Overview of forest carbon inclusion in certification schemes and need for improvement

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This report heavily relies on the peer-reviewed paper by Barbara Haya *et al*. (March 2023) on the same topic: https://www.frontiersin.org/articles/10.3389/ffgc.2023.958879/full. Where relevant, the scope was extended in particular by including methodologies from other standards than those proposed in the study. In addition, this analysis also covers the sustainability criteria not investigated in the publication by Haya *et al* (2023).

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1. Executive Summary

Improved forest management (IFM) can help mitigate climate change by increasing carbon sequestration in forests and wood products while ensuring the highest possible sustainable level of forest carbon stocks, taking into account natural disturbances. In Europe, these practices could be encouraged, especially to counterbalance the decline in forest sinks in some countries. There is an opportunity to incentivize these projects under the European Carbon Removal Certification Framework (CRCF) regulation. Forest features and improved forest management strategies need to be properly integrated within this new scheme.

This work identified 16 IFM methodologies that are relevant in our context. The work builds on the analysis carried out by Haya *et al* (2023) of 8 methods from standards based in North America, which we have supplemented with 8 other methods, 2 of which are validated by European standards. For each of these methods, we looked at which carbon pools were considered, we assessed various criteria such as non-permanence tools, additionality and the baseline scenario. Sustainability criteria were also assessed as well as the methods used to quantify the carbon stocks of harvested wood products.

The study identifies four main challenges related to IFM project certification:

1. **Diversification of management practices under carbon certification**

   Improving forest management can mean many different things, but most international methodologies focus on reduced harvesting. We need to develop additional methodologies that encompass a wider range of practices, backed by science, to demonstrate carbon impact and risk reduction.

2. **Baselines: the main risk of carbon certification projects**

   The primary risk linked to carbon certification standards lies in the establishment of the baseline, which can lead to over-crediting. We recommend:

   - Limiting the choices available to project developers for defining their baseline, in order to reduce information asymmetry and bias.
   - Exploring the use of dynamic baselines.
   - Choosing baselines that are close to initial carbon stocks.
   - Measuring and verifying carbon stock increments.

3. **Carbon certification tools need to better integrate the future impact of climate change to ensure carbon permanence**

   The future impact of climate change on forests is likely underestimated in current non-permanence management tools. Larger buffer pool deductions, along with regular updates to protocols based on the latest science, would help address this issue. Methodologies that reduce the risk of catastrophic wildfires and increase long-term resilience should also be considered.

4. **Increase visibility and robustness of sustainability criteria**

In practice, there is significant heterogeneity between IFM methodologies in how they integrate sustainability impacts. Each methodology sets its own rules, leading to a lack of clarity for project financiers. Guidelines for integrating and measuring sustainability issues should be developed to ensure greater consistency between methodologies and greater transparency for projects.

2. Introduction

Result-based payments have existed for a long time through carbon certification frameworks
Carbon certification is nothing new. There is a lot of expertise internationally, especially with private standards which have been operating for about 20 years. There is also expertise in Europe with the development of domestic standards, both in the wake of the Kyoto Protocol through Joint Implementation (CDC Climat Research, 2012) and more recently for the voluntary offset market (I4CE, 2019; Baren *et al*., 2023).
Historically, international private standards have not been very active in Europe. Accordingly, in the gap between the demise of Joint Implementation, in 2012, and the new rise of domestic standards at the end of the decade, very few carbon projects were certified on European soil despite an important domestic demand. The double-claiming issue largely explains this absence. Double claiming in Carbon certification refers to the situation where the same carbon offset is claimed multiple times by different parties. As carbon projects are – in principle – visible in the host country's national inventory, they help achieve the national emissions reduction targets. Although this type of double claiming between a company and its host country is natural and does not undermine environmental integrity (I4CE, 2015), voluntary standards previously required host countries to exclude certified emission reductions bought by private companies from their inventory. This non-sensical stance and the resulting administrative nightmares explain why very few voluntary carbon projects have been certified by international standards in Europe. It also explains why several countries started designing their own – often public – carbon certification frameworks, so that local projects could benefit from a credible MRV framework and generate domestic carbon credits.

Many carbon certification projects in temperate forests have been developed in the USA and Australia, and methodologies have therefore been developed primarily in these countries. However, recent scientific reviews have revealed methodological issues, questioning the credibility of these credits in both the USA (Badgley, 2022; Stapp *et al*. 2023) and in Australia (Macintosh *et al*., 2024). Solutions to address some of these issues have been proposed. But the question remains how applicable these methodologies are on the more fragmented and smaller spatial scale of European forestry.

Methodologies at the heart of certification systems
Certification mechanisms typically provide a set of rules, procedures, and requirements for a range of eligible activities to verify that they have reduced emissions or removed GHGs through sink enhancements and are eligible for certification/payment. Two types of rules can be distinguished within certification mechanisms:

- *Mechanism architecture* – Every certification mechanism also has an overarching architecture that applies principles and approval frameworks to evaluate and certify methodologies and their associated removals to ensure that that they are of acceptable quality (i.e., real, additional, permanent, etc.) (McDonald *et al*., 2021). This includes general guidelines on how to quantify emissions and removals and typically applies to all project types.
- *Methodological* – The mechanisms also provide methodologies for quantifying and certifying on-the-ground carbon mitigation/removals. They are technical, including calculation methods, default data (e.g., emissions factors), and instructions to quantify removals, as well as rules and tests to demonstrate the quality of removals (e.g., related to additionality, etc.). Methodologies are usually specific to a given project

type (e.g. afforestation, increased rotation length, reduced-impact logging, …). A single certification mechanism can have single or multiple methodologies (McDonald *et al.*, 2021).

Note that there can be an intermediary level, namely "tools", that apply to a specific issue in several project types (e.g. the "AFOLU Non-Permanence Risk Tool" in the Verra standard explains how to quantify the risk that stored carbon is subsequently re-emitted for all agriculture and forestry projects).

In this analysis, we evaluate existing improved forest management (IFM) methodologies worldwide. The IFM methodology quantifies the carbon sequestration benefits of forests, providing a carbon finance incentive for landowners to achieve a higher standard of sustainable forest management. Today, there are at least fifty forest certification methodologies in the world, including fifteen IFM methodologies. IFM projects have generated 193 million carbon credits since the first credits were issued in 2008. This represents 28% of all forest carbon credits (the majority being REDD+ credits) and 11% of all offset credits generated. Most of these credits have been issued in the United States under Air Resources Board (ARB) certification (80% of credits) (Haya *et al*., 2023).

3. Overview of existing forestry and IFM methodologies

3.1. Overview of all forestry methodologies

To begin this analysis, we have listed all the existing forestry methodologies available as of March 2023. We looked at 15 standards (table 1), defined here as certification mechanisms. Eleven of them have forestry methodologies.

Table 1: list of looked at standards

Certification standards <u>with</u> forestry methodologies	Certification standards <u>without</u> forestry methodologies
American Carbon Registry (North America)	Moor Futures (Germany)
Climate Action Reserve (North America)	Climate Austria (Austria)
Air Resources Board (North America)	Greendeal (Netherlands)
Emission Reductions Fund (Australia)	Puro.Earth (Nothern Europe)
Gold Standard (International)	
Registro Huella de Carbono (Spain)	
Label Bas Carbone (France)	
Clean Development Mechanism (International)	
Verra / VCS (International)	
Woodland Carbon Code (United Kingdom)	
Life Climarkt (forestry methodology in development)	

For forestry methodology or related methodology (mangroves, agroforestry and peatlands), we distinguished five status and listed the number of associated projects (table 2):

- Validated: these methodologies have been approved and can be used for carbon projects.
- In progress: as of March 2023, these methodologies were currently under review and could not be used for the time being.
- Pending: these methodologies have been put on hold. We do not know if or when they will be validated.
- Inactive: these methodologies have been removed; they still appear on the standards websites but can no longer be used.
- Not found: these methodologies were listed in the literature a few years ago but are no longer listed on the standards sites.

It should be noted that some methodologies are often referred to as protocols, when they group together several practices, such as the Climate Action Reserve (CAR) Forest protocol, for example.

Out of 50 forest-related methodologies, 42 are focused on one or several of the three forest carbon strategy types: Afforestation/Reforestation (AR), Improved Forest Management (IFM) and Reduction of Emissions due to Deforestation and Degradation (REDD) , with a similar number of methodologies for each type (Figure 1). The seven remaining methodologies cover mostly peatlands, and to a lesser extent mangroves and urban trees, and are associated with 18 projects.

Table 2: list of forestry methodologies and related methodologies

Standard	Project type	Name	Code	Status	Geographical area	Projects areas	Number of projects
ACR	AR	Afforestation and Reforestation of Degraded Lands - v1.2	N/A	validated	everywhere		9
ACR	IFM	Improved Forest Management (IFM) on Non-Federal U.S. Forestlands - v2.0	N/A	validated	US		71
ACR	IFM	Improved Forest Management (IFM) on Canadian Forestlands - v1.0	N/A	validated	Canada		0
ACR	IFM	Improved Forest Management (IFM) on Small Non-Industrial Private Forestlands - v1.0	N/A	validated	US		0
ACR	Peatland	Restoration of California Deltaic and Coastal Wetlands - v1.1	N/A	validated			3
ACR	Peatland	Restoration of Pocosin Wetlands - v1.0	N/A	validated			1
ACR	REDD	Avoiding Conversion of U.S. Forests - v1.0	N/A	in progress			0
ACR	IFM	Improved Forest Management (IFM) on U.S. Timberlands	N/A	not found			1
ACR	REDD	REDD - Avoiding Planned Deforestation - v1.0	N/A	not found			0
ACR	REDD	REDD Methodology Modules - v1.0	N/A	not found			0
ACR	Peatland	Restoration of Degraded Wetlands of the Mississippi Delta - v2.0	N/A	inactive			2

ACR	AR	Southwestern Forest Restoration: Decreased Wildfire Severity and Forest Conversion -	N/A	inactive			0
ARB	AR-IFM-REDD	Compliance Offset Protocol - U.S. Forest Projects	N/A	Validated	US		663
CAR	AR-IFM-REDD	U.S. Forest 5.0	N/A	validated	US		IFM (voluntary): 23 IFM (compliance): 126 R (voluntary): 4 R (compliance): 9
CAR	Urban / IFM	Urban Forest Management 1.1	N/A	validated	US		0
CAR	Urban /AR	Urban Tree Planting 2.0	N/A	validated			
CAR	AR-IFM-Agroforestry	Mexico Forest 3.0	N/A	validated	Mexico		188
CAR - ARB	IFM	Conservation-based forest management / California Forest Protocols	N/A	validated	California		5
CAR		Panama Forest 1.0	N/A	in progress			
ERF	REDD	Avoided clearing of native regrowth	F2015L00164	validated	Australia		13
ERF	REDD	Avoided Deforestation 1.1	F2015L00347	validated	Australia		64
ERF	IFM	Human-induced regeneration of a permanent even-aged native forest 1.1	F2018C00125	validated	Australia		426
ERF	AR	Measurement-based methods for new farm forestry plantations	F2014L01130	validated	Australia		3
ERF	AR	Native forests from managed regrowth	F2015C00578	validated	Australia		38
ERF	AR	Plantation Forestry	F2017L01038	validated	Australia		56
ERF	AR	Reforestation and Afforestation 2.0	F2015L00682	validated	Australia		19
ERF	AR	Reforestation by Environmental or Mallee Plantings - FullCAM	F2015C00581	validated	Australia		132
ERF	IFM-REDD	Savanna fire management 2018	F2018L00562	validated	Australia		97
Gold Standard	AR	Methodology for afforestation/reforestation (A/R) GHG Emission reduction & sequestration - v2.0	401.13 AR	validated			13

Gold Standard	Forest protocol	Land-use & Forests Activity Requirements - v1	N/A	not found			0
Registro Huella de Carbono	AR	Afforestation actions with associated land-use change	type A	validated	Spain		424
Registro Huella de Carbono	IFM	Actions, in forest areas affected by forest fires, to restore an already existing forest stand.	type B	validated	Spain		
Label Bas-Carbone	AR	Boisement	N/A	validated			218
Label Bas-Carbone	AR	Reboisement	N/A	validated			151
Label Bas-Carbone	IFM	Balivage	N/A	validated	France		3
CDM	AR	Afforestation and reforestation of lands except wetlands - v1.0.0 (large scale)	AR-ACM0003	validated			6
CDM	AR	Afforestation and reforestation of degraded mangrove habitats (large scale). V 3.0	AR-AM0014	validated			1
CDM	AR	Afforestation and reforestation project activities implemented on wetlands --- Version 3.0	AR-AMS0003	not found			3
CDM	AR	Afforestation and reforestation project activities implemented on lands other than wetlands --- Version 3.1	AR-AM0007	inactive			0
CDM	AR	Simplified baseline and monitoring methodology for small-scale A/R project activities on grasslands or croplands	AR-AMS0007	inactive			10
CDM		Grid-connected electricity generation using biomass from newly developed dedicated plantations	AM0042	inactive			NA
Verra	IFM	Methodology for Improved Forest Management through Extension of Rotation Age - v1.2	VM0003	validated	everywhere	USA	3
Verra	REDD	Methodology for Conservation Projects that Avoid Planned Land Use Conversion in Peat Swamp Forests - v2.0	VM0004	validated			1
Verra	IFM-REDD	Methodology for Conversion of Low-productive Forest to High-productive Forest - v1.2	VM0005	validated	tropical rainforest	NA	2
Verra	REDD	Methodology for Carbon Accounting for Mosaic and Landscape-scale REDD Projects - v2.2	VM0006	validated			19
Verra	REDD	REDD+ Methodology Framework (REDD-MF) - v1.6	VM0007	validated			74

Verra	REDD	Methodology for Avoided Ecosystem Conversion - v3.0	VM0009	validated			19
Verra	IFM	Methodology for Improved Forest Management: Conversion from Logged to Protected Forest - v1.3	VM0010	validated	everywhere	China (12) /Australia …	20
Verra	REDD	Methodology for Calculating GHG Benefits from Preventing Planned Degradation - v1.0	VM0011	validated			2
Verra	IFM	Improved Forest Management in Temperate and Boreal Forests (LtPF) - v1.2	VM0012	validated	temperate and boreal Forest	USA-Canada-Romania	5
Verra	REDD	Methodology for Avoided Unplanned Deforestation - v1.1	VM0015	validated			86
Verra	Mangrove	Methodology for coastal Wetland Creation - V1.0	VM0024	validated			0
Verra	Peatland	Methodology for Rewetting drained Tropical Peatlands - V1.0	VM0027	validated			NA
Verra	REDD	Methodology for Avoided Forest Degradation through Fire Management - v1.0	VM0029	validated			0
Verra	Mangrove	Methodology for Tidal Wetland and Seagrass Restoration, v1.0	VM0033	validated			6
Verra	REDD	British Columbia Forest Carbon Offset Methodology - v2.0	VM0034	validated			6
Verra	Peatland	Methodology for Rewetting drained Temperate Peatlands - V1.0	VM0036	validated			6
Verra	REDD	Methodology for Implementation of REDD+ Activities in Landscapes Affected by Mosaic Deforestation and Degradation - v1.0	VM0037	validated			6
Verra	IFM	Improved Forest Management Methodology Using Dynamic Matched Baselines from National Forest inventories - V1.0	VM0045	validated	everywhere		0
Verra	IFM	Methodology for Improved Forest Management through Reduced Impact Logging - v1.0	VM0035	not found	everywhere		NA
Verra	AR	Afforestation/Reforestation of Agricultural Lands		pending			NA
Verra	IFM	Improved Forest Management in Boreal Improved Forest Management on Lands Subject to Unextinguished Indigenous Rights and Title (LtPF) production Forests		pending			NA
Verra	IFM	Methodology for Improved Forest Management in Non-industrial Private Forests		pending			NA
Verra	REDD	Consolidated REDD Methodology		in progress			NA

Verra	IFM	Methodology for Improved Forest Management through Targeted, Short-Term Harvest Deferral		in progress				NA
Verra	AR	New Methodology for Afforestation, Reforestation and Revegetation (ARR) project activities		in progress				NA
Verra	AR	Estimation of carbon stocks in the litter pool (CP-L), v1.0	VMD0003	inactive				NA
Verra	IFM	Performance Method for Reduced Impact Logging in East and North Kalimantan v1.0	VMD0047	inactive				NA
Woodland Carbon code	AR	Woodland creation	N/A	validated				424

	validated methodology
	methodology in progress
	pending methodology
	not found methodology
	inactive methodology

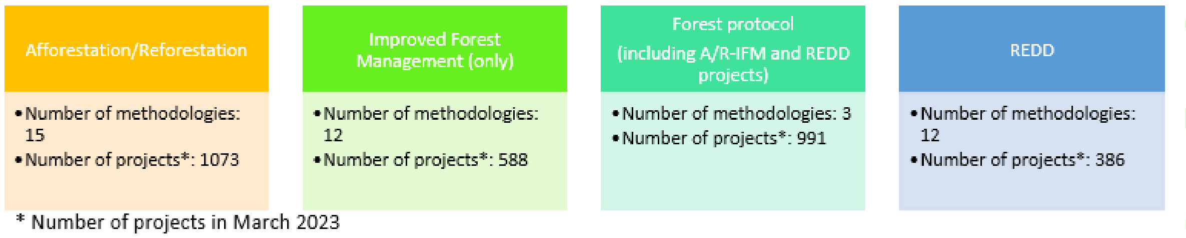

Figure 1: number of methodologies and projects for each type of forestry methodologies. Note that the number of projects is not necessarily a good proxy for activity: REDD has the fewest projects and the largest number of issued credits, meaning that each REDD project abates much more than other project types. In 2023, 28.3 MtCO2 of REDD+ credits were exchanged globally for 2.4 MtCO2 of IFM credits (Ecosystem Marketplace, 2024).

3.2. Focus on IFM methodologies: practices involved

The improved forest management (IFM) methodologies include more than twenty different practices that project leaders can implement (Table 3). Only two methodologies focus on a single practice (LBC's coppice-to-high stand conversion and Verra's extension of rotation age). Some methodologies propose up to five different practices, such as the CAR Mexico protocol, the ERF methodology or the ARB Forest protocol.

Table 3: IFM practices and number of methodologies using them

CATEGORY	IFM PRACTICES	METHODOLOGY REFERENCE NUMBER (defined in Table 4)

Conservation (harvesting stopped or reduced)	Conservation / Stopping logging	3-6-12-13
	Protecting logged or degraded forests from further logging or protecting unlogged forests from future logging	11-13
	Increasing harvest age / rotation age	1-2-3-4-5-7-10-15
	Increasing planting density / increased forest density	1-2-3-4-5-7
Improving forest management	Managing competing brush and short-lived forest species / non-native vegetation	4-5-7-8-15
	Maintaining stocks at a high level (high density)	4- 5
	Excluding livestock / Controlling feral animals	8
	Managing the timing and extent of grazing	8
	Stopping the destruction of native regrowth	8
	Conversion of coppice to high forest	9
	Liberation thinning, and/or enrichment planting	11-15
	Encouraging natural regeneration	15
Increasing the resilience of forest	Increasing forest productivity by thinning diseased and suppressed trees, and selecting the best genotypes	4-5-6-7
	Reducing litter and surface fuels in fire-prone ecosystems	7
	Planting additional trees in urban areas	6
	Treating and monitoring diseased trees	6
	Re-planting after a forest fire	16
Improving harvesting practices	Improved harvest planning	14
	Improving logging / skid trail planning and/or monocable winching	14
	Reduction in width of haul roads and size of log landings.	14

Colours code: ACR methodologies – ARB- CAR-ERF-LBC-Verra-RHC

We can also see that most methodologies propose the same practices (table 3):

- 8 methodologies offer to extend the rotation age,
- 6 methodologies offer to increase density and/or forest stocking,
- 5 methodologies offer to stop logging.

The practices most frequently proposed in the IFM methodologies are therefore reducing harvesting compared with the baseline as emphasized by Haya *et al*., 2023. Although some projects support the types of technical improvements commonly understood under the term IFM - for example, species change, fertilization, improving forest health for greater productivity and resilience, and reducing the impacts of logging - so far the majority of credits have come from less rather than more management, in the form of increased rotation length, conservation and avoided degradation (Haya *et al*., 2023). The study by Nabuurs *et al* (2017) proposes encouraging Climate Smart Forestry to maximise the role of European forests in meeting climate objectives. Promoted measures include the establishment of forest reserves, afforestation on abandoned land and conversion of coppice to high forest, all of which are incentivised by the methods studied.

Optimising the use of wood to promote the effects of material and energy substitution is also among the Climate Smart Forestry measures of Nabuurs *et al*. (2017) and is found in a fragmented way in the methodologies studied. Indeed, these effects are mainly promoted through incentives or certification in wood transformation sectors (e.g. building sector).But there are also IFM measures that are not or are rarely, found in the forestry methods studied: species diversification, enhanced thinning of stands, reducing the impact of natural disturbances, peat soil management, planting of more site-adapted species also in future climate change scenarios, and regeneration using faster-growing species. The international scope of the study, with most of the practices originating in North America, largely explains why these fine management measures, which are more suited to the European forests, are not found there.

4. Analysis

4.1. Scope and criteria for the analysis

4.1.1. Scope: which methodologies are analysed

Haya *et al*. (2023) based their analysis on the four voluntary offset market standards that have generated the vast majority of IFM offset credits globally to date—Air Resources Board (ARB), American Carbon Registry (ACR), Climate Action Reserve (CAR), and Verified Carbon Standard (VCS). They reviewed all IFM protocols with projects (and credits) issued on voluntary market registries as of March 2022 (in yellow in Table 4). We have extended the analysis to all IFM methodologies validated in March 2023, whether they have projects or not (Table 3). This adds eight methodologies to Haya's eight, including two European methodologies from Label Bas-Carbone (LBC) and Registro Huella de Carbono (RHC) and one Australian methodology from Emission Reduction Fund (ERF).

Table 4: IFM protocols reviewed for the analysis

Standard	Methodology	Name	Code/meth. Ref nb*	status	nb of projects
ACR	IFM	Improved Forest Management (IFM) on Non-Federal U.S. Forestlands - v2.0	N/A 1	validated	71
ACR	IFM	Improved Forest Management (IFM) on Canadian Forestlands - v1.0	N/A 2	validated	0
ACR	IFM	Improved Forest Management (IFM) on Small Non-Industrial Private Forestlands - v1.0	N/A 3	validated	0

ARB	AR-IFM-REDD	Compliance Offset Protocol - U.S. Forest Projects	N/A 4	Validated	663
CAR	AR-IFM-REDD	U.S. Forest 5.0	N/A 5	validated	IFM: 23 IFM: 126 R: 4 R: 9
CAR	Urban / IFM	Urban Forest Management 1.1	N/A 6	validated	0
CAR	AR-IFM-Agroforestry	Mexico Forest 3.0	N/A 7	validated	188
ERF	IFM	Human-induced regeneration of a permanent even-aged native forest 1.1	F2018C00125 8	validated	426
Label Bas-Carbone	IFM	Balivage (Coppice-to-high-forest conversion)	N/A 9	validated	3
Verra	IFM	Methodology for Improved Forest Management through Extension of Rotation Age - v1.2	VM0003 10	validated	3
Verra	IFM-REDD	Methodology for Conversion of Low-productive Forest to High-productive Forest - v1.2	VM0005 11	validated	2
Verra	IFM	Methodology for Improved Forest Management: Conversion from Logged to Protected Forest - v1.3	VM0010 12	validated	20
Verra	IFM	Improved Forest Management in Temperate and Boreal Forests (LtPF) - v1.2	VM0012 13	validated	5
Verra	IFM	Methodology for Improved Forest Management through Reduced Impact Logging - v1.0	VM0035 14	validated	NA
Verra	IFM	Improved Forest Management Methodology Using Dynamic Matched Baselines from National Forest inventories - V1.0	VM0045 15	validated	0
Huella de Carbono	IFM	Replantation on a stand affected by a forest fire	Tipo B 16	validated	NA

	Methodologies in Haya *et al*. 2023
	Methodologies added for this analysis

* The methodology reference number is used in the following text to quickly identify the methodology in question

4.1.2. Criteria for the analysis

Carbon certification is a tool used almost exclusively today for carbon offsetting (mainly voluntary). Voluntary commitments to reduce emissions are partly triggered by the limited progress of mandatory carbon pricing. In 2022, only 20% of global emissions are covered by emissions trading or carbon taxes (I4CE, 2022). Because these commitments are voluntary, their cost is mostly justified by satisfying the explicit or assumed environmental demands of consumers and shareholders. Offsetting part or all of a firm's carbon footprint is often perceived as a straightforward way to communicate the environmental actions of the firm to its consumers and shareholders.

Offsetting means financing emissions reduction or carbon storage outside the direct activities of the firm. The concept seems simple, but it is difficult to guarantee in practice. A carbon credit must represent at least one metric tonne of additional CO_2 emission reductions or removals that are unique, permanent, quantifiable, and verifiable.[1] In addition, most standards require that offset credits come from activities that do not contribute significantly to other social or environmental damage[2].
Today, the main carbon market guidelines (CCP of the ICVCM[3], VCMI[4], ICROA[5], Carbon offset guide) each propose their fundamental criteria. The most common criteria are:

- *Additionality* in the context of carbon credits refers to the principle that a project's emissions reductions or carbon sequestration should be additional to what would have occurred without the project.
- *Quantifiability* refers to the ability to accurately measure and quantify the amount of greenhouse gas emissions reduced, avoided, or sequestered by a particular project. Quantifiability involves establishing robust measurement methodologies, collecting relevant data, applying appropriate calculation techniques and estimating associated uncertainties.
- *Transparency* refers to openness and accessibility of information related to the generation, certification, and trading of carbon credits. This is accomplished through Monitoring, Reporting and Verification (MRV) frameworks.
- *Permanence* refers to the assurance that carbon stored or sequestered through a project remains stored over the long term, thus effectively reducing the atmospheric concentration of greenhouse gases for an extended period.
- *Sustainability* refers to ensuring that emission reduction projects not only contribute to mitigating climate change but also promote broader sustainable development goals, including social, environmental, and economic benefits.

In the remainder of this analysis, we describe the approaches used by forestry methodologies to meet the quality criteria listed above. Part of the challenge is that a methodological solution to guarantee a given criterion – e.g. additionality – can seem sound on paper, but its actual effectiveness can only be tested after several projects have been implemented. This mismatch between ex-ante and ex-post assessments highlights the need for a continuous improvement of methodologies and the standards that support them.

[1] Most of these terms have their origin in regulatory criteria established for air pollutant credits under the U.S. Clean Air Act in 1977.
[2] https://www.offsetguide.org/high-quality-offsets/
[3] https://icvcm.org/the-core-carbon-principles/
[4] https://vcmintegrity.org/vcmi-claims-code-of-practice/
[5] https://icroa.org/icroa-code-of-best-practice/

4.2. Technical robustness (scope and precision of MRV) of carbon methodologies

4.2.1. Scope: all methodologies include living biomass and dead wood, rarely soil - sufficient rules but too much flexibility increasing over-crediting risk.

This section explores the compartments included for carbon gain accounting and assesses the methods for accounting for the carbon stored or lost in each compartment.

- **Emissions/Storage estimation: direct measurements and models**

It is important to bear in mind that the obligation of the result does not necessarily mean a direct measurement of the result, i.e., a final verification of the carbon gain by flux tower in the forest or by sampling in the agricultural soils. Result-based tools can work with quantitative estimates through look-up tables for example. It is then up to the decision-makers to find a trade-off between the cost of MRV and the expected precision to limit the margin of error while keeping the cost affordable for the project developers (I4CE, 2022).

All methodologies integrate above-ground and below-ground biomass (Table 5) with an exception for one methodology - Verra: Conversion from Logged to Protected Forest, which does not take below-ground biomass into account, because it presumes that root biomass is likely to remain constant or increases moderately (Haya *et al.*, 2023).

Dead wood is also systematically integrated (except for the Verra methodology already cited) but for almost half of them in an optional way. Wood products are covered by two-thirds of methodologies. Except for the LBC, only their storage effect is accounted for, not the potential substitution of fossil fuels.
Soil carbon is considered very rarely, whereas linked methane emissions are integrated into a third of the methods (table 5).

Table 5: included compartments for each methodology

	Live biomass	dead wood	HWP	soil carbon	CH_4	Other
ACR -IFM on Non-Federal U.S. Forestlands – v2.0 -1						
ACR – IFM on Canadian Forestlands – v1.0-2						
ACR – IFM on Small Non-Industrial Private Forestlands – v1.0-3						
ARB – Compliance Offset Protocol – U.S. Forest Projects-4						
CAR – U.S. Forest 5.0-5						
CAR – Urban Forest Management 1.1-6						
CAR Mexico Forest 3.0-7						
ERF – Human-induced regeneration of a permanent even-aged native forest 1.1 -8						Fire (emissions)

LBC- Coppice-to-high-forest conversion-9						litter substitution
Verra – IFM Methodology through Extension of Rotation Age – v1.2-10						
Verra – Methodology for Conversion of Low-productive Forest to High-productive Forest – v1.2- 11						
Verra – IFM Methodology Conversion from Logged to Protected Forest – v1.3-12						
Verra – IFM in Temperate and Boreal Forests (LtPF) – v1.2-13						CO_2 combustion by forestry engines
Verra – IFM Methodology through Reduced Impact Logging – v1.0 -14						
Verra IFM Methodology Using Dynamic Matched Baselines from National Forest inventories – V1.0-15						Other GHG
Replantation on a stand affected by a forest fire – v10-16						

included	optional	included and optional

Box 1: « Precision of carbon estimation and information asymmetry » (Bellassen et Shishlov, 2017).

The implementation of monitoring rules prescribed by the regulator comes with an uncertainty range: the exact amount of GHG emissions likely differs from the amount reported by an agent. Agents may or may not be aware of this difference, which effectively results in the presence or absence of information asymmetry between an agent and the regulator.

In the specific context of soil carbon sequestration, Antle *et al*. (2003) consider the trade-off between improved efficiency of environmental scheme and cost of information, assessing the worth of monitoring soil carbon at the finer *agro-ecozone* scale rather than the default regional scale.
In the field of climate policy, (Montero 2000) considers asymmetrical information on abatement costs in the case of voluntary opt-in programs. It demonstrates that asymmetrical information results in a trade-off between efficiency gains due to the involvement of low-cost emissions reductions and excess emissions due to the adverse selection of firms that produce a level of emissions below the permit allocation.

Bellassen and Shishlov, 2017 assess the environmental and economic efficiency of the three different approaches implemented by regulators to treat monitoring uncertainty in climate policy, namely prescribing uncertainty, setting minimum certainty thresholds and pricing uncertainty through a discount. Their model of the behaviour of profit-maximizing agents demonstrates that under the simplest set of assumptions the regulator has no interest in reducing monitoring uncertainty.

However, in the presence of information asymmetry, monitoring uncertainty may hamper the economic and environmental performance of climate policy due to adverse selection. In a mandatory policy, prescribing a reasonable level of uncertainty is preferable if the regulator has enough information to determine this level. **For voluntary mechanisms, such as carbon offsets, allowing agents to set their monitoring uncertainty below a maximum threshold or discounting carbon revenues in proportion to monitoring uncertainty are the best approaches for the regulator to mitigate the negative effects of information asymmetry**.

Limiting monitoring uncertainty allows the regulator to reduce the excessive participation of agents with overestimated emissions reductions/removals and increase the insufficient participation of agents underestimating their climate impact. The regulator thus has to find a balance between the stringency of monitoring requirements which optimizes the participation of each agent and the additional costs this stringency imposes (Bellassen et Shishlov, 2017).

This finding has a simple and important consequence for monitoring rules: it is not worth demanding a very precise monitoring of variables or parameters for which it can reasonably be assumed that project proponents do not know better than the regulator (e.g. highly technical parameters such as the emission factors).

Carbon accounting in the context of IFM methodologies includes a variety of measurement and estimation techniques that attempt to accurately and precisely quantify carbon stocks in biomass and harvested wood products, as well as changes in these stocks that result from project activities (Haya *et al*. 2023). Major sources of uncertainty in estimating onsite carbon stocks in the biomass pools fall into four categories: (i) accuracy of measurements in the field; (ii) choice of allometric models (including selection of wood density values, root:shoot ratios and aboveground biomass allometric equations); (iii) sampling uncertainty related to plot size; and (iv) sampling uncertainty related to statistical representativeness of the plots within the whole landscape (Chave *et al*., 2004**;** Temesgen *et al*. 2015).

- **Analysis of carbon accounting for each compartment**

Aboveground biomass: The methodologies tend to provide appropriately rigorous, high-level guidance on inventory design under a stock change approach that aligns with recommendations from the IPCC (2019). The protocols allow flexibility in carbon accounting such that project developers can adapt methods to local conditions and efficiently conduct monitoring, reporting, and verification increases (Haya *et al*., 2023). IFM projects in regions with fewer relevant datasets to build the allometric models may use less appropriate equations and thus less robust estimates of aboveground biomass (Yuen *et al*., 2016). Depending on the methods used, overestimation of aboveground carbon stocks can occur (Clough *et al*., 2016), as well as underestimation (Calder, 2022) but this is likely to be less consequential to the overall validity of a forest carbon project than other considerations (e.g., baselines and leakage).

Belowground biomass: Belowground biomass refers to living roots, typically comprising 15–25% of total living biomass in a forest (Jackson *et al*., 1996).
Belowground biomass estimation models vary widely across protocols. Because empirical measurement of belowground biomass is difficult and time-consuming (requiring excavating, cleaning, sorting, and weighing roots), belowground biomass is estimated indirectly based on aboveground biomass measurements. The IFM protocols estimate belowground biomass using allometric equations

or root:shoot ratios, which are inherently unable to capture detailed natural variation and, additionally, may introduce systematic errors by being inappropriately matched to the system in question[6] (Ledo *et al.*, 2018). Because relatively little empirical belowground biomass data exists for validating either the allometric or root:shoot ratio approaches, it is not well-understood which of these approaches is preferable, what magnitude of error they may introduce, and whether they are systematically over- or underestimating belowground biomass according to vegetation type, region, or climate regime (Xing *et al.*, 2019).

Soil carbon: In the methodologies which cover soil carbon, the pool is only considered as a potential source of emissions that may mitigate the climate benefits of the project, such as losses from disruptive management activities or site preparation (Haya *et al.*, 2023).
IFM protocols rarely require the measurement or estimation of soil organic carbon (SOC) stocks and fluxes due to the assumption that changes in the soil pool are negligible relative to credit volumes and due to the considerable expense and logistical challenge of measuring the soil carbon stock accurately and comprehensively (Paustian *et al.*, 2019).
Site preparation and ongoing management can cause significant disturbance to soil stocks, especially in litter, organic, and topsoil carbon pools, partially eroding the benefits of biomass stock increases (Jandl *et al.*, 2007; Achat *et al.*, 2015).

Harvested wood products (HWP): Regarding the carbon stock changes associated with HWPs, the methodologies require an estimate of the carbon stock for both baseline and project HWPs. When IFM projects reduce the harvesting intensity, HWP stocks can only be estimated in the baseline scenario.
In general, HWP estimations follow a similar process where project proponents must estimate (a) the volume of timber harvested, (b) the merchantable carbon in these HWPs and its distribution in wood products categories, the carbon loss due to mill processing, and (c) the decay of HWP carbon in final products and landfills over a 100-year horizon (Table 5b). This decay rate varies based on the lifetime of the product category (Haya *et al.*, 2023). Several methodologies follow the requirements of Winjum *et al.* (1998).

Table 5b: HWP evaluation for a selection of methodologies

Methodology	Standard	Carbon pools and emission sources		HWP quantification
		included	optional	
Improved Forest Management (IFM) on Non-Federal U.S. Forestlands - v2.0	ACR	aboveground live biomass; belowground live biomass; harvested wood products	standing dead wood; lying dead wood	Four steps process of calculation: - Determining the amount of carbon in harvested trees that is delivered to mills (model output for baseline and verified 3rd party reports for a project); - Accounting for mill efficiencies (from a national database) - Estimating the carbon remaining in in-use wood products 100 years after harvest (table in methodology)

[6] Root:shoot ratios assume that belowground biomass occurs in a fixed ratio to aboveground biomass, whereas allometric equations allow for non-linear relationships.

				- Estimating the carbon remaining in landfills 100 years after harvest (table in methodology)
U.S. Forest 5.0	CAR	standing live carbon; standing dead carbon; wood forest product; soil carbon (for emission estimates)		Four steps process of calculation (with a worksheet): - Determining the amount of carbon in trees harvested that is delivered to mills ; - Accounting for mill efficiencies ; - Estimating the carbon remaining in in-use wood products 100 years after harvest ; - Estimating the carbon remaining in landfills 100 years after harvest
Human-induced regeneration of a permanent even-aged native forest 1.1	ERF			Not in the scope
Balivage (conversion from coppice to high stand forest management)	Label Bas-Carbone	aboveground live biomass carbon; belowground live biomass carbon; litter; soil carbon	dead wood; wood products; energy or material substitution	The harvested wood is shared in 4 categories (sawn timber, panel timber, paper wood and wine-pole wood). Half-life time are given for each category (LULUCF regulation values) and used as a parameter of a decreasing exponential equation.
Methodology for Conversion of Low-productive Forest to High-productive Forest - v1.2	Verra	aboveground biomass; dead wood; wood products	belowground biomass	HWP only quantified in the baseline. Methodology from Winjum *et al.* (1998) with 5 categories: sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other
Improved Forest Management in Temperate and Boreal Forests (LtPF) - v1.2	Verra	aboveground biomass; belowground biomass; dead wood; wood products	CO2 (combustion of fossil fuel)	Three steps calculation process: - Carbon contained in harvested timber - Computation of mill efficiency - Share in 3 categories with different storing : 1. Short-lived wood products – immediate emission of all carbon upon harvest 2. Medium-lived wood products – carbon stored will decrease by 1/20th for the next 20 years after harvest 3. Long-lived wood products – no loss of carbon (permanent storage)

Improved Forest Management Methodology Using Dynamic Matched Baselines from National Forest inventories - V1.0	Verra	aboveground biomass; belowground biomass; dead wood	aboveground woody non tree biomass N2O (amendments) CO2-CH4-N2O (burning of biomass)	The fraction of wood remaining stored after 100 years is accounted for as a removal. This fraction is computed from the share of harvested wood in pulpwood and sawn wood for soft- and hardwood and from log mass remaining stored in use and landfills after 100 years (given for US regions)

Substitution effect: except the LBC methodology for the conversion of coppices to high stands, all of the protocols we reviewed ignore their possible substitution effect (displacement of other fossil-intensive alternatives). For WWF (2020) and Valade (2022), the replacement by wood of other more carbon-intensive materials/energies can be calculated (with many uncertainties) at the scale of a country or a sector, but it is inconceivable to make this calculation on the scale of a small forest owner. It argues that controlling the substitution effect of wood energy is a question for producers of energy and wood materials (builders and developers), not for forest owners.
Substitution benefits are typically higher for construction-based materials, such as when timber is replacing steel or concrete (Smyth *et al*., 2017; Geng *et al*., 2019) than for energy products, such as biomass used to generate electricity and heat (Cabiyo *et al*., 2021). Ignoring these benefits possibly overestimates the benefits of reduced harvesting, thus resulting in some over-crediting and also shifting protocol incentives towards projects that reduce harvesting. Let's note however that even generous accounting of substitution effects does not reverse the higher carbon merit of reduced harvesting (e.g. Smyth 2014, Valade 2017, Soimakallio, 2022).

Methods for estimating onsite carbon stocks in the protocols allow for a great deal of flexibility. If implemented properly, current rules are sufficient to ensure high integrity. However, this flexibility also allows for less accurate carbon accounting, including using reference literature for allometric equations and root:shoot ratios that may not be appropriate or conservative for the project under development. (Haya *et al*., 2023).
The choice of which compartments are included in the methodologies depends on the effects of the practices implemented in that compartment. **Typically, when a carbon pool is excluded from project-level carbon accounting, the decision is justified by an assumption that the change in the pool will be negligible under approved project activities** or will result in net carbon accumulation and thus can be excluded for conservative estimation (Haya *et al*., 2023).
Methods for quantifying forest carbon stocks and their changes are rapidly evolving, including through the integration of field-based methods and remote sensing. Although challenges associated with accurately measuring changes in below-canopy forest structure for some remote sensing types (e.g. optical imagery) may limit their application to IFM projects (Asbeck and Frey, 2021). Moreover, optical remote sensing sensors often saturate over dense biomass environments, like the majority of European temperate forests (Lu *et al*.). Therefore, combining satellite imagery with models might be an interesting avenue for future biomass assessments (Neumann *et al*., 2016).

4.2.2. Sustainability criteria: variable integration - need for more specific guidelines to increase consistency and transparency

Integration of sustainability criteria within the methodologies differs greatly from one standard to another (Table 6). For example, Verra and ERF certifications give no indication (other than to follow the very general principles of compliance with the Sustainable Development Goals (SDGs) for Verra). No mention is made of this in the methodologies, and no tools exist for these two certifications either. Note, however, that project proponents willing to be serious about sustainability criteria while using Verra for carbon tend to apply simultaneously for another certification such as the Climate, Community & Biodiversity Standard (CCBS).

In the remaining standards, the integration of sustainability criteria appears in three forms (Table 6):

- Requirements for ACR methodologies
- Safeguards for ARB and CAR methodologies US forest and CAR Mexico
- Co-benefits for LBC, RHC and CAR Urban Forestry methodologies.

The form of this integration is of some importance as there is not the same degree of obligation between a co-benefit and a requirement.

However, form is not everything, and it is also interesting to look at the elements that are integrated. There are two different types of elements. Elements linked to sustainable forest management (mandatory certification of sustainable management or to have a management plan, for example) or integration of biodiversity elements in addition to forest management only. Table 6 shows that:

- The ACR standard sets requirements, but this only concerns forest management and with no additional focus on biodiversity;
- The other standards (ARB, CAR, RHC and LBC) go beyond sustainable forest management and request (safeguards) or propose (co-benefits) the specific biodiversity indicators or criteria (such as the diversification of species, favouring native species, etc.).

In the end, only three methods (ARB, CAR US Forest, CAR Mexico) include specific and mandatory requirements on biodiversity.

Although the principle of co-benefits is suitable for highlighting virtuous projects, how they are assessed, verified and monitored is crucial. For instance, WWF's evaluation of LBC's first forestry projects shows that the lack of clearly defined rules means that co-benefits can sometimes be claimed to be high without any real positive impact on the ground, for example on biodiversity" (WWF, 2020). The use of the Index of biodiversity potential (Larrieu and Gonin, 2008), easy and time-efficient to apply, could be a useful proxy used in combination with species-based monitoring approaches (Zeller and al., 2022).

The WWF recommends that the use of co-benefits in the LBC should be better supervised and that the non-deterioration of biodiversity, soil and water resources should be a mandatory prerequisite so that projects can be carbon and biodiversity winners (WWF, 2020).

Table 6: type of integration and type of sustainability criteria in each methodology

Methodology	Presence of sustainability criteria (SC)		Type of SC: sustainable harvesting practices		Type of SC Biodiversity elements
	yes/no	**Status of SC: DNSH/ co-benefits**	**SFM certification required?**	**Forest management plan required?**	**Biodiversity elements considered**
ACR -IFM on Non-Federal U.S. Forestlands - v2.0 -1	yes	requirements	yes	yes	no
ACR - IFM on Canadian Forestlands - v1.0-2	yes	requirements	yes	yes	no
ACR - IFM on Small Non-Industrial Private Forestlands - v1.0-3	yes	requirements	yes	yes	no
ARB - Compliance Offset Protocol - U.S. Forest Projects-4	yes	safeguards	one of them	one of them	native species (composition) distribution of Age Classes structural elements of ecosystem balancing age and habitat classes
CAR - U.S. Forest 5.0-5	yes	safeguards	one of them	one of them	species composition forest structure native species (composition) distribution of age classes structural elements of ecosystem
CAR - Urban Forest Management 1.1-6	yes	co-benefits	no	no	native species non-native species physical characteristics climate change resilience air quality water management
CAR Mexico Forest 3.0-7	yes	safeguards	no	no	native species (composition) distribution of age classes structural elements of ecosystem maintain or increase tree canopy soil disturbance
ERF - Human-induced regeneration of a permanent even-aged native forest 1.1 -8	no				
LBC- Coppice-to-high-forest conversion -9	yes	co-benefits	optional Recognised as a co-benefit	yes	biodiversity inventory species diversity structural elements
Verra – IFM Methodology through Extension of Rotation Age - v1.2-10	no	**Very general principles to be observed**			
Verra - Methodology for Conversion of Low-productive Forest to High-productive Forest - v1.2- 11	no				
Verra – IFM Methodology Conversion from Logged to Protected Forest - v1.3-12	no				
Verra - IFM in Temperate and Boreal Forests (LtPF) - v1.2-13	no				
Verra – IFM Methodology through Reduced Impact Logging - v1.0 -14	no				
Verra IFM Methodology Using Dynamic Matched Baselines from National Forest inventories - V1.0-15	no				
Replantation on a stand affected by a forest fire – v10-16	yes	co-benefits	Optional Recognised as a co-benefit	yes	Exclusion of short rotation coppice native species non-native species physical characteristics climate change resilience Protected area network (Natura 2000)

Legend:

colours	Type of integration of sustainability criteria
requirement	sustainability criteria are integrated as requirements
safeguards	sustainability criteria are integrated as safeguards
co-benefits	sustainability criteria are integrated as co-benefits
	not found
	no information about sustainability criteria but very general principles to be observed

More generally, **the inclusion or non-inclusion of sustainability criteria is very open-ended, and each standard or even methodology within these standards has its own rules, creating a lack of clarity** for project financiers. **A lack of clear rules on the definition of sustainability criteria creates vagueness and puts elements of biodiversity or good management practices on the same level. In addition, measurement guidelines could also be drawn up to ensure greater consistency between methodologies and greater transparency on projects.**

Box 2: Biophysical effects: what would be the conditions for albedo to be incorporated into IFM methodologies?

Land cover changes (LCC) have a recognized effect on climate through two different processes: modifications in the net flux of greenhouse gases such as CO2, from changes in vegetation and soil carbon (biogeochemical effects); and variations of the surface energy budget mediated by albedo, evapotranspiration, and roughness (biophysical effects) (Betts, 2000).

The land surface and LCC contribute to biophysical effects in the following way: incoming solar energy is partly reflected into the atmosphere depending on the surface albedo (reflectiveness), and partly absorbed at the surface and subsequently partitioned into latent and sensible heat fluxes depending on the soil water balance, canopy conductance and vegetation aerodynamic properties (roughness) (Costa and Foley, 2000, Feddema *et al*., 2005, Davin and de Noblet-Ducoudré, 2010, Mahmood *et al*., 2014).

Various studies have attempted to quantify the global significance of the biophysical effects of historical LCC compared to CO2 fluxes (Betts 2000, Marland *et al*., 2003, Schwaiger and Bird, 2010). Due to the high uncertainties in quantifying their impacts, the IPCC concluded there is low agreement on the sign of the net change in global mean temperature because of biophysical LCC effects (Myhre *et al*., 2013).

To integrate biophysical effects into forestry carbon certification methods today, and albedo in particular, we need to look at the conditions under which this could be done.

Two elements seem important to integrate it:

Albedo must have a non-negligible effect (*de minimis* rule).

The *de minimis* rule is very frequently used in IFM methodologies. As a first example of the de *minimis* rule, fossil fuel emissions caused by wood harvesting are systematically excluded from the scope, because they are considered negligible in relation to the overall GHG balance (except in the ERF methodology). More specifically concerning CAR Mexico Forest, the CO_2 emissions from ongoing project operation and maintenance are excluded. « *These emissions are unlikely to be significantly different from baseline levels and are therefore not included in the GHG Assessment Boundary* ».

Regarding Verra's projects, they apply UNFCCC rules: « *Following the guidance of the Executive Board of the CDM, emissions caused by combustion of fossil fuels and through the use of fertilizers are considered insignificant and are not considered here* (UNFCCC CDM EB 44, UNFCCC CDM EB 42) ». Even in the reduced impact logging methodology, fossil fuel emissions are excluded. The LBC methodology is based on another study to neglect fossil fuel emissions: *Gonzalez-Garcia*, *et al*. (2014)

A second example of the de *minimis* rule can be found in the ACR, ARB, CAR (except CAR US Forest) and Verra methodologies, where soil carbon is excluded: *"Changes in the soil carbon pool are considered de minimis as a result of project implementation*."

The uncertainty of the calculations must be reasonable

For example, Giraldo *et al* (2023) calculated the uncertainty associated with taking two different compartments into account: biomass (in agroforestry and hedgerow management projects) and soil carbon (in cover crop and temporary grassland projects). In forestry projects, biomass is systematically included in the compartments, whereas this is very rarely done for soil carbon (table 5).

First, The uncertainty associated with taking biomass into account is calculated at between 10% and 23% for agroforestry and hedgerow management projects, without exceeding 60% (without monitoring). It can therefore be considered relatively low. Second, the uncertainty associated with soil carbon is between 25 to 38% and exceeds 100% without monitoring (Giraldo *et al*., 2023). There is more uncertainty linked to soil carbon, which is one of the explanations for the fact that soil carbon is rarely included in IFM methodologies. Thus, in CAR Mexico Forest, Soil carbon is excluded from sinks with this justification: "*Soil carbon is anticipated to increase as a result of most carbon enhancement project activities that do not include intensive site preparation. Due to challenges in measurement of soil carbon and associated soil emissions, soil carbon cannot be included as a credited reservoir/pool at this time*".

The albedo effect differs for different biogeographical regions

Considering these two principles (de minimis rule and moderate uncertainty rule), the biogeographical region of the project implementation must be considered.

Model results indicate that a modification of biophysical processes at the land surface has a strong regional climate effect, and non-negligible global impact on temperature (Perugini *et al*., 2015). Luyssaert *et al* (2018) demonstrated that the combined biogeochemical and biophysical effects of a forest-management portfolio that reduces the near-surface air temperature come without a significant effect on the radiative imbalance at the top of the atmosphere. But it could contribute to a 0.3 K cooling over Scandinavia while having much less effect on temperature over the rest of Europe (Figure 2).

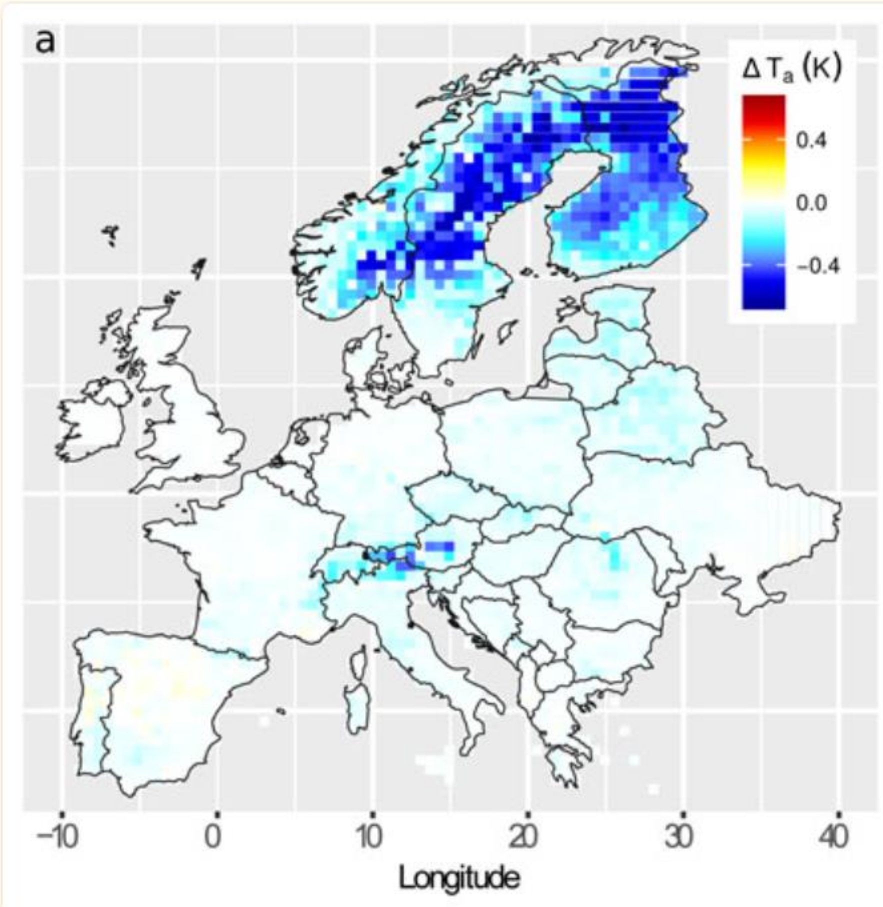

Figure 2: Changes and main drivers of air temperature in February and March by the turn of the 21st century for a forest-management portfolio that reduces the near-surface air temperature. (Luyssaert *et al*., 2018)

Biophysical effects, and particularly albedo, are therefore more relevant in boreal forests, where albedo has a significant effect, than in temperate or Mediterranean forests, where this effect seems more negligible. Indeed, afforestation projects in boreal areas could be considered a false good idea as the albedo of forest cover is lower than the albedo of snow (Betts, 2000).

However, before considering the inclusion of biophysical climate effects of and cover changes under the UNFCCC, science has to provide robust tools and methods for estimation of both country and global level effects (Perugini *et al*., 2015). Assessment tools are emerging, in particular with remote sensing development (Duveiller *et al*., 2020) but they are focused on land use change projects such as AR and REDD+. As IFM projects are expected to modify the land surface less intensively, they will more likely have a lower impact on biophysical effects.

Another challenge to integrate biophysical effects into carbon certification methods, lies in finding a common metric. Scientific studies use temperature changes to combine biogeochemical and biophysical effects, but carbon projects commonly use the tCO_2 unit to give a monetary value to the practice change. Methodologies to compute tCO_2 flux equivalent from temperature change due to biophysical effects are to be explored to integrate these effects into the existing tCO_2 market.

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4.3. Certification efficiency

4.3.1. Non-permanence risk management: generally through a buffer pool, likely insufficient to cover all risks

Carbon sequestration projects in biomass or soils present a risk of non-permanence, i.e. the re-emission of carbon into the atmosphere. Forest carbon can be released by “unavoidable” natural disturbances such as fire, drought, disease, and storms, and by “avoidable” human actions such as harvesting and land-use conversion.
The methodologies address these reversal risks with commitments to maintain carbon storage over a designated period, and remedies if reversals occur (buffer pool, rebate, insurance, etc.). The duration of “permanence” varies between methods ranging from project duration (between 1 and 100 years) to 100 years. Decisions about the appropriate duration of carbon storage depend fundamentally on assumptions about the future, and academics have called the default choice of 100 years as "political" (Archer *et al*., 2009; Allen *et al*., 2016). Even considering that projects do not represent permanent offsets (Herzog *et al*., 2003), questions remain about whether the current approach (relying on buffer pools) can achieve the promised durability (Haya *et al*., 2023).

All the methodologies provide for a buffer pool (only one method (LBC) uses a discount, which is a simplified version of the buffer system) to replace credits in the event of reversals (Table 7 and Haya. *et al*, 2023). The ACR methodologies offer a choice between a buffer, an insurance or “other techniques approved by ACR (but no example is given)”. Note however that the standard always dictates the risk management system, except for ACR which allows for several possibilities. The role of the methodology is only to specify how to assess the risk of each project and how to determine the actual discount or share of “buffer” credits.

Table 7:Non-permanence risk management assessment for each methodology

Methodology	Non-permanence risk considered			Management system				
	yes/no	unavoidable risks*	avoidable risks*	buffer pool	insurance	discount	Compensation by the project proponent	other
ACR -IFM on Non-Federal U.S. Forestlands - v2.0 -1	yes							
ACR - IFM on Canadian Forestlands - v1.0-2	yes							
ACR - IFM on Small Non-Industrial Private Forestlands - v1.0-3	yes							
ARB - Compliance Offset Protocol - U.S. Forest Projects-4	yes						For avoidable risks	
CAR - U.S. Forest 5.0-5	yes						For avoidable risks	
CAR - Urban Forest Management 1.1-6	yes						For avoidable risks	
CAR Mexico Forest 3.0-7	Yes						For avoidable risks	

ERF - Human-induced regeneration of a permanent even-aged native forest 1.1 -**8**	no								
LBC- Coppice-to-high-forest conversion -**9**	yes								
Verra – IFM Methodology through Extension of Rotation Age - v1.2-**10**	Yes								
Verra - Methodology for Conversion of Low-productive Forest to High-productive Forest - v1.2- **11**	Yes								
Verra – IFM Methodology Conversion from Logged to Protected Forest - v1.3-**12**	Yes								
Verra - IFM in Temperate and Boreal Forests (LtPF) - v1.2- **13**	Yes								
Verra – IFM Methodology through Reduced Impact Logging - v1.0 -**14**	Yes								
Verra IFM Methodology Using Dynamic Matched Baselines from National Forest inventories - V1.0-**15**	Yes								
Replantation on a stand affected by a forest fire – v10- **16**	Yes							For avoidable risks	

	included in the methodology
	elements included in toolkit (not directly included in the methodology)
	no element found
unavoidable risks	fire, storm, pest attacks…
avoidable risks	modification of the landowner's forest management…

Other * = other risk mitigation measures approved by ACR.

In simple terms, the buffer pool can be thought of as similar to an insurance policy that seeks to ensure that each carbon credit will deliver 1 ton of CO_2 emissions removals, even if some carbon stocks are unexpectedly lost.
In practice, a portion of the carbon credits generated by nature-based projects is set aside and placed in a buffer pool instead of being sold. These buffer credits can be canceled from the pool if a "reversal" takes place, with the aim of ensuring the integrity of previously issued credits.[7]

Each protocol has a different approach to allocating buffer pool credits. Notably, the ACR and VCS buffer pools can be used to cover both intentional and unintentional reversals, while ARB, CAR-U.S., CAR-Mexico and RHC buffer pools can only be used to cover unintentional reversals (Table 7). Unintentional reversals are caused by factors not within the direct control of the project developer, including natural causes such as fire, wind, disease or drought whereas intentional reversals are directly caused by the project developer or other stakeholders. It includes clear cut for example. Under these protocols, intentional reversals must be replaced at the expense of the project proponent. The LBC standard uses the term "avoidable" risk of reversals which also include unintentional reversal, but that project developers can avoid by implementing *had-hoc* measures.

[7] Sylvera: What is a carbon credit buffer? https://www.sylvera.com/blog/carbon-credit-buffer-pools

Interestingly, the VCS allows a portion of buffer pool credits to be returned to the saleable credit pool if the risk of reversal within the project lifetime can be shown to decline over time (Haya *et al.*, 2023), thus providing an incentive to continue monitoring even when the physical storage has stopped.

Buffer pool contributions are designed to cover the calculated likelihood that those carbon stocks will be reversed, i.e., re-emitted to the atmosphere. Programs and projects vary widely across project terms, risk of reversal, and reversal recourse. (Haya *et al.*, 2023) (Figure 3).

Registry	Minimum term	Recourse
ACR	40 years*	23.5 ± 2% buffer pool, for both intentional and unintentional reversals
ARB	100 years	16.1 ± 2.8% buffer pool reversal risk assessment includes unintentional and intentional reversals; intentional reversals must be replaced with similar credits
CAR-U.S.	100 years	7.7 ± 2.6% buffer pool, intentional reversals must be replaced
CAR-Mexico	1 year	8% buffer pool, primarily for unintentional reversals but can be used at the discretion of CAR
VCS	20 years*	17.4 ± 11.4% buffer pool, for both intentional and unintentional reversals. Verra is the only registry that allows buffer pool credits to be returned to the salable credit pool as the risk of reversal within the project lifetime diminishes over time.

*From project start date, not the date credits are issued. Verra is considering extending the monitoring of reversals into the post-crediting period for compensation by the buffer pool.[1]

Figure 3: Durability terms and buffer pool contributions (Haya et al., 2023)

While the use of buffer pools is widespread, their size has been criticized as being too small by several scientific studies for the following reasons:

- First, none of the reviewed protocols take climate change into account in estimating buffer pool allocations and so may not reflect increasing risks of reversal over decadal time scales (Haya *et al.*, 2023). For example, the ARB methodologies include a buffer allocation of 2–4% for fire, 3% for biotic risks, and 3% for "other episodic catastrophic events" (e.g., drought). Registro Huella de Carbono set a 10% buffer pool for all natural disturbance types. However, because annual acreage of forest fires in the United States is projected to quadruple by the end of the century even under a moderate emissions scenario (Anderegg *et al.*, 2022), current buffer pool allocations may prove insufficient based on wildfire risk alone. For Europe similar trends of increasing natural disturbances have been observed and are projected for the future (Senf *et al.*, 2018 ; Forzieri *et al.*, 2021 ; Grünig *et al.*, 2023 ; Patacca *et al.*, 2023)
- Second, some registries may not have a sufficiently diversified offset portfolio to effectively mitigate risk through the buffer pool mechanism. Such systemic risks may arise when a large proportion of projects in a registry are similar and/or exist in a constrained geographic area or ecological type (Haya *et al.*, 2023).
- Third, a buffer pool is defined by the quality of its constituent credits, buffer pools are composed of low-quality credits having little value. The recent criticisms on the quality of land-

based offset projects across protocols (e.g., Haya, 2019; West *et al*., 2020; Badgley *et al*., 2022), and in particular REDD+ projects which constitute the lion's share of the VCS buffer pool, thus questions the quality of buffer pools.

In addition, to limit the risk of intentional reversion, particularly at the end of the project, it may be necessary to add a specification on the follow-up to be given to the project once it has been completed (WWF, 2020).

4.3.2. Additionality and baseline: despite the different methods used, this is the main weakness of carbon certification.

Table 8: definition of baseline and additionality criteria for each methodology. NPV = Net Present Value

	Baseline						Additionality			
	Economic baselines	historical trend	initial carbon stocks approach	Common Practice Baseline	legal baseline	other	exceed regulation	exceed common practices	exceed financial barrier	performance test
ACR -IFM on Non-Federal U.S. Forestlands - v2.0 -1	NPV									
ACR - IFM on Canadian Forestlands - v1.0-2	NPV									
ACR - IFM on Small Non-Industrial Private Forestlands - v1.0-3	NPV									
ARB - Compliance Offset Protocol - U.S. Forest Projects-4										
CAR - U.S. Forest 5.0-5										
CAR - Urban Forest Management 1.1-6										
CAR Mexico Forest 3.0-7										
ERF - Human-induced regeneration of a permanent even-aged native forest 1.1 -8										
LBC - Coppice-to-high-forest conversion -9						pre-defined baseline (Most plausible scenario)			NPV	
Verra – IFM Methodology through Extension of Rotation Age - v1.2-10										
Verra - Methodology for Conversion of Low-productive Forest to High-productive Forest - v1.2- 11										
Verra – IFM Methodology Conversion from Logged to Protected Forest - v1.3-12										
Verra - IFM in Temperate and Boreal Forests (LtPF) - v1.2-13						most plausible scenario				

Verra – IFM Methodology through Reduced Impact Logging - v1.0 -**14**						region-specific RIL-C performance method					
Verra IFM Methodology Using Dynamic Matched Baselines from National Forest inventories - V1.0-**15**						dynamic performance benchmark approach					
Replantation on a stand affected by a forest fire – v10-**16**			Initial stock = no stock			Pre-defined baseline (no biomass stock)					

	individual baseline*
	generic baseline

*The baseline approach for Improved Forest Management Projects is a standardized set of assumptions t

	test required to validate additionality
	Test required to validate additionality – information available in a separate toolkit
	Tests required to validate additionality - automatically validated as part of these IFM methodologies

Baseline

A project's baseline represents land management that most likely would have occurred in the absence of the carbon project and is the scenario against which a project's carbon impact is measured. The baseline (counterfactual) is inherently uncertain because once a project takes place, the baseline cannot be observed. Baseline choice has a large effect on the number of credits issued, so baseline credibility and conservativeness are important to the quality of offset credits (Griscom *et al*., 2009).

Virtually all the methodologies (except two Verra methodologies: "Reduced Impact Logging Improved Forest Management" and "Using Dynamic Matched Baselines from National Forest inventories") use individual baselines, although most use standardised data for specific projects (table 8). An individual baseline is specific to each project, whereas a generic baseline is the same for a set of projects (all projects in a given geographical area, for example). However, to keep procedures simple, most methodologies provide guidance for the use of standardised data. This is the case with the Balivage methodology (Label Bas-Carbone), which provides an individual baseline, but the data used to define the scenario are generic and depend on the baseline chosen (there are no individualised measurements). Surprisingly, the Registro Huella de Carbono (RHC) standard does not mention any baseline scenario. This implicitly assumes that the biomass carbon stock is maintained at zero in the baseline.

Several types of baselines are used in the IFM methodologies (Table 8):

- **Economic baseline - Net present value (NPV) method**: Project baselines are typically set to a 20-year crediting period and based on a 100-year NPV-maximizing harvest schedule. However, this method may poorly predict the management decisions of landowners who may manage for multiple goals like ecosystem or recreation benefits (Butler *et al*., 2016). This method is used by ACR methodologies.
- **Historical trend**: When past management actions are used as baselines. To define the historical baseline, CAR Urban Forest management uses the following approach. To develop a project baseline for a UFM Project, a trend line is developed by calculating an historic estimate of carbon stocks and a recent estimate of carbon stocks. *The trend line must pass through at least two historical inventory estimates that are at least 10 years apart and with the earliest point no earlier than 1990. For instance, if a project starts in 2018, the historical estimates may be done using aerial imagery from 2005 and 2015, since the two points pre-date the Project Start Date, are at least 10 years apart from one another, and do not predate 1990. Both estimates are developed by first estimating the tree canopy area for each date from remotely sensed data and applying the ratio estimators.*
- **Initial stock approach (historical management):** CAR Mexico which used this approach, defines the "Initial carbon stock" approach as follows: *A Forest Project can be issued credits to the extent forest carbon stocks have increased above and beyond baseline forest carbon stocks. The initial baseline is defined as the sum of carbon (CO2e) in the required carbon pools at the start date.* Using initial carbon stocks as the baseline can be more conservative than other protocols and reduces over-crediting risk (Haya, 2023).
- **Dynamic baseline:** The use of dynamic baselines is similar to control plots in experimental science. In this system, properties similar to the offset property in past management, market conditions, ecosystem, landowner type, etc., can be used as the baseline for offset projects (Verra, IFM methodology - Using Dynamic Matched Baselines from National Forest inventories). Matching methods developed for causal inference can be used to create

comparison sets (Andam *et al*., 2008; Ferraro and Hanauer, 2014). Each year, the carbon values of the offset and the baseline properties can be compared, and credits can be issued based on this comparison.

- **Case of CAR US Forest and ARB:** The baseline is defined as the average onsite carbon stocks over a modelled 100-year baseline management scenario that should be no lower than the minimum baseline level allowed. Typical baselines are set at around 30% below initial carbon stocks and just above the common practice (Haya, 2023). Setting the baseline below initial or historic carbon stocks raises an over-crediting concern. Instead of being credited for taking action, the forest owner is credited for not taking action that would have reduced the carbon stocks on their lands (Haya, 2023).
- **Combination of various methods:** Verra IFM methodologies use multiple approaches to baseline-setting, including historical baselines, legal baselines, common practice baselines, and baselines based on documented management activities (most plausible approach). However, the flexibility allows project developers to pick the most advantageous baseline, which may lead to over-crediting (Haya, 2023).

Additionality

For IFM projects, it is hard to distinguish additionality from baselines. Additionality (would the project activities have occurred without the offset income?) and baselines (what would have happened without the offset income?) are closely related questions. **ARB and CAR protocols combine them and treat all divergence from the baseline as additional**, while ACR and VCS use separate baseline and additionality assessments (Haya *et al*., 2023).

IFM methodologies propose 4 tests to validate additionality (Table 8). Each methodology requires to validate between one and three tests. The four-prong to validate additionality test are:

- They exceed currently effective and enforced laws and regulations,
- They exceed common practice in the forestry sector and geographic region,
- They face a financial implementation barrier,
- They validate a performance test.

<u>Definition of performance test for each standard to demonstrate additionality</u>

CAR/ARB: "Forest Projects must achieve GHG reductions or removals above and beyond any GHG reductions or removals that would result from engaging in Business as usual activities".
Verra: "Projects must exceed the region-specific performance benchmark for each impact parameter & project must exceed the baseline value".
ACR: "To establish the performance standard for this methodology, project activities under this methodology were evaluated in relation to common practice and ACR implementation barriers (common practices analysis and financial and institutional barrier)".The performance test is based on the definition of the baseline. This generally involves achieving a carbon gain (GHG reductions or removals) greater than the baseline and sometimes greater than a regional average (Verra). In the case of IFM projects, the performance test is therefore automatically validated.

ACR and LBC methodologies require to exceed regulations, exceed common practices, and face a financial implementation barrier (a NPV analysis can be carried out in the LBC) to demonstrate additionality. The demonstration looks strong on paper but needs to be reviewed to see whether it is useful (is it really necessary to validate 3 tests to demonstrate additionality?) and effective (is it only strong on paper or does it really guarantee the additionality of the projects).

VCS uses two additionality tools for its forestry projects, which both closely mirror the Clean Development Mechanism (CDM) approach to additionality testing. Landowners must demonstrate that the project is not the most cost-effective land management approach or that other barriers would have prevented the landowner from carrying out the land management credited under the offset project. The landowner must also demonstrate that the credited land management approach is not common practice. In general, these tests have proven to be insufficient in ensuring the additionality of CDM projects (Haya, 2010; Cames *et al*., 2016).

Box 3: controversy surrounding REDD+ projects which are often over-credited because of a false baseline

In January 2023, the Guardian[8] revealed that more than 90% of Verra's credits from REDD+ (Reducing Emissions from Deforestation and forest Degradation) projects were "phantom credits" and did not guarantee any real emissions reductions. This 9-month study by the Guardian, Die Zeit and Source Material is based on an analysis of scientific studies on Verra's rainforest projects.
Among other things, the study revealed that:

-Only a handful of Verra's rainforest projects showed evidence of deforestation reductions, according to two studies, with further analysis indicating that 94% of the credits were not actual emissions reductions.

-The threat to forests had been overstated by about 400% on average for Verra projects, according to the analysis.

In August, the study that gave rise to this investigation was published in Science by West *et al*. They analysed 26 projects on 3 continents. They found that most of the projects did not significantly reduce deforestation, and for those that did, reductions were significantly lower than claimed (West *et al*., 2023).

The study uses a standard method in empirical economics, which consists in identifying a control site which was comparable to the project site before the project but did not benefit from the project. Once this tricky "matching" site is found, the statistical analysis is the same as for clinical trials: the effect of the treatment – that is the project – is the reduction in deforestation rate that is higher than what is observed in the control site.

In this study, control sites were identified for 18 out of 26 projects with sufficient publicly available information on baseline deforestation rates. Only one project's baseline was lower than the selected control site, and only one project's baseline was similar to the control site. All other ex-ante baselines predicted more deforestation than estimated ex-post based on control sites. According to the projects'

[8] https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe

ex-ante estimates, up to 89 million carbon offsets could potentially have been generated by these 18 REDD+ projects through 2020. By replacing the ex-ante baselines adopted by the projects with the deforestation observed in the control sites, West *et al.* estimates that only 5.4 million (6.1%) of the 89 million expected offsets from REDD+ projects would be associated with additional carbon emission reductions.

Furthermore West *et al*. argue that: "*Ex-ante baselines that exaggerate the deforestation that would occur without REDD+, likely facilitated by methodological flexibility in their construction and exacerbated by adverse site selection, are a major reason for the gap between projected ex-ante offsets and actual offsets estimated ex-post*". The poor performance of REDD+ projects (inability to *de facto* reduce deforestation) may also be a factor.
They call for the methodologies used to construct deforestation baselines for carbon offsetting interventions to be urgently revised to correctly attribute deforestation reduction to the projects.

Following the survey, Verra had already commented extensively on the pre-publication in January. In particular, the organism questioned the methodology adopted by West *et al*., such as the choice of geographical sectors for controls with no threat of deforestation or satellite images with a resolution that was not precise enough.
Verra has again published a response to the study[9]. Verra argues firstly that the size of the study sample (26 projects), when 93 projects are currently certified, is insufficient to reach a conclusion (an argument already put forward in January). They also highlight the role of scientists in improving these methodologies, and the REDD+ methodologies have been revised, with new versions published in November 2023.

Baselines that reflect current carbon stocking of the participating parcel are usually more conservative than broad regional averages (Haya, 2023). On the other hand, individual baselines tend to be more flexible, and thereby carry higher risks of manipulation by project proponents. A recent meta-analysis finds that the balance of both risks leads to preferring standardized baselines, although this finding remains laden with substantial uncertainty (Saint-Cyr *et al*., 2023).

Furthermore, several studies identified asymmetric information as a pervasive, inherent problem in baseline setting for IFM projects. Asymmetric information creates uncertainty for the program administrator and third-party verifier but not the project developer, who implements a project with full information (van Kooten *et al*., 2009; Asante and Armstrong, 2016; Gren and Aklilu, 2016).

4.3.3. Leakage: heterogeneous evaluation

Leakage is assessed in most of the methodologies where the harvest of timber is reduced in the project compared to the baseline. Rates of leakage vary a lot.

[9] https://verra.org/response-to-new-west-et-al-study-in-science-magazine/

Table 9: leakage evaluation for a selection of methodologies

Methodology	Standard	Leakage evaluation
Improved Forest Management (IFM) on Non-Federal U.S. Forestlands - v2.0	ACR	Calculated according to the decrease in total wood products produced by the project relative to the baseline: - if less than 5%, L=0 - if between 5 and 25%, L=10% or 20% according to the type of owner - if more than 25%, L=30%
Human-induced regeneration of a permanent even-aged native forest 1.1	ERF	No assessment
Balivage (conversion from coppice to high stand forest management)	Label Bas-Carbone	No assessment
Replantation on a stand affected by a forest fire	Registro de Huella de Carbono	No assessment – considered null
Methodology for Conversion of Low-productive Forest to High-productive Forest - v1.2	Verra	Assessment grid with discount between 0 and 70%. If leakage are outside the country: 0%.
Improved Forest Management in Temperate and Boreal Forests (LtPF) - v1.2	Verra	Choice between different assessment tools with discount between 0 and 70%.
Improved Forest Management Methodology Using Dynamic Matched Baselines from National Forest inventories - V1.0	Verra	Leakage factors varying between 10 and 70%

5. Conclusions

Carbon certification has the potential to create significant incentives for forestry projects with mitigation benefits via sequestration in the forest and storage in wood products. This analysis shows how existing or future improved forest management methodologies can be improved (particularly in the context of the European carbon absorption framework) to bring them into line with the scientific literature, in particular to limit the risk of over-crediting, but also to take better account of the effects of climate change in the management of non-permanence risk or to improve the integration of sustainability issues.

There are currently at least fifty forest certification methodologies in the world and nearly fifteen improved forest management (IFM) methodologies. IFM projects have generated 193 million carbon credits since the first credits were issued in 2008. This represents 28% of all forest carbon credits and

11% of all offset credits generated. Furthermore, most of these credits were issued in the United States under ARB certification (80% of credits).

Our analysis of these IFM methodologies, drawing heavily on the study by Haya *et al.*, (2023) identifies four key messages:

- The main risk identified lies in the establishment of the baseline, the direct consequence of which is over-crediting. In order to reduce this risk, it is necessary to change the way baselines are determined. All methodologies, with the exception of the CAR-Mexico protocol, offer substantial flexibility in setting project baselines. Where there is flexibility, project developers have a financial incentive to choose the option that generates the most credits. Several changes to the methodologies could result in more accurate and conservative baselines:
    - Choosing baselines close to initial carbon stocks to avoid adverse selection. This type of baseline allows landowners to change their land management practice (compared to the past, present, or other similar lands dynamically), rather than for not changing it.
    - Using dynamic baselines which are adjusted ex-post by comparing the outcome of the project to changes in similar areas without projects.
    - Not giving project sponsors a choice in defining their baseline, to limit information asymmetry and uncertainties with the risk of over-crediting.

  For these reasons, the most important avenue for improvement in project monitoring does not lie in state-of-the art sensors and monitoring technologies, but rather in more careful guidelines on baseline setting, using both theoretical and empirical knowledge from economics (e.g.. information asymmetry, selection bias, and how to minimize their effects).

- As regards the practices implemented, the methodologies focus on a few practices around conservation and avoided degradation. A diversification of practices could propose more innovative methodologies of Climate Smart Forestry (Nabuurs *et al*., 2017) including enhanced thinning of stands leading to additional growth and higher quality raw material, risk management strategy, regrowth with new species, planting of more site-adapted species, and regeneration using faster-growing species but requires an assessment of the biodiversity issues at the selected sites. Moreover, the current observation that conservation-oriented projects and methodologies dominate may also mean that the more technical options above do not store enough carbon to offset project costs.

- Current and future advances in remote sensing techniques could facilitate certain advances in quantification, for example by facilitating the selection of reference plots, which are essential for dynamic baselines or by monitoring changes in soil carbon that are often excluded in methodologies.

- Regarding the management of non-permanence risk, the methodologies likely under-allocate credits to the buffer pool, in large part because they do not adequately address the increasing risk of reversal due to climate change. Larger buffer pool deductions along with regularly updating the protocols based on the latest science would help to address this issue. Methodologies may also consider incentivizing, and avoid dis-incentivizing, practices that reduce carbon in the short run but increase resilience in the long-run, like thinning and fuels treatments that reduce the risk of catastrophic wildfire.

- Regarding sustainability aspects, there is significant heterogeneity between methodologies: some do not include any sustainability criteria, and when they do, the approach is very different from one standard to the other. Guidelines for integrating and measuring environmental and biodiversity issues could be drawn up to ensure greater consistency between methodologies and greater transparency for projects.

6. Next steps for INFORMA

Based on this work, we have pre-identified several methodological "innovations", which could help improve forest carbon MRV. Those "innovations" will then be discussed within task 5.2, and one to three of them will be chosen for further analysis.

Potential areas for innovation	Problem description	Potential innovations and questions to explore
Quantification: soil carbon	• Soil carbon is hardly ever included within existing forest carbon methodologies	• Can we measure significant soil carbon change for IFM practices? • Is the measurement worth it (accuracy vs carbon gain)? • Is the measurement accessible for project developers (accuracy vs cost)?
Quantification: harvested wood products	• HWP are included in 2/3 of cases but there is a diversity of modalities	• Which products to promote? • How to deal with double counting risk?
Quantification: biomass	• Poor accuracy and uncertainty are linked to land-use accounting • Accuracy at all costs is not necessarily worth it • In the EC expert group for forestry, a combination of direct measurement, remote-sensing (RS) and modelling is recommended	• Is this combination relevant/worth it for forest biomass? Which contribution from each tool? • Could tools like look-up tables be a viable option? For which type of accounting (ex-ante, ex-post)?
Risk of non-permanence	• Current buffers are probably underestimated for future climate change impact • De-risking practices are not very represented and their effect if hard to demonstrate • Carbon projects are not always required to present climate adaptation criteria	• How to integrate CC impact within baseline and project scenario projections? In buffer design? • What tools are accessible to project developers? • Can we demonstrate the effectiveness of de-risking practices?

Baselines	• Baseline represents the main risk of over-crediting	• Can we have robust generic baselines for forestry? • What potential for dynamic baselines? Where and when is it possible? Is it worth it? Is it usable with any type of quantification method?
Sustainability criteria	• CRCF requires mandatory positive impacts on biodiversity, but there are no consensual indicators yet	• Explore the use of structural diversity as a biodiversity indicator for carbon projects. • Explore the relevance of IBP?
Eligible forest management practices	• Most practices are based on stock conservation, is there room for management practices in the EU?	• Compare with work from WP1 on forest management practices?

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