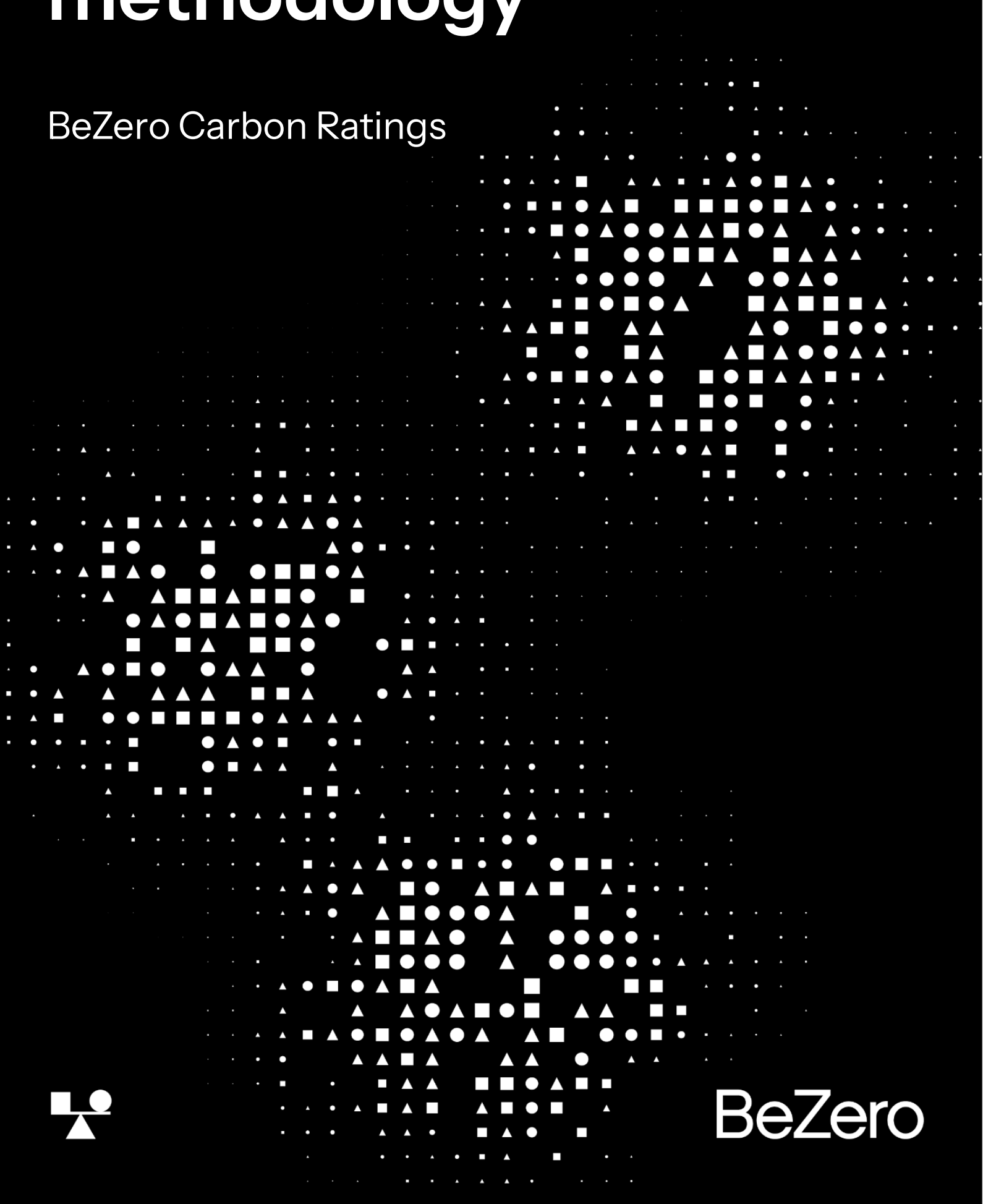
Mangroves methodology

BeZero Carbon Ratings



BeZero

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Glossary

Alkalinity: This is a measure of the capacity of water to resist acidification, and is largely due to the presence of carbonate, bicarbonate, and hydroxide ions. High alkalinity means water can more effectively neutralise acids, as it increases the water's buffering capacity.

Allochthonous carbon: Organic carbon that originates outside of a specific ecosystem and is imported into it

Baseline: A baseline scenario is the amount of emissions that are assumed to occur in the absence of any project intervention.

BeZero Carbon Rating (BCR): The BeZero Carbon Rating is a hybrid analytical framework that fuses financial, scientific, and policy-based analysis. It provides an opinion on the likelihood that a given credit achieves a tonne of CO_2e avoided or removed.

Blue carbon: All biologically driven carbon fluxes and storage in marine systems that are amenable to management.

Buffer pool: The buffer pool is an account of non-tradable credits that projects contribute towards and serves as a communal reserve for Nature Based Solutions. Contribution amounts are based on the methodology. If a project loses its carbon stocks, for example to fire or disease, buffer pool credits can be used to compensate for the loss. Alternatively, projects that effectively mitigate the risk of carbon loss can regain the credits they contributed to the buffer pool.

Carbon finance: Financial resources allocated to carbon project activities that reduce or avoid greenhouse gas emissions. It is an additional source of revenue that seeks to make such activities more financially viable.

Carbon pool: Ecosystem components that have the capacity to release, sequester and/or store carbon. These include above and belowground biomass, soil organic carbon, soil inorganic carbon, deadwood, litter and harvested wood products.

Commitment period: The duration of time over which a project plans for its activities to take place.

Deforestation: The intentional clearing of forests and conversion to another land use.

Ecological leakage: Unintended displacement of positive or negative impacts across the wider ecosystem as a result of project activities.

Eutrophication: The process by which a body of water becomes overly enriched with nutrients.

Forest degradation: A transitory or long-term deleterious change in forest condition that impacts forest functions, properties, or services.

Leakage belt: An area surrounding or close to (but not overlapping with) the project area, which may be vulnerable to leakage, for example, due to the displacement of deforestation drivers. The nature of the leakage belt is dependent on the type and scale of leakage risks identified by the project.

Mangrove: A tree or shrub that inhabits the coastal intertidal zone. Mangroves are adapted to their habitat in coastal saline waters through dense root networks which provide stabilisation, and aerial roots to uptake atmospheric oxygen during periods of inundation.

Methodology: A framework that sets out a process and parameters for quantifying the carbon benefits of a project. Methodologies enable project developers to quantify baselines, assess key aspects like

additionality, and define necessary monitoring practices to ensure the greenhouse gas emission reductions are verifiable, additional, and quantified.

Mosaic deforestation: Land use practice and population pressures drives deforestation across a patchwork of cleared land.

Nature-based solutions (NBS): Nature-based solutions aim to achieve emission removals or avoidance in the natural environment; these include forestry, soil carbon, and blue carbon.

Normalised difference vegetation index (NDVI): NDVI is a numerical indicator used in remote sensing and geospatial analysis that measures the density of green vegetation and the health of vegetation cover in a specific area by comparing near-infrared and red light (which are respectively reflected and absorbed by photosynthetic plants). The comparison generates NDVI values between -1 and 1. Numbers closer to 1 indicate greener vegetation, while numbers closer to -1 indicate more barren environments. By monitoring an area's NDVI over time, we track changes to vegetation cover and measure the impact of land use and climate on plant health.

Ocean acidification: The ongoing decline of pH in oceans, primarily due to the uptake of carbon dioxide from the atmosphere. When carbon dioxide dissolves in seawater, there are a series of reactions through which the concentration of hydrogen ions increases, which lowers the pH of the water, increasing acidity.

Particulate organic carbon (POC): Organic carbon found in particulate form suspended in water. This can include organic matter from plants, animals, and microbial organisms.

Project area: The geographical boundaries within which project activities take place.

pH: The measure of acidity or basicity of a solution. It is a logarithmic scale ranging from 0 to 14, with 7 representing neutrality, lower values indicating acidity, and higher values indicating basicity.

Rating Committee: A group of members with extensive experience within and across all sectors who discuss and debate the assignment of BeZero Carbon ratings. The Rating Committee oversees the analytical process and ensures consistency in the application of ratings criteria, methodologies, and comparability of ratings across sectors and countries.

Stakeholders: Individuals and/or groups of people who may be affected by the implementation and activities of a project.

Standards bodies: Organisations that develop and revise methodologies to determine the greenhouse gas benefits of various types of carbon projects, and inform when and how many credits projects can issue.

Vintage: The vintage year refers to the period of time when the emission reduction or removal associated with a credit occurred.

Voluntary carbon market (VCM): Carbon markets that exist outside of the regulation and frameworks of international agreements, and are fuelled by commitments of individuals, as well as private and public organisations, to reduce greenhouse gas (GHG) emissions through the trading of carbon credits.

Introduction

BeZero Carbon is a global ratings agency for the voluntary carbon market (VCM). Our ratings provide a publicly available, risk-based framework for assessing carbon efficacy. We rate qualifying carbon credits in all sectors.

We take a research-first mindset, fusing traditional capital markets research practices with expertise in environmental sciences and technology. We think creatively about climate problems and build solutions the whole market can use.

We have developed extensive analytical frameworks to rate carbon credits on their likelihood of delivering on their promised carbon emissions avoidance or removal. These analytical frameworks are deeply sector nuanced and bring to the fore our extensive experience in rating hundreds of projects across dozens of sub-sectors.

Our ratings team is made up of 60 analysts who create the models and perform the analysis for every rating. They combine expertise in climatic, biological, and Earth sciences, in disciplines from remote sensing, forest ecology, ecosystem disturbance, peatlands and blue carbon through to statistics, machine learning, artificial intelligence, sell-side financial research, industrial engineering, and public policy. They hold over 20 PhDs, have published over 200 academic papers and have been cited over 10,000 times in peer-reviewed, scientific academic literature.

As the market's number one risk metric, our ratings are available on our website and dozens of marketplaces, and alongside extensive analysis and research on our BeZero Carbon Markets platform.

What are mangroves carbon projects?

"Mangroves projects are those that sequester carbon in coastal wetland systems with a substantial component of mangrove trees, either by increasing tree cover or by avoiding forest loss/degradation relative to a no-project baseline. BeZero Carbon's Mangroves methodology is a tool for users of the BeZero Carbon Rating to better understand our multifaceted ratings approach to this sub-sector within Blue Carbon.

Mangrove projects can issue both avoidance and removal credits by avoiding deforestation in existing mangrove forests and/or planting mangroves. These project types can operate on local and regional scales. Existing mangrove projects operate on scales ranging from 1,200 hectares to over 250,000 hectares. In the BeZero Sector Classification system, Mangrove projects are one of three sub-sectors within the Blue Carbon sector group (Figure 1).

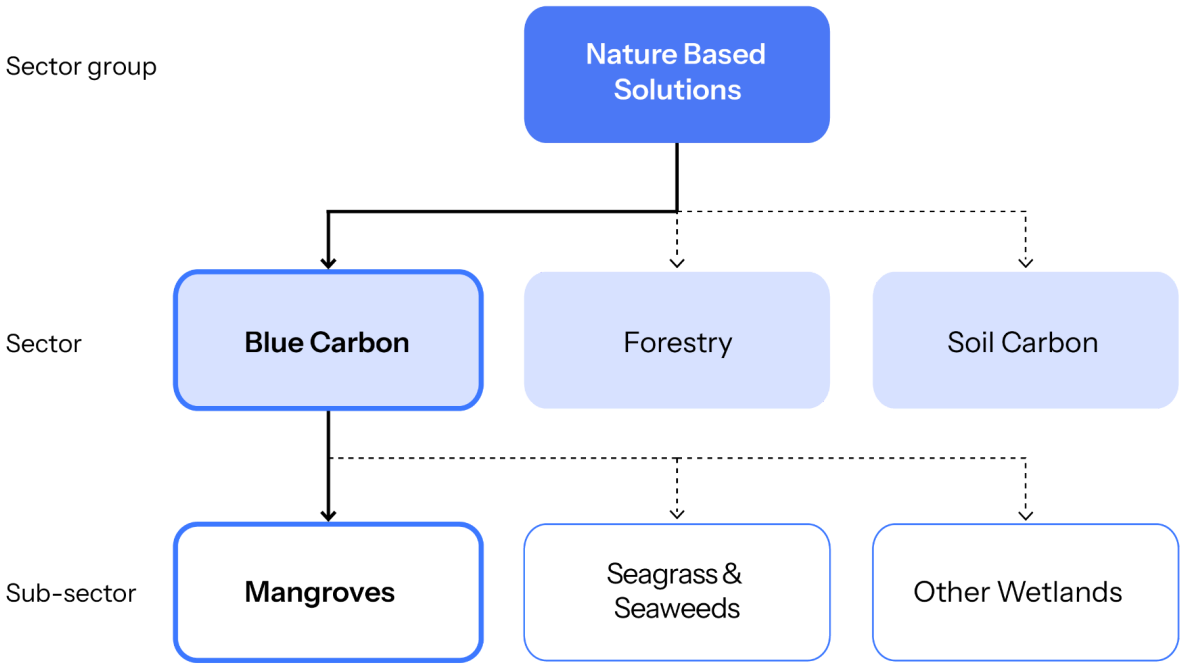


Figure 1. The Mangroves sub-sector within BeZero's Sector Classification System.

Additional sub-sector qualifiers for Mangroves

In addition to our sector classification, each sub-sector can have additional unique qualifiers to enable project labelling and grouping. For the Mangroves sub-sector, these qualifiers are afforestation, reforestation, or restoration (ARR) and avoided deforestation (AD). Below we describe the key features that determine qualifying labels:

1. **Mangrove afforestation, reforestation, and restoration (ARR):** These projects aim to increase carbon sequestration in biomass and soil by establishing or increasing tree cover in mangrove systems.

2. **Mangrove avoided deforestation (AD):** These projects aim to stop planned or unplanned deforestation on mangrove forest lands. Planned deforestation is both legally authorised and officially documented, often with a clear agent of deforestation. In contrast, unplanned deforestation would occur without prior authorisation or planning, and may be illegal. Unplanned deforestation can stem from a variety of drivers and agents that are not clearly identified.

BeZero Carbon Rating analytical framework and process for Mangroves

We have designed an approach to assessing the carbon efficacy risk for issued carbon credits. This framework is applicable to any project type in any sector accredited by any standards body, and leverages a blend of qualitative and quantitative factors; financial, environmental, policy assessment techniques; and primary and secondary data sources.

Our BeZero Carbon Rating Methodology details our risk based assessment for understanding and interrogating the efficacy of issued carbon credits of any type, in any sector and country.

The BeZero Carbon ex ante Rating Methodology similarly describes our framework for assessing carbon efficacy of credits yet to be issued from projects of any type, in any sector and country. Ex ante ratings will also consider project execution risk.

Sector methodologies are nested within the overarching ex post and ex ante methodologies. The overall rating definitions, risk factors and risk driver categories are common across all projects while the sector methodologies provide more detail on our sector-specific analytical approach.

This document provides an extension to our overarching rating methodologies. It presents BeZero's detailed analytical framework and process for Mangrove projects. It showcases the various parameters through which we assess risk to the carbon quality of these credits, and how this sub-sector implements our overarching ratings methodologies.

Holistic assessment

The assessment of a carbon credit's efficacy includes a detailed, project-specific, bottom-up and top-down analysis to provide a comprehensive assessment of risk. Further details on the risk factor definitions, the rating process, and the overall risk assessment can be found in our BeZero Carbon Rating Methodology and BeZero Carbon ex ante Rating Methodology.

Important elements of the BeZero Carbon rating process that are applicable to all project types are described in detail in these overarching methodologies and are not repeated here. These include:

- The steps in the rating process
- The project governance assessment
- Project boundary auditing
- Assessing the risks of double counting
- The integrity of reported issuance
- Assessing rating eligibility (whether projects meet our three primary qualifying criteria)
- The rating assignment process
- The role of the BeZero Carbon Rating Committee
- Ongoing monitoring and 'rating watch' process

Geospatial and Earth Observation

For all NBS projects, data and analysis from our Geospatial and Earth Observation team forms a core part of the analytical process. The team draws on a diverse set of data inputs, including but not limited to airborne and spaceborne LiDAR, synthetic-aperture radar, and multispectral measurements, with spatial resolutions ranging from centimetres to kilometres, and temporal frequency and coverage from days to decades.

Other geospatial inputs include data on road and river networks, human demographics, land ownership and governance, soil and climate data, and biodiversity. We also draw on our extensive database of ground-measured carbon, spanning thousands of forest inventory sites globally. These geospatial data are combined in statistical and machine learning frameworks to inform project- and vintage-level risk associated with common practice, over-crediting, leakage and non-permanence.

Three geospatial capabilities are central to our current Mangroves analysis and are referred to throughout this document.

1. **Monitoring of vegetation density and health:** Spectral indices such as the Normalised Difference Vegetation Index (NDVI) are used as a proxy for assessing vegetation health, density, and, to some extent, biomass. In our assessment we use NDVI in combination with global

mangrove datasets such as Global Mangrove watch (v3) and Global Mangrove Watch annual extent (10m) to identify areas of *water, mud, open canopy and closed canopy mangroves and any changes between these classes over time, to identify changes in mangrove density overtime both within the project and the surrounding area. This allows us to identify changes in the project mangrove cover relative to local trends in regeneration and historical vegetation changes in the project area itself.*

2. ***Forest Loss and degradation:*** *We use a combination of* The JRC Tropical Moist Forest (TMF) analysis and GLAD UMD Global Forest Change analysis to detect vegetation loss, degradation, and re-growth in mangroves in the project area and surrounding buffers. Where we rely on this data to interrogate removals, we do so qualitatively and in combination with literature evidence, rather than treating them as a precise measure of change.

3. **Forest inventory integration.** We maintain the BeZero Carbon Plots Database, which combines ground-measured carbon from private collections, national inventories, international plot networks, academic studies and research partnerships, spanning more than 300,000 sites across all six forested continents as of September 2026. It harmonises stem-level estimations of tree volume and species-specific wood density, linked with allometries, geospatial information and our markets data. Where national inventories are absent or otherwise unreliable, our analysis is driven by literature values and, where appropriate, remote sensing.

Carbon efficacy assessment

Whilst the foundational questions that underpin a BeZero Carbon Rating converge at the risk factor level, the inputs used to answer these questions show increasing specificity at the sub-sector and project levels.

Additionality

The likelihood that a project's activities are materially different from the counterfactual or business-as-usual activities.

Whilst the foundational questions that underpin a BeZero Carbon Rating converge at the risk factor level, the inputs used to answer these questions show increasing specificity at the sub-sector and project levels.

Table 3 sets out the risk drivers within our assessment of additionality. In the sections that follow we detail the key parameters that factor into each level of risk assessment.

Table 3. Sub-components of additionality assessed.

Risk factor	Risk driver category	Risk driver
Additionality	Activity analysis	Common practice
		Alternatives to the proposed project
		Project effectiveness
	Financial analysis	Prior consideration of carbon finance
		Investment analysis
		Barrier analysis
		Benefit sharing
	Legal and policy	Land and carbon rights
		Policy support

Activity Analysis

Common practice

Common practice is a major driver of our additionality analysis for Mangrove projects. Our objective is to determine whether the project's mangrove protection or restoration corresponds to activities that are commonly implemented without carbon finance in similar regional contexts. If so, the project activities are less likely to be additional. The assessment is specific to comparable land tenure, mangrove type and land-use pressures, and distinguishes conservation from restoration activities.

We establish what constitutes common practice through literature and third-party industry data. We identify comparable mangrove conservation and restoration initiatives implemented with and without carbon finance, and consider their scale and effectiveness. Comparability is assessed based on

geography, hydrology, land ownership class, jurisdiction, and forest type. We also leverage our internal markets and geospatial databases to assess the location and prevalence of other voluntary carbon market projects registered on the major standards bodies at different spatial scales, to appropriately exclude similar initiatives that also leverage carbon finance from our assessment of common practice without carbon finance.

Comparisons are restricted to mangrove ecosystems, and where geospatial evidence is used to establish common practice we apply a mangrove mask to avoid conflating terrestrial forest dynamics with mangrove change. We also compare changes in mangrove condition within the project area to changes in ecologically and socio-economically comparable areas. Depending on the project, this may include mangrove-specific buffers or other comparison areas with similar land tenure and land-use pressures. We use satellite imagery and time-series vegetation metrics, including Normalised Difference Vegetation Index, to assess trends in loss, degradation, planting, and regeneration.

For Mangrove ARR projects, we additionally consider whether mangrove cover gain is already occurring through natural regeneration or non-carbon-funded planting, and whether project intervention types are common at a comparable scale in absence of carbon finance. We assess mangrove cover gain using historical satellite imagery and vegetation indices to identify trends in vegetation recovery in the project area and comparable areas.

For Mangrove AD projects, we consider whether mangroves in comparable areas are already being effectively protected without carbon finance by leveraging the World Database on Protected Areas and relevant literature on protected area effectiveness. Mangrove deforestation and degradation is similarly detected using satellite imagery and vegetation indices to identify whether mangrove loss is occurring despite protected status.

Our conclusion on common practice therefore reflects whether the project's activities are commonly applied on similar lands in the region absent carbon finance, and whether there is a discernable difference in scale and effectiveness that may justify additionality in cases where the activity itself is common. Risk is highest when comparable activities are already implemented at scale in the project landscape, and lowest where no mangrove conservation or restoration is identified in nearby or similar systems.

We recognise limitations with the use of satellite imagery and vegetation indices in mangrove ecosystems. Where data quality or ecological comparability are insufficient for a reliable comparison, we state that limitation and weigh the remaining evidence accordingly.

Alternatives to the proposed project

This risk driver addresses the range of plausible counterfactual scenarios—regardless of the baseline scenario selected by the project—and asks whether the project delivers a greater carbon benefit than those counterfactuals. If so, this supports additionality. Findings from this analysis are carried consistently into our carbon accounting assessment of the baseline, but risks assessed under additionality are not penalized a second time in the carbon accounting score.

For Mangrove ARR projects, we assess the land uses that could credibly persist or arise without the project, including continued degradation, aquaculture, agriculture, natural regeneration, government-, NGO-supported or private restoration, and other planting.

For Mangrove AD projects, we identify the agents and drivers that could plausibly cause mangrove loss or degradation, including aquaculture, agriculture, timber or fuelwood extraction, settlement, infrastructure and other locally relevant pressures.

Mangrove ARR. We assess both historical land-use practices and future trends to determine whether mangrove restoration or natural regeneration could plausibly occur without carbon finance. We use historical land-use evidence, literature and mangrove-specific remote sensing to assess whether the project area was already regenerating, whether mangrove vegetation has increased, decreased or remained stable over time, and the drivers of these changes. Where mangrove vegetation has historically increased, we assess the likelihood that natural recovery could continue and achieve an extent comparable to that delivered by the project. We also assess whether similar restoration activities were already occurring in the project area without carbon finance and whether project activities represent business-as-usual. Where activities are business-as-usual and there is no evidence that carbon finance is necessary to sustain or expand them, we find risk to additionality.

We complement this historical assessment with evidence on likely future land-use trajectories. Using literature, third-party industry data and mangrove-specific remote sensing, we assess whether natural regeneration or restoration is likely to occur without carbon finance over time. This includes assessing whether land uses that inhibit regeneration, such as aquaculture or agriculture, are advancing towards the project area and whether relevant market trends are likely to increase or decrease these pressures. We also assess the likelihood and expected extent of future restoration through government programmes, NGO interventions, private initiatives or other funding sources. Where natural regeneration is likely to achieve outcomes comparable to the project, or restoration is expected through alternative funding at the same or greater extent than that planned by the project, we find additionality risk.

Mangrove AD. We assess both the historical presence and likely future evolution of the agents and drivers that could cause mangrove loss or degradation. We consider pressures including aquaculture, agriculture, timber or fuelwood extraction, settlement, infrastructure and other locally relevant drivers, assessing their historical presence, economic attractiveness and accessibility to the project area. Where the project lies within or close to a protected area, we assess the designation and timing of protection, resource management and observed effectiveness of protection rather than treating legal protection as a binary indicator of avoided deforestation risk.

We then assess whether these drivers are likely to change in scope or intensity over time and how this may affect the likelihood and rate of future mangrove loss. Using literature, third-party industry data and mangrove-specific remote sensing, we assess whether deforestation or degradation frontiers are advancing towards the project area and, where possible, the rate of their advance. We identify the material drivers of historical deforestation and assess whether they are likely to strengthen or weaken, including in response to changes in market demand for relevant agricultural or other commodities. We also consider whether new or emerging drivers could increase future pressure on the project area. Where a deforestation frontier is advancing towards the project area and independent evidence indicates that relevant pressures, such as strong market demand for deforestation-linked products, are likely to intensify, additionality risk may be reduced.

Our conclusion reflects the counterfactual scenario best supported by independent evidence and the extent to which it differs from the project scenario.

Project effectiveness

Project effectiveness is assessed where sufficient time has elapsed to observe whether project activities have produced beneficial carbon outcomes. It is principally an ex post risk driver. For Mangrove AD projects, we compare mangrove loss and degradation after project implementation with pre-project trends and with appropriate mangrove comparison areas. We use mangrove-specific geospatial analysis wherever possible, including forest-loss and degradation datasets, satellite imagery and vegetation-index time series. Where terrestrial vegetation is present within broader buffers, we distinguish it from mangroves and only use terrestrial trends where they are informative of the same underlying driver. We interpret a divergence between project and comparison areas alongside the timing and nature of project activities and wider changes in land-use pressure. Where there is no clear

divergence in forest loss trends between the pre- and post-project periods, and post-project implementation forest loss trends follow regional trends, this suggests that the project has not caused a reduction in deforestation, weighing against additionality.

For restoration projects, a project that is unsuccessful in establishing or maintaining vegetation may no longer outperform the most plausible without-project scenario, even if the original intervention was additional in principle. We compare achieved sequestration with ex ante expectations on a per-hectare basis and by reviewing high-resolution imagery and vegetation-index time series for areas showing limited or no growth. Where underperforming areas can be identified, we estimate the share of expected or issued credits associated with them. We then compare the observed project outcome with the alternative scenarios established above. If a plausible counterfactual now stores as much carbon than the observed project, the resulting risk is treated as an Additionality finding under project effectiveness.

Financial Analysis

Prior consideration of carbon finance

We assess whether carbon finance was a material consideration before project implementation or before a material expansion of project activities. We review the chronology of planning, implementation, registration, financing and expected issuance, together with evidence that commitments or activities were contingent on access to carbon revenue. A project that was already financially sustainable and proceeding at the same scale before carbon finance was contemplated presents a weaker case for additionality. Conversely, evidence that implementation, continuation or expansion depended on anticipated carbon revenue supports additionality. The weight placed on this driver depends on the quality of the available documentary evidence and its relevance to the activities that generate the rated credits.

Investment analysis

Our objective is to determine whether the project's ongoing implementation is dependent on carbon finance. If the project's activities are financially attractive in the absence of carbon finance, then it is reasonable to assume that the project is not reliant on carbon finance, and the project is unlikely to be additional. For Mangrove projects we primarily assess the direct costs and opportunity costs associated with implementing the project activity, the existence of other revenue generating activities, and implementation costs. We do not consider costs of developing, administering, and marketing the carbon project; only the direct costs of the activities that drive carbon benefits are relevant.

We then assess the extent to which carbon revenues are capable of mitigating direct costs and opportunity costs. Where there is little or no cost associated with the project scenario, or where carbon finance covers only a small proportion of it, additionality risk is elevated. Opportunity cost is commonly introduced as a result of the prevention of baseline activities such as aquaculture, conversion to plantations and resource extraction. This is more commonly seen in Mangrove AD projects where carbon finance is normally used to provide alternative revenue or alternative livelihood options in community-based mangrove deforestation projects.

We assess the existence of other revenue streams and their materiality on project finances. Other revenue streams commonly seen in Mangrove projects include ecotourism, payments for ecosystem services, philanthropic support, and the sale of forest products. We weigh these contributions against carbon finance to determine their impact on the project's financial viability. Where ecotourism materially supports the cost of mangrove conservation, additionality risk may increase. Where philanthropic support is provided, we assess the origination and nature of the funding. Philanthropic support does not

always weigh against additionality, as in some cases it is tied to the project's design as a carbon project and in other cases is limited and unreliable.

Where sufficiently detailed information is disclosed, we reconstruct and validate the project's own financial analysis using project-reported costs and revenues and independent evidence from the relevant period and geography. We assess whether reported prices, costs and returns are plausible, and whether non-carbon revenue would have been sufficient to make the project viable at a comparable scale. This is particularly relevant for Mangrove ARR projects where the most common cost is the direct cost of planting. Where disclosure is insufficient for a numerical reconstruction, we confine our conclusion to what the available evidence supports and explicitly reflect the uncertainty.

Barrier analysis

Barrier analysis considers obstacles that can prevent implementation, even when the activity appears desirable in principle, and assesses whether carbon finance is the mechanism to overcome them. For many mangrove projects the necessity for technical support, nurseries, training, infrastructure, or alternative livelihoods can undermine a project's additionality. These barriers are often unique to the project's location and circumstance. To assess the presence and scale of these barriers, our mangrove project analysis incorporates geospatial and desk-based approaches.

We identify barriers reported by the project and independently reported for comparable activities in the jurisdiction. Each is tested for credibility, project specificity and materiality using project documentation, feasibility studies, geospatial evidence, government or NGO reporting and academic literature. If similar landholders routinely overcome the same barrier without carbon finance, the barrier provides weaker support for additionality. Where the project is an expansion of pre-existing activity, the relevant question is whether the barrier applies to the expansion rather than to the activity in general.

We then trace how carbon finance is used to address the barrier. Carbon revenue may fund nurseries, planting inputs, technical assistance, infrastructure, early cash flow, training or institutions needed to aggregate landholders. A barrier that remains unresolved does not support additionality merely because it exists; it may instead indicate project-execution or permanence risk.

Benefit sharing

Benefit sharing is assessed when communities, individual landowners, or other stakeholders control the land or the actions needed for project implementation. The objective is to determine whether the project through carbon finance provides a credible incentive for stakeholders to adopt activities they would otherwise be unlikely to undertake.

We identify formal revenue-sharing or profit-sharing arrangements and non-financial benefits, including planting materials, technical support, training, employment, alternative livelihoods, access to forest products, cooperative structures and community infrastructure. We assess who receives each benefit, when it is delivered, whether it is conditional on vegetation survival or credit issuance, and whether the organisational arrangements allow the intended stakeholders to access it.

The value and timing of benefits are considered against foregone income, labour requirements, maintenance costs and other livelihood impacts introduced by the project. A mechanism supports additionality where it is sufficient and appropriately targeted to change behaviour or sustain participation. The reliability of delivering promised benefits, and the risk that failure causes withdrawal or non-compliance, are assessed separately under Stakeholder engagement in Permanence.

Legal and policy

Land and carbon rights

This risk driver is typically not applicable for Mangrove projects. They are material to permanence, and for Mangrove projects are assessed under the *Project management and carbon rights* risk driver within Permanence. Where relevant, land and carbon rights may be considered in Additionality where they affect the credibility or legality of the counterfactual. For example, an asserted agent of mangrove conversion may not have held the rights needed to undertake that conversion, or pre-existing legal protections may materially constrain the project's claimed baseline. Where this arises, the finding is reflected in *Alternatives to the proposed project* and, where relevant, the *Baseline scenario.*

Policy support

Our objective is to determine the extent to which existing policies, incentives and mandates encourage or require mangrove protection or restoration in the absence of carbon finance. Projects in jurisdictions where relevant policies are effectively implemented and substantially reduce barriers to project activities are more likely to face additionality risk. Where policies are weak, poorly funded, inconsistently enforced or actively undermined, carbon finance may remain important to implementation.

We identify policies and regulations that directly bear on project activities, including mangrove protection, coastal land-use restrictions, restoration mandates, and protected-area requirements. We assess their geographic applicability, timing, implementation and enforcement, including observed mangrove outcomes where suitable evidence is available. We separately identify government programmes and financial support mechanisms that could fund comparable conservation or restoration that deliver carbon benefits beyond the counterfactual. We assess whether the project area or proponent is eligible for or enrolled in those programmes, their uptake and effectiveness in the region, and whether they could plausibly support project activities at a comparable scale. Conversely, we also identify policies that may threaten mangrove preservation or restoration, including infrastructure development or the promotion of aquaculture expansion.

The practical significance of a given policy instrument to an individual landowner is often not evident from formal descriptions of the policy, including the text of relevant laws and regulations. Each policy identified is therefore assessed with input from analysts with experience of the relevant jurisdiction, and we are explicit where a policy's status or effect on forest management decisions is uncertain.

Carbon Accounting

'The likelihood that or degree to which climate benefits are accurately or conservatively quantified.

Table 4 sets out the risk drivers within our assessment of carbon accounting.

Table 4. Sub-components of our over-crediting assessment.

Risk factor	Risk driver category	Risk driver
Carbon Accounting	Direct accounting	Baseline scenario
		Project scenario
		GHG conversions
	Leakage accounting	Activity displacement
		Market leakage

Reconstructing the project's crediting structure

Our assessment of carbon accounting begins by reconstructing how a project arrived at its net issuance across the rated vintage period, so that the effect of each subsequent finding can be located within that structure.

Using project-reported values, we establish the project's total gross emissions reductions as the difference between project-area carbon stocks under the baseline and project scenarios. We then decompose that total into its avoidance and removals components, since the two are subject to different risks, different leakage treatments, and different vintage profiles. Removals reflect increases in project-scenario carbon stocks beyond any increase that the baseline itself assumes; avoidance reflects the carbon loss assumed in the baseline that the project scenario avoids. From gross emissions reductions we then account for the project's leakage deduction and its buffer pool contribution to arrive at claimed net emissions reductions.

Separately, we construct the equivalent quantities on our own terms to obtain our best estimate range for comparison. Where our analysis of the risk drivers below leads us to a different view of the counterfactual, of reported project emissions, of growth rates, or of the appropriate leakage deduction, we quantify the emissions reductions that our own assumptions would imply, and arrive at a BeZero view of net emissions reductions for the rated vintages. The proportion of the project's claimed net issuance that our analysis does not support is the central output of our carbon accounting assessment, and the primary determinant of the risk factor score.

Three points of method follow from this. First, quantification is attempted wherever the evidence permits it, including where we conclude that a project's accounting is conservative rather than aggressive. Second, non-trivial assumptions are sometimes unavoidable. Third, in many cases we also need to consider the range and shape of uncertainty, strength of the scientific consensus that underpins the estimations, the likelihood of other unknowns, and other more qualitative considerations. Where the evidence supports a range rather than a point estimate, we present a range, and in conditions of material uncertainty we prefer to do so.

Direct accounting

Baseline scenario

Our objective is to determine the range of plausible without-project carbon-stock trajectories, to determine whether the project's selected baseline scenario is conservative with respect to this range, and if not conservative, to quantify the effect on issuance.This is a major risk driver for Mangrove projects, and the analytical approach differs between Mangrove AD and Mangrove ARR projects.

For Mangrove AD projects, we assess the rate, spatial pattern and type of mangrove deforestation or degradation assumed in the baseline. This includes the relevance of identified agents and drivers, the representativeness of any reference region, the historical reference period, model selection and the frequency with which the baseline is reassessed. We use mangrove-specific masks and independent geospatial analysis of mangrove loss and literature data to test whether historical and subsequent mangrove loss support the project's assumed counterfactual, and we consider changes in governance, commodity markets, access and other drivers that may make historical rates unrepresentative of future conditions.

For Mangrove ARR projects, the baseline scenario assessment is two-fold. First, we assess whether the project's accounting approach appropriately accounts for any pre-existing mangrove cover in the project area. We compare project accounting to our own geospatial assessment using a mangrove mask, a visual inspection of the project area, and remotely sensed vegetation indices including NDVI to determine the extent of mangrove cover classify the landscape into broad cover types (water, mud, open-canopy and closed-canopy). Second, we identify the range of plausible counterfactual land use scenarios from the

Additionality assessment and quantify the carbon trajectory that would plausibly have occurred without the project, with particular attention to pre-existing mangrove cover and natural regeneration. We use project documentation, visual interpretation and mangrove-specific NDVI or related analyses to identify open- and closed-canopy mangrove present before project implementation, assess transitions between vegetation classes through time, and determine whether the project baseline has appropriately captured existing biomass and expected regeneration. Where the project has underestimated the baseline starting mangrove vegetation stock and/or the project assumes no less baseline mangrove growth than occurs in plausible counterfactuals, we attribute over-crediting risk.

Where the project assumes alternative land uses such as aquaculture or agriculture, we compare the project's carbon assumptions with literature and geospatial evidence for those land uses. Where the evidence supports a range of plausible baseline carbon stocks or trajectories, we retain that range and reflect the associated uncertainty.

Several limitations bear on this analysis and are disclosed where they apply. The accuracy of geospatial forest loss datasets varies substantially between mangrove geographies, and often over- or underestimates mangrove loss in these ecosystems. We validate our conclusions using visual inspection of satellite imagery over areas marked as mangrove loss. We also use regional literature data to validate mangrove deforestation rate trends identified through forest loss data products.

Project scenario

Our assessment of project scenario accounting has two components; accounting of project scenario forest loss (Mangrove AD) or growth (Mangrove ARR) and accounting of project emissions (e.g. boat fuel).

In Mangrove AD projects, we examine reported forest loss and degradation against independent observations and assess whether any loss is appropriately deducted from the project's net issuance. We assess whether the project's forest loss and degradation detection methods are likely to sufficiently capture mangrove cover changes over time and we note any associated risks of underdetection where applicable.

In Mangrove ARR projects, we examine the rate of planted mangrove growth relative to the project's claimed biomass and soil organic carbon removals (where applicable). We use a combination of NDVI and satellite imagery time series to assess the rate of mangrove growth and sapling survival since planting date, tracking changes in closed- and open-canopy, mud and water pixels over time. We compare this data to the project's claimed mangrove condition and credited growth area and make an assessment on whether the project has appropriately accounted for realised mangrove growth and mortality.

We also identify project emissions that should be deducted where material, including emissions from land preparation, fertiliser, transport, machinery, infrastructure, acquisition of planting material and other implementation activities.

GHG conversions

This risk driver assesses the variables and equations used to convert measured or modelled project outcomes into tonnes of CO_2e. Our analysis focuses on carbon pools, stock estimates, growth or accumulation rates, allometry, non-CO_2 greenhouse gas flows and sampling approaches.

We assess which carbon pools are included or excluded and whether that treatment is conservative for the project scenario relative to the baseline. Relevant pools include above- and below-ground biomass, dead organic matter and soil organic carbon. For mangroves, soil organic carbon can be a major component of credited carbon and is therefore assessed separately from biomass where appropriate. Where soil organic carbon is excluded from project crediting, this can be a major factor in reducing

carbon accounting risk, even compensating to some degree for risks identified elsewhere, due to its generally large contribution to the ecosystem carbon stock.

For Mangrove AD projects, the primary assessment of live biomass is the quantification of the starting inventory and the methods used. For Mangrove ARR projects, the primary assessment is the quantification of mangrove growth and associated carbon sequestration rate. In both cases, we assess the project's field measurement sampling approach, including whether sampling design is representative of project strata and whether measurements support the inputs used in the accounting. For biomass, we assess the project's allometric equations, biomass expansion factors, root-to-shoot ratios, wood density and carbon fractions. We consider their specificity to the species, geography, hydrological setting and salinity regime, and compare project-reported stocks and growth with field inventories, the BeZero Carbon Plots Database, remote-sensing products and peer-reviewed literature.

For soil organic carbon, we assess baseline stocks, sampling depth and design, bulk density and analytical methods, the assumed rate of accumulation, assumptions regarding baseline-scenario erosion, and whether accumulation is credibly attributable to the project. We consider site history, sediment supply and hydrological setting. We also carefully consider the oxidation model for carbon from eroded soils (AD projects) and the origins of carbon in newly deposited soils (all projects crediting for growth in the soil carbon pool). In particular, in mangroves it can be important to account appropriately for stable forms of carbon that can be long-lived in the water column. Avoiding the loss of such carbon via erosion does not deliver a large or immediate atmospheric carbon benefit. Accumulating such carbon in newly deposited soils (recalcitrant allochthonous carbon) does not represent an atmospheric benefit of the project.

Where the methodology or project accounts for allochthonous carbon, we assess the treatment used to distinguish externally supplied stable carbon from carbon sequestered through project activities, and we independently assess the appropriateness of the deduction using peer-reviewed literature and project reported data carbon data. Where a project has not applied an allochthonous carbon deduction and we view it relevant, we calculate a deduction using peer-reviewed literature and project reported data soil carbon data, using methods described in relevant methodologies.

We also assess methane and nitrous oxide in both the project scenario and the baseline where they are material to the project's hydrological setting or activities, including the suitability of emission factors and the consistency of their application. The objective is to ensure that conversion factors and carbon-stock assumptions are ecologically appropriate and supported by evidence rather than selected solely because they are permitted by the project methodology. To understand the magnitude of any potential over- or under-crediting from these greenhouse gas species, we typically convert to carbon dioxide equivalent via 100-year global warming potentials.

Leakage accounting

Activity displacement

Activity displacement assesses whether carbon-emitting activities that previously occurred, or would have counterfactually occurred, within the project area have been shifted elsewhere as a consequence of project implementation. We first establish the relevant pre-project or counterfactual activities and whether project activities materially restrict or replace them.

For Mangrove AD projects, potential displacement can include aquaculture, agriculture, timber or fuelwood extraction and other resource use. We identify where those activities could move based on the geographic flexibility of the responsible agents, local land-use trends and stakeholder evidence. Here, we do not restrict our analysis to mangrove systems, as many of these activities can shift from mangroves to other terrestrial or intertidal systems. Where a project's methodology utilises a leakage belt, we assess the appropriateness of the defined area and determine the likelihood that activities will be displaced to this area based on access, vegetation type and proximity to the project. One particular consideration for

mangroves is the fact that displaced activities specific to intertidal systems (e.g. salt production and saltwater aquaculture) are unlikely to shift to a leakage belt which contains predominantly terrestrial vegetation.

For Mangrove ARR projects, displacement risk depends strongly on prior land use. Where planting occurs on heavily degraded land or mudflats with little active use, displacement may be limited. Where the project replaces active aquaculture, agriculture or resource use, we assess the likely receiving area and the carbon-density change associated with displaced activity.

We use visual inspection, land-use data, mangrove and forest-loss analysis and appropriate buffer or reference areas to look for changes consistent with displacement. We also consider alternative livelihoods, benefit-sharing and other measures intended to reduce displacement. The carbon consequence depends on both the scale of displaced activity and the ecosystem into which it moves. We assess whether the project has made a leakage deduction and whether it sufficiently addresses the displaced activities.

Market leakage

Market leakage assesses whether project activities alter commodity supply and demand in a way that causes additional production and emissions elsewhere. It is relevant where the counterfactual would have produced a market commodity and the project materially reduces that production. Where prior land-uses relate to subsistence, market leakage is usually considered negligible.

We identify the forgone commodity and estimate the scale of production relative to the relevant market. We assess regional or national production trends, demand, prices and the availability of alternative production areas. For commodities such as aquaculture products, salt, firewood, or agricultural crops, we consider whether replacement production is likely to occur and the land-use change and carbon density associated with that production.

Where the project applies a market leakage deduction, we assess the basis for that deduction and whether it remains appropriate for the project's scale, commodity and market context. Where reliable attribution to a specific project is not possible, we are explicit about the uncertainty and focus on whether a material market response is plausible and sufficiently accounted for.

Ecological leakage

Ecological leakage is assessed where project activities alter hydrological processes beyond the credited boundary. Mangrove restoration can involve breaching embankments, changing tidal connectivity, modifying channels or otherwise changing water levels. These interventions can affect greenhouse gas fluxes or carbon stocks in adjacent wetlands and coastal areas.

We identify the hydrological intervention and the area over which it may influence water levels or flows. We review project monitoring, satellite imagery and scientific literature to assess whether off-site effects have been considered and whether they could create unaccounted emissions or losses. This risk driver is not applied where the project activities do not materially alter hydrology outside the project area.

Permanence

The likelihood that the climate benefits of the project will persist for the time committed.

Our analysis of this risk factor considers the permanence of climate benefit as it relates specifically to the contractual commitment of a given project and its credits. We distinguish the contractual commitment embodied in a carbon credit from the durability of carbon avoided or removed over 100 to 1,000 years or longer; the latter concept as applied in the carbon market is beset by inconsistencies and contradictions. To avoid confusion between contractual reality and theoretical debate, our assessment focuses on how

long is actually committed to ensuring the carbon avoided or removed remains so, the mechanisms in place to guard against losses, and the strength and accuracy of the claims made.

Our assessment addresses four questions:

- How likely is it that the project's claimed carbon benefit will reverse before the end of its commitment period?
- What is the severity of any carbon stock losses, and how does this compare to the project's credit issuance?
- How likely is it that carbon losses are transient - that is, recovered through future project activity such as regrowth or replanting?
- Is the project properly mitigating this risk through a risk buffer and/or other mechanisms, so as to limit the risk to its issued credits?

Identifying the commitment period

All identified risks to permanence are then considered in relation to the identified commitment period. Because we assess reversal risk over the period actually committed, the first step in any permanence analysis is to identify that period. Commitment periods are labelled differently by different standards bodies - as commitment period, project longevity, or minimum project term, among others. In some cases, the commitment period coincides with the crediting period. In some cases, the commitment period is implicitly specified in the choice of 100 year global warming potentials for short-lived greenhouse gas species.

Assessing risk within the committed period allows for comparability between credits on the basis of what has actually been promised

For each permanence risk driver, we estimate the likelihood that a reversal occurs before the end of the commitment period, and the proportion of the project area, carbon stock, and/or carbon benefit expected to be affected. Together these give an expected reversal, which we then translate into an impact on the project's carbon stocks per hectare and compare against the project's issuance. We then consider the effect of the risk buffer and of any other mitigation, such as replanting or committed future deductions, to arrive at a residual, unmitigated risk to the carbon stocks over the commitment period.

Framing the assessment as an expectation rather than a binary outcome matters, because the same expected reversal can be constructed in different ways: a high likelihood of a small reversal and a low likelihood of a total reversal may imply comparable expected losses, and both are captured. Individual risk drivers are assessed on this common basis, which allows risks of very different character - fire, drought, pests, encroachment, loss of rights - to be compared and aggregated coherently.

Table 6 sets out the risk drivers within our assessment of permanence.

Table 6. Sub-components of permanence assessed

Risk factor	Risk driver category	Risk driver
Permanence	Natural risks	Fire
		Extreme weather
		Pests and diseases
		Sea level change
	Anthropogenic risks	Project management and carbon rights
		Encroachment risk
	Risk mitigation instruments	Risk buffer and mitigation
		Stakeholder engagement

Natural risks

Fire

Fire is generally unlikely to pose a major risk in mangroves, as they are reliably tidally inundated, but can still pose some risk in specific cases. At a project level, we use Earth observation datasets from NASA to quantify burned area (MODIS MCD64A1) and the number of active fire detections (VIIRS VNP14IMGML). Our assessment includes historic fire occurrences and changes over time, based on burned area time-series starting in 2001 and active fire detections starting in 2012. We combine this historic perspective on fire activity with a wider view of fires in the larger landscape (10-km and 50-km buffer zones around the project) to provide context on project-specific fire risk. Pivotal to our assessment of fire risk is that our datasets are considered within the context of the project, its ecosystem, and the causes of fire in the project's region. We consult academic literature, national datasets, and industry research to observe any wider regional or national trends that may affect a project.

We also consider project activities that aim to monitor and mitigate fire risk, such as employing fire marshalls, introducing fire breaks, reducing fuel loads, coppicing activities, as well as the effectiveness of such activities where appropriate. These are usually absent in mangrove projects, commensurate with the low risk from fire.

Extreme weather

Drought. We characterise drought history for the project area using the Standardised Precipitation Index (SPI) and the Standardised Precipitation Evapotranspiration Index (SPEI). Values are calibrated to the project's own location and to typical climatic conditions there, and are therefore not comparable across projects. We interpret the frequency, magnitude and trend of drought events, and consider whether decadal conditions are stable, deteriorating, or improving. A future drought analysis is then performed for the time period present-2100, based on CMIP6 climate models for four future scenarios: SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5. Analysis results include future projections of the SPEI drought index up to 2100, and derived future return period of drought extremes.

The consequence of drought for carbon stocks depends on the forest. We therefore establish which species within the project area are likely to be impacted by drought through changes in salinity, by first assessing the degree to which local salinity is likely to be sensitive to rainfall locally or in relevant river catchments, and second assessing species salinity tolerance, and their share of the composition. Overall, we form a view on whether projected conditions would push species beyond their tolerance to the point of materially increased mortality. We place these metrics in a wider context using academic and industry sources. Such context includes ecosystem type, topography, hydrological regime, regional land use, predominant species, and oceanic oscillations such as El Niño.

Cyclones. Where cyclone tracks are recorded within the project's vicinity, we detail the events identified and the damage level implied by their intensity. Where tracks intersect the project area within the rated vintage period, we cross-reference our forest loss observations to establish whether loss resulted and whether it has been sufficiently accounted for. Forward-looking risk is assessed by reference to the probability of damaging events occurring near the project under the most likely climate scenario over the commitment period.

We also observe how extreme weather risk may change under future climate conditions through an examination of regional and national climate predictions. Sources for this analysis include, but are not limited to, academic literature, regional and national datasets from recognised national bodies, and industry research. Finally, where extreme weather events have occurred previously within the project area or region, we use geospatial analysis to observe the impact on mangrove systems, to provide an estimate of future permanence risk should events reoccur.

Pests and diseases

The presence of pests and diseases can cause a loss of vegetation in Mangrove projects, lowering the overall carbon stock and resulting in a reversal event. To assess the risks from pests and diseases, we look at the presence of these within the project area, region or country, and resilience of the project species. We assess historical incidents in the project area, common pests or diseases on a regional or country scale. We use a range of national datasets, such as forest inventories and pest and disease maps, in combination with academic and industrial literature to assess these parameters.

Next, we identify project mitigatory activities and the resilience of the forest, whether the project area has historically been exposed to pests or disease, and whether the project has adequately accounted for pest and disease risk as part of its risk buffer assessment. Two considerations govern interpretation: that identified pests and diseases are genuinely relevant to the species present, and that their documented effects on tree health and mortality are understood, since presence in a region does not by itself imply material loss of carbon stocks.

Sea level change

Essentially all mangroves are exposed to impacts from sea level change. Rising sea levels can drive tree mortality through prolonged flooding beyond the depth tolerance of the mangroves, saltwater intrusion for the least tolerant species, and increased risk of catastrophic erosion or flooding from storm surges. To interrogate this risk, we predict the extent of sea level rise within the project area for the project's commitment period relative to a baseline from 1995 to 2014, using data from NASA and the IPCC 6th Assessment Report. Our analysis includes two scenarios, a 2 °C and 3 °C increase in global mean surface temperatures towards the end of the century, to predict sea level change and associated uncertainty based on an ensemble of global climate models relative to the project's commitment period. We then place these predictions within the local context (such as topography, hydrological regimes, planted species, land use, sediment transport, and tectonic and isostatic uplift in relevant areas) using academic literature. Mangrove forests are able to mitigate the effects of sea level change if sufficient sediment is available to facilitate vertical uplift at a faster rate than sea level rise. We also assess local land use and topography to evaluate whether sea-level rise can be mitigated by inland migration of mangroves, or whether this is suppressed by coastal squeeze. If available, the project's assessment of risks from sea level rise is also interrogated to evaluate whether the project has adequately accounted for and mitigated these risks through its buffer pool contributions.

Rising sea levels also increase the risk of salinisation due to saltwater intrusion, which can be exacerbated by reduced freshwater flow due to upstream management. Salinity that is above the tolerance of the mangrove species can inhibit reproduction, and induce stress leading to damage and mortality. We assess the potential risk from this source using data on salinity from the project documentation and literature values relevant to the project area. We also use literature values to assess the salinity tolerance of mangrove species within the project area, which may mitigate the risk. We note that many mangroves are tolerant to the salinity of ocean water, and for these species sea level rise may actually mitigate rather than exacerbate risk associated with hypersaline events.

Anthropogenic risks

Project management and carbon rights

Carbon rights are property rights that enable the ownership and trading of accredited carbon units. Our assessment determines ownership of these rights and potential permanence risks. Details are found in project documents or literature.

Failure to secure land/carbon ownership, or reliance on traditional land rights, can pose permanence risks, as the project may occur on land to which it does not have legal title. This can result in legal conflict over the project, potentially leading to its discontinuation or the reallocation of carbon rights/credits. Our analysis identifies the owners and users of the project land, including customary and overlapping claims, and verifies land titles, registry information, concessions, leases, easements and other evidence where it is available.

Where the developer does not own the land, we review the contractual transfer of land-use and carbon rights, the duration and renewal provisions, restrictions on withdrawal or transfer, remedies for breach and the relationship between the contract term and the commitment period. Free, prior and informed consent and equivalent consent principles are considered when communities or customary rights holders are affected. Claims are tested against national and subnational law and independent evidence on tenure security and land conflict. Clear land ownership by the project developer or local stakeholders reduces risks by decreasing the likelihood that projects will be discontinued due to legal conflicts.

Finally, we assess the technical capability of the proponent and landowner, including the number of forest carbon projects they have previously been involved in and whether there is a precedent for them to carry out the specific activities the project requires.

Encroachment risk

In Mangroves, encroachment and subsequent clearance of pre-existing or planted trees may occur when project activities are insufficient to deter agents of deforestation. We use a range of national and international datasets, including those that pertain to concessions for natural resource extraction to assess the anthropogenic threat to the project. For example, risk may be introduced if a high proportion of the project area overlaps with concessions. Risk is generally tempered if there is no evidence of concessions or other anthropogenic risks (such as conflict).

Infrastructure changes that result in changes to hydrology can also confer permanence risk. For example, upstream dam construction and water withdrawal can restrict freshwater flow, which increases permanence risk from salinisation and drought. Sediment flow may also be restricted, which can impede the long term resilience of mangrove forests, especially in the context of sea level rise. Mangrove forests may also face anthropogenic risk due to pollution. We use a variety of sources including literature, model, and geospatial evidence to determine how the combined changes in hydrology, sediment loads, salinity, and precipitation alter environmental conditions, compared with tolerance thresholds for mangroves species. Similarly, we use academic literature, and industry reports to determine how nutrient loads or pollutants will likely impact the project area and the species established there.

Risk mitigation instruments

Risk buffer and mitigation

Our objective is to determine whether the project's buffer pool contributions, or other mitigatory measures, are sufficient to counter the residual permanence risk our analysis identifies. If contributions do not adequately reflect the risks the project faces, reversals are less likely to be appropriately accounted for.

We extract the project's own permanence risk assessment and the breakdown of its buffer contribution, and compare the materiality of the risks the project has identified against those identified through our own analysis. A buffer contribution consistent with our assessment of residual risk indicates adequate

mitigation; a contribution that falls short of it, and in particular the absence of any contribution, indicates that reversal risk is unaccounted for.

In conjunction with buffer pool contributions, projects may reduce risk through mitigatory activities. These are implemented by the project developer to reduce the likelihood of permanence risks causing reversals or withdrawals from the buffer pool. Within the Mangrove sub-sector, mitigatory activities may include setting up patrols, demarcating project boundaries, positive engagement with local communities, beneficial hydrological interventions, and clear, well-resourced plans for re-planting in the event of significant mortality.

Stakeholder engagement

Stakeholder engagement is assessed for projects where communities, landholders, or other affected parties can materially influence the continuation of project activities or the maintenance of carbon stocks. The analysis considers both the risk of withdrawal or non-compliance and the project's ability to deliver promised benefits.

We identify relevant stakeholders from project documentation and independent sources and assess whether free, prior and informed consent or equivalent informed agreement was obtained. We review the accessibility and independence of grievance and dispute-resolution mechanisms, the identification of affected groups, communication in appropriate languages and formats, reported disputes and the project's plans for resolution. Landholder contracts are reviewed for withdrawal provisions, penalties and whether the project could recoup the carbon impact of exit.

For benefit delivery, we compare promised mechanisms with project records, stakeholder reporting, relevant media and the performance of comparable projects. We consider administrative, legal and market barriers that may delay or prevent payments or non-financial benefits, and the measures used to bridge those failures. The conclusion reflects whether engagement and benefit delivery are likely to sustain participation for the commitment period.

We then determine how withdrawal or dissatisfaction could affect land management and carbon stocks. The absence of effective engagement may cause risks to materialise, including local communities encroaching on project areas, damaging carbon stocks, or, ultimately, withdrawing from carbon projects. Replacement enrollment is not automatically treated as mitigation because replacement landholders may face the same reasons for withdrawal, and prior investment or credited carbon may already have been lost.

To evaluate this risk, we apply a bottom-up approach that evaluates the presence and success of stakeholder consultations, grievance channels, benefit-sharing structures, and alternative livelihood activities through project-specific case studies, academic literature and project documents. Risks can be countered through strong evidence of community support and integration with project activities.

Appendix I: Literature sources

Our curated database of literature sources spans all types of peer-reviewed literature and industry research, with hundreds of entries for every sector, region or risk factor.

The number of relevant literature-based sources specific to the Mangrove sub-sector runs to over 500 as of January 2025.

Sample of academic literature sources

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Appendix II: Geospatial data sources as of October 2026

Our Geospatial and Earth Observation team uses data from, but not limited to, the following:

Aboveground carbon in mangroves (Caltech / Simard et al. 2018), Aboveground carbon northern Africa (NASA / Tucker et al. 2023), Administrative districts (OpenStreetMap), Amazon indigenous territories (RAISG), American Indian, Alaska Native, and Native Hawaiian Areas (U.S. Census Bureau), BeZero Carbon Boundaries Database (curated in-house from registry data and other public sources), BeZero Carbon Plots Database (curated in-house from private collections, national inventories, international plot networks, academic studies, research partnerships, and other sources), Brazil indigenous lands (Terrabrasilis), Brazil mining concessions (Brazil National Departament of Mineral Production), Brazil protected areas (National Registry of Conservation Units - CNUC), Brazilian Cadastro Ambiental Rural (Brazilian government), Brazilian Sistema de Gestão Fundiária (Brazilian government), California timber harvesting plans (California Department of Forestry & Fire Protection), Cambodia mining concessions (Open Development Cambodia), Cameroon community forest (Ministère des Forêts et de la Faune), Cameroon Forest Management Units (Global Forest Watch), Cameroon mining permits (Cameroon Ministry of Mines and Technological Development), Cameroon production forests (Ministère des Forêts et de la Faune), Canada mining permits (various open sources), Chloris Above-ground biomass stock (Chloris Geospatial), Colombia agricultural frontier (El Sistema de Información para la Planificación Rural Agropecuaria (SIPRA)), Colombia mining titles (Tierra Minada), Colombia national parks (Parques Nacionales Naturales de Colombia), Congo peat maps (University of Leeds), Consejo Comunitario Titulado (Datos Abiertos Agencia Nacional de Tierras Colombia), CORINE landcover (Copernicus), Cost maps for ARR (Busch et al. 2024), Crop Sequence Boundaries (USDA), Cropland extent and change (GLAD/UMD), Decadal Land Use and Land Cover Classifications across India (Roy et al. 2016), Democratic Republic of the Congo mining permits (DRC Cadastre Minier), Dynamic World (Brown et al (2022)), EBA Brazil aboveground carbon (INPE), Ecoregion map (Resolve), Ejido territories (Registro Agrario Nacional - Catastro Rural), ERA5 Land climate variables (ECMWF), ESA Biomass Climate Change Initiative (Santoro, M.; Cartus, O. (2026)), ESRI Sentinel-2 10m land use land change time-series (ESRI), EU Farm Structure Survey (European Commission), European Union Tropical Moist Forests (IFORCE), Florida conservation lands (FLMA) (Florida Natural Areas Inventory), Forest Extent and Height Change, 2000-2020 (GLAD/UMD), Forest/Non-Forest (JAXA), Forest Type Groups of the United States (USDA Forest Service - Forest Inventory and Analysis (FIA) Program & Geospatial Technology and Applications Center (GTAC)), Forest ownership in the conterminous United States circa 2022 (Harris et al. (2025)), Forest Planning Open Data (Hokkaido Forest Planning Division, Forestry Bureau), Forisk North American Mill Capacity Database (Forisk), Gabon mining permits (Gabon Ministry of Mines, Petroleum, and Hydrocarbons & WRI), GEDI L2B canopy cover (NASA/UMD), GEDI L4A Footprint aboveground carbon

(NASA/UMD), GEDI L4B Gridded aboveground carbon (NASA/UMD), GEDI Level-2A vegetation height (NASA/UMD), Global Canopy Height (ETH Zürich), Global Distribution of Mangroves (UNEP-WCMC), Global Forest Change (GLAD/UMD), Global Human Settlement Layer (GHS-SMOD) (Schiavina M., Melchiorri M., Pesaresi M. (2023)), Global Mangrove Watch (JAXA), Global mining extent polygons (Maus et al. 2022), Global mining extent polygons (Tang & Werner 2023), Global naturally regenerating forests (UN FAO), Global peatlands (CIFOR, Wetlands International, Indonesian Ministry of Agriculture, Indonesian Ministry of Transmigration and Land Resources), Global planted forest (UN FAO), GlobBiomass above and below ground carbon (ESA), HURDAT2 hurricanes (NOAA), IBTrACS hurricanes (NOAA), Integrated Deforestation Alerts (Global Nature Watch), IPCC AR6 Sea level rise (NASA/IPCC), IUCN Red List of Threatened Species (IBAT), Key Biodiversity Areas (IBAT), Köppen-Geiger climate classification (Beck et al. (2023)), Landsat 5, 7, 8 and 9 L2 Surface Reflectance (NASA/USGS), Land cover (JAXA), Malaysia logging concessions (Global Forest Watch), MapBiomas Brazil land cover (MapBiomas Brazil), MapBiomas Colombia land cover (MapBiomas Colombia), MapBiomas Paraguay land cover (MapBiomas Paraguay), MapBiomas Peru land cover (MapBiomas Peru), Mapbox visual basemap (Mapbox), Maxar Imagery Surface Reflectance (Maxar Technologies), MCD12Q1 Land Cover Type (NASA), MCD64A1 Burned area (NASA/UMD), Mexico mining concessions (Secretaria de Economia), Mineral Resources Data System (USGS), Minnesota DNR Management Units (Minnesota Department of Natural Resources), MOD44B Vegetation Continuous Fields (NASA), MYD10A2 Snow cover (NASA), MYD13Q1 Vegetation Indices (NASA), National Cropland Data Layer (USDA), National Flood Hazard Layer (FEMA), Navigable water (OpenStreetMap), New York Protected Area Database (NYPAD) (New York Natural Heritage Program), New York state (DEC) lands (New York State Department of Environmental Conservation), NEX-GDDP-CMIP6 (NASA/NCCS), Northern Forest land ownership map (Northern Forest Center), Oil and gas concessions (various government sources), Peru cadastral and concessions (Digital Government Secretariat Peru), Peru mining concessions (Ingemmet), Peru native community boundaries (Peru Ministry of Culture), Planet Forest Carbon Diligence (Planet Labs), Planet Quarterly visual basemaps (Planet Labs), PlanetScope Imagery Surface Reflectance (Planet Labs), Population density (WorldPop), Primary designated management objectives of forest (UN FAO), Primary humid tropical forests (GLAD/UMD), PRODES Amazon deforestation (INPE), Regrid US land parcel data (Regrid), Republic of the Congo mining permits (Republic of the Congo Ministry of Mines and Geology), Roads (OpenStreetMap), Root-shoot ratios (Huang et al. 2021), SDPT plantations, planting year and planted species (WRI / Du et al. 2022), Sentinel-2 L2A Surface Reflectance (ESA Copernicus), SkySat Imagery Surface Reflectance (Planet Labs), Soil cation exchange capacity (ISRIC), Soil nitrogen (ISRIC), Soil organic carbon (ISRIC), Soil type classification (ISRIC), Soil water pH (ISRIC), Species Rarity-weighted Richness (IBAT), SRTM Digital Elevation Model (NASA), STAR Species Threat Abatement and Restoration Metric (IBAT), STORM Cyclone historical baseline (Bloemendaal et al. (2020)), STORM Cyclone future projections (Bloemendaal et al. (2022)), US Forest Type Groups of the United States (U.S. Department of Agriculture - Forest Inventory and Analysis (FIA) Program & Remote Sensing Applications Center (RSAC)), US National Conservation Easement Database (U.S. Endowment for Forestry and Communities), US Native lands (U.S Department of the Interior Bureau of Land Management), US Protected Areas Database (United States Geological Service (USGS)), US stand age (2005) (United States Geological Service (USGS)), US state boundaries (United States Census Bureau), USA Census of Agriculture (USDA), VARDA Global FieldID (VARDA), VNP14IMGML Active fire detections (NASA/UMD), World Database on Protected Areas (IBAT), Worldclim climatology (SEI), Global Population Data (unconstrained 100m) (WorldPop).

Appendix III: Additional reading

Check out the ratings resources page on our website to find links to all of our published methodologies, in addition to our series of risk factor assessment frameworks, our frameworks for assessing project methodologies and country-level risks, deep dives on factors influencing the carbon efficacy of projects in various sectors, and more.

Updates and reviews

Version number	Date	Description
1.00	21/12/23	Initial release
1.01	31/01/24	Formatting updates
1.02	03/10/24	Clarification on additionality as a limiting factor
2.0	17/02/25	Updated risk factor framework
2.01	27/10/26	Formatting updates and edits

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