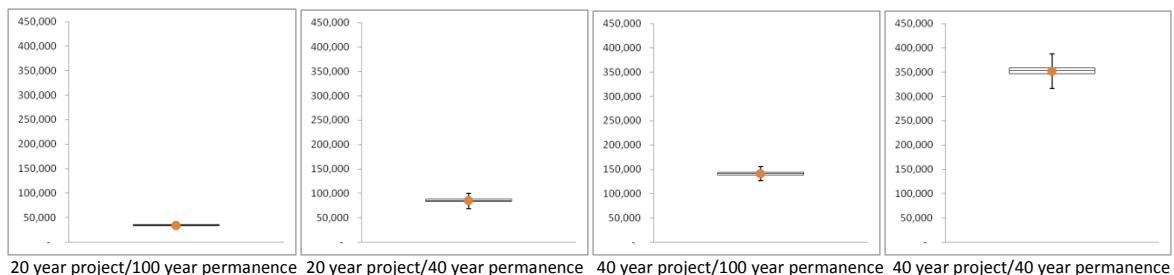


Figure AF-1. Total credits generated in a 1,000 ha project assuming a tonne year approach, both 40- and 100-year permanence periods, and 20- and 40-year project lives.

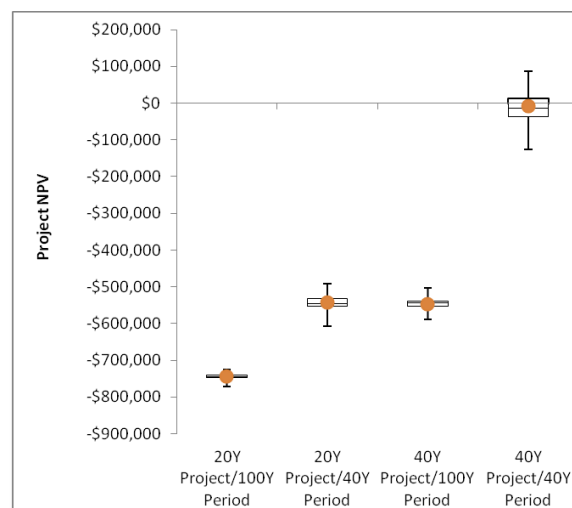


Figure AF-2. Project NPV for a 1,000 ha project assuming a tonne year approach, both 40- and 100-year permanence periods, and 20- and 40-year project lives.

Buffer Set Aside

As with tonne year, we find that similar trends exist in both 20,000 ha and 1,000 ha project examples operating under a buffer approach. 1,000 ha projects tend to perform poorer, financially, due in part to economies of scale with regard to transaction and implementation costs.

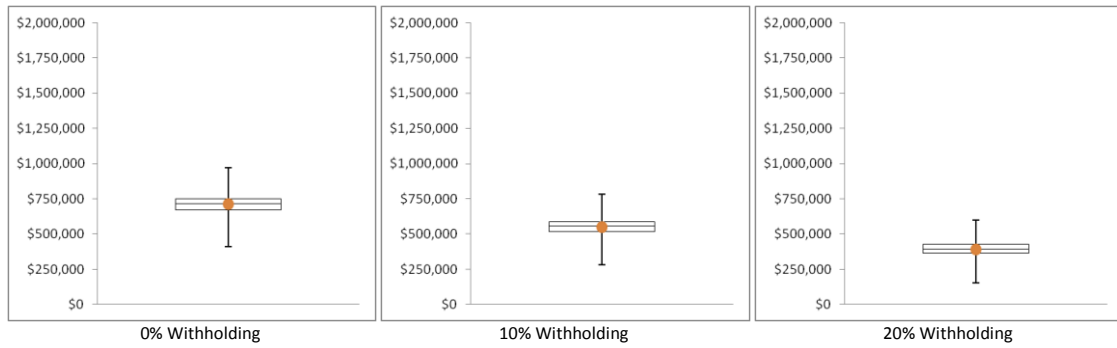


Figure AF-3. Project NPV for 0 percent, 10 percent, and 20 percent buffer for a 1,000 ha project over a 20-year period.

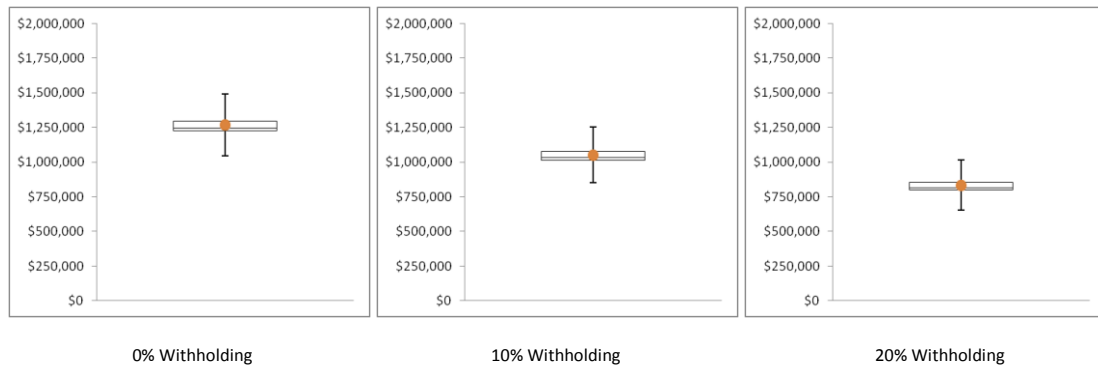


Figure AF-4. Project NPV for 0 percent, 10 percent, and 20 percent buffer for a 1,000 ha project over a 40-year period.

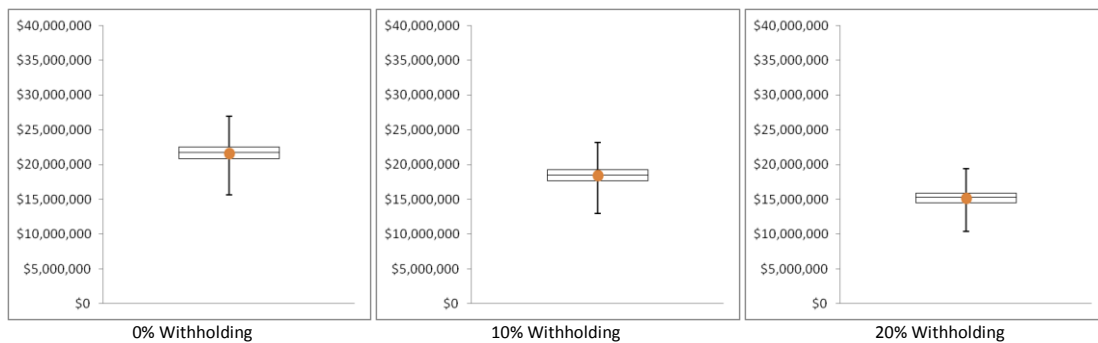


Figure AF-5. Project NPV for 0 percent, 10 percent, and 20 percent buffer for a 20,000 ha project over a 20-year period.

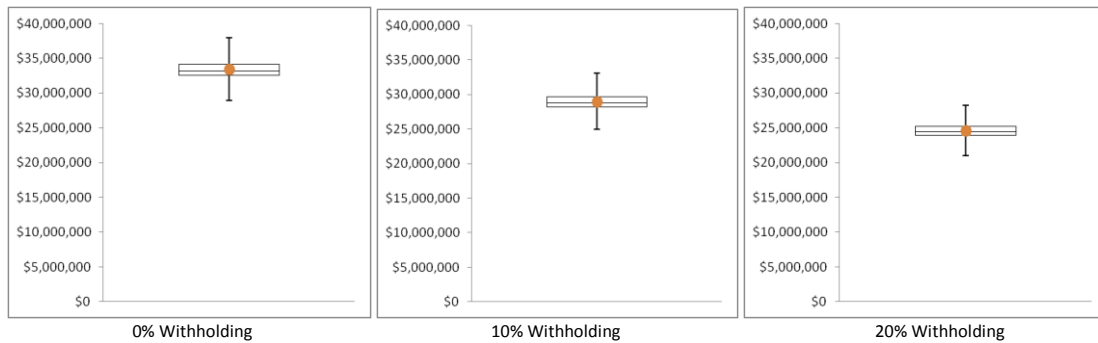


Figure AF-6. Project NPV for 0 percent, 10 percent, and 20 percent buffer for a 20,000 ha project over a 40-year period.

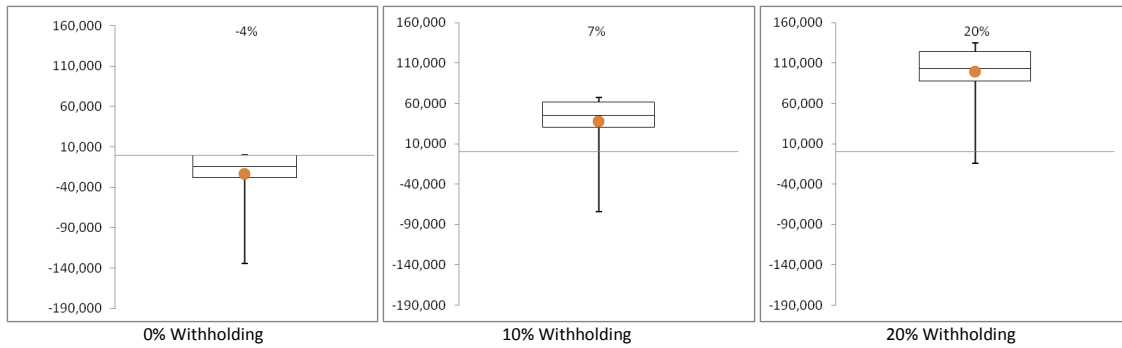


Figure AF-7. Ending buffer balance for 0 percent, 10 percent, and 20 percent buffer for a 1,000 ha project over a 40-year project life. Percentage above figure indicates the mean loss as compared to total credits earned by the project.

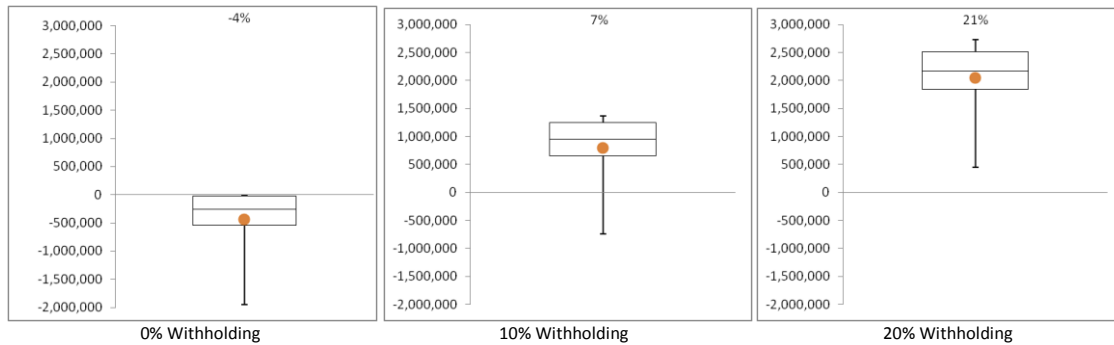


Figure AF-8. Ending buffer balance for 0 percent, 10 percent, and 20 percent buffer for a 20,000 ha project over a 40-year project life. Percentage above figure indicates the mean loss as compared to total credits earned by the project.

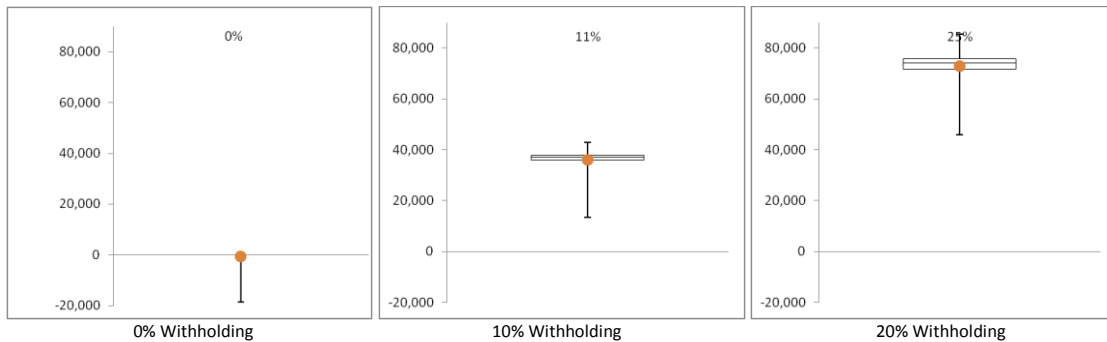


Figure AF-9. Ending buffer balance for 0 percent, 10 percent, and 20 percent buffer for a 1,000 ha project over a 20-year project life. Percentage above figure indicates the mean loss as compared to total credits earned by the project.

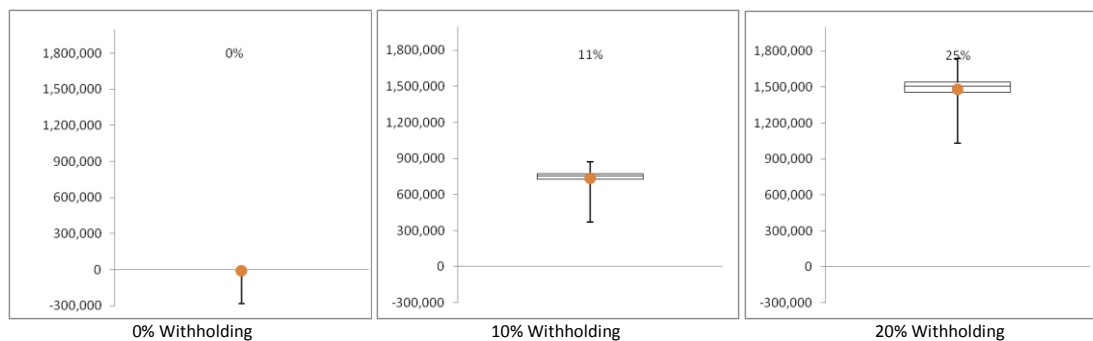


Figure AF-10. Ending buffer balance for 0 percent, 10 percent, and 20 percent buffer for a 20,000 ha project over a 20-year project life. Percentage above figure indicates the mean loss as compared to total credits earned by the project.

Commercial Insurance

Although risk of loss, and premiums and deductibles by extension, are all different, 1,000 ha projects tend to perform similar to the 20,000 ha examples. Both project lengths generate positive net present values and, as with other approaches, the longer project performs better.

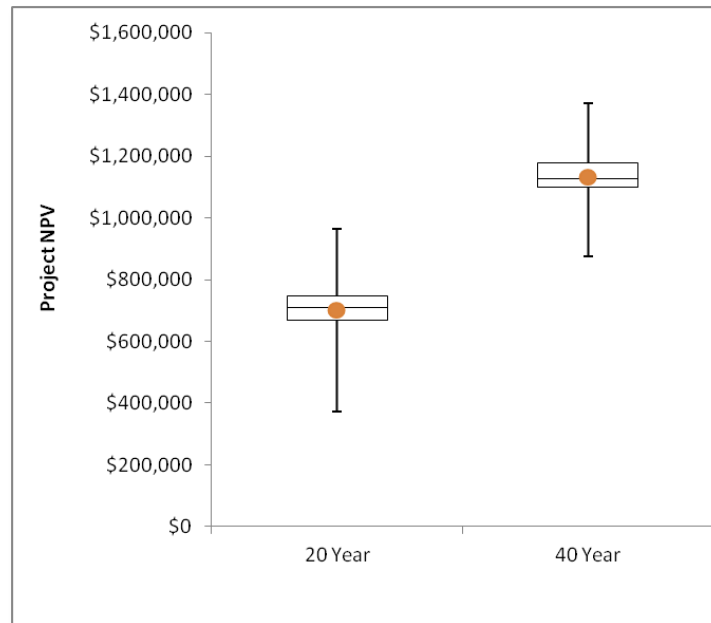


Figure AF-11. Project NPV for a 1,000 ha project assuming full value option insurance coverage over both 20- and 40-year project lives.