Food and Agriculture Organization of the United Nations

Options for addressing the risk of non-permanence for land-based mitigation in carbon crediting programmes

Options for addressing the risk of non-permanence for land-based mitigation in carbon crediting programmes

Food and Agriculture Organization of the United Nations

Rome, 2024

REQUIRED CITATION:
FAO. 2024. *Options for addressing the risk of non-permanence for land-based mitigation in carbon crediting programmes*. Rome. https://doi.org/10.4060/cd3083en

ISBN 978-92-5-139312-3

Contents

Boxes

Figures

Tables

Acknowledgements

This paper was written by Lambert Schneider and Isabel Haase (Öko-Institut), Derik Broekhoff (Stockholm Environment Institute), and Till Neeff (Food and Agriculture Organization of the United Nations [FAO]). The authors are grateful for contributions and feedback from Anne Siemons and Donna Lee, and would also like to express their thanks to the following for their feedback: the team at FAO (Amy Duchelle, Astrid Agostini, Lucio Santos, Marieke Sandker, Martial Bernoux, and Julian Fox); Manuel Estrada from the World Bank; Dirk Nemitz, Jenny Wong and Keiichi Igarashi with the United Nations Framework Convention on Climate Change (UNFCCC); Owen Hewlett with the Gold Standard Foundation; Current Masunungure with Verra; Jon Remucal and Kristen Gorguinpour with the Climate Action Reserve (CAR); Sandro Federici with the Technical Support Unit of the Intergovernmental Panel on Climate Change (IPCC); and a group of officials with the Government of the United Kingdom of Great Britain and Northern Ireland.

Copyediting was completed by Alex Gregor, with graphic design by Massimiliano Martino. Vanessa Vertiz supported the publication process. This paper was produced by FAO under its AIM4Forests programme thanks to finance from the Department for Energy Security and Net Zero of the United Kingdom of Great Britain and Northern Ireland.

Abbreviations

°C	degrees Celsius
ACR	American Carbon Registry (former name)
ART-TREES	the REDD+ Environmental Excellence Standard of the Architecture for REDD+ Transactions
CAR	Climate Action Reserve
CDM	The Clean Development Mechanism
CO_2	carbon dioxide
COP	Conference of the Parties to the UNFCCC
FCPF	the World Bank's Forest Carbon Partnership Facility
GHG	greenhouse gas
GS	the Gold Standard programme
IFM	improved forest management
IPCC	Intergovernmental Panel on Climate Change
ITMO	internationally transferred mitigation outcome
NDC	nationally determined contribution
REDD+	Reducing Emissions from Deforestation and Forest Degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
tCO_2e	tonnes (t) of carbon dioxide (CO_2) equivalent (e)
UNFCCC	United Nations Framework Convention on Climate Change
VCS	the Verified Carbon Standard programme
ZLIMP	the Zambézia Integrated Landscape Management Program

Executive summary

To avoid the worst effects of climate change, the world must reduce greenhouse gas (GHG) emissions and scale up carbon dioxide (CO_2) removal from the atmosphere. Carbon crediting programmes, which issue tradable credits for each tonne of CO_2 equivalent (tCO_2e) reduction or removal, are one way to incentivize these activities. However, this approach relies on the assumption that each carbon credit represents an equivalent amount of mitigation, regardless of its source. This is not always the case, especially for land-based mitigation, which often faces a risk of "non-permanence".

Non-permanence, or reversal risk, refers to the possibility that carbon stored in reservoirs, such as trees and soils, will be rereleased into the atmosphere (for example, due to natural disturbances like fires or human activities like harvesting). Reversals are quantified by comparing changes in carbon stocks or emissions/removals relative to a counterfactual baseline (what would have happened without the mitigation activity).

The risk of reversal often depends on the specific circumstances of an individual mitigation activity. However, three general factors contribute to reversal risk:

- **Susceptibility to depletion:** Biospheric carbon reservoirs like forests and wetlands are more vulnerable to natural disturbances (fires, pests, disease outbreaks) and human activities (logging, agriculture) than geologic reservoirs or fossil fuel reservoirs.
- **Drivers of depletion:** Mitigation efforts that address the underlying drivers of carbon reservoir depletion (for example, providing alternative livelihoods to reduce deforestation pressure) are more likely to be permanent than those that merely restrict the supply of carbon.
- **Size of the reservoir:** Larger carbon reservoirs can buffer the impact of disturbances. For example, a fire may wipe out a small reforestation project, while a jurisdiction-scale programme may experience only a temporary reduction in its overall carbon removal rate.

Carbon crediting programmes use a variety of approaches to manage reversal risk. Most carbon crediting programmes require conducting reversal risk assessments, and may require, or provide incentives for, activity proponents to reduce reversal risk. To compensate for reversals, the following approaches are used:

- **Crediting based on monitoring and compensation for reversals:** Carbon crediting programmes can require the activity proponents to monitor and report whether any reversals occur and to compensate for any reversals by cancelling other carbon credits. Key choices include for how long such monitoring is required and how to assign responsibility for compensating for reversals. Some carbon crediting programmes also require or allow updating the baseline when reversals have occurred.

- **Temporary crediting:** In temporary crediting, carbon credits expire, and carbon credit buyers must renew them or replace them with other carbon market units. Ongoing monitoring of continued carbon storage is therefore guaranteed.

- **Issuance deductions:** To account for future reversal risk, carbon crediting programmes can issue carbon credits only for a fraction of the emission reductions or removals achieved through the mitigation activity.

Next to these approaches, a few carbon crediting programs have also proposed tonne-year crediting, where programmes can issue a fraction of carbon credits for each year that carbon remains stored.

Reversal risks pose a particular challenge for host countries because they are ultimately responsible for any reversals that occur within their territories, irrespective of the carbon crediting programmes' approaches for compensating for reversals, such as pooled buffer reserves. This is because any compensation of reversals (through the cancellation of carbon credits by activity proponents, or from a carbon crediting programme's pooled buffer reserve) will not be captured in host countries' emissions balances used to assess the achievement of their nationally determined contributions (NDCs) under the Paris Agreement. This disconnect can create an imbalance for host countries: if they authorize the carbon credits to be internationally transferred under Article 6 of the Paris Agreement, they can no longer use the underpinning emission reductions or removal to achieve their own NDCs but still have responsibility for future reversal. These risks are further exacerbated if the emission reductions or removals are not covered by the current NDC or are not yet visible in national GHG inventories. To manage this liability, host countries should:

- ensure that all mitigation outcomes, including those authorized as carbon credits, are accurately reflected in their national GHG inventories and that the relevant sector, emission source and carbon pools are covered by the NDC (this may require improving the granularity of their inventory systems and adjusting the scope of their NDCs);

- consider implementing policies to ensure a fair sharing of mitigation benefits between the host country and buyers of carbon credits, considering host country's ultimate responsibility for reversals (this could involve setting baselines conservatively, limiting the share of mitigation that is authorized for sale as carbon credits, or establishing fees for carbon credit issuance); and

- develop clear criteria for authorizing carbon crediting activities, prioritizing activities that minimize reversal risk (this might include focusing on activities that address the drivers of deforestation, promoting the use of climate-resilient species, and avoiding activities in areas with high risks of natural disturbances).

Ultimately, managing reversal risk requires recognizing that no land-based mitigation activity can guarantee permanent carbon storage. The goal should be to minimize risks over the long term, while acknowledging that future reversals are possible and planning accordingly.

Introduction

To avoid dangerous levels of global warming, human beings must rapidly reduce greenhouse gas (GHG) emissions and scale up efforts to remove carbon dioxide (CO_2) from the atmosphere (IPCC, 2022). One prominent policy approach being pursued internationally and in multiple jurisdictions around the world is carbon crediting. Under carbon crediting programmes, including the Clean Development Mechanism (CDM) of the Kyoto Protocol, the new Article 6.4 mechanism under the Paris Agreement and multiple independent programmes, tradable carbon credits are issued for each tonne of CO_2 equivalent (tCO_2e) reduction or removal achieved by a mitigation activity. Buyers can purchase and retire these credits to count them towards a mitigation target, and thereby provide needed revenue to the mitigation activity.

The underlying premise of these markets is that each carbon credit has equal mitigation value. This means that the credits can be traded and used interchangeably. However, ensuring this is not always straightforward. A particular concern arises when credited mitigation is not guaranteed to be permanent. If an activity removes and stores carbon in trees, for example, there is a risk that the carbon could be re-emitted in the future due to natural disturbance (e.g. fire) or human activity (e.g. harvesting). The effect would then not be equivalent to mitigation activities that permanently reduce or remove GHG emissions.

Approaches to address “non-permanence” are garnering attention, as interest has grown in leveraging carbon markets to support nature-based mitigation and various forms of CO_2 removals. This paper aims to inform discussions on the approaches for addressing non-permanence for nature-based mitigation activities under the Article 6.4 mechanism and in other carbon crediting programmes.

The publication is organized as follows:

- Section 1 provides an introduction.
- Section 2 describes the issue of non-permanence in more detail, identifies for what types of mitigation activities it is a concern, and explains why it matters for the environmental integrity of carbon markets.
- Section 3 describes various approaches to address non-permanence that have been applied by carbon crediting programmes, as well as assesses them according to their practical feasibility and environmental integrity.
- Section 4 explores why reversal risks create a potential liability for countries hosting mitigation activities and how countries can strategically manage reversal risks.
- Section 5 draws conclusions.

1

What reversals are and why they matter for carbon crediting

The risk of "non-permanence" is intuitively easy to understand: carbon stored as a result of a mitigation activity, such as tree planting, could be released to the atmosphere in the future, undercutting the activity's contribution to slowing climate change. In the context of carbon crediting programmes, such a release is called a "reversal".

This section: examines how reversals are quantified and accounted for (Section 2.1); identifies factors that contribute to reversal risk (Section 2.2); and examines different conceptual models for including non-permanent (reversible) mitigation in carbon crediting programmes (Section 2.3). These conceptual models have important implications for how carbon crediting programmes address reversals.

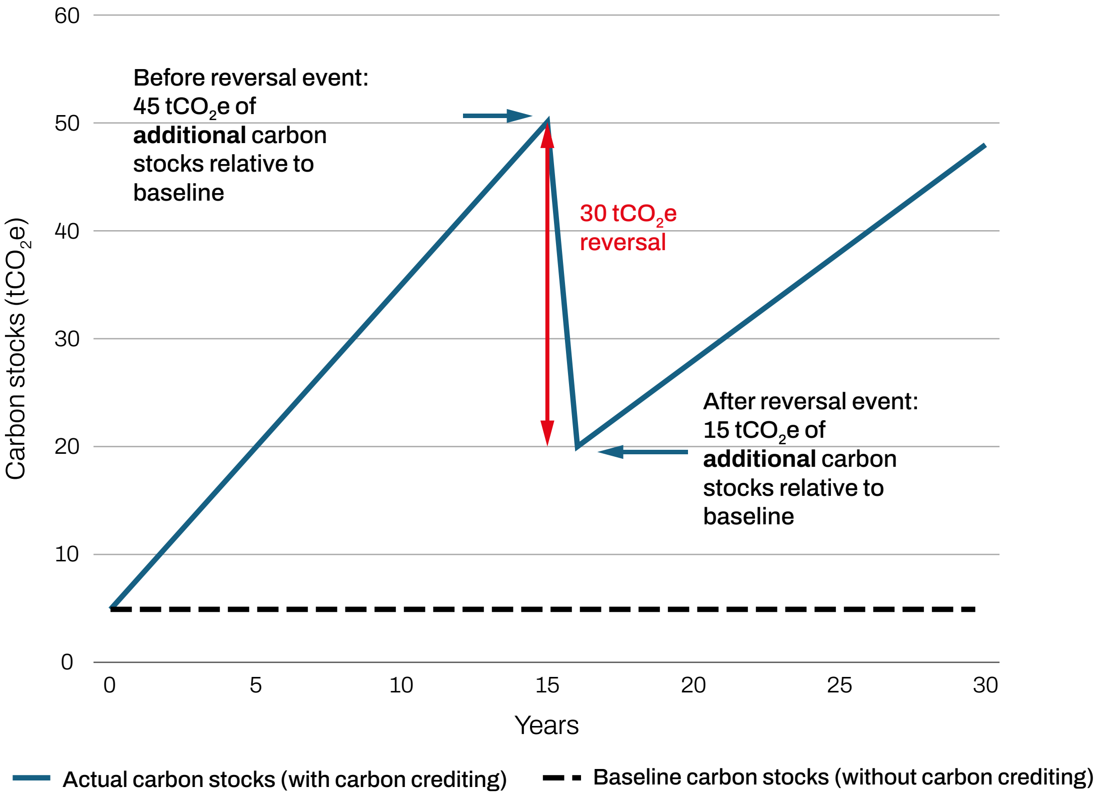
2

2.1 What reversals are and how they can occur

Carbon crediting programmes issue tradable carbon credits for climate change mitigation activities that either reduce emissions of GHGs to the atmosphere or enhance removals of GHGs from the atmosphere. Emission reductions and enhanced removals are quantified against a counterfactual baseline that represents the emissions or removals that would have occurred in the absence of any carbon crediting.

For many kinds of mitigation activities, the effect of reducing emissions or enhancing removals will be to increase – relative to the baseline – the quantity of gases (typically CO_2)[1] stored in one or more reservoirs. A tree planting (reforestation or afforestation) project, for example, will remove CO_2 from the atmosphere and store the carbon in trees, vegetation and soils. A reversal will occur, however, if at any point in time the cumulative quantity of additional CO_2 stored in these reservoirs – relative to the baseline – is reduced. Figure 1 illustrates this with respect to a hypothetical afforestation project.

Figure 1 Illustration of a reversal of removals using carbon stock accounting

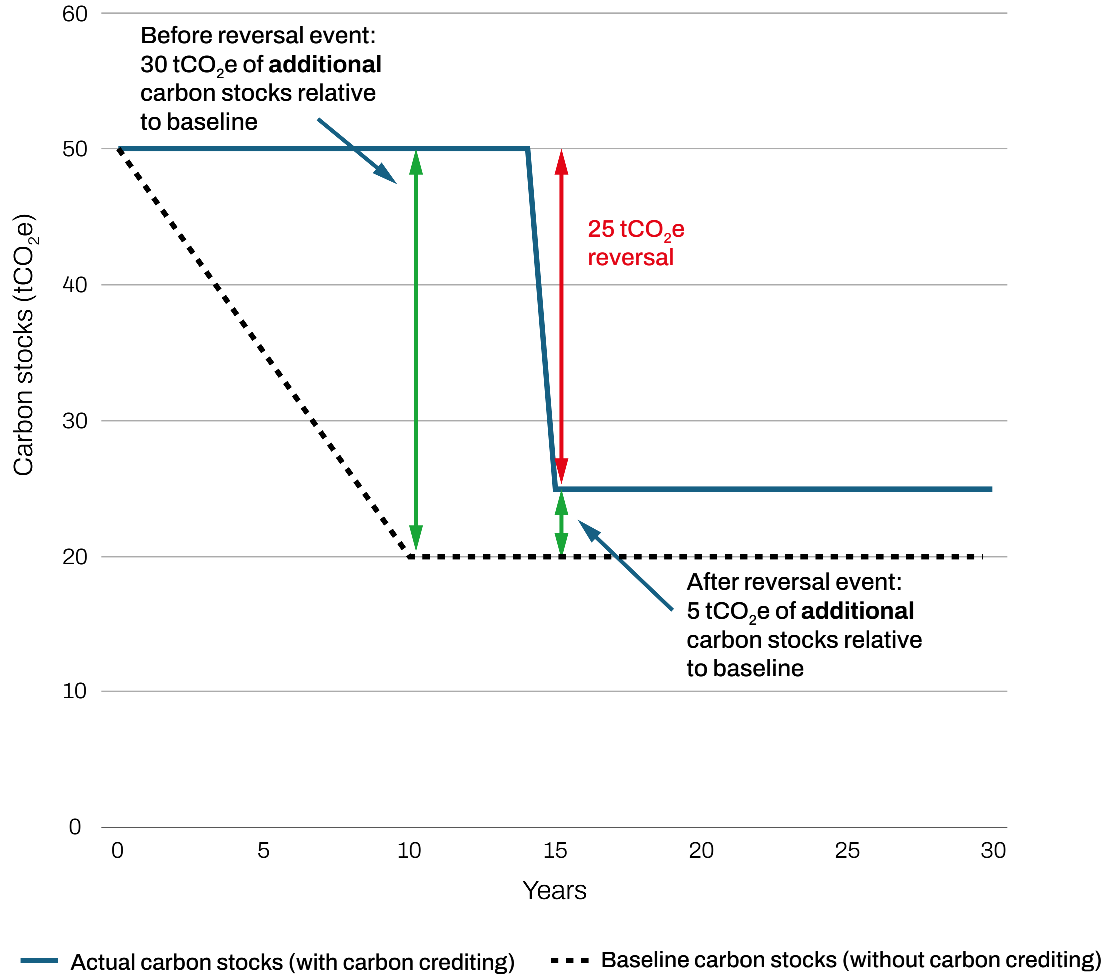


Note: In this stylized illustration, an afforestation project is initiated that removes CO_2 from the atmosphere and stores it in trees. In the baseline, 5 tonnes of CO_2 would have been maintained over time on land (e.g. in vegetation and soils) within the project area. With the project (enabled by carbon crediting), total carbon stocks increase to 50 tonnes after 15 years, due to enhanced removals achieved by growing trees. Cumulative enhanced removals, compared to the baseline, are therefore 45 tonnes. However, a reversal event (e.g. due to harvesting or a wildfire) reduces carbon stocks to 20 tonnes in the following year. Cumulative enhanced removals (relative to the baseline) are reduced to 15 tonnes, leading to a reversal of 30 tonnes.

[1] In rare cases, an activity may enhance storage of a non-CO_2 gas. Projects that cap orphaned gas wells and prevent the release of methane, for example, lead to increased storage of methane relative to their baselines.

One occasional misconception is that reversals are only a risk for activities that remove carbon from the atmosphere, and not for those that reduce or avoid emissions. In fact, emission reductions can also be reversed under certain circumstances. This can occur, for example, if a mitigation activity avoids emissions from a carbon reservoir for a time, thereby enhancing the reservoir's carbon stocks compared to the baseline, but then emissions occur that reduce the cumulative quantity of carbon stored relative to the baseline. This is illustrated in Figure 2 for a hypothetical "improved forest management" (IFM) project, which avoids emissions by reducing logging activity, but is affected by a wildfire that reduces cumulative storage of carbon relative to the baseline. Box 1 describes a real-world example of a reversal occurring for an IFM project under the State of California's carbon crediting programme.

Figure 2 Illustration of a reversal of avoided emissions using carbon stock accounting



Note: In this stylized illustration, an IFM project is initiated that avoids harvesting that would have occurred in the baseline. In the baseline, carbon stocks would have been depleted over time to 20 tCO_2e, resulting in 30 tCO_2e of emissions to the atmosphere. The project reduces harvesting such that forest carbon stocks are maintained at 50 tCO_2e, meaning that 30 tCO_2e of emissions are avoided. In Year 16, a wildfire occurs, reducing carbon stocks to 25 tCO_2e, such that cumulative avoided emissions total only 5 tCO_2e. For simplicity, it is here assumed that the wildfire would not have affected carbon stocks in the baseline scenario (e.g. because less understory vegetation is available). Also for simplicity, harvesting is assumed to result in immediate emission of CO_2 (e.g. ongoing carbon storage in harvested wood products is ignored).

Note that not all emission-reducing activities lead to an increase in GHGs stored in a reservoir. Activities that destroy or avoid the formation of non-CO_2 GHGs – such as methane, nitrous oxide, and various industrial gases – do not result in increased storage of these gases. As such, the emission reductions achieved by these activities are not reversible.[2] In other words, reversals are a phenomenon specific to GHG reservoirs: what is added to a reservoir can later be released, leading to a reversal.

Finally, one question that can arise is whether reversal accounting should include other effects a mitigation activity has on GHGs, outside the specific reservoir targeted by the activity. For example, an afforestation project may establish trees that remove CO_2 from the atmosphere, but it might also cause emissions from use of equipment and fertilizer applications. If the trees were subsequently lost due to harvesting or disturbance, the total effect of the project might be a net increase in emissions, relative to its baseline. Most carbon crediting programmes restrict reversal accounting to the net balance of GHGs stored in a targeted reservoir (for example, carbon stored in the trees in an afforestation project) and consider other emission effects separately. Any excess net emissions could be considered a separate liability, but not part of the reversal.

Box 1. Reversals in California's regulatory carbon crediting programme

In 2021, a large wildfire burned more than 167 000 hectares of forest in the Klamath Basin of southern Oregon in the United States of America. More than 40 000 of these hectares were enrolled in a carbon crediting project registered under California's cap-and-trade programme. The project, developed by the Green Diamond timber company, was designed to both avoid forest carbon emissions and enhance removals by slowing the pace of logging.[a] The fire caused around 3.3 million tonnes of CO_2 to be emitted to the atmosphere, completely reversing all the avoided emissions previously attributed to the project, which were about 1 million tonnes (relative to the project's baseline scenario).*

In other words, all 1 million tonnes of additional carbon preserved by the project were lost, along with 2.3 million tonnes of "baseline" carbon (which would have been lost even if the project had not been implemented, presuming the same fire event occurred).** The project, called "Klamath East IFM", was subsequently terminated.

To compensate for this reversal, California regulators cancelled credits from a "pooled buffer reserve" designed to insure against such losses for a period of 100 years (see Section 3.3.4 for a further discussion of buffer reserves). However, the Klamath Basin project is not the only California carbon offset project to suffer reversals. All told, wildfires have destroyed around 11 million tonnes worth of carbon credits under California's programme. Although California's buffer reserve has been large enough to absorb these losses, one analysis suggests that regulators may have underestimated wildfire risks (which are exacerbated by climate change) when determining how many credits to set aside, leading to uncertainty about whether the buffer reserve will be sufficient to cover losses in the future.[b]

[2] Subsequent activities might later create more of these gases, but such activities would only lead to a "reversal" if they were a direct consequence of the original mitigation activity (i.e. the emissions would not have occurred if the original mitigation activity had not occurred).


© flickr/ Bootleg Fire

Notes:

* For more information, see https://acr2.apx.com/mymodule/reg/prjView.asp?id1=273

** The implication is that, in the project's baseline scenario, the same wildfire would also have caused emissions from carbon stocks present in the baseline (i.e. the fire burned both "project" and "baseline" trees). The Klamath East IFM project was terminated in this situation. As discussed further in Section 3.3.3, however, some carbon crediting programmes allow baselines to be adjusted in these situations, so that projects can continue to generate credits for avoiding emissions or enhancing removals. The challenge is that the quantity of emissions that would have occurred in the baseline can be difficult to estimate. With fewer trees present, for example, it is possible that losses would not have been as severe. This means estimates of the net mitigation achieved by the project going forward would be subject to greater uncertainty.

Sources:

[a] Bernton, H. 2023. A giant Oregon wildfire shows the limits of carbon offsets in fighting climate change. *OPB*, 2 August 2023. https://www.opb.org/article/2023/08/02/climate-change-carbon-offset-oregon

[b] Badgley, G., Chay, F., Chegwidden, O. S., Hamman, J. J., Freeman, J. and Cullenward, D. 2022. California's forest carbon offsets buffer pool is severely undercapitalized. *Frontiers in Forests and Global Change*, 5: 930426. https://doi.org/10.3389/ffgc.2022.930426

2.1.1 Quantifying reversals: measuring stocks or flows

The examples above illustrate reversals by assessing the change in the amount of carbon stored in a reservoir. Reversals can indeed also be quantified by assessing the difference between actual and baseline carbon stocks in the targeted reservoir (that is, relative changes in the amount of carbon or GHGs stored in a reservoir). Rather than considering carbon or GHG stocks, reversals can also be quantified by comparing actual and baseline emissions and removals (that is, relative flows into and out of a reservoir). Either way, the math is identical and delivers the same quantity of reversals. Specifically:

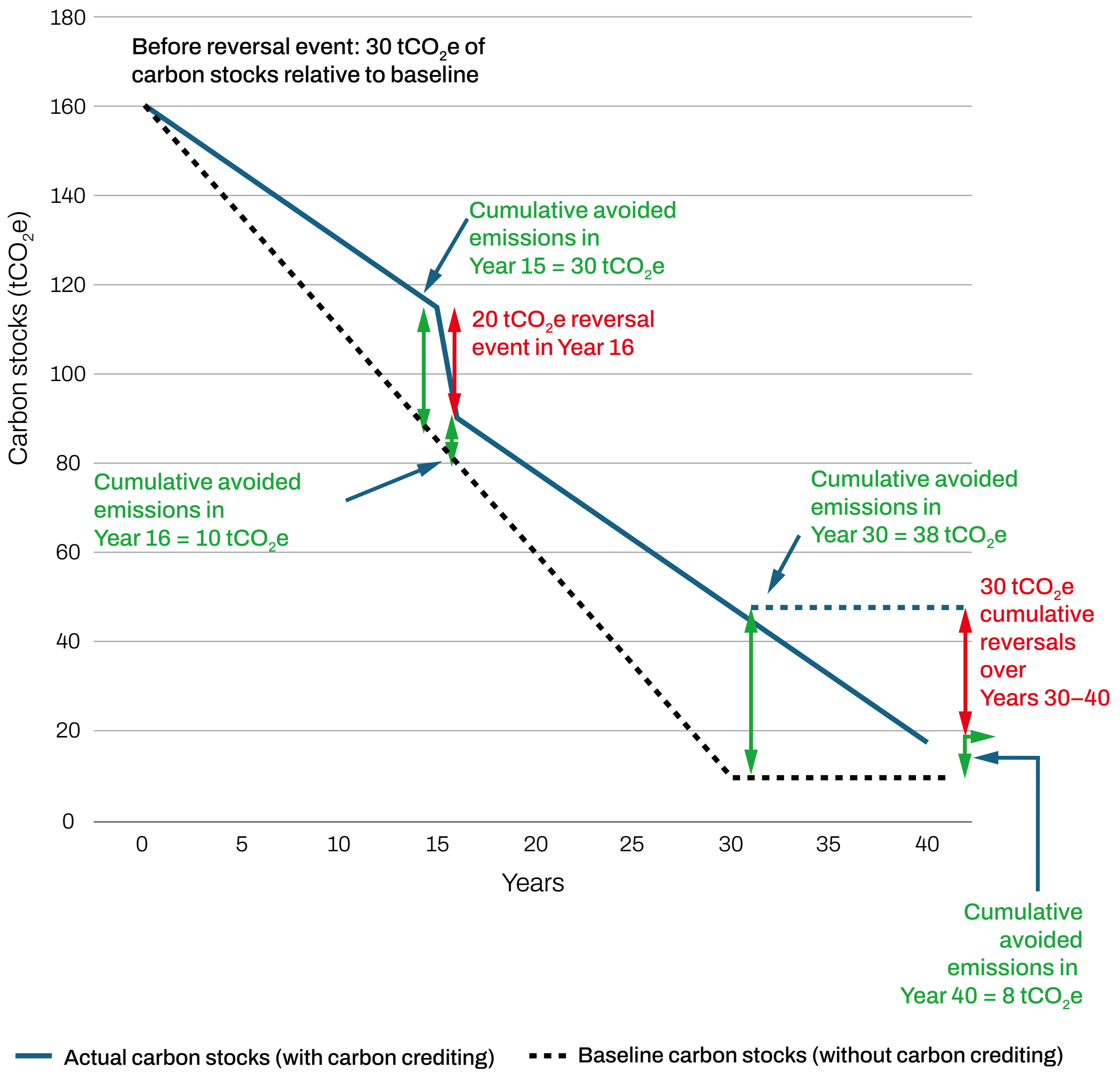
- When considering stocks, a reversal occurs if, at a future point in time, the difference between actual and baseline stocks in a targeted reservoir is reduced (that is, the difference gets smaller). This is illustrated in both Figure 1 and Figure 2.
- When considering emissions and removals, a reversal occurs if, at a future point in time, either:
  - actual emissions from the targeted reservoir exceed baseline emissions; or
  - actual removals into the targeted reservoir drop below baseline removals.

Either outcome is equivalent to a reduction in the difference between actual and baseline carbon stocks.

Although either approach works, quantification based on emissions and removals is typically done when direct measurement of the change in carbon or GHG stocks in a reservoir would be difficult or infeasible. This could be the case, for example, when capturing CO_2 and injecting it into a geologic reservoir, where accumulated carbon is measured based on flow rates, rather than in situ measurements in the reservoir. It can also be the case for avoided deforestation activities, where emission reductions are calculated based on imputed emission rates per area of deforested land, rather than an assessment of the total change in carbon stocks across an entire forest area. Box 2 describes a real-world example where reversals were quantified based on changes in emission rates across forested areas in Mozambique.

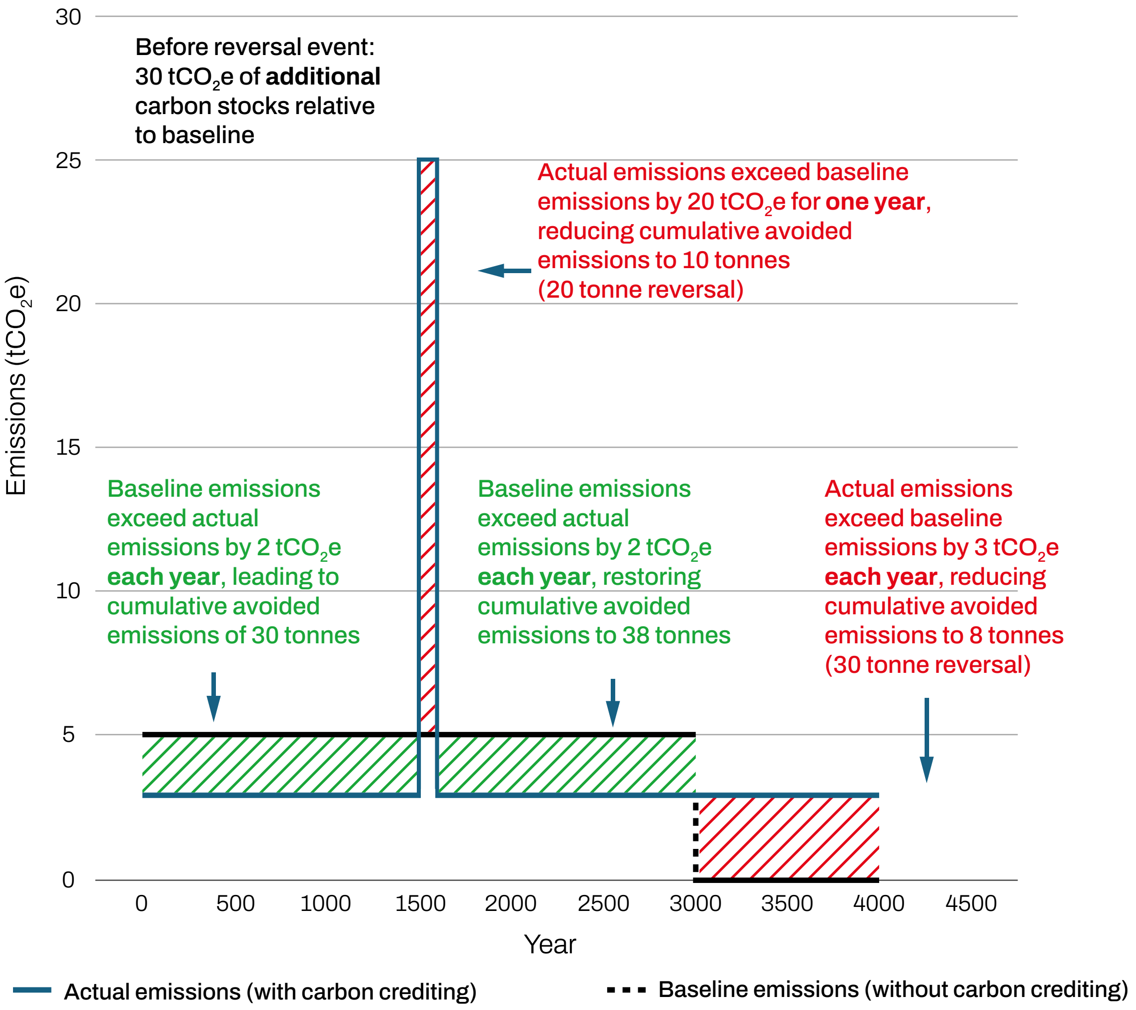
To illustrate the connection between stock and flow accounting, Figure 3 provides a stylized example of an avoided deforestation activity, where reversals are quantified based on changes in carbon stocks. Figure 4 presents the same example but illustrates how changes in stocks translate into actual and baseline emission rates.

Figure 3 Illustration of reversal accounting for an avoided deforestation project, using carbon stocks



Note: In this stylized illustration, an avoided deforestation project is initiated that avoids emissions from forest loss that would have occurred in the baseline. The forest area is assumed to start with 160 tCO_2e of total carbon stocks. In the baseline, these stocks are depleted at a rate of 5 tonnes per year, falling to 10 tCO_2e by the end of Year 30. The project slows this rate of emission to 3 tonnes per year, so that total carbon stocks are 30 tonnes higher in Year 15 than in the baseline. In Year 16, a wildfire destroys part of the preserved forest and reduces the difference between actual and baseline carbon stocks to 10 tCO_2e, leading to a 20 tCO_2e reversal. After this, the project maintains the carbon stock depletion rate at 3 tonnes per year. In the baseline, however, carbon stock depletion ceases in Year 30, on the assumption that there would be little forest left to exploit. The result is that the difference between actual and baseline carbon stocks is steadily reduced, leading to cumulative reversals of 30 tonnes.

Figure 4 Illustration of reversal accounting for an avoided deforestation project, using emissions



Note: This figure is based on the same stylized avoided deforestation project presented in Figure 3, but illustrates reversal quantification using relative emission rates instead of carbon stocks. Following the example in Figure 3, deforestation would have caused emissions of 5 tCO_2e per year in the baseline scenario. The project, however, slows this rate to 3 tCO_2e per year, leading to 2 tCO_2e of avoided emissions every year. This amounts to 30 tCO_2e of cumulative avoided emissions by the end of Year 15. In Year 16, a fire leads to 25 tCO_2e of emissions. This exceeds baseline emissions by 20 tCO_2e, so a reversal of 20 tCO_2e occurs. Over the next 14 years, the project avoids another 28 tCO_2e of emissions. However, after Year 30 baseline emissions go to zero, while project emissions continue, leading to ongoing reversals totalling 30 tCO_2e.

The stylized examples presented here – and the case study presented in Box 1 – are premised on a natural disturbance, such as a wildfire, causing reversals. However, across different kinds of mitigation activities, reversals can be caused by numerous factors, including human activity (indeed, many wildfires are human-caused – see MacCarthy *et al.* [2024]). For avoided deforestation activities, a reversal risk can arise from multiple sources that drive actual deforestation emissions above baseline emissions. This occurred in 2021 and 2022 under a programme designed to slow deforestation rates in Mozambique (Box 2).

Box 2. Reversal under a national-scale programme to slow deforestation in Mozambique

The Zambézia Integrated Landscape Management Program (ZILMP)* is an avoided deforestation initiative implemented in Mozambique and supported by the World Bank's Forest Carbon Partnership Facility (FCPF), which provides funding for efforts to slow deforestation in multiple jurisdictions around the world. The FCPF operates in part as a type of jurisdiction-scale carbon crediting programme, by quantifying the emission reductions achieved by the programmes and initiatives it supports, as well as providing financial payments for their performance. The ZLIMP is one of two jurisdictional initiatives implemented under the FCPF in Mozambique.

Between 2000 and 2014, the Zambézia province lost 268 000 hectares of forest, driven primarily by slash-and-burn agriculture, charcoal production, and illegal logging.[a] The ZLIMP was initiated in 2015; under FCPF, it began quantifying avoided emissions starting in 2018. Between 2018 and mid-2021, total credited emission reductions – as measured against the programme's baseline – were quantified close to 3.8 million tCO_2e.** Of this total, around 1.3 million tCO_2e were allocated to a "pooled buffer reserve" operated by the FCPF to compensate for possible reversals.

Over 2021 and 2022, however, deforestation pressures – primarily from slash-and-burn agriculture – increased, causing quantified emissions from forest loss to exceed the programme's baseline levels.*** All told, emissions rose to over 7 million tCO_2e, reversing all previously quantified emission reductions, and exceeding the total quantity of emission reductions allocated to the buffer reserve.

This example illustrates the challenges of managing for reversal risk, even at the scale of jurisdictional (e.g. province-level) mitigation activities.

Notes:

* For more information, see https://documents.worldbank.org/en/publication/documents-reports/documentdetail/945201525957363451/zambezia-integrated-landscape-management-program-towards-a-sustainable-forest-management-and-improved-livelihoods-of-rural-communities

** As reported in verification reports here and here.

*** See verification report here.

Sources:

[a] World Bank. 2018. *Zambézia Integrated Landscape Management Program: Towards a Sustainable Forest Management and Improved Livelihoods of Rural Communities.* Washington, DC, World Bank Group. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/945201525957363451/zambezia-integrated-landscape-management-program-towards-a-sustainable-forest-management-and-improved-livelihoods-of-rural-communities

2.1.2 How baseline uncertainty impacts the quantification of reversals

After a mitigation activity is implemented, reversals can in principle occur at any time in the future, even many decades later. This presents a challenge for quantifying reversals (or even determining whether a reversal occurred), since the quantity of reversals depends as much on assumptions about an activity's baseline as it does on actual disturbances. In the illustration in Figure 3, for example, reversals occur after Year 30 because actual emissions continue past the point at which they would have ceased in the baseline. An important inference is that, for activities that reduce emissions – including projects or programmes that avoid deforestation – avoiding a reversal requires ceasing actual emissions before they would have halted in the baseline.

The challenge is that the further one looks into the future, the more difficult it is to confidently determine an activity's baseline. One method that some crediting programmes use to address uncertainty is to conservatively update baseline projections over time. Under the REDD+ Environmental Excellence Standard of the Architecture for REDD+ Transactions (ART-TREES) programme,[3] for example – which credits avoided emissions from activities that reduce deforestation across entire jurisdictions – baselines are set for discrete five-year periods. In each successive period, the baseline against which future avoided emissions are calculated cannot exceed the actual emission level achieved in the prior period. Among other things, this helps ensure that the programme does not inadvertently fail to account for reversals that would occur due to uncertain baseline emission rates.[4]

[3] REDD+ refers to Reducing Emissions from Deforestation and Forest Degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.

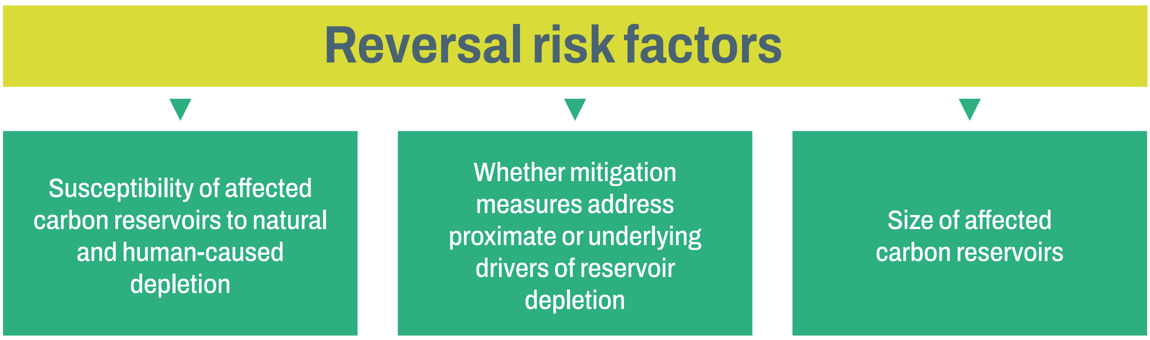
[4] The "true" quantity of reversals that might occur depends on the what the "true" baseline would have been. Because the baseline is a counterfactual scenario, however, there is considerable uncertainty in estimating this quantity. Crediting programmes often approach such uncertainty by adopting conservative quantification approaches that err on the side of underestimating cumulative avoided emissions or enhanced removals – in this case by potentially overestimating reversals.

2.2 What factors contribute to reversal risk

Not all mitigation activities that avoid emissions from carbon reservoirs, or enhance the flow of removals into such reservoirs, are subject to the same level of reversal risk. Strictly speaking, for example, all activities that reduce the use of fossil fuels – such as boosting renewable energy generation, or enhancing energy efficiency – avoid CO_2 emissions from fossil carbon reservoirs. Yet carbon crediting programmes treat such avoided emissions as "permanent" and not susceptible to reversal. The reason has to do with the relative risk of reversal for these types of activities (Box 3), compared to the risks that arise for many types of land-based mitigation activities (and many types of mitigation involving CO_2 removal).

While the reversal risk for any individual activity can depend on specific circumstances, there are some general factors to consider in assessing relative reversal risk across different types of activities (Figure 5). These factors are important for carbon crediting programmes to consider, since how (and whether) reversals are managed (Section 3) can depend on the likelihood that they will occur.

Figure 5 Key reversal risk factors



Box 3. Why fossil fuel emission reductions are considered permanent

Technically, mitigation activities that reduce the use of fossil fuels result in an increase in carbon stored in fossil fuel reservoirs, compared to their baseline scenarios. In principle, this means emission reductions from reducing fossil fuel combustion are reversible. Yet carbon crediting programmes typically treat these reductions as permanent (not subject to reversal). The reason has to do with the relatively low risk of reversal, based on the following considerations.

First, fossil fuel reservoirs are not susceptible to any significant level of natural depletion (Section 2.2.1). This is a key distinction from many land-based mitigation activities, for example, which store carbon in reservoirs that may face future depletion due to natural disturbances (e.g. fires, disease, weather events, or the cumulative effects of climate change).

Second, most measures that reduce fossil fuel use do so by reducing demand for fossil fuels, for example, by reducing energy demand, or by meeting this demand with renewable sources. Thus, the same basic need for energy services is met through alternative technologies that alleviate the underlying drivers of fossil fuel consumption (Section 2.2.2).* Many land-based activities, by contrast, depend in one way or another on restricting the supply of carbon in land-based reservoirs. Many forestry projects, for example, are not designed to alleviate pressure to deplete forest carbon reservoirs (for example, by increasing efficiency of agricultural production, or replacing agricultural and forest products with alternatives that alleviate deforestation pressure), or else they struggle to do so. In some instances, activities have been proposed for carbon crediting that would restrict the supply of fossil fuels, for example, by paying for the early shutdown of oil fields, or to cover the opportunity cost of not extracting fossil fuels. These activities are usually subject to reversal risk, because they typically do not address underlying fossil fuel demand – for example, the “protected” oil field could be reopened in the future, reversing any associated emission reductions.

Finally, one remaining risk for fossil fuel emission reductions is that reversals could occur due to the exhaustion of fossil fuel reserves, analogous to the reversals illustrated in Figure 3 (where, after Year 30, baseline carbon is no longer being depleted and baseline emissions drop to zero). If globally all that is accomplished is a delay in fossil fuel emissions, then technically all fossil fuel emission reductions could be reversed.** However, to meet the goals of the Paris Agreement, the world must transition away from fossil fuel use long before fossil fuel reservoirs are globally depleted, which – even at current rates of use – would happen far in the future.[a]

Notes:

* Related to this, most activities that reduce fossil fuel demand do not simply delay demand. Delaying demand could lead to reversals if, for example, emissions are reduced for a time but then rebound to levels higher than would have been the case in the activity’s baseline. Renewable energy and energy efficiency measures do not induce this kind of delayed demand, because (at least for a time) they replace fossil fuel demand. The emission reductions they produce are therefore permanent, regardless of what happens after these activities end.

** Because markets for fossil fuels are globally interconnected, and activities that reduce or avoid fossil fuel use typically do not target specific fossil fuel deposits or reserves, the size of the carbon reservoir affected by these mitigation activities is effectively global.

Sources:

[a] Welsby, D., Price, J., Pye, S. and Ekins, P. 2021. Unextractable fossil fuels in a 1.5 °C world. *Nature*, 597(7875): 230–34. https://doi.org/10.1038/s41586-021-03821-8

2.2.1 Susceptibility of affected carbon reservoirs to natural and human-caused depletion

Reversals can result from natural or human-caused processes. Natural disturbances affect some kinds of reservoirs more than others. Carbon contained in fossil fuel reservoirs, for example, is typically highly stable and not subject to natural disturbance risk. Carbon that is captured and stored in geological reservoirs may leak out over time – including, for example, if the integrity of a reservoir is compromised by seismic activity – but the risk of reversal from natural disturbances is usually quite low. By contrast, biospheric carbon reservoirs, such as forests or wetlands, can be subject to natural disturbances like fire, disease, drought or windstorms – disturbances whose frequency and severity may increase over time due to climate change itself.

Human-caused reversal risk also differs across different types of reservoirs. Forests and wetlands may be affected by human activity, such as logging, land clearing, agricultural production or development. Similarly, fossil carbon reservoirs are subject to ongoing depletion to meet human energy demands. By contrast, carbon that is captured and stored in geologic reservoirs typically faces little to no human-caused demand pressure (Figure 6).

Figure 6 Relative susceptibility of carbon reservoirs to natural and human-caused depletion

Susceptibility to natural depletion		Susceptibility to human-caused depletion: Lower	Susceptibility to human-caused depletion: Higher
	Lower	Geologic reservoirs (e.g. used for carbon capture and storage) Mineral reservoirs (e.g. limestone created through enhanced weathering)	Fossil fuel reservoirs
	Higher	Hard to exploit, and/or low economic value, biospheric carbon reservoirs (e.g. plankton created through ocean fertilization) Wood products or other low-durability human-made materials	Accessible, or high economic value, biospheric carbon reservoirs (forests, soils, grasslands, peatland, etc.)

Whether reversal risks arise primarily from natural or human-caused depletion (or both) can make a significant difference in how risks are managed. Because of their stochastic nature, for example, natural disturbance events can in principle be insured against, for instance, using pooled buffer reserves to compensate when such reversals occur (see Section 3.3.4). Human-caused depletion risk, on the other hand, may be more challenging to manage, depending on its underlying drivers (see Section 2.2.2). If the entity implementing a mitigation activity has an incentive itself to cause reversals – for example, if a landowner would profit by converting conserved forest land into a new development, thus reversing any previously avoided emissions – the risk may be uninsurable.[5] For this reason, carbon crediting programmes typically obligate landowners to compensate for reversals that they intentionally caused (see Section 3.3.2).

[5] In insurance terms, this would be an example of a "moral hazard" where the entity being insured has no incentive to avoid a loss.

2.2.2 Whether mitigation measures address the proximate or underlying drivers of reservoir depletion from human activity

In circumstances where human activity could cause the loss of carbon stocks, a key factor influencing reversal risk is whether mitigation efforts are designed to simply "wall off" an affected reservoir, preventing its depletion by human activity, or whether they address the underlying drivers of human activity.

In the context of avoided deforestation, for example, a mitigation programme that works by suppressing illegal logging through policing boundaries of a forest reserve would directly address the proximate cause of deforestation, but there is a risk that the effects may be merely temporary, as illegal encroachment could bounce back once enforcement is withdrawn. Another mitigation programme may seek to alleviate encroachment pressure by providing alternative livelihoods for local communities through improved agricultural methods (that is, addressing the underlying driver of forest clearing), and thus may offer better prospects for permanent emission reductions. For many land-based mitigation measures, addressing the underlying drivers of human-caused emissions is often challenging (and can be especially difficult or infeasible at smaller scales, where systemic change is hard to achieve) (Geist and Lambin, 2002).

2.2.3 Size of the affected greenhouse gas reservoirs

Many climate change mitigation activities included in carbon crediting programmes target (relatively) small and discretely defined carbon reservoirs. Tree planting and forest conservation projects, for example, are typically implemented across tens to thousands of hectares. By contrast, jurisdiction-scale forest conservation programmes may seek to slow deforestation across millions of hectares. This matters because size can act as a buffer against certain kinds of stochastic disturbance events (whether natural or human-caused). The effect of a wildfire on a small-scale project, for example, can be to fully reverse all the mitigation it has achieved (as illustrated by the example in Box 1). At a jurisdictional scale, by contrast, the incidence of various disturbances may be greater (that is, across an entire country, there are likely to be multiple such events in any given year), but even multiple events may simply slow the rate at which emission reductions or removals occur across the entire reservoir, rather than driving jurisdiction-wide emissions above baseline levels and causing reversals. The risk of reversals is therefore likely to be lower for activities implemented at jurisdictional scale than at project scale.[6]

[6] The absolute level of risk, of course, still depends on the total size of affected areas and the nature of the disturbance events. The wildfires affecting Canada in 2023, for example, generated massive amounts of CO_2 emissions that – if Canada had been seeking carbon credits for avoided forest emissions in prior years – likely would have resulted in major "reversals" even at a national scale (MacCarthy *et al.*, 2024).

2.3 Possible approaches for crediting non-permanent mitigation

Scientific understanding has solidified behind the idea that CO_2 emissions must stay within a cumulative "carbon budget" in order to meet the Paris Agreement's goal of limiting global warming to 1.5 °C (Allen *et al.*, 2022). The budget does not depend on how quickly or slowly emissions accumulate (Allen *et al.*, 2009), and any temporary overshoot would need to be compensated for by additional removals in the future. Thus, to keep warming below 1.5 °C, emission reductions and removals must be effectively permanent (that is, they cannot be reversed for thousands of years, or if they are reversed, additional measures must be taken to compensate).

At the same time, meeting the goals of the Paris Agreement will require enhancing and retaining carbon stored in forests and other natural reservoirs at large scales. Many of these activities run the risk of storing carbon only temporarily (even if "temporary" means many decades). They are not equivalent to reducing emissions from fossil fuel combustion. How, then, can these activities be included in carbon crediting programmes? Among existing carbon crediting programmes, and within academic literature, at least three approaches have been proposed (see following three subsections).

2.3.1 Crediting based on delayed climate damage

One school of thought suggests that – notwithstanding the science behind a fixed carbon budget – there could be benefits to merely delaying emissions instead of permanently avoiding them. Under this paradigm, the present-day value of delaying climate damages could be used to infer an "equivalence" ratio between temporary carbon storage and permanent mitigation (Marshall and Kelly, 2010; Parisa *et al.*, 2022; Balmford *et al.*, 2023). Using economic discounting, for example, the present-day cost of an emission occurring in the future will be less than the cost of an emission today.[7] This avoided cost can be compared to the avoided cost of permanently reducing emissions to calculate an amount of temporary carbon storage that is "equal" to permanent carbon storage.

This approach is the basis for tonne-year crediting, discussed in Section 3.6. Under tonne-year crediting, reversals do not need to be compensated for. Instead, a reversal simply results in the cessation of further crediting. Any credits issued prior to the reversal are considered valid on the basis that they represent avoided emissions (or enhanced removals) maintained for a sufficient duration ("tonne-years") to be equivalent to permanent mitigation. One hundred tonnes of CO_2 stored for 10 years, for example, could be issued 10 credits, as if it were equivalent to 10 tCO_2e of permanent storage.

Implicitly, however, this approach is not consistent with the Paris Agreement's goal of limiting global warming to 1.5 °C. That is, all else equal, it could allow temperatures to exceed 1.5 °C as long as this occurs far enough in the future and the costs are appropriately discounted (Cullenward, 2023; Brander and Broekhoff, 2023). This makes tonne-year crediting challenging to implement in the context of the Paris Agreement, where crediting programmes – such as the Article 6.4 mechanism – must, in principle, ensure the achievement of the Paris Agreement's temperature goal.

7 Different methods can be used to estimate "costs" under these approaches. Some rely on estimates of the social cost of carbon, while others consider physical effects due to radiative forcing over a fixed time period (e.g. 100 years). See, for example, Chay *et al.* (2022).

2.3.2 Crediting based on a contribution to reducing peak warming

Under some scenarios, temporary carbon storage could help to lower the maximum increase in global temperature. A key condition for this is that carbon storage must persist long enough that reversal emissions occur after the point at which peak global warming is reached – which could still be many years in the future (Cullenward, 2023; Matthews *et al.*, 2022a). Furthermore, if the goal is to remain within a cumulative global carbon budget (in line with the temperature goal of the Paris Agreement), temporary carbon storage must serve as a complement to permanent mitigation measures, not a substitute (Matthews *et al.*, 2022a).

Recognizing that there could be benefits to reducing peak warming, one proposal is to use tonne-year crediting, discussed in Section 3.6, as a type of incentive mechanism for enhancing and maintaining temporary carbon storage (Matthews *et al.*, 2022b). Under this approach, however, carbon credits for temporary carbon storage would not be interchangeable with credits issued for permanent mitigation. Because of this lack of interchangeability, existing carbon crediting programmes have not adopted this approach. Furthermore, the approach would be difficult to reconcile with programmes like the Article 6.4 mechanism, which is premised on treating different types of mitigation as interchangeable.

2.3.3 Crediting non-permanent mitigation but requiring compensation for reversals

Under this approach, non-permanent mitigation can be credited, but only if mechanisms are in place to compensate for reversals when they occur. Compensation consists of ensuring that additional mitigation (for example, either permanent or non-permanent avoided emissions or enhanced removals) is used to cover reversals once they occur. This approach is followed by most current carbon crediting programmes, with variations of how it is implemented. Among the three approaches discussed here, it is most closely aligned with achieving the long-term temperature goals of the Paris Agreement, which requires maintaining cumulative emissions within a carbon budget. It also aims to preserve the "environmental integrity" of carbon markets – that is, ensuring that emissions are globally no higher *with* emissions trading than they would have been without it (Schneider and La Hoz Theuer, 2019).

This approach treats crediting of non-permanent mitigation as a means to "buy time". For example, some permanent mitigation measures that are expensive or infeasible today may become less so in the future, for example, through continued technological improvement. Pursuing cost-effective non-permanent mitigation can allow the world to stay within a carbon budget until permanent mitigation options become more available.[8] Alternatively, activities that temporarily store carbon could be consecutively renewed over time – perhaps indefinitely – to maintain a balance in global cumulative emissions.[9]

Different carbon crediting programmes have implemented this approach in different ways:

- *Monitoring and compensation* approaches – discussed in Section 3.3 – require ongoing efforts to detect reversals and compensate for them when they occur, typically in combination with "pooled buffer reserves" used to insure against natural disturbance events.
- *Temporary crediting* methods – discussed in Section 3.4 – put an explicit expiration date on credits, and require that the users of such credits replace them once they expire, ensuring that any reversals that occur are ultimately compensated.
- *Issuance deduction* approaches – discussed in Section 3.5 – forgo crediting some of the mitigation that is achieved, on the premise that if reversals occur, the uncredited portion will compensate for the reversals.

These approaches are further explained and assessed in the next section.

[8] One challenge is that, in practical terms, reversals cannot be monitored and compensated for forever. As discussed in the next section, for example, carbon crediting programs typically commit to monitoring and compensation only for a fixed period (e.g. 40 or 100 years). As such, compensation-based approaches – either implicitly or explicitly – place an obligation on future decision-makers to ensure that cumulative CO_2 emissions remain within a safe carbon budget.

[9] This is sometimes referred to as "horizontal stacking", where a required level of carbon storage is maintained in aggregate over time despite ongoing emissions and removals.

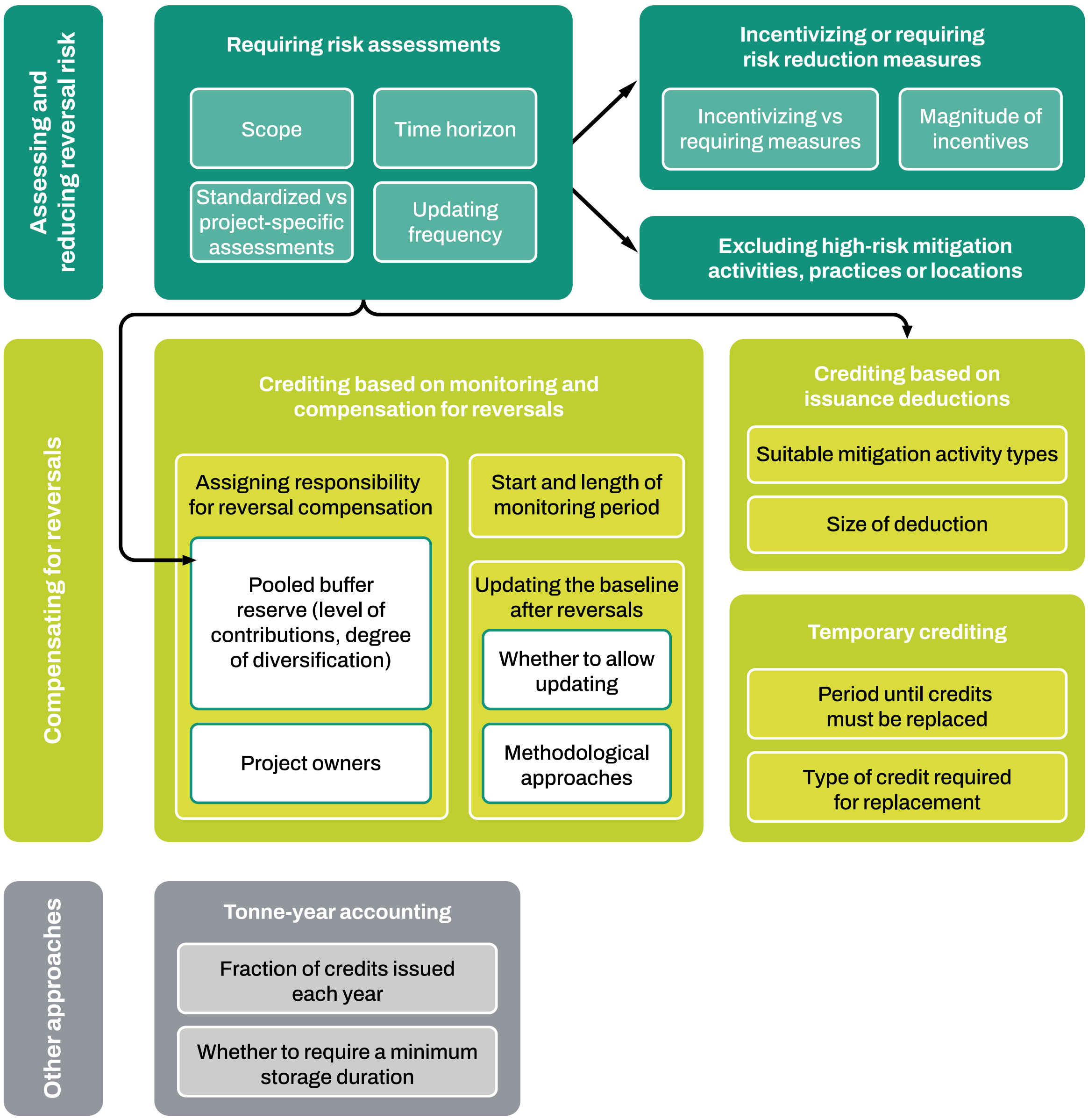
How carbon crediting programmes manage reversal risks

3

3.1 Overview of approaches used by carbon crediting programmes

Carbon crediting programmes use a variety of approaches to manage reversal risks. Most programmes seek to ensure that reversal risks are assessed and reduced. In addition, they typically require that any reversals are compensated for. Figure 7 provides an overview of the approaches commonly implemented and highlights key design choices.

Figure 7 Approaches to managing reversal risks and their substeps



To assess and reduce reversal risk, most carbon crediting programmes require conducting risk assessments. The outcome of the risk assessment may be used to establish requirements or provide incentives for project proponents to reduce reversal risks. In addition, programmes may exclude high-risk mitigation activities, practices or locations.

To compensate for reversals, the following approaches are used:

- **Crediting based on monitoring and compensation for reversals:** Carbon crediting programmes can require the activity proponents to monitor and report whether any reversals occur and to compensate for any reversals by cancelling other carbon credits. Key choices include for how long such monitoring is required and how to assign responsibility for compensating for reversals. Some carbon crediting programmes also require or allow updating the baseline when reversals have occurred.

- **Temporary crediting:** In temporary crediting, carbon credits expire, and carbon credit buyers must renew them or replace them with other carbon market units. Ongoing monitoring of continued carbon storage is therefore guaranteed.

- **Issuance deductions:** To account for future reversal risk, carbon crediting programmes can issue carbon credits only for a fraction of the emission reductions or removals achieved through the mitigation activity.

Next to these approaches, a few carbon crediting programmes have also implemented tonne-year crediting, where programmes can issue a fraction of carbon credits for each year that carbon remains stored, based on the concept of delayed climate damage (Section 2.3.1).

Most carbon crediting programmes use a combination of these approaches for managing reversal risk. Table 1 provides an overview of which approaches have been used by the largest carbon crediting programmes and Table 2 briefly describes these programmes. Most programmes require risk assessments, incentivize or require risk reduction measures, and require monitoring and compensating for reversals.

Each approach to managing reversal risks has potential advantages and disadvantages. The remainder of this section categorizes these approaches, identifies their key design elements, and analyses them regarding their practical feasibility and the degree to which they uphold – or pose risks to – environmental integrity. In doing so, the paper provides examples of how these approaches are implemented by different carbon crediting programmes; it also provides a comprehensive overview of these programmes.

Table 1 Reversal risk management approaches for mitigation activities in the land-use sector under major carbon crediting programmes

ACR	ART-TREES	CAR	CDM	GS	VCS
Assessing and reducing reversal risks					
Requiring risk assessments	Requiring risk assessments	Requiring risk assessments	Requiring risk assessments	Requiring risk assessments	Requiring risk assessments
Incentivizing or requiring risk reduction measures	Incentivizing or requiring risk reduction measures	Incentivizing or requiring risk reduction measures	Incentivizing or requiring risk reduction measures	Incentivizing or requiring risk reduction measures	Incentivizing or requiring risk reduction measures
Excluding high-risk mitigation activities, practices or locations	Excluding high-risk mitigation activities, practices or locations	Excluding high-risk mitigation activities, practices or locations	Excluding high-risk mitigation activities, practices or locations	Excluding high-risk mitigation activities, practices or locations	Excluding high-risk mitigation activities, practices or locations
Compensating for reversals					
Crediting based on monitoring and compensation for reversals	Crediting based on monitoring and compensation for reversals	Crediting based on monitoring and compensation for reversals	Crediting based on monitoring and compensation for reversals	Crediting based on monitoring and compensation for reversals	Crediting based on monitoring and compensation for reversals
Temporary crediting	Temporary crediting	Temporary crediting	Temporary crediting	Temporary crediting	Temporary crediting
Crediting based on issuance deductions	Crediting based on issuance deductions	Crediting based on issuance deductions	Crediting based on issuance deductions	Crediting based on issuance deductions	Crediting based on issuance deductions
Other approaches					
Tonne-year accounting	Tonne-year accounting	Tonne-year accounting	Tonne-year accounting	Tonne-year accounting	Tonne-year accounting

Note: Tonne-year accounting is used as an alternative to monitoring and compensating for reversals under some of CAR's methodologies in the land-use sector. Issuance deductions have only been applied by smaller carbon crediting programmes not listed here.

Table 2 Major carbon crediting programmes referred to in this study

Carbon crediting programme	Description
ACR (formerly known as the American Carbon Registry)	An independent carbon crediting programme that serves primarily North America. It recognizes multiple land-based mitigation project types, including afforestation/ reforestation, IFM, and avoided land conversion.
The REDD+ Environmental Excellence Standard of the Architecture for REDD+ Transactions (ART-TREES)	An independent carbon crediting programme focused on crediting emission reductions achieved through slowing deforestation at a jurisdictional (national or subnational) level. It does not credit individual project activities.
The Clean Development Mechanism (CDM)	A multilateral carbon crediting programme under the Kyoto Protocol for mitigation activities in developing countries. The CDM is historically the world's largest carbon crediting programme. Although only a small component of the CDM market, the CDM issued credits for some afforestation and reforestation activities.
Climate Action Reserve (CAR)	An independent carbon crediting programme serving primarily North America. CAR was initially created by the California legislature, and developed several methodologies (including for forest activities) that have been incorporated in California's regulatory cap-and-trade programme. CAR recognizes multiple land-based project types, including avoided grassland conversion and agricultural soil carbon enhancement.
The Gold Standard (GS)	The GS is an independent carbon crediting programme with global operations. It began as a "premium" certification for CDM activities, but then also started to issue its own carbon credits. Like the CDM, the GS issued credits for some afforestation/ reforestation activities.
The Verified Carbon Standard (VCS) operated by Verra	The VCS is the largest independent carbon crediting programme and operates globally. It has developed multiple methodologies for various kinds of mitigation activities in the agriculture, land-use, and forestry sectors.

3.2 Assessing and reducing reversal risk

As noted in Section 2.2, the reversal risk of mitigation activities differs between activity types as well as according to context and operational modalities. For many activities, it is possible to reduce this risk, for example, through a structured assessment of potential risks and implementing improvements to the activity design. Existing carbon crediting programmes use three types of measures to assess and reduce reversal risk, which are often applied together:

- requiring risk assessments;
- incentivizing or requiring risk reduction measures; and
- excluding high-risk mitigation activities, practices or locations.

3.2.1 Requiring risk assessments

Risk assessments determine the risk of reversals for mitigation activities, considering different risk categories. They are an important measure in the programmes' repertoire to address non-permanence, as they make it possible to tailor further measures to reduce reversal risk. All major programmes, except for the CDM, require a risk assessment, but approaches differ.

Key design choices for risk assessments include the following:

- **Scope of risk assessments:** Carbon crediting programmes typically provide a framework or methodology to assess reversal risks. These frameworks differ in the risk categories and aspects that are considered, such as geographic conditions, susceptibility to natural disasters, political and social circumstances, or project management and financial risks. To avoid underestimating reversal risk, it is important to consider all relevant risk factors, including risk factors related to human behaviour (such as financial or political risks) and natural risk factors (e.g. fires, diseases or other natural disasters). Moreover, as the impacts of climate change are likely to increase reversal risks (e.g. due to more extreme weather events), including climate change impacts in the risk assessment improves its accuracy. For example, the VCS revised its risk assessment tool in 2023 to include the projected impact of climate change.

- **Time horizon of risk assessments:** Another important factor is over which time horizon reversal risks are assessed. For example, the VCS requires using a 100-year time horizon, even though reversals may be monitored and compensated only for shorter periods (see Section 3.3.1). Longer time periods support environmental integrity because future reversal risks are better reflected.

- **Standardized versus activity-specific assessments:** Some programmes, such as the ACR and ART-TREES, implement a highly standardized approach to estimate reversal risk. For example, ACR uses default values for all risk categories. ART-TREES assumes for the reversal risk a starting level of 25 percent, which may be lowered to up to 5 percent, by applying default subtractions for factors that mitigate reversal risks. In contrast, some programmes, such as the VCS, use more activity-specific risk assessments. Activity-specific assessments have the advantage that they could, in principle, more accurately reflect the specific circumstances of a mitigation activity. Standardized risk assessments reduce the risk that activity proponents make assumptions that result in an underestimation of the actual reversal risk.

- **Updating risk assessments:** The context in which a mitigation activity operates might evolve over time. Therefore, most programmes require the risk assessment to be updated to ensure that the reversal risk is determined as accurately as possible. The interval ranges between 1 to 10 years, sometimes aligned with the frequency of verification. Moreover, some programmes also require an update when reversals occur to account for the changed circumstances. Furthermore, the update of the risk assessment can imply an adjustment to risk compensation measures. For example, the CAR and the VCS change a project's contribution to the pooled buffer reserve to reflect any newly estimated reversal risk.

The costs of risk assessments depend on the degree to which they are standardized. Highly standardized assessments have low costs, whereas activity-specific assessments come with some costs for activity participants. Risk assessments could pose a risk to environmental integrity if they systematically underestimate reversal risks and thus lead to inadequate risk reduction measures (Badgley *et al.*, 2022). Risk assessments are subject to uncertainty, and some risks may be easier to quantify than others. Moreover, risk assessments are carried out by the activity proponents, who have an economic interest in downplaying reversal risks to reduce the costs of related measures, such as contributions to a pooled buffer reserve or risk mitigation measures. Therefore, how exactly a risk assessment is designed and validated is crucial.

3.2.2 Incentivizing or requiring risk reduction measures

A variety of measures can reduce the risk of reversals, such as the use of mixed species in tree planting, fire treatments or addressing local drivers of deforestation. Risk mitigation measures may also include legal instruments, such as legally binding agreements with the landowners, management plans as submitted to local government or financial institutions, or conservation easements.

Several carbon crediting programmes provide incentives to implement such measures by allowing for lower contributions to a pooled buffer reserve, or lower crediting deductions, if measures are implemented. In cases where risks are assessed to be especially high, some programmes require the implementation of risk reduction measures. One programme, the GS, does not establish incentives for risk mitigation measures but requires all mitigation activities to implement them.

Programmes incur few administrative costs for incentivizing or requiring risk mitigation measures, but activity proponents may incur costs for implementing them. However, if an activity proponent implements measures because of incentives, the additional costs of the measure may be compensated by the financial gain from potentially lower buffer reserve contributions or other deductions. Moreover, activity proponents may occur less costs in the long term if they do not incur the costs of compensating for reversals.

Key design choices for risk reduction measures include the following:

- **Incentivizing versus requiring risk mitigation measures:** If risk mitigation measures are merely incentivized, activity proponents might not implement them if they are more costly than the financial gain from the incentive. Requiring risk mitigation measures ensures their implementation.

- **Magnitude of incentives:** If risk mitigation measures are incentivized, the magnitude of the incentives determines what measures the activity proponents implement to reduce reversal risk. In practice, the costs for these measures may vary greatly, depending on an activity's location, species composition or other local factors.

3.2.3 Excluding high-risk mitigation activities, practices or locations

If a risk is unacceptably high, some carbon crediting programmes exclude mitigation activities, practices or locations altogether. They may reject individual activities based on the results of the risk assessment or exclude categories of high-risk activities more broadly through eligibility criteria.

Carbon crediting programmes incur few administrative costs for excluding high-risk activities. For activity proponents, exclusion can lead to lost investments if a project is rejected, or to costs for implementing additional risk reduction measures to lower the risk to a level acceptable to the carbon crediting programme. As each programme's risk assessment is structured differently, the threshold to exclude mitigation activities based on risk also varies. Mitigation activities might be excluded if their overall risk is deemed too high, but also if they receive an unacceptably low score in one category. For example, if a project receives a "fail" in any risk category in the VCS's risk assessment, the project is not eligible for crediting, unless the activity proponent takes measures to address the risk.

© UN-REDD/Cory Wright

3.3 Crediting based on monitoring and compensation for reversals

Carbon crediting programmes can address reversal risks through monitoring, and, when a reversal occurs, compensating for reversals by cancelling carbon credits. This typically involves several elements as discussed below.

3.3.1 Monitoring and reporting provisions

Most carbon crediting programmes require activity proponents to submit regular monitoring reports to track the occurrence and magnitude of reversals. However, the total time horizon for which monitoring must be conducted differs among programmes, varying from 5 years (e.g. ART-TREES) to 100 years (e.g. CAR). Programmes also vary in the frequency in which they require activity proponents to submit monitoring reports and the consequences if activity proponents fail to hand in the monitoring report. Well-designed monitoring and reporting regimes can ensure that reversals are identified, quantified and compensated for within an appropriate time frame. However, more frequent monitoring and reporting entails higher costs for activity proponents.

Key design choices for monitoring and reporting include the following:

- **Total time horizon for monitoring and compensating for reversals:** A longer obligation to monitor and compensate for reversals is preferable from an environmental integrity perspective. However, a longer period also increases monitoring costs and the potential liability for activity proponents. The provisions on the time horizon for monitoring and compensation for reversals vary substantially among carbon crediting programmes. Some programmes tie the time horizon to the length of crediting periods (e.g. VCS), while others define the term independently (for example, ACR defines a fixed term of 40 years, irrespective of the length of the crediting period), or establish a post-crediting period (for example, CAR requires monitoring for 100 years after the last issuance of carbon credits). Some programmes prescribe a fixed term (e.g. ACR), while others provide flexibility to activity participants to choose between different time horizons (for example, the VCS allows activity proponents for Agriculture, Forestry, and Other Land Uses (AFOLU) mitigation activities to choose between at least 40 and a maximum of 100 years, depending on how often the crediting period is renewed). The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) requires monitoring until its end date in 2037. The Article 6.4 mechanism does not prescribe any specific minimum period but allows activity proponents to request termination of monitoring if they can demonstrate that the "stored GHGs are at negligible risk of reversal" or "the potential future reversals are remediated".[10] This approach still needs to be further operationalized. Fixed terms have the advantage that they provide upfront clarity to activity proponents for how long reversals must be monitored. They also create a level playing field among mitigation activities.

[10] https://unfccc.int/sites/default/files/resource/A6.4-SBM014-A06.pdf

- **Start of the total time horizon for monitoring and compensating for reversals:** Most programmes count the time horizon for which reversals must be monitored and compensated from the start of the first crediting period. This approach has the disadvantage that reversals with respect to emission reductions or removals achieved towards the end of the crediting period would only need to be monitored and compensated for a very short period. For example, with a minimum term of 40 years, removals achieved in Year 35 could be reversed in Year 41, with no compensation following such reversals. The CAR is the only programme that counts the time horizon for forestry activities from the date when the last credit issuance took place. This approach provides for higher environmental integrity.

- **Frequency of submitting a monitoring report:** How often a monitoring report has to be submitted varies from programme to programme. For example, while the CDM requires submitting monitoring reports every five years, CAR requires submitting them yearly. Generally, more frequent reporting leads to a timelier detection and compensation for reversals. However, it also comes with substantial costs (Pan *et al.*, 2022) and may lead to temporary variations in carbon stocks (e.g. due to thinning) to be classified as reversals, though the stocks may be regenerated within relatively short time frames (e.g. due to regrowth).

- **Compensation policy if monitoring and reporting ceases prematurely:** If activity proponents fail to submit a monitoring report, reversals may go undetected. Programmes handle this risk differently. For example, CAR and GS consider a failure to hand in a report to be a full reversal of all emission reductions or removals, so all issued credits have to be compensated for. By contrast, ART-TREES only requires compensation for a share of the issued credits. Moreover, the time frame within which compensation must take place varies substantially. For example, the VCS regards emission reductions or removals to be reversed if a verification report has not been submitted for 15 years, whereas the CAR terminates a project if verification has not been completed within 3 years after the end of the reporting period.

3.3.2 Assigning responsibility for reversal compensation

Once a reversal is identified, carbon credits equal to the determined size of the reversal must be cancelled. Likewise, if an activity proponent fails to hand in a monitoring report, all or a fraction of the issued carbon credits must be compensated for. A key design question is how the responsibility for such compensation is assigned. Under existing programmes, the responsibility is mainly assigned to activity proponents, pooled buffer reserves or financial insurance policies. The responsibility typically depends on whether a reversal was intentional (e.g. caused by harvesting) or unintentional (e.g. caused by a wildfire).

Key design choices for assigning responsibility include the following:

- **Responsibility for unintentional (unavoidable) reversals:** For unintentional reversals, carbon crediting programmes typically use "pooled buffer reserves" to compensate for reversals. Buffer reserves act as programme-administered insurance mechanisms: each time carbon credits are issued to a mitigation activity that has reversal risk, a percentage of the credits are set aside into the buffer reserve. In the case of reversals, these credits may be cancelled to compensate for reversals. Buffer reserves may be “pooled” or “standalone”. Programmes commonly use pooled reserves. In this case, many mitigation activities contribute to one reserve, which is used to compensate for reversals for all contributing mitigation activities. This helps to diversify risks, alleviate the costs of covering reversals for individual mitigation activities and lowers individual contributions to the buffer. Some programmes (e.g. ACR) allow mitigation proponents to opt for alternative insurance products, such as private insurances that directly compensate for a reversal. However, these are seldom (if ever) used.

- **Responsibility for intentional (avoidable) reversals:** Because intentional reversals are caused by a landowner's or an activity proponent's wilful intent and could therefore be avoided, they are effectively uninsurable. Compensating for these reversals using a buffer reserve would therefore create a "moral hazard", because activity proponents could choose to remove carbon stocks (e.g. through logging or land development) without liability. Because of this, most carbon crediting programmes require activity proponents to compensate for intentional reversals.

- **Mechanisms to enforce compensation obligations on activity proponents:** The mechanisms for enforcing compensation obligations on activity proponents differ among carbon crediting programmes. The CAR, for example, requires activity proponents to sign legal agreements obligating them to compensate for intentional reversals using non-buffer reserve credits. This may provide higher assurance that activity proponents will compensate for reversals, in particular if the obligation is legally enforceable, and that activity proponents "walk away" in the event of larger reversals, without compensating for them.

- **Fallback if obligations are not enforceable:** While most existing carbon crediting programmes place the obligation to compensate for intentional reversals on activity proponent, some proponents may be unable to fulfil this obligation (e.g. because they become financially insolvent). For this reason, programmes may use their pooled buffer reserves as a "last resort" to cover intentional reversals. However, programmes differ in how explicit they are about this guarantee.

- **Fallback if the carbon crediting programme ceases operations:** Some carbon crediting programmes have explicit provisions in place to ensure continued operation in the event that they cease operations. For example, if the ACR is no longer operational or able to manage its pooled buffer reserve, it will be managed by its parent organization, Winrock International.

Other approaches to assigning compensation liability are also possible. The rules for carbon capture and storage projects under the CDM, for example, require all reversals to be compensated first by activity proponents. If activity proponents are unable to (fully) compensate, a (project-specific) buffer reserve is used. Any residual liability is then the responsibility of either the host country government or the buying country government. This approach, however, would require effective enforcement mechanisms.

3.3.3 Updating the baseline after reversals

Some reversals, such as from wildfires, might affect some carbon stocks within the area of the mitigation activity even if the mitigation activity had not been implemented. In this case, some amount of carbon that is assumed to be stored in the baseline scenario might have been emitted. Because of this, some programmes allow baselines to be updated to reflect the (estimated) effects of reversals on baseline carbon stocks.

Key design choices for updating the baseline after reversals include the following:

- **Whether to allow for updating the baseline:** Some programmes do not allow for any updates (e.g. CAR), while others allow lowering baseline carbon stocks to reflect the impacts that any disturbances would have had in the baseline scenario (e.g. VCS). In principle, allowing updates to the baseline is intended to reflect such impacts and determine the effect of the mitigation activity more accurately. In practice, estimating the impact of the disturbances on the amount of carbon stock losses in the baseline scenario is inherently uncertain and methodologically challenging. For example, a wildfire affecting an IFM project might also have occurred in the baseline scenario, but if so, it might have led to fewer carbon stock losses – or might not have burned the project area at all – because less biomass would have been available to burn. Due to the inherent uncertainty when determining the amount of carbon stock losses that would have occurred in the baseline scenario, allowing for updates to the baseline may lead to environmental integrity risks.

- **Methodological approaches for estimating carbon stock losses in the baseline scenario:** The possible methodological approaches for estimating how many carbon stocks would have been lost in the baseline scenario due to a disturbance may differ in their robustness and conservativeness.

3.3.4 Implementing pooled buffer reserves

In implementing pooled buffer reserves, carbon crediting programmes need to make several choices. Key design choices include the following:

- **Basis for determining buffer pool contributions:** In general, the higher the share of carbon credits that activity proponents must deposit into the buffer pool, the more likely the buffer will be sufficiently capitalized to cover reversal risks. However, requiring high contributions could undermine the financial viability of mitigation activities, since these credits are not available for the activity proponent to sell. Among existing carbon crediting programmes, there are two main methods to determine the buffer pool contributions: Using a fixed share of issued credits (e.g. GS) or using a share dependent on the results of a risk assessment (e.g. CAR and the VCS). Some programmes also establish a minimum share that mitigation activities must contribute. In 2023, the VCS introduced a minimum risk rating of 12 percent. ART-TREES has a minimum risk rating of 5 percent. Some programmes also allow the release of the portion of credits from the pooled buffer reserve if the risk for reversals reduces over time.

  A share based on assessed risks does not necessarily result in a higher capitalization of the buffer pool than a fixed share. For example, all major carbon crediting programmes with shares dependent on a risk assessment have a lower average contribution compared to the GS, which requires a fixed contribution of 20 percent. The degree to which current approaches are appropriate to provide sufficient buffer reserve capacity is an open question. A study of the buffer reserve for California's carbon crediting programme in the United States of America, for example – to which mitigation activities contribute based on risk assessments – concluded that it is very likely undercapitalized (Badgley *et al*., 2022). Similarly, Anderegg *et al*. (2024) found that applying Verra's Non-Permanence Risk Tool (Version 4.2) likely leads to buffer pool contributions that do not cover the impact of natural disturbances.

- **Degree of diversification:** The more diverse the carbon credits in a buffer pool are, either geographically or by mitigation activity, the more the risk of reversals is spread. Consequently, most programmes pool credits from different types of mitigation activities or geographic regions into one buffer reserve. However, some programmes implement only standalone buffers (for example, the CDM with respect to carbon capture and storage projects).

- **Treatment of buffer credits at end of the time horizon for monitoring and compensating for reversals:** After the time horizon for monitoring and compensating for reversals ends, reversals can still occur. Some programmes, such as ART-TREES and the VCS, aim to address this risk by cancelling all carbon credits that have been deposited by the mitigation activity into the buffer pool. Other programmes, such as CAR and the GS, leave the carbon credits in the reserve, where they can continue to be used to compensate for reversals from other mitigation activities. This latter approach promotes environmental integrity to a lesser extent, as future reversals for the mitigation activity in question may not be addressed at all, since the carbon credits may be used to compensate for reversals from other mitigation activities during the time horizon for which monitoring and compensation is required. It should be noted, however, that the overall length of the time horizon for monitoring and compensating for reversals and the capitalization and diversity of the pooled buffer reserve are more relevant to environmental integrity than the treatment of carbon credits at the end of the period.

3.4 Temporary crediting

Temporary crediting is another approach to compensate for reversals. Under this approach, carbon credits expire, and carbon credit buyers must renew them or replace them with other carbon market units. Thus, carbon credit buyers bear the ultimate liability for reversals. This approach allows for "horizontal stacking" strategies, where buyers can effectively support non-permanent mitigation options for a time until permanent mitigation opportunities become more widely available (see Section 2.3). It also creates a mechanism by which mitigation activities are paid on an ongoing basis to maintain carbon storage, rather than taking on long-term obligations in exchange for an upfront payment. For some activity proponents, this could be an attractive alternative.

Temporary crediting is, in theory, a conservative approach, as all carbon credits must ultimately be replaced, either by credits for permanent mitigation or by newly issued temporary credits. In practice, however, it could be difficult to ensure that the institutional infrastructure for managing replacements will remain in place over long time periods. Furthermore, temporary crediting approaches must include contingencies for when buyers might be able to fulfil their obligation to replace credits (e.g. due to bankruptcy).

Only the CDM has implemented temporary crediting as an approach to compensating for reversals. In the CDM's case, it proved infeasible because few buyer countries were interested in using temporary credits, and private actors had limited incentives to purchase them because they could not be used for regulatory compliance (e.g. within the European Union's emissions trading scheme). For these reasons, afforestation and reforestation activities make up less than 1 percent of registered CDM activities (UNFCCC, 2022). Moreover, as the second commitment period of the Kyoto Protocol ended in 2020, and no third commitment period has been agreed upon, compensation for reversals will no longer be implemented under the Kyoto Protocol.

Key design choices for temporary crediting approaches include the following:

- **The period of time until credits must be replaced.** Under the CDM, two types of temporary credits were established: one expiring within 5 or 8 years (linked to Kyoto Protocol commitment periods) and one expiring after 30 years. Shorter periods may be more attractive for activity proponents, providing steady revenue or the option to terminate their mitigation activities. Longer periods could be more attractive to buyers, but to ensure integrity, monitoring, reporting and compensation within that period would be required to ensure carbon remains stored for the full duration.

- **Type of carbon credit required for replacement:** Under the CDM, carbon credits either had to be replaced with other temporary credits after each commitment period, or they were valid until the end of the crediting period, and then had to be replaced with permanent credits. Ultimately, all temporary carbon credits had to be replaced with permanent units. This requirement intended to ensure that permanent mitigation would be achieved within a reasonable time frame, reducing the risk that replacement obligations could not be enforced in the long term. Alternatively, programmes could in principle allow temporary credits to be indefinitely replaced by additional temporary credits (for example, from the same mitigation activities, if carbon remains stored and no reversals occur, or from newly implemented mitigation activities). This would provide more flexibility to buyers but could face more long-term enforcement challenges.

3.5 Crediting based on issuance deductions

Issuance deductions mean that carbon crediting programmes issue carbon credits only for a fraction of the emission reductions or removals achieved through the mitigation activity to compensate for any future reversals. Issuance deductions have only been applied by smaller carbon crediting programmes, such as the Australian Emission Reduction Fund, the French Label Bas Carbone, or the Alberta Offset Program in Canada.

Issuance deductions are simple to implement; they do not require monitoring for reversals, assigning responsibility for compensating, or implementation and enforcing compensation mechanisms. They also provide greater certainty for activity proponents. However, they do not provide incentives for activity proponents to maintain carbon storage and may thus lead to moral hazard risks and hence higher reversals compared to other approaches. The approach is therefore not suitable to address any intentional reversals. The environmental integrity implications hinge on whether the size of the deduction reflects at least the reversal risk. As future reversals are not monitored, the approach thus strongly hinges on the robustness an ex-ante assessment of future reversals, which are associated with large uncertainties.

Key design choices for issuance deduction approaches include the following:

- **Suitable mitigation activity types:** As this approach does not provide incentives to maintain carbon storage, it may be more suitable for mitigation activities where activity proponents have no control over the carbon reservoir and where it is not possible or practical to monitor reversals. Examples could include efficient cookstove projects, which aim to perverse carbon stocks in forests by reducing the consumption of non-renewable biomass, or projects storing carbon in building materials. Carbon crediting programmes could thus limit this approach to such type of activities.

- **Size of the deduction:** Carbon crediting programmes could assess the reversal risk for the type of mitigation activity to determine the size of the deduction applied to the mitigation activity type. In assessing this risk, the time horizon considered is a key choice. Longer time horizons may have higher environmental integrity but also lead to larger deductions. Moreover, to ensure integrity, it is important to consider the uncertainty associated with the risk assessment and choose a conservative value.

3.6 Tonne-year accounting

Under tonne-year accounting, mitigation activities initially receive only a fraction of a carbon credit for each tonne of CO_2 of emission reductions or enhanced removals they achieve. For each year that the carbon associated with these reductions or removals remains stored, the fractional amount of issued credits increases, such that a mitigation activity receives one credit for each tonne only at the end of a predefined time period. The underlying premise is that at the end of this predefined period (e.g. 100 years), the mitigation achieved is equivalent to "permanently" reducing or removing CO_2. This approach has been applied by CAR for some methodologies.

While this approach requires ongoing monitoring for reversals, no compensation is required. Instead, after a reversal occurs, crediting simply ceases, on the assumption that the fraction of previously issued credits still represents a fraction of "permanent" mitigation.[11] As explained in Section 2.3, this approach aligns with the "delayed climate damage" paradigm for crediting temporary carbon storage (Section 2.3.1). However, if the goal is to limit cumulative emissions of CO_2 – which is required to meet the Paris Agreement's temperature goal – this approach raises environmental integrity concerns.[12] Specifically, under this approach, carbon could be stored for only a few years and then released (back) to the atmosphere, with no net change in cumulative emissions. One rationale for the approach, however, is that by doling fractional credits out over time, an incentive is provided to maintain carbon storage.

Key design choices for tonne-year accounting approaches include the following:

- **Determining the fraction of credits issued in each year:** Different methods have been proposed for how to determine the fraction of credits issued each year, including using economic equivalence ratios. The simplest approaches simply divide by the number of years required – for example, if the target is 100 years, then one-one hundredth (1/100) of a credit is issued for each year that carbon remains stored. Alternatives are to issue larger fractions in earlier years, which could make the approach more feasible for activity proponents who need upfront financing, or to issue larger fractions in later years, which could give activity proponents an incentive to maintain carbon storage for longer (to the extent that this is within their control).

- **Whether to require a minimum storage duration:** Under the simplest form of tonne-year crediting, there is no minimum duration for carbon storage – an activity could store carbon for only one year and still receive a fraction of a credit. Under certain CAR methodologies, however, mitigation activity proponents are expected to commit to maintaining carbon storage for a minimum initial period, and to compensate for reversals if they occur over this period. The initial fraction of credits issued is based on the duration of the commitment compared to 100 years. For example, if the activity proponents commit to maintaining 30 years of storage from the date that credits are issued (and compensating for reversals when they occur over this period), they would receive 0.3 credits for each tonne of CO_2 removed or reduced in the first year. The fraction issued may then be increased if the activity proponents extend their commitment. This approach aims to strike a balance between maintaining environmental integrity (based on 100 years of storage) and providing flexibility to activity proponents.

[11] Note that CAR combines its tonne-year crediting approach with an initial commitment period (e.g. 30 years), during which compensation is required, since the initial fraction of credits issued is based on this minimum commitment.

[12] The approach was considered but not further pursued by the Article 6.4 Supervisory Body due to these concerns.

How reversal risk creates potential liability for host countries

Countries are often keen to attract investments in forest mitigation activities – but they also have an inherent incentive to reduce liabilities from potential reversals. Many countries have pledged ambitious mitigation targets in their NDCs and long-term low-emission development strategies (LT-LEDS). If emission reductions or removals from carbon crediting activities are reversed, achieving these targets may become more difficult for host countries. However, at the same time, stringent requirements related to reversal risks could reduce the financial attractiveness or practical feasibility of using carbon crediting for implementing forest mitigation activities. Striking an appropriate balance between these trade-offs is an important challenge.

A key challenge is that rules under the Paris Agreement for accounting for NDCs and international transfers of emission reductions or removals do not include explicit provisions for managing the risk of non-permanence. As will be explained in this section, host countries are ultimately responsible for any reversals, regardless of the approaches implemented by carbon crediting programmes to compensate for reversals, such as pooled buffer reserves. This could have implications for how host countries approach crediting of nature-based mitigation activities, including whether they pursue crediting based on authorized or non-authorized carbon credits (see Box 4).

4

Box 4. Two types of carbon credits in the era of the Paris Agreement

In exploring the implications of reversals risks for host countries, it is important to distinguish between the two types of carbon credits that exist in the era of the Paris Agreement:

- **Authorized carbon credits:** These represent emission reductions or removals that have been authorized by the host country under Article 6.2 of the Paris Agreement for use towards NDCs and/or "other international mitigation purposes" (OIMP), such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). These are also referred to as internationally transferred mitigation outcomes (ITMOs). In this case, the underlying emission reductions or removals cannot be used by the host country to achieve its own nationally determined contribution (NDC) but may be claimed by the countries or entities using the ITMOs. This is ensured through the application of "corresponding adjustments": for each transferred ITMO, the host country makes an addition of one tonne CO_2 equivalent to its emissions balance, while a buying country may make a subtraction.
- **Non-authorized carbon credits:** These represent emission reductions or removals that have not been authorized for use under Article 6 of the Paris Agreement. In this case, the emission reductions or removals may be used by the host country to achieve its own NDC; corresponding adjustments are not applicable.

Most carbon crediting programmes are planning to issue both types of carbon credits. This includes the Article 6.4 mechanism and non-governmental carbon crediting programmes such as the Verified Carbon Standard (VCS) or Architecture for REDD+ Transactions (ART).* Under the Article 6.4 mechanism, authorized carbon credits are referred to as "authorized Article 6.4 emission reductions" and non-authorized carbon credits are referred to as "mitigation contribution Article 6.4 emission reductions". Under other governmental and non-governmental programmes, carbon credits that have been authorized for use under Article 6 of the Paris Agreement are tagged accordingly in their respective registry systems.

Note:

* REDD+ refers to Reducing Emissions from Deforestation and Forest Degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.

4.1 A potential misbalance between current benefits from emission reductions or removals and future responsibility for reversals

Host countries can face the risk of a potential misbalance between current benefits from emission reductions or removals and future liability for reversals. This misbalance could occur because NDC coverage and GHG inventory visibility are expected to enhance over time.

Under the Paris Agreement, all countries participating in Article 6 must quantify their NDC in tCO_2e and regularly report a national GHG inventory. To account for their NDC, countries compare the actual emissions and removals that are covered by their NDC with this quantified NDC target. Any ITMOs are accounted for by making additions or subtractions to the emissions covered by the NDC. This results in an adjusted emissions balance. The application of corresponding adjustments and the resulting emissions balance is reported in a "structured summary" that forms part of biennial transparency reports (BTRs).

In theory, any reversals are automatically accounted for in a country's emissions balance, as the host country would report any changes in emissions or removals that may result from reversals. In practice, however, emission reductions, removals or reversals may also remain "unaccounted". Whether they are "accounted" or "unaccounted" depends on the following factors:

- **NDC coverage:** While countries' national GHG inventory under the Paris Agreement should cover all sectors of their economy, they do not have to include all emission sources, gases, activities and carbon pools in the scope of their NDC. The emissions balance is only applied to the scope of the NDC, meaning that only the emissions and removals covered by the NDC – and not the entire national GHG inventory – are compared to the target level. In current NDCs, about 85 percent of the countries include emissions from land use and its changes (UNFCCC, 2023). In those countries where land-based emissions or removals are not covered, the host country does not account for reversals when establishing the emissions balance. However, countries are expected to enhance the scope of their NDCs over time.[13] It is therefore likely that future reversals will be covered by most NDCs.

- **Inventory visibility:** Even if land-based emissions or removals are included in the NDC, the national GHG inventory may not have sufficient granularity to pick up emission reductions, removals and reversals from specific mitigation actions. This issue has been referred to as "inventory visibility"(Prag *et al.*, 2013; Schneider *et al.*, 2022). Inventory visibility is a particular challenge for the land-use sector (Schneider *et al.*, 2022; Herold and Böttcher, 2018), where it hinges, among other things, on what activities or land-use categories are covered, which pools are accounted for, how "forests" are defined, whether the age structure of forests is reflected, the treatment of natural disturbances, or how harvested wood products are accounted for. Moreover, country-level inventories may not necessarily capture small-scale interventions. These issues may be particularly salient for developing countries which are still in the process of implementing national inventory systems to fulfil the new reporting requirements arising from Article 13 of the Paris Agreement. If emission reductions, removals and reversals are not visible in inventories, then the host country does not account for them when establishing the emissions balance. However, GHG inventories are expected to improve over time which is likely to also enhance inventory visibility. Future reversals are therefore more likely to be captured by inventories.

[13] Article 4.4 of the Paris Agreement encourages developing countries to move over time towards economy-wide emissions targets. At COP28 in Dubai, countries further strengthened this provision by encouraging countries to "come forward in their next NDCs with ambitious, economy-wide emission reduction targets, covering all GHGs, sectors and categories and aligned with limiting global warming to 1.5 °C, as informed by the latest science, in the light of different national circumstances" (paragraph 39, Decision 1/CMA.5).

- **Accounting approach chosen for single-year targets:** If countries have multiyear targets, emission reductions, removals and reversals are counted in all years of the NDC implementation period. Most countries have, however, communicated only single-year targets in their NDC (UNFCCC, 2023). In this case, emissions, removals and reversals occurring in the target year (e.g. 2035) would be counted towards the NDC but those occurring in non-target years (e.g. 2031 to 2034) may not necessarily be accounted for, depending on the accounting approach chosen by the host country (Siemons and Schneider, 2022). In international climate negotiations, the implications of single-year targets on accounting will be further explored. These processes may lead to more comprehensive accounting over time, which may ensure that reversals are always accounted for, irrespective of the year in which they occur.

In summary, while reversals may currently not be fully captured in emission balances of countries, it is plausible that, over time, most (larger) reversals would be accounted for when host countries establish their emission balances. Such improvements could lead to a misbalance between current benefits from emission reductions and removals and future responsibility for reversals.

If a country has excluded the land-use sector from its current NDC, the emission reductions or removals achieved by a mitigation activity would not show up in its emissions balance, which is based on the emissions and removals covered by the NDC. If the country then expands its NDC over time, as encouraged under the Paris Agreement, and includes the land-use sector, it will have to account for future reversals from the mitigation activity.

Similar considerations apply to inventory visibility. National GHG inventories are expected to improve over time which is likely to also enhance inventory visibility. If the emission reductions or removals from a mitigation activity are not visible with the current inventory, then the removals do not show up in the emissions balance and cannot be used by the country to achieve its NDC. If improved inventory methods are implemented in course of subsequent NDC implementation periods, then the host country would have to account for any reversals that may occur in subsequent NDC implementation periods.

4.2 How host countries have ultimate responsibility for reversals despite carbon crediting programmes' reversal risk management

As discussed in the previous section, host countries will, in many circumstances, account for any (larger) reversals when establishing the emission balances to assess the achievement of their NDC. This means that countries have an ultimate responsibility for reversals. Any reversals would result in increased emissions in their emission balance, and thus make it more difficult to achieve their NDC. This could undermine the ability of countries to achieve their NDC.

This section discusses how the reversal risk management approaches pursued by carbon crediting programmes, as described in Section 3, affect the responsibility of host countries for reversals. We focus on the main approaches pursued by carbon crediting programmes: assessing and reducing reversal risk (Section 4.2.1); monitoring and compensating for reversals (Section 4.2.2) and limiting credit issuance (Section 4.2.3). We explain why approaches by carbon crediting programmes to reduce reversal risk are beneficial for host countries and why approaches to monitor and compensate for reversals, such as pooled buffer reserves, do not offer host countries compensation for any reversals.

4.2.1 Assessing and reducing reversal risks

Most carbon crediting programmes require mitigation activity proponents to assess and reduce reversal risks. This includes requirements to conduct risk assessments, which are often the basis for requiring risk reduction measures, providing incentives to reduce reversal risks, or excluding mitigation activities with high reversal risks (see Section 3.2).

Given that host countries have the ultimate responsibility for any reversals, they may prefer mitigation activities that have a low reversal risk. Therefore, host countries have an interest that the carbon crediting programme's approaches towards risk mitigation be robust and effective.

To ensure that they still attract investment in forest carbon mitigation activities, they also have an interest in making sure that risk assessments do not exaggerate the risk. If resulting risk assessments are too high, contributions to pooled buffer reserves or issuance deductions will also be set too high, restricting the ability to attract carbon finance. If, in turn, risks are underestimated, host countries face a higher risk that they may need to address any future reversals, potentially undermining their ability to achieve future NDCs.

4.2.2 Monitoring and compensation for reversals

Many carbon crediting programmes pursue approaches that involve monitoring for reversals and, when a reversal occurs, compensating for the reversals by cancelling carbon credits. For intentional reversals, the responsibility to compensate is typically assigned to activity proponents; for unintentional reversals, many programmes use pooled buffer reserves (see Section 3.3).

While these approaches may compensate for any reversals at the level of mitigation activities, they do not absolve host countries from the responsibility to also account for the reversals. This is because any compensation through the cancellation of carbon credits by activity proponents or from a carbon crediting programme's pooled buffer reserve does not translate into a benefit in the host country's emissions balance used to assess the achievement of its NDC.

This disconnect applies to any carbon crediting programme, including the Article 6.4 mechanism and non-governmental programmes alike – and to both authorized and non-authorized carbon credits. In all cases, the host country remains responsible for compensating for any reversals because these reflects in its NDC.

This issue arises because the provisions for establishing the emission balance under the Paris Agreement do not specifically address compensation for reversals at the level of carbon crediting programmes. We illustrate this through a simplified example.

In our example, an afforestation project results in the removal of 100 tCO_2 over the 2020–2045 period. The project puts 20 percent of its issued carbon credits into a pooled buffer reserve. The project developer thus obtains 80 carbon credits over this period. In the period 2045–2050 period, a wildfire destroys part of the forest, resulting in reversals of 40 tCO_2. The reversals are compensated for by drawing on the pooled buffer reserve and cancelling 40 carbon credits.

However, the compensation for these reversals through the pooled buffer reserve would not have any implications for the country's emissions balance. This is because:

1. In the period up to 2045, all removals achieved by the project are also accounted for by the host country in its emissions balance. Thus, carbon credits deposited in the pooled buffer reserve would not be "set aside" from the host country's perspective.
2. In the period after 2045, the cancelling of credits to account for reversals would have no implications for the host country's emissions balance, as the credits are cancelled and not provided to the host country to achieve its NDC. Similarly, if some of the buffer reserve credits were generated by projects in other countries, these credits would not be transferred to the host country and would likewise have no bearing on the host country's emissions balance. This same logic holds if the proponents of our example project were responsible for compensating for reversals (that is, without using the pooled buffer reserve). The host country would see no change in its emissions balance.

The implications for the emissions balance of the host country of our example project also depend on whether the carbon credits are authorized for use under Article 6:

- If the carbon credits are not authorized, then the country could use all removals from the project (including the removals from credits placed in the pooled buffer reserve) to achieve its NDCs in the period up to 2045. In the 2045–2050 period, the country would face an emission increase due to the reversals from the project.
- If the carbon credits are authorized, the country would not be able to use the removals from the project to achieve its NDCs in the period up to 2045, as the additional removals observed in its inventory would be balanced out with the corresponding adjustments it must apply to its emissions (assuming that the carbon credits put in the buffer reserve would also be authorized and considered to be "first transferred" – see Box 5). The reversals in the 2045–2050 period would, however, still show up as emissions (or reduced removals) in the country's emissions balance. As with non-authorized carbon credits, the compensation at the level of the carbon crediting programme does not affect the emissions balance of the country and thus does not alleviate the host country's ultimate responsibility for reversals. Thus, if credits are authorized, this creates a disconnect for the host country in the accounting for removals and reversals. It cannot use the removals achieved by the project to achieve its NDCs, given that these are internationally transferred, but still bears the responsibility for future reversals, which are likely to show up in its emissions balance.

Box 5. When are carbon credits put in pooled buffer reserves subject to corresponding adjustments?

Under the rules of Article 6.2, the obligation for host countries to apply corresponding adjustments arises when internationally transferred mitigation outcomes (ITMOs) are "first transferred". If mitigation outcomes are authorized for use towards nationally determined contributions (NDCs), the "first transfer" occurs when a mitigation outcome is for the first time transferred from the host country to another country. If mitigation outcomes are authorized for use towards "other international mitigation purposes" (OIMP), the host country can choose to define the "first transfer" in three different ways: as the point of (1) authorization, (2) issuance, or (3) use or cancellation (paragraph 2 to the Annex of decision 2/CMA.3).

The rules under Article 6.2 do not explicitly address the situation where carbon credits are put into a pooled buffer reserve. The current rules could have different implications, depending on how the host country defines "first transfer":

- Where a host country defines "issuance" as the "first transfer", the carbon credits put into the pooled buffer reserve may be subject to corresponding adjustments, depending on how "issuance" is interpreted.
- Where "authorization" is chosen as first transfer, the implications may depend on the timing of authorization: if mitigation outcomes are authorized before the respective carbon credits are placed into the pooled buffer reserve, the carbon credits would be backed by corresponding adjustments; by contrast, if a host country only authorizes the mitigation outcomes underpinning the carbon credits only after a fraction has been placed into the buffer pool, and decides to only authorize those units that have not been placed in the buffer reserve, then the carbon credits in the reserve would not be backed by corresponding adjustments.
- If the host country defines "cancellation or use" as the first transfer, the implications could be interpreted in different ways: one could interpret that the placement of the carbon credits into the pooled buffer reserve constitutes a "use" in the context of Article 6.2 (in which case the carbon credits be subject to corresponding adjustments) or one could interpret that only the cancellation of carbon credits in the pool for the purpose of compensating for reversals constitutes a "cancellation" in the context of Article 6.2 (in which case only those carbon credits that are used to compensate for reversals would be subject to corresponding adjustments). This latter case raises, however, a timing issue: reversals may occur decades after the emission reductions or removals are achieved. By that point in time, the emissions balance of the host country of the carbon credits may have already been finalized and closed, and the country may no longer apply any corresponding adjustments (paragraph 12 in the Annex to decision 2/CMA.3).

Finally, in the case of cooperative approaches between two countries, the current provisions could be interpreted such that carbon credits put into the pooled buffer reserve are not subject to corresponding adjustments, as the underlying mitigation outcomes are not internationally transferred between two countries.

When the rules for "first transfer" were adopted at COP26 in Glasgow in 2021,* countries may not have considered the implications for pooled buffer reserves. This situation is similar to the lack of provisions for defining "first transfer" in the context of carbon credits transferred to the Adaptation Fund or carbon credits used towards an overall mitigation in global emissions (OMGE), which were both considered in the deliberations at COP27 in Sharm El Sheikh in 2022 and COP28 in 2023. There may thus be an opportunity for countries to clarify that, for authorized carbon credits, the deposit of the credits into pooled buffer reserves be considered as a "first transfer".

Note:

* COP refers to the Conference of the Parties to the UNFCCC.

For the outlined reasons, unless international accounting rules are modified, monitoring and compensating will not effectively manage reversal risk for host countries. However, these approaches may still have indirect benefits for host countries. First, approaches to monitor and compensate for reversals usually create incentives for mitigation activity proponents to avoid or reduce reversals. Second, most carbon crediting programmes make the contributions of mitigation activities to the pooled buffer reserve dependent on the reversal risk. If reversal risks are appropriately quantified, this may (partially) internalize the cost of managing reversals and steer investment towards those forest mitigation activities that have lower reversal risks. For example, this might mean that mitigation activities in areas that are less prone to fire risk have lower buffer contributions and are thus economically more viable than activities in areas with high fire risks. Similarly, jurisdictional approaches that effectively address underlying drivers of deforestation and work towards systematic change may have lower buffer contributions.

4.2.3 Issuance deductions

Issuance deductions are applied by some carbon crediting programmes, mostly for specific methodologies or activity types (see Section 3.5). The implications for host countries depend on whether the carbon credits are authorized, when the reversals occur, and how large they are.

For non-authorized carbon credits, limiting credit issuance would not change NDC accounting at all. Even if fewer credits are issued, the host country could still use all mitigation outcomes to achieve its NDC but would also have to account for any reversals in its emissions balance. The implications are thus similar to those from monitoring and compensation approaches.

By contrast, in the case of authorized carbon credits, limiting credit issuance can have implications for NDC accounting. During the crediting period, fewer credits are issued than actual mitigation outcomes occur, and hence fewer mitigation outcomes are “first transferred”. The implications depend on when reversals occur and how large they are:

- If no reversals occur during the crediting period, the host country could use that part of the emission reductions or removals that has not been first transferred as ITMOs to achieve its own NDC. This is because the host country would observe the full emission reductions or removals in its GHG inventory, while only a part of the actually achieved emission reductions or removals is issued as carbon credits.
- If reversals occur during the crediting period, but these are smaller than the limitation on credit issuance as applied during the relevant NDC implementation period, the limited issuance will compensate for the reversals and thus enable the host country to still achieve its NDC. If many activities with reversal risks are implemented in the host country, the limited issuance across the portfolio may also help to compensate for larger reversals in one single activity.
- If reversals occur during the crediting period, but these are larger than the limitation on credit issuance as applied during the relevant NDC implementation period, the limited issuance will not fully compensate for the reversals and the host country would thus need to compensate for the shortfall.
- After the end of the crediting period, the host country would need to account for the full amount of any reversals when accounting for its NDC.

In the case of authorized carbon credits, requiring longer crediting periods and sufficiently large issuance deductions may thus help the host country to manage reversal risks. A diverse portfolio of mitigation activities would also spread the risk as reversals in one activity may be compensated for by limited issuance in others. However, in contrast to the approach of monitoring and compensating for reversals, limiting credit issuance does not provide incentives for activity proponents to continue to maintain carbon stocks, and may thus involve larger reversal liabilities for host countries.

4.3 How host countries can strategically manage reversal risk

The analysis illustrates that reversal risks are an important consideration for host countries pursuing carbon crediting. Reversals from credited mitigation activities make it harder for host countries to achieve their NDCs because countries bear the ultimate responsibility for any reversals, irrespective of the carbon crediting programmes' approaches for compensating for reversals. This problem is likely to exacerbate over time, as the scope of NDCs expands and the granularity of GHG inventories is improved. Countries may thus need to develop a strategy for managing reversal risk when they engage in carbon crediting approaches, taking into account the carbon crediting programme's reversal risk management.

A key strategic question for host countries is whether they should authorize mitigation outcomes with reversal risks for use under Article 6 of the Paris Agreement, or whether they should only allow non-authorized carbon credits. When host countries authorize mitigation outcomes, they cannot use the mitigation outcomes towards their own NDC but are still responsible for future reversals. This may create an imbalance since the benefits for host countries are limited, but they still have responsibility for future reversals.

Where countries wish to authorize mitigation outcomes with reversal risks for use under Article 6 of the Paris Agreement, they could pursue different strategies to balance the benefits and future liabilities:

- **Ensuring that mitigation outcomes are accounted for:** Where host countries authorize mitigation outcomes for use under Article 6, and therefore must subsequently apply corresponding adjustments, it is important that the credited mitigation is counted when establishing the countries' emissions balance. If the credited mitigation is not accounted for, it would become more difficult for countries to achieve their NDC, as the mitigation would not appear in their emissions balance, but corresponding adjustments would nevertheless have to be applied. To ensure that credited mitigation is accounted for, the relevant sector, emission sources and carbon pools should be covered by the NDC. In addition, national GHG inventories need to ensure that the mitigation is visible.

- **Fair sharing of mitigation outcomes in the light of reversal risks:** Countries could pursue measures to ensure that the mitigation achieved through carbon crediting is shared in a fair manner between the host country and the buyer of the carbon credits. Such fair sharing could factor in the host country's ultimate responsibility for reversal risks. Only a part of the achieved mitigation outcomes might be authorized for use under Article 6 of the Paris Agreement and the remainder be used by the host country to achieve its own NDC. This can be achieved by different means, including baselines that are set below business-as-usual (BAU) (thus not crediting some of the mitigation), the cancellation of a share of carbon credits, or crediting periods that are shorter than the duration of the mitigation activity (thus not crediting future emission reductions or removals occurring after the end of crediting periods). Countries could also establish fees for the registration of mitigation activities or issuance of carbon credits that could be used to fund other mitigation activities in the host country, thereby implicitly reducing the implications of any future reversals.

↘ **Establishing criteria for eligible mitigation activities:** Many countries are in the process of establishing national strategies and criteria for approval of mitigation activities and authorization of mitigation outcomes. As part of these efforts, countries could establish criteria to manage reversal risks, such as:

- limiting the eligibility of mitigation activities to certain carbon crediting programmes (for example, only programmes that provide for a thorough risk assessment);
- limiting the eligibility to activities that work towards systemic change and avoiding activities targeting only transient carbon storage (for example, excluding short-term, commercial tree planting);
- limiting eligibility of mitigation activities to certain features (for example, using species that are well-adapted to the future climate in the host country) or to certain locations (for example, excluding regions within the host country that are particularly prone to fire risk);
- establishing further requirements that mitigation activities must satisfy (for example, requiring a certain minimum duration of monitoring within the range that a carbon crediting programme allows activities to choose from); and
- establishing other safeguards (for example, committing mitigation activity proponents to maintaining the land as forest land).

The risk of a misbalance for host countries between current benefits and future responsibility could potentially also be addressed by establishing rules that incorporate the compensation for reversals by carbon crediting programmes into accounting rules under the Paris Agreement. While the accounting rules under the Paris Agreement have been largely finalized at COP26 in Glasgow, countries could consider amending them in the future, for example, as part of the review of the rules under Article 6 and Article 13 of the Paris Agreement, scheduled to take place in 2028.


© UN-REDD/Alice Van der Elstraeten

Conclusions

5

Global efforts to mitigate climate change must include measures that enhance and preserve carbon stocks in trees, soils and other land-based reservoirs. Many of these kinds of "nature-based solutions" come with the added benefits of protecting and enhancing ecosystems and achieving a range of other critical sustainable development goals. Yet, because carbon stored in land-based reservoirs may not remain there permanently, measures to enhance removals or reduce emissions from land use and its changes are not equivalent to reducing fossil CO_2 emissions. This presents a challenge for carbon markets, which necessarily treat the carbon credits originating from different kinds of mitigation activities as interchangeable.

If the primary goal of carbon markets, including under Article 6 of the Paris Agreement, is contributing to the achievement of the temperature goals of the Paris Agreement, then robust approaches to managing reversal risk are needed. Existing carbon crediting programmes have adopted a range of such approaches, which most often involve a combination of measures to both reduce reversal risk and to monitor and compensate for reversals when they occur. However, these approaches can be designed in different ways, and current practice suggests multiple options for balancing the need for environmental integrity with feasibility of implementation.

From reviewing existing carbon crediting programmes, the following elements could be considered as part of a "good practice" approach:

- **Ensuring risk reduction:** To effectively manage reversal risk, programmes should provide strong incentives (or requirements) to identify reversal risks and implement risk *reduction* measures. These can include measures to reduce the potential impact of natural disturbances, as well as activity designs that reduce human-caused reversal risk. In some cases, it may make sense to simply exclude activities where reversal risk is too high. Risk reduction measures may be particularly important from the perspective of the host countries, who may otherwise face risks in meeting future NDCs if reversals occur.

- **Establishing robust, pooled buffer reserves:** Buffer reserves are a key means for insuring against reversals from natural disturbances and other "unintentional" risks. To be effective, however, they must be sufficiently "capitalized" – that is, stocked with sufficient credits to adequately cover reversal risks over a long time horizon (e.g. 100 years). Ideally, this may be done through activity-specific risk assessments, which – if performed correctly – can ensure risks are covered without unfairly undermining an activity's financial viability. However, evidence suggests that existing methods (as in California's regulatory crediting programme) may underestimate activity-specific risk. Robust buffers should also be sufficiently diversified, ideally with a mix of credits from different types of activities in different geographies.

- **Clearly assigning liability for reversals and avoiding "moral hazards":** While pooled buffer reserves can be an effective tool for addressing unintentional reversals, they should not be the primary means to manage intentional reversals. Otherwise, moral hazards could occur – for example, if activity owners have the option to cause reversals by deliberately over-harvesting trees, or even "walk away" to pursue activities with higher financial value. Liability for intentional reversals should be clearly assigned to activity proponents and enforced, ideally, through legal agreements. If monitoring ceases prematurely (without evidence of a natural disturbance), a conservative approach for environmental integrity would be to treat this as equivalent to a full, intentional reversal and require compensation accordingly.

- **Ensuring a sufficiently long time horizon for monitoring and compensating for reversals:** Existing crediting programmes differ in the length of time they require for monitoring and compensation of reversals. From a scientific perspective, no duration is technically "long enough" if the objective is contributing to the achievement of the temperature goals of the Paris Agreement – in this case, emission reductions and removals would need to be "permanent". From a practical standpoint, the goal should be to actively manage reversal risk for as long as feasible (which may differ for different contexts). Robust practices in this regard would include setting fixed monitoring periods, and linking the start of monitoring periods to the date of credit issuance (so that each credit is guaranteed to have a fixed, minimum period of monitoring and compensation).

Some alternative options, like temporary crediting, offer a theoretically robust approach for managing reversal risk and ensuring environmental integrity. However, temporary crediting requires effective enforcement of the obligation to replace credits when they expire, which can be difficult to ensure (for example, across multiple buyers in multiple jurisdictions, and over long time horizons). Also, because temporary credits expire, buyers may have limited interest in them, which raises feasibility concerns (as occurred under the Kyoto Protocol).

Other alternatives, such as issuance deductions and tonne-year accounting, have some feasibility advantages. They can be relatively easy to implement, for example, and provide flexibility to activity proponents. However, they are less robust from an environmental integrity perspective than monitoring and compensation approaches, in particular as they do not ensure a minimum duration for the preservation of carbon stocks. In some contexts, tonne-year accounting combined with minimum storage duration requirements could provide a useful “compromise” between these two types of approaches.

Reversals are an important risk that host countries of mitigation activities should consider and manage strategically. Under most circumstances, host countries will have to account for any reversals when establishing their emission balances to assess the achievement of their NDCs. Future reversals from mitigation activities could also compromise the ability of host country governments to meet future NDC targets. Host countries therefore have an inherent interest in ensuring that reversal risks are well managed. However, current accounting rules under Article 6 of the Paris Agreement do not take into account the operation of pooled buffer reserves, which are a key element of most existing monitoring and compensation approaches. Host countries need to carefully balance current benefits from mitigation activities against the risk of future reversals when authorizing mitigation outcomes for use under Article 6 of the Paris Agreement, and consider supplementary strategies to reduce reversal risk.

At the end of the day, none of the approaches identified in this paper can truly guarantee the permanence of land-based emission reductions or removals. For many types of activities, some level of reversal risk is likely to remain in perpetuity. From a policy perspective, the goal should be to effectively manage reversal risks for as long as feasible, with clear recognition that future reversals could create liabilities for both host countries for achieving future NDCs and achieving the temperature goals of the Paris Agreement.

References

6

Allen, M.R., Frame, D.J., Huntingford, C., Jones, C.D., Lowe, J.A., Meinshausen, M. and Meinshausen, N. 2009. Warming caused by cumulative carbon emissions towards the trillionth tonne. *Nature*, 458(7242): 1163–66. https://doi.org/10.1038/nature08019

Allen, M.R., Friedlingstein, P., Girardin, C.A.J., Jenkins, S., Malhi, Y., Mitchell-Larson, E., Peters, G.P. and Rajamani, L. 2022. Net Zero: Science, Origins, and Implications. *Annual Review of Environment and Resources*, 47(1): 849–87. https://doi.org/10.1146/annurev-environ-112320-105050

Anderegg, W.R.L., Trugman, A.T., Vargas, G., Wu, C. and Yang, L. 2024. *Current forest carbon offset buffer pools do not adequately insure against disturbance-driven carbon losses*. https://doi.org/10.1101/2024.03.28.587000

Badgley, G., Chay, F., Chegwidden, O.S., Hamman, J.J., Freeman, J. and Cullenward, D. 2022. California's forest carbon offsets buffer pool is severely undercapitalized. *Frontiers in Forests and Global Change*, 5: 930426. https://doi.org/10.3389/ffgc.2022.930426

Balmford, A., Keshav, S., Venmans, F., Coomes, D., Groom, B., Madhavapeddy, A. and Swinfield, T. 2023. *Realising the social value of impermanent carbon credits*. https://doi.org/10.33774/coe-2023-5v93l-v4d

Brander, M. and Broekhoff, D. 2023. Methods that equate temporary carbon storage with permanent CO_2 emission reductions lead to false claims on temperature alignment. *Carbon Management*, 14(1): 2284714. https://doi.org/10.1080/17583004.2023.2284714

Chay, F., Badgley, G., Martin, K., Freeman, J., Hamman, J. and Cullenward, D. 2022. *Unpacking ton-year accounting.* CarbonPlan. https://carbonplan.org/research/ton-year-explainer

Cullenward, D. 2023. *A Framework for Assessing the Climate Value of Temporary Carbon Storage.* Carbon Market Watch. https://carbonmarketwatch.org/publications/a-framework-for-assessing-the-climate-value-of-temporary-carbon-storage

Geist, H.J. and Lambin, E.F. 2002. Proximate Causes and Underlying Driving Forces of Tropical Deforestation. *BioScience*, 52(2): 143. https://doi.org/10.1641/0006-3568(2002)052[0143:PCAUDF]2.0.CO;2

Herold, A. and Böttcher, H. 2018. *Accounting of the Land-Use Sector in Nationally Determined Contributions (NDCs) under the Paris Agreement.* Oeko Institute. https://transparency-partnership.net/system/files/document/Guide%20Accounting%20of%20land-use%20sector%20in%20NDCs(vf)_20181010.pdf

IPCC. 2022. *Climate Change 2022: Mitigation of Climate Change. Summary for Policymakers. Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SPM.pdf

MacCarthy, J., Tyukavina, A., Weisse, M. and Harris, N. 2024. *Canada's Record-breaking 2023 Wildfires Released Nearly 4 Times More Carbon than Global Aviation*. World Resources Institute. https://www.wri.org/insights/canada-wildfire-emissions

Marshall, E. and Kelly, A. 2010. *The Time Value of Carbon and Carbon Storage: Clarifying the Terms and the Policy Implications of the Debate*. SSRN Scholarly Paper. ID 1722345. Rochester, New York, Social Science Research Network. https://papers.ssrn.com/abstract=1722345

Matthews, H.D., Zickfeld, K., Dickau, M., MacIsaac, A.J., Mathesius, S., Nzotungicimpaye, C.-M. and Luers, A. 2022a. Temporary nature-based carbon removal can lower peak warming in a well-below 2 °C scenario. *Communications Earth & Environment*, 3(1): 65. https://doi.org/10.1038/s43247-022-00391-z

Matthews, H.D., Zickfeld, K., Koch, A. and Luers, A. 2022b. *Reimagining tonne-year accounting to capture the climate benefit of temporary carbon storage*. https://doi.org/10.21203/rs.3.rs-2260548/v1

Pan, C., Shrestha, A., Innes, J.L., Zhou, G., Li, N., *et al.* 2022. Key challenges and approaches to addressing barriers in forest carbon offset projects. *Journal of Forestry Research*, 33(4): 1109–22. https://doi.org/10.1007/s11676-022-01488-z

Parisa, Z., Marland, E., Sohngen, B., Marland, G. and Jenkins, J. 2022. The time value of carbon storage. *Forest Policy and Economics*, 144: 102840. https://doi.org/10.1016/j.forpol.2022.102840

Prag, A., Hood, C. and Barata, P.M. 2013. *Made to Measure: Options for Emissions Accounting under the UNFCCC.* OECD/IEA Climate Change Expert Group Paper No. 2013(1). Paris, Organisation for Economic Co-operation and Development, and International Energy Agency. http://doi.org/10.1787/5jzbb2tp8ptg-en

Schneider, L. and La Hoz Theuer, S. 2019. Environmental integrity of international carbon market mechanisms under the Paris Agreement. *Climate Policy*, 19(3): 386–400. https://doi.org/10.1080/14693062.2018.1521332

Schneider, L., Weber, F., Füssler, J., Moosmann, L. and Böttcher, H. 2022. Visibility of carbon market approaches in greenhouse gas inventories. *Carbon Management*, 13(1): 279–93. https://doi.org/10.1080/17583004.2022.2075283

Siemons, A. and Schneider, L. 2022. Averaging or multi-year accounting? Environmental integrity implications for using international carbon markets in the context of single-year targets. *Climate Policy*, 22(2): 208–21. https://doi.org/10.1080/14693062.2021.2013154

UNFCCC. 2022. CDM Database for PAs and PoAs. https://cdm.unfccc.int/Projects/projsearch.html

UNFCCC. 2023. *Nationally Determined Contributions under the Paris Agreement.* FCCC/PA/CMA/2023/12. https://unfccc.int/sites/default/files/resource/cma2023_12.pdf?download

For more information, please contact:

Forestry Division – Natural Resources and Sustainable Production

NFO-Publications@fao.org

www.fao.org/forestry/en

Food and Agriculture Organization of the United Nations
Rome, Italy

With the financial support of

UK Government

ISBN 978-92-5-139312-3

9 789251 393123

CD3083EN/1/11.24