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Forest-Based Carbon Markets

Pitfalls and Opportunities

MAURICIO CÁRDENAS · JUAN JOSÉ GUZMÁN AYALA

Abstract

Forest-based carbon markets could become an important source of income for countries in Africa, Latin America and Asia-Pacific. Estimates indicate that under a high carbon prices scenario, the value of the forest-based carbon credit market could increase from US$1.3 billion in 2021 to US$25 billion per year by 2030. Apart from the climate and monetary benefits, forest based carbon markets also have pitfalls that must be avoided. Without the right institutions in place, at the national and local level, forest projects can generate negative externalities, such as population displacement, increases in food prices, and biodiversity degradation.

The value chain in carbon credits involves a number of high value-added upstream and downstream activities that tend to take place outside the countries where the projects are located. Industrial policies are required for host countries to receive a higher share of the revenue stream, including in areas such as structuring, monitoring, verification, and surveillance. Countries need to promote actions in labor training, research and development, and access to long-term capital. The paper proposes the creation National Carbon Federations as institutions to resolve several market failures, while preventing conflict, ensuring adequate savings of the additional income, and strengthen democratic governance. These organizations can also provide key public goods, so that local communities benefit from the development of carbon credits from tropical forests.

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Forest-Based Carbon Markets: Pitfalls and Opportunities

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1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC), reductions in deforestation and forest degradation have the potential to mitigate global greenhouse gas (GHG) emissions by 0.4–5.8 GtCO2e per year (IPCC, 2022), contributing between 1.2% and 18% of the emissions cut required to meet the 1.5°C warming goal set out by the Paris Climate Agreement (UNFCCC, 2019).[1] In addition to the climate effects, the "forest carbon economy" is also an economic opportunity for countries with jurisdiction over tropical forests, such as the Amazon rainforest, El Chaco and the Maya biosphere in South and Central America, the Congo rainforest in Central Africa, the Australasian rainforest in New Guinea and northeastern Australia, Sundaland in Indonesia, Malaysia and Brunei, and the tropical forests of the Indo-Burma region in South East Asia (Butler, 2020). All of them are uniquely positioned to reduce global GHG emissions and, in the process, accelerate their own development through project-based and jurisdictional opportunities in voluntary and compliance carbon markets.[2]

Nature-based solutions including the conservation and restoration of carbon-rich ecosystems, as well as improved land management, not only have a large GHG mitigation potential but can also become an important source of income as the protection of tropical forests transitions from an aid-based to a market-based model.[3] However, not all countries are equally positioned to benefit from the development of forest-based carbon markets. Only those able to put in place the right institutions and policies could benefit from the expected increase in carbon credit demand. In other words, the ability of countries to implement natural climate solutions will depend on the development of adequate governance and regulatory frameworks (Griscom et al., 2020).

At the same time, although there are significant revenue opportunities, forest-based carbon markets bring new challenges. Some of the risks that should not be overlooked include:

i. The uncertainty associated with the evolving nature of compliance and voluntary carbon markets (in other words, the uncertainty regarding the actual demand for carbon credits).
ii. The potential harm to vulnerable communities who currently inhabit and/or depend on forests for their livelihood due to deficient enforcement of land ownership rights,

1 A gigaton (Gt) is equivalent to a billion metric tons. CO2e is CO2 equivalent.

2 Project-based carbon credit issuance processes involves targeted efforts within limited forest areas to reduce emissions and enhance carbon sequestration. Jurisdictional REDD+ is a more comprehensive approach that integrates forest conservation, emission reductions, and sustainable development across larger regions. It aims to align various stakeholders and policies under a unified framework, often led by public authorities with participation from private and civil society actors. Voluntary carbon markets allow private entities to buy carbon credits voluntarily. Compliance carbon markets are regulated, requiring entities to combine emissions reductions and/or the acquisition of carbon credits to meet legal emission reduction requirements.

3 Protect refers to the prevention of loss of native ecosystems, restore refers to the expansion of native cover types, manage refers to avoidance of CO2 emissions or enhance carbon sinks though improved management practices that do not reduce agricultural and livestock production.

bureaucratic barriers to land titling for vulnerable communities such as indigenous peoples, and land grabbing.

iii. Negative downstream effects in agricultural markets as carbon markets begin to compete with land used for agriculture and livestock which could impact food prices and the demand for rural labor.

iv. The concentration of revenues on high value-added activities in the carbon market value chain in the hands of external intermediaries limiting the revenue perceived by rural entities and communities.

v. Negative externalities when large monocropping reforestation and afforestation projects cause the loss of biodiversity and ecosystem degradation and transformation.[4] A "carbon tunnel vision" could result in losses of plant, fauna, and fungi biotic diversity, and associated ecosystem services.[5]

Maximizing the opportunities and minimizing the risks associated with the development of carbon credit markets—including a carbon value chain—requires strengthening state capacity at the national and local level. In particular, it is necessary to:

i. Enhance the capacity of local governments, enterprises, and communities to capture a greater share of the revenues generated by the carbon value chain.

ii. Develop robust safeguards and procedures to mitigate the potential negative social consequences of poorly governed and executed carbon credit-generating projects.

iii. Avoid unintended consequences that affect the delicate balance of local ecosystems. It is necessary to anticipate strategies to price and/or protect biodiversity and ecosystem services within carbon credit market mechanisms.

The purpose of this note is to provide inputs for the design of governance and regulatory frameworks to preemptively address these challenges. The paper offers suggestions as to how these issues could be addressed to guarantee the growth of robust, just and liquid carbon markets, incorporating social and nature-related safeguards.

4 For example, an afforestation project that uses exotic and water-thirsty species such as eucalyptus trees to convert a large area of a natural grassland into a monocropped forest potentially altering ecosystem biophysical dynamics, functionality, and biodiversity.

5 The concept of the carbon tunnel vision, developed by Jan Konietzko from the Maastricht Sustainability Institute, refers to the scenario where "we solely strive for 'net' zero emissions while ignoring other sustainable development goals," leading to a potential disregard of climate policy as it relates to broader developmental goals (Achakulwisut et al., 2022).

2. Understanding the role of forests and carbon markets

Forests are essential not just as GHG sinks. They also ensure biocultural conservation, provide ecosystem services, and host the world's biodiversity. While aid-based forest financing was originally intended to conserve biodiversity and protect communities that depended on these ecosystems, the rise of compliance and voluntary carbon markets has made forests an attractive asset as sources of carbon credits. This new trend is shifting the balance between development-aid financing for forest management and conservation, and the carbon credit sector with the goal of optimizing credit production. An increasing share of forest financing is falling into commercial market dynamics and away from aid-based systems.

In the past, ministries of the environment typically invested part of their limited budgets in protected areas to conserve biodiversity and key ecosystems including forests, grasslands, and wetlands, among others. Interest from other areas of the government was very limited, while private sector engagement was almost non-existing.[6] Today, public (including planning, agriculture, and finance ministries) and private sector actors (including large corporations), are increasingly interested in market-based instruments for forest financing, which brings both risks and opportunities.

Why are tropical forests relevant to mitigate greenhouse gas emissions?

Jurisdictions endowed with carbon-rich biomes such wetlands and tropical forests, facing high levels of deforestation and land use change could particularly benefit from developing carbon credit markets. A carbon credit is a non-physical fungible good, analogous to a commodity.[7] It can be traded or used in exchange for the right to emit a certain amount of CO2e in a given period of time. To "originate" a credit an actor must prove a reduction in GHG emissions, either by decreasing positive flows of carbon to the atmosphere (such as those produced from the burning of fossil fuels) or increasing negative flows (such as capturing atmospheric carbon through the restoration of a carbon-rich biome). The key to understanding the value and potential of carbon credits for forests in tropical countries is to recognize the net positive flow of GHGs coming from the depletion of carbon

6 Public pressure and diplomatic negotiations on addressing biodiversity loss gave rise to the Convention on Biological Diversity (CBD) in 1992, a multilateral treaty ratified by 196 states, with three main objectives: i. the conservation of biological diversity, ii. the sustainable use of its components, and iii. the fair and equitable sharing of benefits arising from genetic resources (UN, 2023).

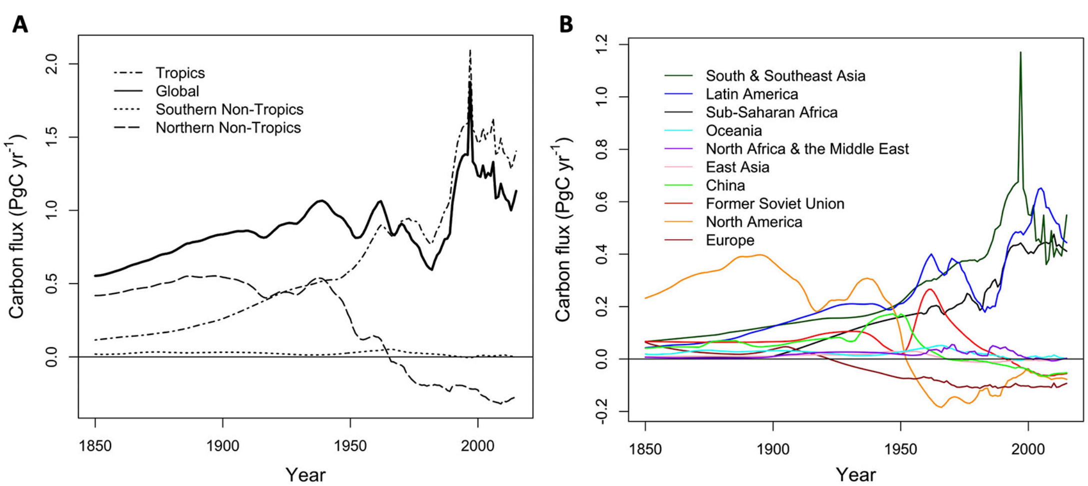
7 The debate remains on whether carbon credits are to be categorized as commodities or as its own asset class. While certain actors along carbon value chains do not distinguish between the origin and characteristics of a given carbon credit (treating it like a fungible good), others place differing values on the underlying attributes of a credit (treating it as its own asset class). Under mechanisms that align carbon credit projects, such as the United Nations Sustainable Development Goals (SDGs), the Warsaw Framework for REDD+, and corporate-specific goals that may include factors such as biodiversity and social co-benefits, carbon credits could be differentiated. Such an approach would result in systemic and idiosyncratic risks and demand-side preferences that differ from commodity dynamics.

stocks in tropical country biomes, and the net negative flows of GHGs from restoration and forest/ land management.

Net emissions from land use and land cover change (LULCC) are originated mostly in tropical regions as emissions in the northern non-tropics rapidly decreased and turned negative by the 1960s (Houghton and Nassikas, 2017) (See Figure 1).[8] GHG emissions in South and Southeast Asia, Latin America and Sub-Saharan Africa have increased since the 1950s due to land clearing and deforestation, and the harvesting of wood for industrial uses and fuel (Houghton and Nassikas, 2017). While LULCC emissions rates have decreased since the 2000s in part due to falling deforestation rates, net carbon flows from LULCC in tropical regions remains high at around 1.3 PgC/year.[9] Tropical jurisdictions can simultaneously conserve unique and biodiversity-rich ecosystems, protect communities that depend on them for their livelihoods and cultural wellbeing, contribute towards the global goal of limiting the planet's average temperature increase to 1.5°C above pre-industrial levels, and progress towards increased levels of human wellbeing and development through the use of carbon markets, if done properly.

An interesting case is that of High Forest Low Deforestation (HFLD) areas such as those under indigenous territories. Their participation in forest-based carbon markets remains in a limbo as there is a debate around whether credits generated from them meet the principle of additionality (Sebastian, 2022). Further developments are needed for HFDL jurisdictions to be able to access carbon markets, likely as a form of compensation for protecting large natural carbon reservoirs.

FIGURE 1. Annual net emissions from land use and land cover change (LULCC) globally for three latitudinal bands (A) and 10 global regions (B)



Note: Negative emissions represent removals of carbon from the atmosphere.
Source: Houghton and Nassikas, 2017.

8 Negative emissions represent net removals of GHGs from the atmosphere due to increases in carbon stocks in soil and vegetation.
9 A petagram of carbon (PgC) is equal to a gigatonne of carbon (GtC).

Additionality, permanence, leakage, and quantification integrity

Since the first carbon credits were transacted under the Clean Development Mechanism (CDM), established by the Kyoto Protocol in 1997, concerns have emerged on the highly technical complexities of measuring and accounting for GHG emissions and removals. Market transactions have used third-party certifications to ensure projects are "additional" and provide permanent reductions in GHGs to the greatest extent possible. Certifiers also need to assess the risk for leakage (See Table 1), and estimate unavoidable leakage to deduct the corresponding volume from the number of credits issued. While third-party certification has rapidly become the norm in carbon credit markets to mitigate the reputational risks associated with low quality carbon credits, recent analyses and public scandals have casted doubt over the real reductions achieved by certified projects suggesting they have been overstated (T. West et al., 2020).

Authors such as T. West et al. (2020), Guizar-Coutilño et al. (2022) and T. West et al. (2023) conducted extensive analysis comparing crediting baselines established ex-ante by projects in several jurisdictions against ex-post counterfactuals based on observed deforestation in control sites.[10] In one instance, the analysis of 12 Voluntary Carbon Standard-certified REDD+ (VCS)[11] projects in Brazil over the period spanning from 2008 to 2017, yielded no significant evidence that the projects had mitigated forest loss, and no systematic evidence that associated credits claimed are additional reductions (T. West et al., 2020). A broader analysis from 2023 that looked at 27 projects in six countries in three continents found similar results: most projects did not reduce deforestation, and reductions were substantially lower than claimed (T. West et al., 2023). Alternatively, a study from 2022 analyzing 43 VCS-certified projects found 30 projects achieved a 47% reduction in deforestation and a reduction in degradation in the first five years of each project's lifetimes (Guizar-Coutiño et al., 2022). These deviating conclusions are likely the result of methodological differences considering that control areas may not always be reliable due to their geographic location being distant from the project area as well as differences in key factors that drive deforestation such as forest type, economic activity, and neighboring agricultural practices, among others. Additionally, Guizar-Coutiño et al.'s (2022) analysis focuses on deforestation and degradation rates only, not specific conversions to emission reductions which is another source of controversy. Imperfect data sets and site-specific factors may also complicate the analysis of counterfactual scenarios.

Governments have argued that UNFCCC-specific guidelines and standards should suffice to guarantee the quality of carbon credits associated with both forest-based carbon projects and jurisdictional approaches. In the absence of robust regulations, accompanying legislation and, validated standards, measurements and verification procedures, actors in carbon market value

10 REDD+ is a framework created by the UNFCCC COP to "guide activities in the forest sector that reduces emissions from deforestation and forest degradation, as well as the sustainable management of forests and the conservation and enhancement of forest carbon stocks in developing countries" (UNFCCC, 2023). See below for a discussion on the interaction of REDD+ mechanisms with broader forest-based carbon markets.

11 The VCS program administered by carbon certification company Verra is the world's largest carbon crediting verification program applicable for both individual projects and jurisdictional programs (Donofrio et al., 2021).

chains may shift their preferences away from highly complex forest-based and opt to originate carbon credits with lower perceived risk (such as those from renewable energy projects).

TABLE 1. Quality problems in carbon markets

Quality Concerns	Description
Additionality	Additionality refers to GHG emissions reductions that are additional if they would have not occurred in the absence of a carbon credit generating project. If a project or jurisdictional approach is not deemed "additional," resulting credit would not reflect real reductions in GHG emissions, and their compensatory function would be invalidated.
Permanence	Permanence refers to the challenge of a carbon credit reflecting a permanent reduction in GHG emissions. For land and forest-related carbon credit projects, there is a possibility that carbon is stored in "leaky" reservoirs, meaning a project's permanence in storage is dependent on the integrity of the reservoir. If the soil, forest, or land in question were to be altered, a partial or complete reversal of GHG reduction or removal would occur invalidating the issued credits.
Leakage	Leakage occurs when carbon-reduction projects displace emission-causing activities and produces higher emissions outside the project boundary.
Quantification integrity	Calculation methodologies and data used to estimate carbon stocks and flows from complex ecosystems such as tropical rainforests are highly diverse and heterogenous in their accuracy and robustness. Factors such as soil composition, inter-specie interactions, specie makeup and populations, as well as geochemical flows and biophysical variation between ecosystems and geographic locations make the quantification of carbon flows a challenging process for which there is no standard and perfect answer. The integrity of underlying calculations that support the issuance of carbon credits remains as a source of idiosyncratic risk for carbon credits.

Source: McKinsey, 2020 and authors.

Concerns have gone beyond the technicalities of additionality, permanence, leakage and quantification integrity, and have begun to involve issues around production social and cultural safeguards, as well as consistency with government GHG emissions reductions registries to avoid double counting, among other issues (Taskforce on Scaling Voluntary Carbon Markets, 2021). Insurance, monitoring, and regulatory approval processes will become increasingly stringent in the carbon credit value chain as perceived risks become more salient, there will be greater scrutiny on the quality (Pearson et al., 2014).

3. Carbon pricing instruments (CPIs) and forest carbon finance schemes

Fundamentals of market and non-market mechanisms

At the core of the development of a market for carbon credits is the use of carbon pricing instruments (CPIs). Putting a price on carbon (a term used here to refer to GHGs in general) internalizes the social cost of anthropogenic climate change and creates the conditions for market mechanism for credits to emerge. As CPIs expand, forest-finance mechanisms have benefited from carbon markets.

Carbon markets—where demand and supply forces determine the price at which carbon units are traded—are one outcome of CPIs. There are two types of carbon markets: compliance and voluntary. Compliance carbon markets, commonly called emission trading schemes (ETS), follow a cap-and-trade model whereby regulated (compliance) actors, usually companies, are assigned yearly GHG emissions rights (serving as limits) and are allowed to choose a combination of i. direct emissions reductions by implementing new technologies and processes to reduce scope 1 and scope 2 emissions,[12] ii. buying rights for emissions they are unable or unwilling to abate from other regulated entities (referred to as offsetting), and iii. buy credits from non-compliance entities who choose to contribute their emission reductions to the compliance market. In contrast, in voluntary carbon markets, private actors choose to set emission caps/reduction targets internally and voluntarily, and trade with one another to achieve them. In the case of voluntary credit markets, "there is no such thing as a single 'marketplace,' but rather a diverse and growing landscape of exchanges and over-the-counter (i.e., bilateral) transactions" (Donofrio et al., 2021). Both compliance and voluntary forest carbon markets fall under the broad category of results-based finance where final credits are transacted on the basis of proven and certified emission reductions or removals (See Figure 2).

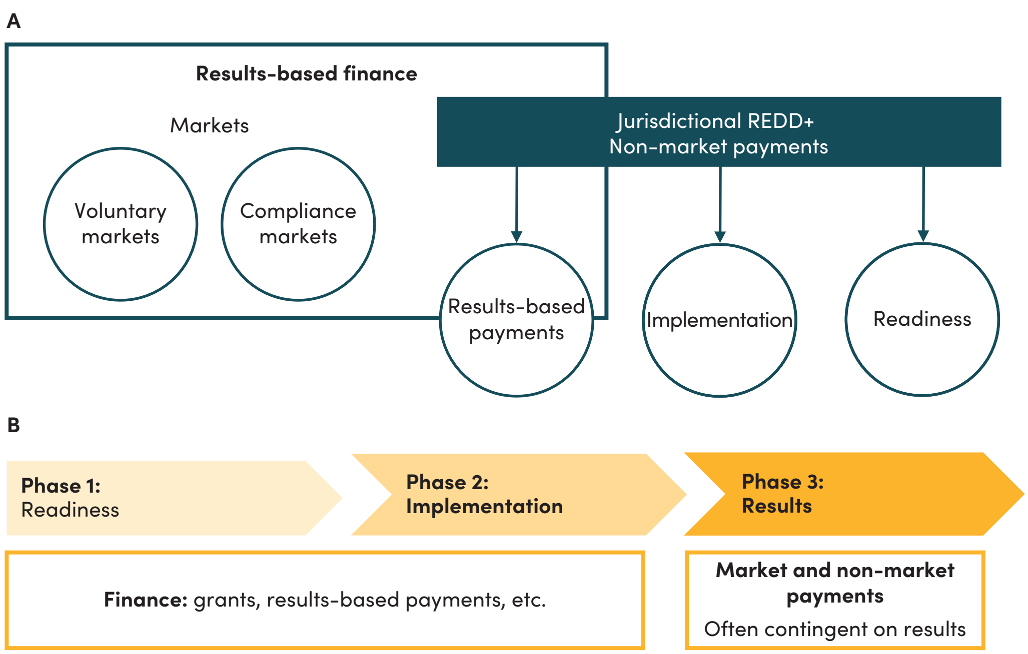
In addition to market mechanisms, forest carbon finance includes non-market approaches at both project and jurisdictional levels under the Reducing Emissions from Deforestation and Forest Degradation plus conservation (REDD+) framework created by the UNFCCC. The principles under which REDD+ projects are governed were agreed to at COP19 in Warsaw in December 2013, resulting in the Warsaw Framework for REDD+ (WFR). The WFR provides methodological and financing guidance for the implementation of REDD+ activities, including through the development of national strategies for REDD+, implementation of national policies for capacity building, technology development and results-based funding, measurement, reporting and evaluation systems (UNFCCC, 2023).

12 Scope 1 emissions refer to direct GHG emissions that occur from assets and processes directly controlled by an organization (e.g., emissions from company-owned internal combustion engine vehicles, steelmaking in a furnace, land clearing for cattle ranching). Scope 2 emissions refer to indirect GHG emissions from electricity purchased by an organization from a third party (e.g., electricity bought from a coal-powered plant operator). Scope 3 emissions refer to all other indirect emissions from purchased goods and services by the organization. Scope 3 emissions tend not to be included within regulated cap-and-trade schemes, particularly in long supply chains, due to the complexity in GHG accounting and attribution. However, newer voluntary schemes such as the Science-based Targets initiative (SBTi) is encouraging companies that commit to emissions reduction targets to include all three emissions scopes.

REDD+ activities proceed in three main phases, each of which may be accompanied by specific non-market financial flows (Donofrio et al., 2021):

i. Readiness: Includes payments and activities associated with the development of national strategies, plans, policies and measures, and capacity-building.
ii. Implementation: Referring to the implementation of the strategies, policies, plans and measures, capacity-building demonstration, and technology development/transfer activities following the readiness phase.
iii. Results-based payments: Financing flows contingent on verified emissions reductions, with most results-based payments under REDD+ coming from developed economies and multilateral/bilateral development finance institutions (DFIs). It is important to note that project-based REDD+ credits can also be transacted in voluntary markets, and REDD+ funding from the private sector has been increasing in the recent past.

FIGURE 2. Landscape of forest carbon finance markets, non-market payments, and results-based finance (A) and the three phases of REDD+ (B)



Source: Adapted from Donofrio et al. (2021).

Project-based vs. Jurisdictional approaches

Unlike project-based approaches, jurisdictional approaches tackle deforestation and forest degradation at a large scale with baselines being defined at a national or subnational level (i.e., a state or province) instead of a discrete property level. Implementation measures go beyond conservation, restoration and forest management, and include policy development and enforcement (including access to credit and tax benefits), land rights protection and coordination amongst actors in timber, agriculture and livestock supply chains leading to a comprehensive governance of forest and land use across entire political territories (CIFOR, 2020; Donofrio et al., 2021; Seymour, 2020). Payments are made to national or subnational jurisdictions, usually governments, but increasingly to private sector actors controlling a large supply chain such as that of oil palm, as a form of results-based payments (Donofrio et al., 2021).

Another important distinction is that between project-based and jurisdictional approaches to forest finance. Project-based forest carbon finance approaches are often criticized for not being fit-for-purpose as they may be unable to fully address many of the underlying objectives of REDD+ including avoiding leakage, creating large-enough incentives to systemically reduce deforestation and forest degradation at a regional level, and ensuring social and environmental integrity standards. For this reason, climate negotiations and private supply chain initiatives are converging on jurisdictional-scale approaches.

Jurisdictional approaches bring several unique efficiency, measurement and governance advantages when compared with project-level approaches that have the potential of improving the reputation and quality of associated financial flows and credits issued:

i. By establishing a deforestation and degradation baseline across an entire jurisdiction using methodologies aligned with international reporting standards, the risk of baseline manipulation and overcrediting is lowered when compared with project-level approaches (Thompson et al., 2022).
ii. Monitoring across a whole jurisdiction allows for the displacement deforestation and degradation to be detected and accounted for (Thompson et al., 2022).
iii. Monitoring, reporting and verification (MRV) systems are often costly and technically complex. Expanding the scope for MRV to a whole jurisdiction allows for economies of scale to emerge as a single system may be able to cover what several project-based systems would at a lower cost and with greater efficiency.
iv. Since jurisdictional approaches are largely administered by national and/or subnational governments, political actors are incentivized to use policy, regulation, and enforcement tools to achieve reduced deforestation and degradation results. Benefits perceived by governments include new revenue sources, avoidance of protectionist measures by external buyers (like tariffs on products from areas with high deforestation) and reputational benefits. Jurisdictional approaches therefore modify the jurisdiction's political process by aligning them with REDD+ goals beyond the benefits of GHG emission reductions (Seymour, 2020). This has the potential of triggering large-scale and systemic changes that are harder to ensure with project-level approaches. One example is the policy-driven decreases in deforestation in countries like Brazil in the early 2000s (Boucher et al., 2013).

v. By directly involving the government apparatus and introducing accountability and safeguard systems that go beyond carbon-specific integrity standards (such as the equitable sharing of perceived benefits with local communities, the conservation of a jurisdiction's biodiversity, and the enforcement of land tenure rights), jurisdictional approaches decrease the risk of low quality carbon credits from being issued (Seymour, 2020).

While jurisdictional results-based payments have been proposed since at least 2005 when Papua New Guinea and Costa Rica formally introduced the creation of jurisdictional finance under REDD+ during COP11 in Montreal, specific marketplaces, systems, and payments to execute on the promise of jurisdictional approaches have faltered until recently. In 2021 Mozambique became the first and only country in the world to receive a $6.4 million dollar results-based payment from the World Bank's Forest Carbon Partnership Facility for reducing emissions from a jurisdictional REDD+ program in its Zambézia province (Favasuli, 2022).

Recent advancements in satellite surveillance, methodological robustness, and artificial intelligence have unlocked what used to be an insurmountable technical problem of measurement, reporting and verification (MRV) for large jurisdictions (Seymour and Busch, 2016). Nonetheless, lack of a critical mass of demand and supply for jurisdictional results-based REDD+ payments continues to limit its potential (Favasuli, 2022). New initiatives such as the LEAF Coalition promise to bridge this execution gap by establishing a mechanism that crowds-in public and private funding to facilitate transactions and secure a large-enough supply to satisfy public and private demand for jurisdictional-level carbon credits (Seymour, 2020). With the initial support of the governments of the US, UK, Norway and nine corporate actors, the LEAF coalition, and its associated Emergent Forest Finance Accelerator, TREES standard, and Architecture for REDD+ Transactions (ART) have secured a $1 billion dollar commitment to pay for 100 MtCO2e at a minimum price of $10 dollars per ton, with the goal of reaching 1 GtCO2e in yearly jurisdictional carbon credit transactions by 2025 (Donofrio et al., 2021). Government failures, lack of interinstitutional coordination, unrealized demand and supply, and greater maturity in carbon credit issuance, remain a challenge for the future expansion of jurisdictional approaches despite its promising potential.

Volume of forest carbon finance

Carbon markets have been developed mostly in response to compliance requirements (23% of global GHG emissions are covered under CPIs, the vast majority which fall under compliance mechanisms (World Bank, 2022)). As shown in Figures 3 and 4, compliance markets are significantly larger ($968 billion in 2022) than voluntary carbon markets (a mere $1.7 billion in 2022).[13] This is not surprising given the fact that voluntary carbon markets are in their infancy, motivated primarily by the need to respond to the preferences of consumers and/or investors.

13 Note the value for world voluntary carbon markets for 2022 is a forecast (Trove Research, 2022).

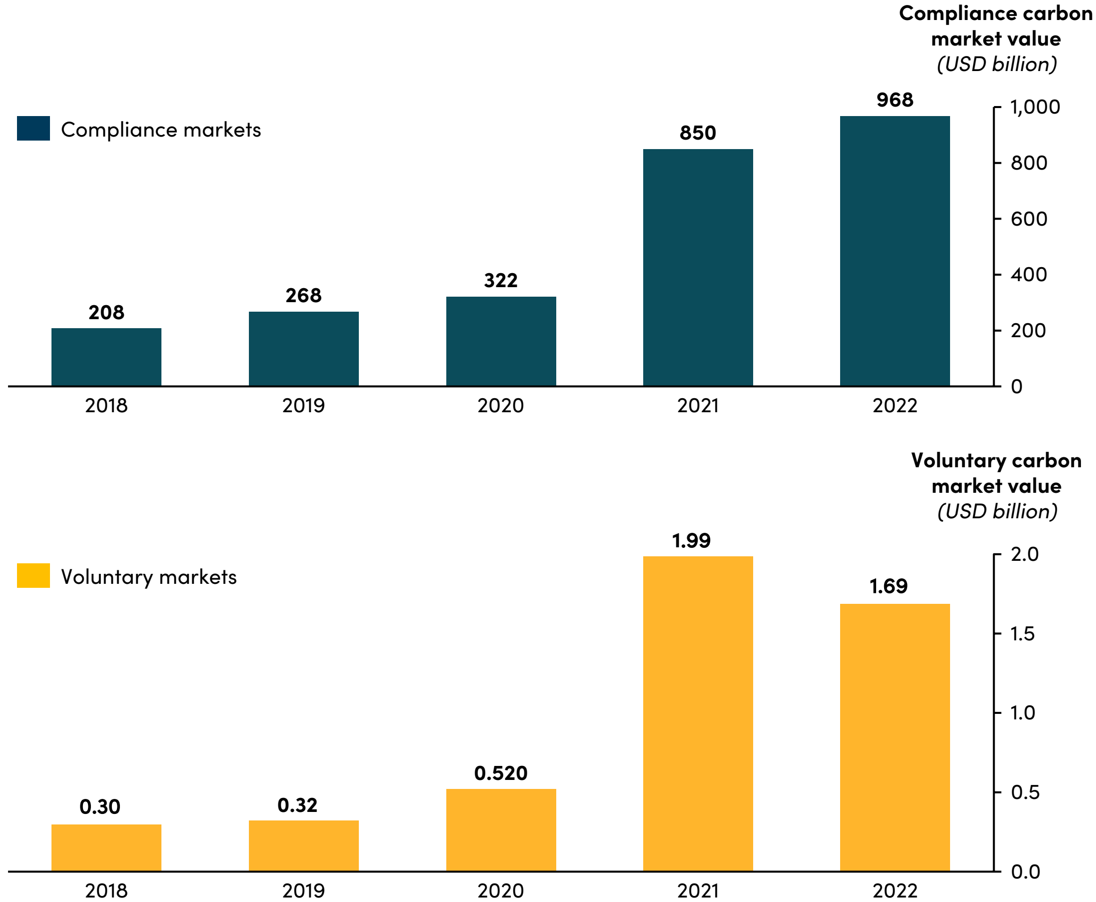
In the specific case of *forest-based* carbon markets the numbers are much smaller and voluntary markets outweigh compliance markets: $799 million in compliance markets for 2019 (latest available data) and $1,328 million in voluntary markets for 2021 (Donofrio et al., 2022; Maguire et al., 2021). Despite widespread skepticism for voluntary forest-based carbon credits, market transactions increased by a factor of 8.3 from 2019 to 2021, indicating a significant rise in demand (Donofrio et al., 2022). The fact that tropical forest-based carbon markets represent only a small share of the total carbon markets indicates that tropical countries have not been able to benefit from the production of carbon credits. This is likely due to regulatory concerns over the degree to which they represent "real" emissions reductions and protect affected communities from harm, compared to emissions reductions from other sectors (Seymour, 2020).

For voluntary forest-specific carbon markets, REDD+ remained the most dominant project type traded in the forestry and land use category in 2021 representing 65% of total transactions, continuing a historical trend (Donofrio et al., 2022). Additionally, pricing trends indicate that not all carbon credits are created equal, lending credence to the idea carbon credits are increasingly seen not as commodities but as a separate idiosyncratic asset class, with credits sold from projects with non-carbon benefits (e.g. supporting local communities and biodiversity conservation) having a price premium over the 2021 Ecosystem Marketplace Global Carbon Price benchmark of $4 / tCO2e, and ranging in prices from $5.05 to $9.34 / tCO2e (Donofrio et al., 2022). This suggests some actors are actively pricing ancillary development and conservation benefits of carbon credits at a premium.

Both compliance and voluntary carbon markets are expected to grow significantly. Compliance markets could surpass the trillion-dollar milestone in 2023, and continue their accelerated growth as existing ETSs expand and mature, and new ETSs become operational. In fact, the expansion of the base of regulated entities, the progressive decrease in emission caps, and the increase in the marginal cost of abatement (as "low-hanging fruit" for scope 1 and 2 emissions reductions are being exhausted) make trading more attractive.

In the case of voluntary markets, rapid change in consumer and stakeholder preferences (including investors) is placing significant pressure on companies to reduce GHG emissions. However, global voluntary carbon market transactions from forestry and other land use (FOLU) are still relatively small ($1.3 billion in 2021) when compared to multi-sector compliance markets more broadly (Donofrio et al., 2022; Refinitiv, 2022). The Taskforce on Scaling Voluntary Carbon Markets (2021) estimates that demand will reach 1–2 GtCO2e per annum by 2030, corresponding to a market size between USD $5 and $30 billion, depending on different price scenarios. Although aspirational, these numbers provide enough motivation to develop this opportunity.

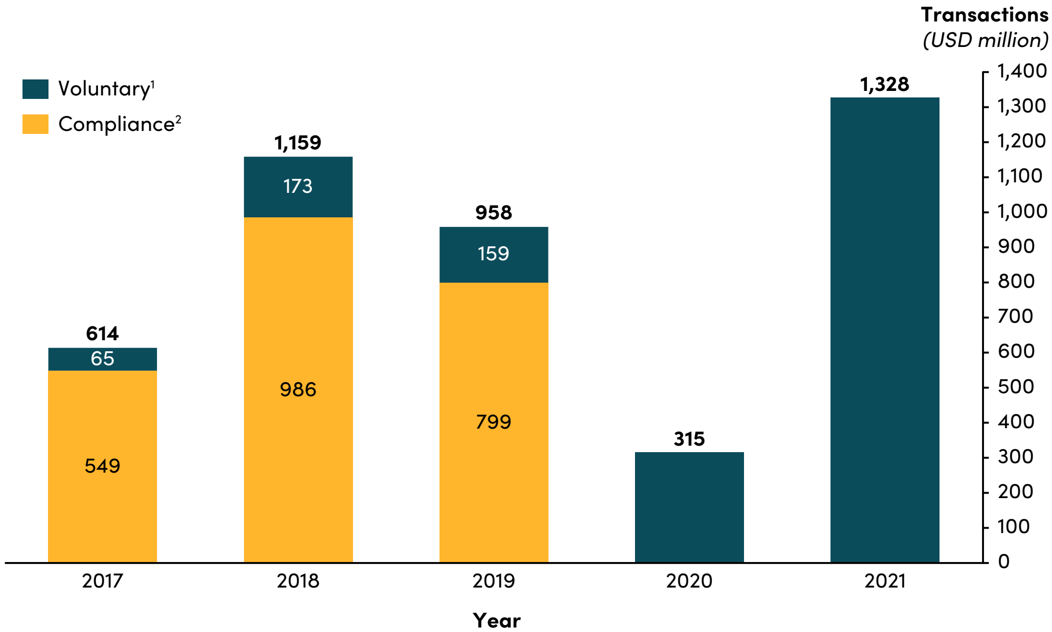
FIGURE 3. Comparison of world compliance and voluntary carbon markets, market value



Source: Authors based on available data from Refinitiv (2022) for the period 2018–2022 for world compliance markets, Donofrio et al. (2022) for the period 2018–2021 for world voluntary markets, and Trove Research (2022) for 2022 forecasts in world voluntary markets.

An additional factor to consider is the expected evolution of carbon prices (see Figure 5) which are still relatively low (ranging from EUR 5 in the China ETS and as high as EUR 65 in the UK ETS). In the future, carbon prices could dramatically increase benefiting countries with a comparative advantage in the production of carbon credits.

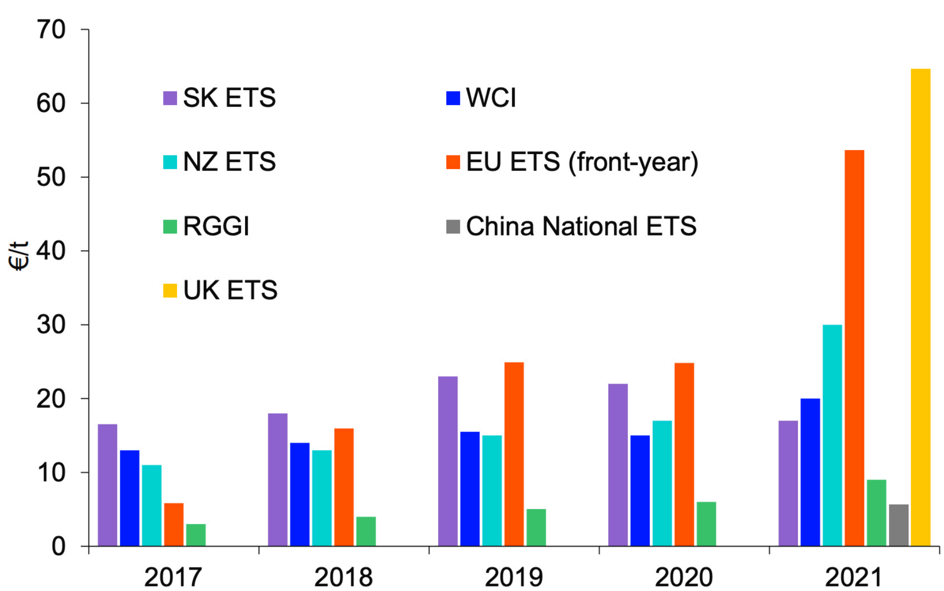
FIGURE 4. Forest-specific voluntary and compliance carbon market transactions



Notes: 1. Refers to voluntary carbon market transaction values in the forestry and land use category. 2. The data for forest-specific compliance markets includes value data for the New Zealand ETS, the Australian Emissions Reduction Fund, the Colombian Carbon Tax, the Korean ETS, the California-Quebec ETS, the Alberta ETS, the British ETS and the China sub-national ETS programs. It does not include other active ETS and compliance mechanisms, likely resulting in an underestimate for total global forest-based compliance transactions. No data is available for 2020 and 2021.

Source: Maguire et al. (2021) for compliance and voluntary forest-specific carbon markets for the period 2017–2019 and Donofrio et al. (2022) for voluntary forest-specific carbon markets for the period 2020–2021.

FIGURE 5. Annual average price per ton (local prices converted to Euros)



Source: Refinitiv (2022).

Although there is clearly an upside in the development of carbon markets, there are also some mounting obstacles that could derail these opportunities. In particular,

i. Markets are very illiquid (causing volatility in prices) as there are very few exchanges with high trade volumes.
ii. Lack of transparency to understand the pricing and underlying project details, especially in the case of over-the-counter transactions between two parties.
iii. Heterogenous buyer preferences that are not easily visible and aggregated into trading prices.
iv. Lack of standardization of different types of credits, making it challenging to adequately measure, compare and price ancillary benefits of underlying projects and jurisdictional approaches.

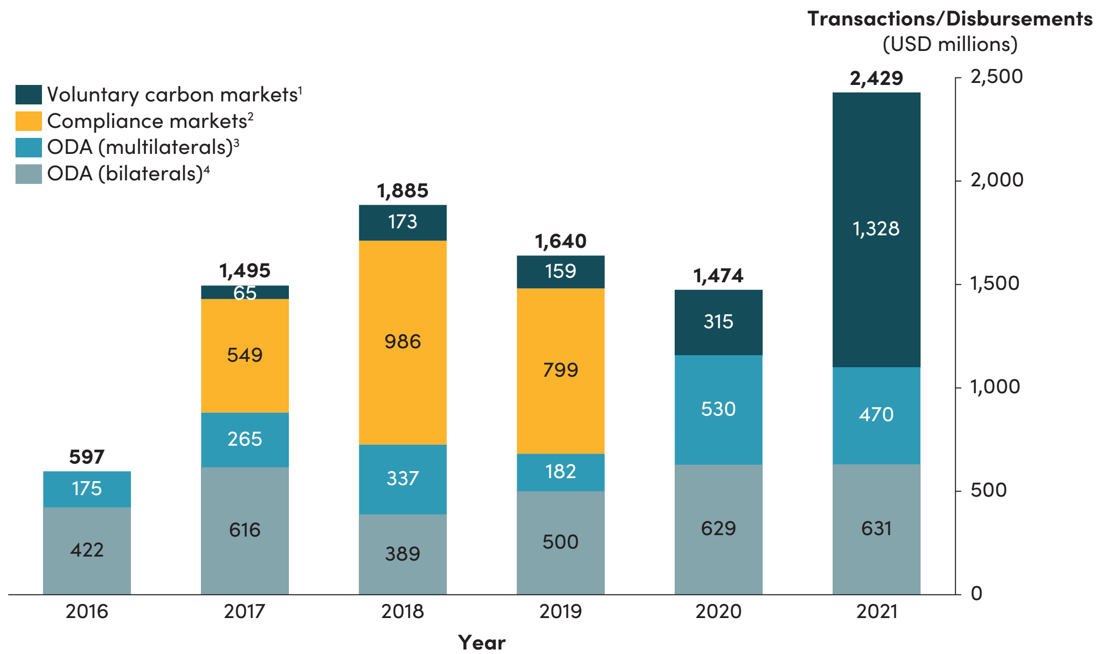
Compliance markets, due to their regulated nature, tend to be more liquid and have higher levels of transparency. Voluntary markets are highly decentralized and opaque, resulting in high risk for project developers (TSVCM, 2021). There is also the problem of green- and social-washing resulting in high levels of skepticism and perceived risk from the buy-side. Consolidating a robust supply-side with strengthened project pre-financing, regulation, scaling, and standards will be indispensable. This will be challenging for forest-based credits.

4. Developing forest-based carbon markets

The composition of financial flows geared towards conserving and managing ecosystems is changing rapidly. As shown in Figure 6, between 2017 and 2018 market-based mechanisms surpassed conventional official development assistance (ODA) as the leading source of forest financing, with market-based mechanisms representing 61.5% of forest-specific international funds reaching forestry projects in 2018. Given the significant rise in transactions in voluntary markets during 2021, this trend is likely accentuating. Note that while ODA is geared towards developing countries, voluntary and compliance market transactions include financing for both developed and developing economies. This comparison should be observed carefully as it does not necessarily indicate market-based mechanisms are surpassing ODA financial flows in developing economies. Further analysis is required to understand whether this broader trend is indicative of market-based mechanisms taking the lead in financing for developing economy efforts to halt deforestation and forest degradation. As discussed earlier, one potentially negative consequence of this trend is that the main focus of forest-specific projects is to optimize carbon-related indicators at the risk of displacing more holistic ecosystem-based and jurisdictional approaches towards forest management in line with the UN Convention on Biological Diversity (CBD) and REDD+ standards under the UNFCCC.

In 2022, at the CBD's Conference of the Parties (COP15), 193 governments failed to deliver strong targets on biodiversity and human health and clear indicators for biodiversity conservation (Wyns, 2023). This is particularly relevant in the context of the implementation of Article 6 of the Paris Climate Agreement which deals with the governance and rules of carbon markets.[14] Without clear biodiversity goals and measurement, parties negotiating the terms of implementation of Article 6 (which include market standard setters, regulators, and environmental authorities) will not be able to ensure that forest-based carbon credit instruments will be beneficial for ecosystems at large. Further discussions around the nexus between carbon market policy and biodiversity conservation are warranted to avoid the potential unintended consequences associated with the one-dimensional *carbon tunnel vision*.

FIGURE 6. Forest-specific voluntary and compliance carbon market transactions and ODA disbursements



Notes: 1. Data is only available for 2017, 2018 and 2019 for forest compliance carbon markets. 2. The data for compliance markets includes value data for the New Zealand ETS, the Australian Emissions Reduction Fund, the Colombian Carbon Tax, the Korean ETS, the California-Quebec ETS, the Alberta ETS, the British ETS and the China sub-national ETS programs. It does not include other active ETS and compliance mechanisms, likely resulting in an underestimate for total global forest-based compliance transactions. 3. ODA to the forestry sector includes disbursements that do not exclusively target forest protection. 4. Bilateral forestry ODA includes constant prices data for the 31 members of the OECD Development Assistance Committee (DAC).

Source: Authors based on voluntary and compliance market data from Maguire et al. (2021) and Donofrio et al. (2022), and ODA data from OECD CRS (2022).

14 Article 6 of the Paris Climate Agreement includes three operative paragraphs (6.2, 6.4, and 6.8), two of which relate to the governance and rules of carbon markets. Current discussions at the climate Conference of the Parties (COP) under the United Nations Framework Convention on Climate Change have so far been unable to reach an agreement in terms of the details governing the rules under which Article 6 will be implemented, limiting the potential for the expansion of inter-country trading of carbon credits and offsets, including those derived from forest-based projects (Ferrato, 2022).

This is especially relevant given the projections made by the Taskforce on Scaling Voluntary Carbon Markets (2021) which place total potential supply of carbon credits in the 8–12 GtCO2e/year range by 2030. The supply of carbon credits by 2030 is expected to come from four sources: (i) technology-based removal; (ii) additional avoided/reduced emissions from efficiency gains and other activities; (iii) nature-based sequestration and (iv) avoided nature loss. Nature-based sequestration (afforestation, forest, and soil management) and avoided nature loss (avoided deforestation and ecosystem degradation) are expected to contribute with more than half of the expected supply.

The estimated volume of credits could lead to a market size between $5–$50 billion by 2030. Lower-end values correspond to “a scenario where buyers purchase the historical surplus of carbon credits and then acquire the lowest-cost credits available” (McKinsey, 2021). The high-end estimate “represents a scenario in which most buyers opt to purchase credits from local suppliers only, even at a premium” (McKinsey, 2021), likely reflecting an absence of liquidity in international markets, thus forcing buyers to purchase credits in local markets even if they are sold at significant markups over international prices. Nature-based sequestration and avoided nature loss will roughly represent between $2.5 billion and $25 billion by 2030 of total carbon credit market transactions.

However, actual numbers can be much smaller as lags between initial investment and sale of credits limit the forest-based project’s financial attractiveness. Also, inefficiencies in credit quality certification can further reduce forest-based credit supply to 1–5 GtCO2e/year by 2030 (McKinsey, 2021).

In addition to concerns related to biodiversity conservation, the development of forest-based carbon markets requires active policies to ensure that an increasing share of carbon-related revenues is received by host countries and local communities. These are the issues discussed in the remainder of this section.

Transaction costs for project-based crediting

High-quality carbon credits produced from reduction and removal projects in carbon-rich land jurisdictions face high transaction costs. These include the costs of transacting and enforcing the contract between buyers and sellers (Lile et al., 1998). According to Dudek (1996) and Milne (2002), these costs include:

i. Origination
ii. Design
iii. Negotiation
iv. Approval
v. Implementation
vi. Insurance
vii. Verification
viii. Enforcement

Project origination costs include the search and identification of a potential area suitable for a high-quality carbon credit issuance. Design costs refer to the development of a project implementation plan given an area-specific biophysical and social context, as well as corresponding monitoring and verification protocols. Negotiation includes costs associated with brokering a transaction between buyers and sellers. Approval costs encompass regulatory, legal, and community compliance procedures required to approve a carbon credit project. Implementation costs cover expenses for labor, capacity building, selection of local contractors and sites, community meetings, technical and management plans, registration of lands and leases, distribution of funds to beneficiaries, and the distribution of planting material and associated inputs. Insurance costs include project risk insurance, and costs of insuring emission reductions. Verification and enforcement expenses are required to prove to investors and regulators the estimated levels of carbon that have been reduced or sequestered from the atmosphere.

According to Grafton (2021), estimates of transaction costs are highly uncertain because of different accounting practices and can be a substantial proportion of the overall costs of forest-based sequestration projects. Pearson et al. (2014) estimate that transaction costs can be as low as 0.3% or as high as 270% of the anticipated income of forest-based projects, suggesting significant variance in this regard. They also find that the three largest cost categories are: i. insurance (41–89% of total costs in voluntary markets); ii. monitoring (3–42%) and iii. regulatory approval (8–50%).

As discussed earlier, jurisdictional-based approaches may be able to resolve some of the issues stated above. Due to their large scale, the potential mobilization of policy and regulatory mechanisms and inter-actor coordination, gains from efficiencies and economies of scale may significantly reduce transaction costs if not outweighed by the accompanying increase in bureaucratic load. This, however, remains to be proved as jurisdictional results-based payments expand.

Value chain

Traditional carbon credit projects tend to be financed through emission reduction purchase agreements (ERPAs), "according to which an investor purchases the right to own the serial number of the registered carbon credits and makes front-loaded payments to project developers and underlying farmers/land owners" (Johnson, 2015). A relevant issue of concern is therefore the distribution of revenue and profits from carbon credit production, verification, and trading between actors along the nascent carbon value chain. This is an issue with the potential to be avoided at least in part by jurisdictional-scale credit generation as strong policy and regulatory approaches guarantee local governments, private sector actors and communities perceive a higher share of carbon credit revenues.

Assuming the continued growth of project-based crediting approaches, policymakers in carbon-credit producing economies will have to design mechanisms to be able to competitively capture high value-added activities. Without effective policies a limited percentage of the expected

$2.5–$25 billion carbon credit market by 2030 will be absorbed by producing jurisdictions. In order to avoid the dynamics of extractive industries, productive development policies (see below) are needed to strengthen domestic activities and the role of domestic players (such as State-Owned Enterprises) in carbon value chains, especially in the midstream stages.

The value chain of carbon credit can be split into three broad stages (Figure 7):

i. Land acquisition, project negotiation and management (upstream);
ii. Approval, measurement, and verification (midstream), and
iii. Insurance and brokerage (downstream).

Forest-based carbon credits from both reduction and removal projects naturally require the use of land, but significant components of the value chain are intensive in skilled labor and capital. These is the case of upstream and downstream activities, where most of the carbon credit's value is accounted. For example, measurement and verification are capital-intensive given the reliance on equipment such as satellites and land surveying technology.

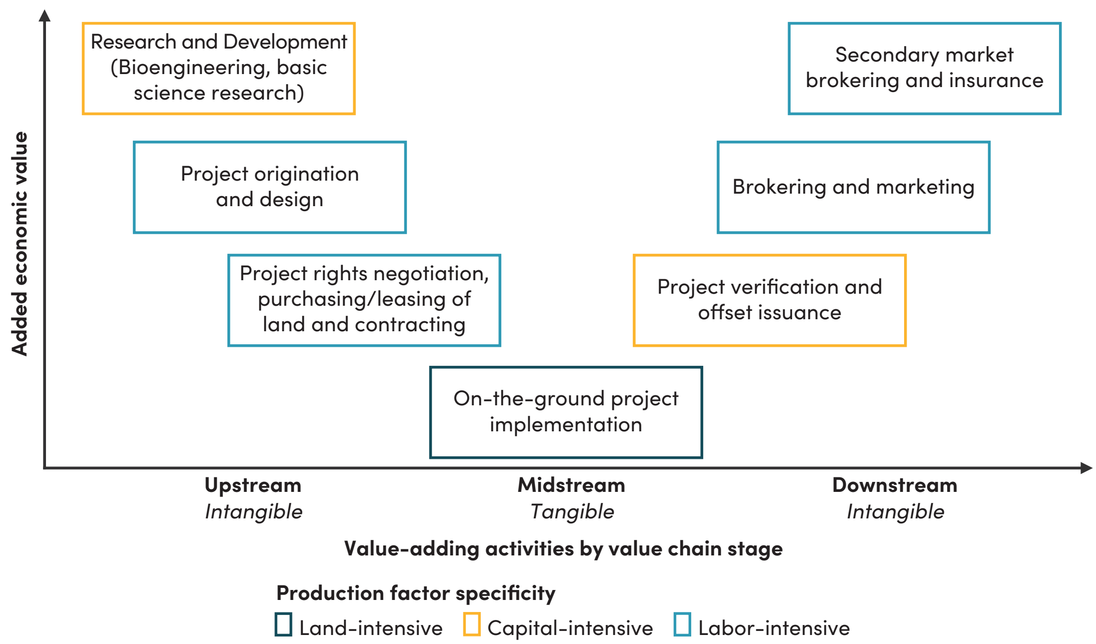
In countries where land for tropical forest-based projects is relatively abundant, and capital and skilled labor are relatively scarce, capturing the benefits of carbon credits can be difficult. This is specially the case when upstream and downstream segments take place in other jurisdictions, and where land represents only a small percentage of the total value of a carbon credit.

In the case of jurisdictional approaches, governments may undertake upstream and downstream activities and thus be able to capture a greater share of revenues from high value-added activities. Such a scenario would increase government revenues, potentially unlocking greater financing for public-led conservation efforts, welfare programs, and policy and regulation enforcement. This, however, assumes governments have the technical capacity (or appetite and ability to develop it) to conduct highly complex processes that demand capital and skilled labor. In developing economies national and subnational jurisdictions where technical capacity, human capital, and budgets are limited, this may prove to be a significant challenge. Readiness and implementation financing schemes under REDD+ would therefore play a key role in enabling governments to undertake this challenge, as they would directly engage in capacity building for local public institutions.

Alternatively, some governments may opt to outsource upstream and downstream services provisions to increase efficiency in jurisdictional carbon market service delivery (Poutvaara, 2020). To determine whether outsourcing is suitable, governments will need to tackle the question of whether they hold a natural monopoly over upstream and downstream services in jurisdictional REDD+ approaches. If a natural monopoly indeed exists, outsourcing may prove to be less suitable as it may result in quality problems (Poutvaara, 2020).

Midstream activities will likely be developed through public-private partnerships, the implementation and enforcement of policy, and/or private-level and community projects. Under certain scenarios, midstream activities could be categorized as "nested REDD+" where governments may transfer the right to generate credit ownership to private entities aligned with jurisdictional baselines and deforestation monitoring (Thompson et al., 2022), yielding a hybrid between project-based and jurisdictional approaches. Nesting is still in its infancy with no established definition and approach, likely resulting in a high degree of variation as jurisdictional approaches mature in their implementation and governments define their corresponding preferences (Thompson et al., 2022).

FIGURE 7. Location of value addition and production factor specificity in the forest carbon value chain



Source: Authors adapting from the Smile Curve conceptual framework (Mudambi, 2008).

5. The interaction between land markets and carbon

Even if other factors of production take a large share of the value added in carbon markets, land is indispensable in forest and land-based carbon credit projects. The expansion of carbon markets to meet voluntary and regulatory commitments and requirements will therefore introduce new pressures on markets for land in areas where deforestation and forest degradation is high.

The main driver of deforestation in tropical countries is the increased demand for land resulting from the expansion of the agricultural frontier. Product types dominating the use of deforested land in tropical countries are beef, oilseeds (oil palm, soy, sunflower, etc.) and forestry products (paper and wood)—mostly export products-, each type responsible for 41%, 18% and 13% of tropical deforestation, respectively. The tensions between carbon credit production and agricultural exports are thus apparent.

For carbon markets to grow, the value of the marginal productivity of land used for the production of land-based goods must be lower than that of land used for removing GHG emissions from the atmosphere. In other terms, the real rent of land used for carbon credit production must be equal to or higher than the real rent of land used for agriculture/forestry. If the nominal value of carbon credits and/or the marginal productivity of land used for carbon reduction/removal is too low, agriculture/forestry activities may outcompete any carbon pricing mechanism. Depending on local conditions such as land abundance and the specific productivity of land in reducing and/or removing carbon (vs. productivity in agriculture), as well as international prices for carbon credits (vs. prices of agricultural goods) incentives to utilize land for agricultural/forestry production may rapidly change towards conservation and/or reforestation/afforestation, and vice versa. This, however, does not factor-in broader public services provided by forests in the form of ecosystem services where avoiding deforestation at a large-enough scale may prevent temperature, precipitation, humidity imbalances at a jurisdictional scale. Current agricultural activities do not widely measure or distinguish value generated from ecosystem services, thus preventing the pricing-in of ecosystem service benefits in agricultural markets.

Busch et al. (2019) estimate marginal abatement cost (MAC) curves for tropical reforestation and avoided deforestation in 90 countries.[15] According to their results, the top ten countries that could increase CO2 removals from tropical reforestation between 2020 and 2050 at a price of US $20 per ton of CO2 are Brazil, Indonesia, the Democratic Republic of the Congo, Mexico, Angola, Colombia, India, Tanzania, Mozambique and Thailand. These countries represent 55% of the total removals. The top ten countries for reducing emissions from deforestation between 2020 and 2050 at US$20 are Brazil, Indonesia, the Democratic Republic of the Congo, Peru, Colombia, Bolivia, Papua New Guinea, Republic of Congo, Venezuela and Malaysia. Latin America represents nearly half of the global reduction in emissions from deforestation at that price. It is also the region with the most low-cost potential for both removals from reforestation and reduced emissions from deforestation.

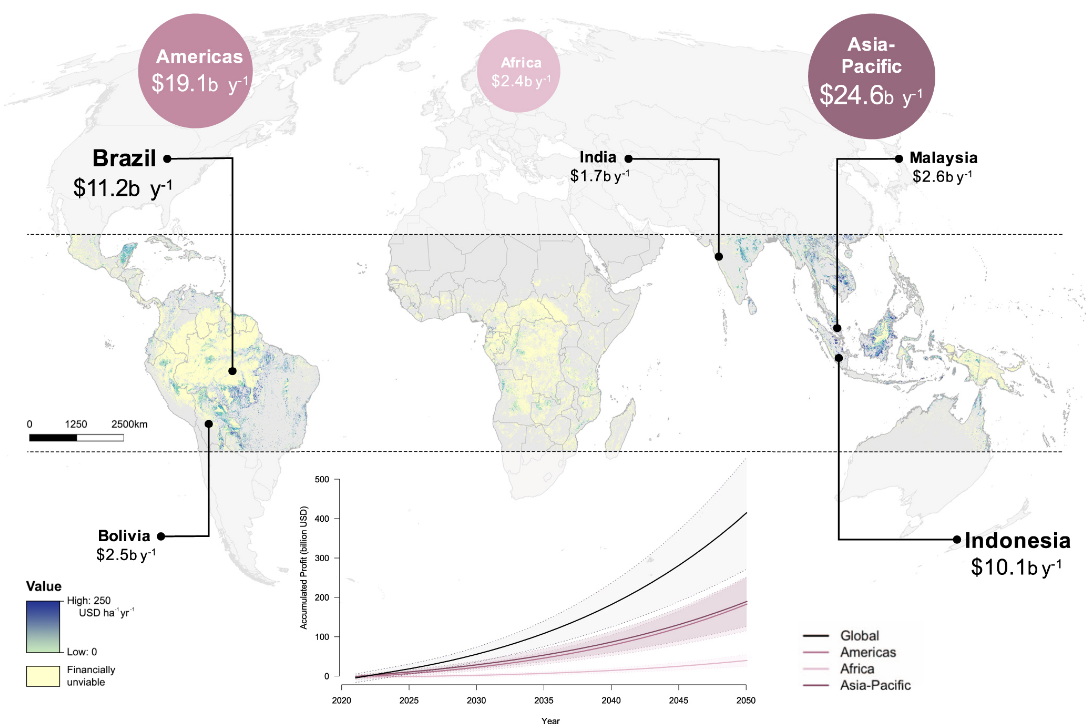
In the same spirit, Koh et al. (2021) calculate the prices at which carbon projects become financially viable in different jurisdictions. The study argues that as the nominal price of carbon increases, the percentage of land devoted to forest conservation increases at a decreasing rate (Figure 8). What this means is that the marginal increase in the nominal carbon price at levels roughly above $50/tCO2e will not necessarily represent significant gains in new land that becomes financially viable to dedicate towards land-based carbon reduction/removal.

Most land gains to make carbon pricing competitive vis-à-vis other land uses occur between the $0 to $25 price range. The calculation of investable forest carbon refers to the estimated total volume of CO2 associated with three carbon pools in tropical forests: aboveground carbon, belowground carbon, and soil organic carbon, while applying Voluntary Carbon Standard (VCS) criteria to account

15 Estimating costs is harder for reforestation than deforestation because it is a slower process. Also, CO2 removal from reforestation is subject to reversals due to harvest or natural loss.

for additionality concerns. To calculate the return-on-investment of forest carbon, the authors employ a series of simplifying assumptions, including the cost of project establishment at an average of $25/ha, annual maintenance costs of $10/ha and a constant carbon price of $5.8/tCO2e for the first five years, with a subsequent increase of 5% per year over the project's lifetime (30 years).[16] The opportunity cost is given by the rents associated with alternative land-uses from agriculture (based on 18 crops) and timber extraction (Koh et al., 2021). Areas where the opportunity cost exceeds the projected NPV for investable forest carbon are therefore excluded, resulting in a significant decrease in climate mitigation potential. The study suggests that at a price of $5.8/tCO2e, the vast majority of carbon-rich tropical forests remain financially unviable for the production of carbon credits (Figure 8). Figure 9, also from Koh et al. (2021), shows the net present values over a 30-year timeframe for the five countries with the highest potential (and estimates also for the regions). The accumulation of profits overtime at the global and regional levels, with shadings around the lines representing standard deviation is also of interest.

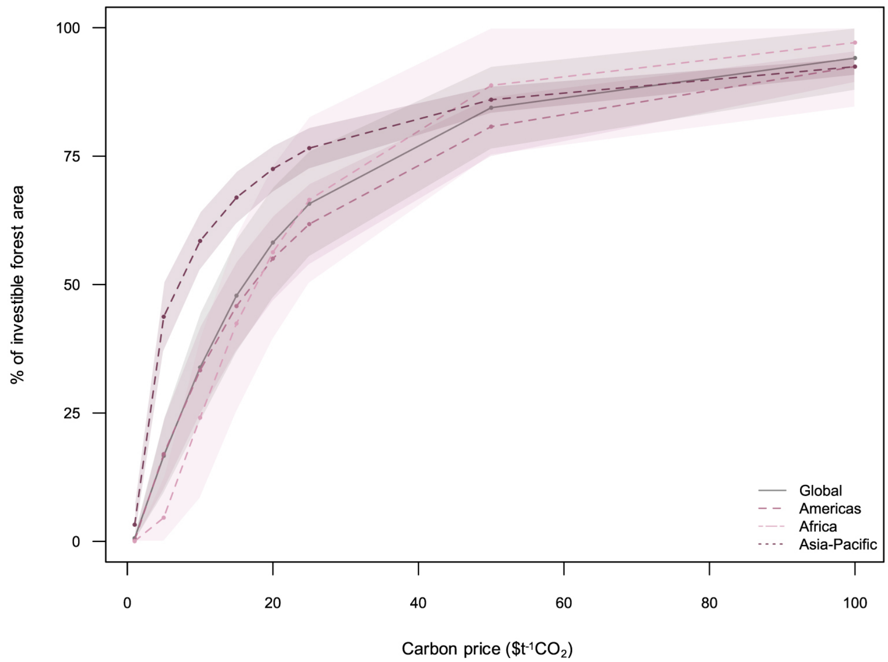
FIGURE 8. Global forest carbon return-on-investment from financially viable sites



Source: Koh et al., 2021.

16 Analyses such as those by Koh et al. (2021) do not tend to price-in positive externalities such as ecosystem services and biodiversity conservation, as well as hard-to-measure intangibles such as the cultural and intrinsic value of nature. They rather focus on calculating opportunity cost based on marketable private goods and services. Given the differing scope of jurisdictional approaches, public goods such as ecosystem services, and intangible assets could be priced-in within opportunity cost calculations changing the outcome of the analysis above.

FIGURE 9. Effect of carbon pricing on the financial viability of forest carbon sites[17]



Source: Koh et al., 2021.

Externalities

The monetization of forest and land-based carbon credits has the potential of generating both positive and negative externalities. Other than benefits resulting from the regulation of the global carbon cycle, forests provide ecosystems services such regulating climate stabilization through the biophysical effects of forest cover (decreasing temperatures and increasing humidity), that benefit areas beyond the scope of a specific project (or jurisdiction) with more stable precipitation patterns and decreased temperatures, both of which benefit agricultural activities and public health (Seymour et al., 2022). These biophysical positive externalities are not currently priced under most carbon credit trading systems, largely in part due to their public goods nature, thus undervaluing forest-specific (Seymour et al., 2022).

Forest-based carbon crediting is also a potential driver of negative externalities. For example, some reforestation projects are characterized by tree monocropping affecting environmental services such as the hydrological cycle and pollinator diversity. Another dimension to consider is the territorial disenfranchisement for local actors. Policies need to ensure that a rapid expansion of carbon markets does not result in negative effects on land, labor, and ecosystem service markets.

17 Graph indicates the proportion of investible forest carbon that are financially viable for carbon finance. Shadings around the lines represent confidence bands based on standard deviation.

One of the less understood effects is a potential increase in land competition with impacts on livestock and agricultural markets, including rural labor market dynamics.

While carbon credit markets represent a significant opportunity to attract foreign direct investment (FDI), increase exports, and decrease or even reverse forest-loss and ecosystem degradation, there are other potentially negative impacts that need to be assessed. There is evidence on the emergence of a "Green Dutch Disease" resulting from to the sudden influx of foreign exchange in undeveloped rural markets. In broad terms, these effects include issues related to corruption, land consolidation, and land grabbing. If not properly designed and implemented, projects can result in mass displacement of indigenous peoples, farmers and other historical inhabitants of the land in question. On a macroeconomic level, a boom in carbon credits can appreciate the currency, reducing the incentives to produce other tradable goods. This can negatively impact agricultural production.

Some preventive measures are needed to avoid a "Green Dutch Disease" from settling in countries with expanding carbon credit projects. While central authorities may be tempted to focus on the enabling environment for carbon credit projects on issues such as regulatory licensing and normative procedures, and the enforcement of property rights, such improvements are not sufficient. Much like it occurs with rents derived from natural resource extraction in certain countries, governments may be tempted to extract rent from the issuance and transaction of carbon credits, further entrenching rent-seeking patterns. A robust domestic market for carbon credits could result in a greater portion of total rents to remain denominated in the local currency, mitigating some of the consequences of the Dutch Disease.

Implications for Latin America and Sub-Saharan Africa

According to the analysis by Koh et al. (2021), initially minor increases in nominal carbon pricing could result in large areas becoming financially viable for forest-based carbon credit removal projects in South America and Sub-Saharan Africa (SSA). The question is then how will agricultural commodity value chains and land tenure patterns change If carbon prices reach high enough levels in the near future.

Land productivity in agriculture has largely grown in Latin America and SSA due to increases in the use of fertilizer, better practices and genetic material, and growth in the use of capital that expanded cultivated area per worker (Andrianarimanana & Yongjian, 2021; Nin-Pratt, 2015). Improved genetic varieties, growth in the use of feed and efficiency gains have also led increases in productivity in the animal stock (Nin-Pratt, 2015). Considering the competitiveness pressures of carbon price increases, agricultural and livestock activities in carbon-rich areas will either be slowed or fully halted once full price transmission takes place.

Productivity in land- and forest-based carbon credit projects has also changed. For reduction credits associated with REDD+, the two main determinants are (i.) the rate at which deforestation and degradation are occurring and (ii.) the carbon content of the specific area and ecosystem in question. Both factors are exogenous to the planning and implementation phases of the project, therefore limiting the impact of policy interventions in reduction-based projects apart from the establishment of more efficient enforcement mechanisms. Endogenous factors that determine the competitiveness of agriculture/livestock expansion versus reduction-based carbon crediting projects are therefore limited to technological innovation on the agriculture/livestock end of the spectrum, and improvements in the efficiency of conservation/area protection enforcement for REDD+ projects.[18]

A different scenario could be experienced under jurisdictional approaches where governments could develop fiscal incentives such as concessional credit, tax breaks, subsidies and other regulatory incentives that could aid in counterbalancing the trade-offs mentioned above.

Removal-based carbon credit projects differ significantly from reduction projects in terms of their determinants of productivity. Unlike REDD+ projects, removal projects are based on active reforestation/afforestation of deforested/non-forested areas, resulting in productivity dynamics very much alike those of forestry and timber operations. However, unlike timber operations where volume and quality of wood are the factors optimized, forest-based removal carbon credit projects target the volume of captured carbon as the main factor to be optimized over the project's lifetime. The efficiency at which a project developer can capture and store the largest amount of carbon in the shortest amount of time with the fewest number of resources becomes crucial.

Much like in the case of agriculture and livestock, determinants of productivity that are endogenous to an area are therefore technical in nature. To maximize the yield of tCO2e/ha/year, project developers can invest in i. improved genetic material that requires less care, is drought and excess rain resistant, and lower amounts of inputs; ii. improved soil management and tree planting mechanisms to optimize soil and vegetation carbon capture and storage, and iii. technology by which the project is monitored, verified and enforced. The consequences of such dynamics suggest that improvements in enforcement are highly effective in areas where deforestation is rampant.

A significant challenge faced by project-based approaches lies in the lack of incentives and resources for governments to improve enforcement capacity, particularly in sparsely populated and remote areas where the rule of law may be non-existent. Under conventional carbon market approaches, government enforcement capacity and appetite may remain lacking, making jurisdictional approaches attractive to align enforcement and resource-allocation actions with REDD+ activities. In areas where deforestation has already occurred, maximizing carbon yields make reforestation more efficient.

18 An example of potential improvements in productivity of REDD+ projects, is the introduction of satellite imaging technology to identify threat areas where deforestation is starting to take place to be able to tackle it at an early stage with fewer number of resources.

6. Productive development policies

The adoption and scale-up of new technologies that reduce carbon emissions is a new key domain of the *green industrial policy*, which entails the additional objective – vis-à-vis traditional industrial policy—of procuring environmental sustainability (Johnstone, Roggea, et al., 2021). The multiple market failures that cause deforestation and forest degradation and prevent reforestation provide a clear rationale for an active role of government. The inability of the market to adequately price the negative externalities associated with GHG emissions in these sectors lies at the core of the problem. In the specific case of forest-based carbon markets the main goal of government interventions is ensuring that the benefits associated with conservation and climate-friendly land management are adequately internalized.

A number of market failures pose significant challenges for effective solutions to the climate crisis. As mentioned by Stern and Stiglitz (2021), insufficient investment in R&D and innovation, and lack of access to long term capital create significant impediments to the specific projects that are consistent with net-zero emissions. Other market failures include the inability to internalize the co-benefits (including air, water and soil pollution) of investments that reduce GHG emissions.

A number, but not all, of these government interventions can be grouped into what can be called "productive development policies." After years in the shadows, industrial policy is back on the scene as an instrument to address climate change. Although the term can be misleading–in part because industrial production is an important cause of the climate crisis—, "productive development policies," "structural transformation policies," or "innovation policies" are certainly a central component in the policy menu to develop a dynamic forest-based carbon market.

Private actors underestimate potential returns to new climate-friendly technologies, so underinvestment tends to occur in the absence of bold government action. Policy instruments include de-risking projects. One way to do this is ensuring initial demand for carbon credits through domestic off-takers (which could be SOEs). Tax deductions and credits on sponsors of projects can be helpful, as well as spending on education and job training in the skills needed to develop this market. Direct budget support for equity investments and lending from domestic development banks can be critical by providing patient capital to support "mission-oriented" innovation and investment (Mazzucato and Penna, 2016; Detter, Fölster, and Ryan-Collins, 2020).

However, it is necessary to bestow these new policy instruments with frameworks to monitor and assess fiscal risks, as well as the best governance practices for state-led innovation policy (Aiginger and Rodrik, 2020; Cherif and Hasanov, 2019; IMF, 2021).

Some specific examples of what needs to be done include:

i. Develop the domestic supply of carbon-specific skilled workers.
ii. Improve the efficiency of measurement, verification, and enforcement mechanisms.

iii. Promote private or mixed ownership of enterprises that provide services to the production, issuance, and transaction of carbon credits.
iv. Encourage the development of a local market for carbon credits, including a role for SOEs as initial off-takers (domestic buyers of carbon credits) for project-level approaches, or national and/or subnational governments in the case of nested approaches.
v. Encourage the vertical integration and the network effects between different providers of services that are part of the value chain in carbon credits, whether through project-based mechanisms, jurisdictional approaches, or nested mechanisms.
vi. Provide income security and prevent the displacement of jobs for groups of the population that could be impacted by the transformation of agriculture/livestock activities into land-intensive carbon credit projects.

The need of effective PDPs should not minimize the importance of good governance for an effective deployment of climate mitigation activities. Griscom et al. (2020) consider the relevance of Worldwide Governance Indicators to conclude that a handful of countries (i.e., Indonesia, Brazil, India, Malaysia, Mexico, and Colombia) that have higher governance indicators (among countries with tropical forests), and strong to intermediate financial capacity (cost of implementation of natural climate solutions as a share of GDP is lower) and where there is also political will (reflected in ambitious Nationally Determined Contributions) are in an unique position to lead (with international co-financing) in the implementation of natural climate solutions.

Establishment of National Carbon Federations

The continuous industrialization of forest-based carbon markets is likely to amplify the volume and depth of the emerging socio-economic and environmental challenges described above.[19] These challenges while new in origin are not new in scope and resemble those of industrialized agri-food systems.

Challenges shared by agri-food and forest-based carbon value chains include:

i. *Producers taking the short end of the stick:* Opportunistic behavior in vertical market relationships where high value-added activities on both ends of the value chain (R&D in the upstream and retail and marketing in the downstream) result in an inequitable distribution of income and profits.
ii. *Land and community governance systems not aligned with market incentives:* Farmers and small-scale forest-based carbon "producers" (indigenous communities, peasants, and SMEs) often govern land and its uses through participatory, collective, and highly decentralized processes that prevent the utilization of economies of scale to rapidly improve the quantity

19 Industrialization in this context can be defined as a "particular way of organizing production assuming there is a constant process of technical and social change which continually increases society's capacity to produce a wide range of goods [and services]" (Hewitt & Wield, 1992).

and/or quality of the commodity being produced (agri-commodities or carbon credits) making them less competitive. This could result in their displacement in favor of large scale and consolidated private operations that can act more expeditiously to meet demand at lower costs.

iii. *Exploitation of informational asymmetries:* Much like in the case of specialty agri-food commodities (e.g., coffee and cacao), farm-gate buyers and offtakers may exploit a producer's absence of technical expertise on the quality and/or implications of a deal to unfairly negotiate the terms of a transaction. A coffee farmer may not know they hold high quality coffee and thus sell at below market-price levels much like an indigenous community may not know the full extent of the value of their activities in a REDD+ project. Lacking regulation and government oversight in contract negotiation and enforcement may also open the door for fraud.

iv. *Inequitable distribution of risk:* High price volatility and rapidly evolving regulatory environments (e.g., new requirements by the European Union for deforestation-free coffee production (Regulation (EU) 2023/1115, 2023); evolving ETS regulation worldwide), results in producers facing high price, financial and regulatory risk. The business characteristics of project intermediaries such as high trading volumes, wide access to diverse markets and access to financing provide them with risk hedging and management mechanisms that remain unavailable for highly disaggregated producers.

v. *Social and environmental protection leakage:* Social and environmental safeguard standards are highly heterogenous in scope depending on the specific certification being used to market agri-food commodities and carbon credits (e.g., Rainforest Alliance versus Smithsonian Bird Friendly for coffee and VCS versus TREES for carbon credits). This heterogeneity is further complicated by non-specialized markets that do not demand high quality commodities and credits. Differing market preferences and absent or deficient regulatory standards in both voluntary and compliance carbon markets, much like in agri-food commodity markets, may result in "social and environmental protection" leakage as a portion of produced credits do not meet strict social criteria (e.g., prior consultation and equitable benefit sharing) and environmental criteria (e.g. conservation of biodiversity).

Agricultural cooperatives emerged in the late 1800s as a form of vertical integration to, among other things, internalize the costs of opportunistic behavior in vertical relationships (Fulton and Giannakas, 2013). To achieve this, agricultural cooperatives form user-owned and managed businesses to provide services such as market access, crop processing and production supply and services procurement, including credit and financial services in the case of financial cooperatives. This model, while imperfect, has contributed to address bargaining power imbalances between buyers and farmers, access to finance, technical assistance provision, education and access to market and weather information. This model may serve as inspiration to tackle the challenges faced by tropical forest countries in need of forest-carbon industrial policy.

The creation of Carbon Federations as national-level cooperatives aggregating small-scale "forest carbon" producers such as indigenous communities, peasant organizations, rural and small-scale municipalities could serve as a mechanism to unlock the benefits of "industrialized" carbon markets for communities and stakeholders who are likely to be overlooked by broader policy processes geared at creating more liquid, efficient and transparent carbon markets.

Carbon Federations could be in charge of:

i. *Providing context-based technical assistance:* Scaling the delivery of technical assistance provision for members to optimize carbon and nature-based processes in their area of influence while addressing potential competing interests (e.g., agriculture and infrastructure development). Federations could comprehensively assess an area and develop land management plans with members that go beyond the optimization of carbon credit production and address the complexities of managing diverse landscapes from an ecological and socio-economic perspective. Additionally, technical assistance provision and advice could provide economy of scale savings for members that may otherwise be prohibitively expensive if procured on a piecemeal basis.
ii. *Meeting regulatory and voluntary standards at scale:* Intermediaries who develop carbon projects are often in charge of procuring quality verification processes while meeting their underlying requirements. A Federation could replace the role of external intermediaries and make this process endogenous to the ultimate beneficiaries of carbon transactions. Due to their potentially large scale, Federations could develop the necessary technical capacity and verification demand volume that would place them as actors able to engage in these highly complex processes.
iii. *Improving bargaining power:* By aggregating supply from carbon "producers," Federations could access both primary and secondary carbon markets at scale, eliminating the need for intermediaries bringing producers closer to local and international markets often found further downstream. The scale of Federations and the volume of credits they generate and transact would provide them with improved bargaining power in negotiating over-the-counter transactions with local and international counterparts, while politically it would give "voice" to the concerns and interests of producers in developing regulation by defining legitimate interlocutors that represent wide membership bases.
iv. *Providing risk management facilities for producers:* The establishment of price stabilization funds, factoring to address liquidity concerns of carbon transactions, the acquisition of exchange rate risk management products, and providing intelligence surrounding upcoming regulatory changes could all be mechanisms used by Federations to extend risk management support for members.
v. *Channeling incentives and access to finance at scale:* The development of carbon markets is increasingly calling for the articulation of fiscal incentives (e.g., tax credits for organizations mitigating emissions) with the scaling-up of credit and financial services provision.

Federations could serve as the central entity to channel those incentives to members and build a pipeline and portfolios of bankable projects that would otherwise be deemed "to small" for financial institutions to consider.

In essence, Carbon Federations would allow small-scale carbon "producers" to access the market opportunities and benefits currently only available for large-scale and sophisticated intermediaries, allowing a certain level of vertical integration that would promote both social and economic equity by bringing producers closer to markets and policy-making processes. Carbon Federation can also deal with issues of coordination failures, pervasive in the development of new markets.

Efficient, transparent, and democratic governance schemes will be fundamental for Carbon Federations to achieve the above while gaining and maintaining legitimacy for its members. Learning from the failures of more than 150 years of agricultural cooperatives will be key to develop systems of trust that translate into concrete socio-economic and ecological benefits for the communities Carbon Federations would represent.

Carbon Federations could serve as part of implementing entities of nested and jurisdictional REDD+ approaches when dealing with highly rural, disaggregated, and diverse landscapes.

The establishment of Carbon Federations offers a viable mechanism for addressing the inherent challenges in industrialized forest-based carbon markets, drawing inspiration from the successes and lessons of agricultural cooperatives. Through strategic vertical integration, these federations could democratize market access, enhance bargaining power, and implement risk management for small-scale producers, thereby fostering social and economic equity.

7. Conclusions

The development of forest-based carbon markets is increasingly seen as a significant opportunity for developing countries. This is specially the case of countries where the world's tropical forests are located in Africa, Latin America and the Asia-Pacific. Estimates indicate that under a high carbon prices scenario, the value of the forest-based carbon credit market could increase from US$1.3 billion in 2021 (Donofrio et al., 2022) to US$25 billion per year by 2030 (McKinsey, 2021). These are not small numbers, compared to other sources of export revenue.

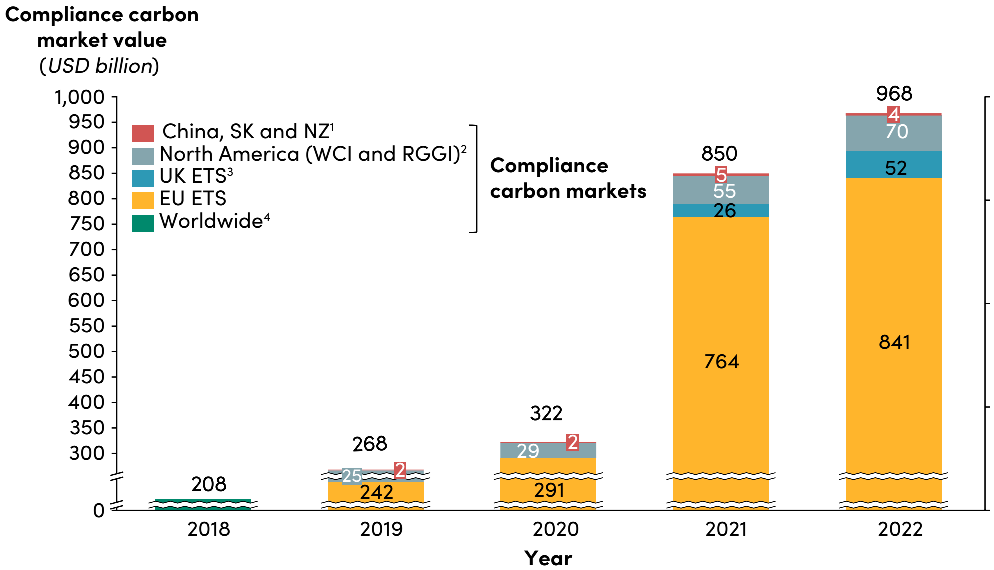
However, to achieve this outcome a more liquid, deep, and transparent market for carbon credits must be developed, and a number of barriers that generate significant transaction costs must be overcome. Governments interested in exploiting these opportunities need to actively engage in industrial policies in order to develop the various components of a complex value chain, that requires labor training, technological developments, access to long term capital, some of which may be achieved through the establishment of National Carbon Federations. Large SOEs (and especially

National Oil Companies) need to be engaged in these activities, including as off-takers of the carbon credits for their own carbon emissions reduction targets.

Forest based carbon markets also have pitfalls that must be avoided. Without the right institutions in place, at the national and local level, forest projects to avoid or abate emissions can generate negative externalities, such as population displacement, increases in food prices, the erosion of biodiversity, and potentially negative effects on indigenous and riverine communities. Also, other resource curse effects, such as corruption and the negative impact on the production of other tradeable goods, must be avoided. Similar to oil and mining, carbon credits could flood the economy with cash. To avoid a Dutch-disease effect, in addition to industrial policies it will be necessary to invest in institutions such as Carbon Federations that prevent conflict, ensure adequate savings of the additional income, enforce rule of law, and strengthen democratic governance. This means an active role for public-private partnerships, including adequate forms of taxation from this income in order to provide key public goods, indispensable for the successful development of carbon markets.

Annex

FIGURE A1. Composition of compliance market, by region



Notes: 1. SK and NZ refer to the South Korea and New Zealand ETSs. 2. WCI refers to the Western Climate Initiative a non-profit corporation which administers the shared emissions trading market between the American state of California and the Canadian province of Quebec as well as separately administering the individual emissions trading systems in the Canadian province of Nova Scotia and American state of Washington. RGGI refers to the Regional Greenhouse Gas Initiative, a power-sector ETS comprising 12 states in the United States. 3. The UK ETS began operating in 2021. 4. There is no disaggregated data by market segment for the year 2018.
Source: Authors based on available data from Refinitiv (2022) for the period 2018–2022 for world compliance markets, Donofrio et al. (2022) for the period 2018–2021 for world voluntary markets, and Trove Research (2022) for 2022 forecasts in world voluntary markets. Maguire et al. (2021) for compliance and voluntary forest-specific carbon markets for the period 2017–2019 and Donofrio et al. (2022) for voluntary forest-specific carbon markets for the period 2020–2021.

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