Valuing the hidden benefits of forest-based climate change mitigation

Summary

Forest conservation and restoration continue to be undervalued, underpriced, and underfunded. Financing for forests mostly focuses on climate change mitigation, valuing forests for their carbon storage capacity. With increasing attention on the importance of biodiversity, ecosystem services, and preservation of indigenous and local cultures, however, it has become clear that there are visible and invisible co-benefits of forests that are equally – if not more – significant than carbon alone. As such, we review evidence supporting an expanded valuation of forests, and assess practical examples to overcome this valuation gap. We do this by first offering an economic framework for our analysis, defining a *social cost of deforestation* (*SCD*). We then use this lens to assess a suite of opportunities to appropriately value and monetize forest co-benefits. These identified tools may help avoid suboptimal outcomes arising from a carbon-centric approach – supporting policy discussions, and unlocking expanded public and private finance for forests.

Keywords

forests, nature-based solutions, climate change mitigation, co-benefits, ancillary benefits, theoretical framework, monetization, ecosystem services, ecosystem valuation, total value capture

INTRODUCTION

Forests provide enormous ecological, economic, and social value (Fuss et al., 2021; Golub et al., 2018; Kappen et al., 2020). The contributions of forests to society include climate change mitigation, biodiversity protection, provision of ecosystem services, preservation of indigenous culture, and human health impacts (Watson et al., 2018). One estimate puts the total economic value of forests between US$50 and $150 trillion, with the upper limit being nearly double the value of global stock markets (Kappen et al., 2020). In addition, forests hold immeasurable intrinsic value for nature and humanity (Dasgupta, 2021). They are an immense natural asset that is essential to the balance of our earth and human systems.

The climate benefits of forests have received growing attention over the last decade, in both scientific and policy spaces. Forest-based carbon mitigation could play a particularly important role in stabilizing and reducing CO2 concentrations while the world transitions away from fossil fuels (Harris et al., 2021; Houghton & Nassikas, 2018). Recent studies support the notion that reforestation, avoided deforestation, and improved sustainable forest management are crucial strategic tools to prevent and reverse the worst long-term impacts of climate change (IPCC, 2019). These mitigation pathways are also the most readily available for implementation (Girardin et al., 2021); in particular, forest conservation offers a large percentage of potential mitigation among natural climate solutions (NCS) and is also among the most cost-effective of NCS abatement pathways (Roe et al., 2019). For these reasons, the climate benefits of forests have received growing attention over the last decade, in both scientific and policy spaces.

Incorporating these benefits into market-based decision making and policy priorities, however, can present a challenge. This is perhaps due to the time lag of these potential climate benefits from the moment of avoided deforestation, when pitted against conflicting priorities with more immediate and concentrated impacts (Lohmann, 2001). Yet these long-term climate benefits are not the only value that forest systems provide. The forest-based climate change mitigation pathways noted above provide biophysical, socioeconomic, and other co-benefits spanning biodiversity, human health, green infrastructure, improved governance, and other benefits yet to be fully articulated (Soto-Navarro et al., 2020). These co-benefits of forest-based climate actions provide a host of more immediate welfare effects, which provide significant additional incentives for decision-makers to deploy them (Ürge-Vorsatz et al., 2014).

Despite these diverse and enormous benefits, preserving global forests is proving to be one of the greatest challenges of our time, as the international community continues to unsustainably deplete their collective natural assets (Dasgupta, 2021). According to FAO estimates, over the last decade the world lost 13 million hectares per year – an area the size of Greece (FAO, 2020). This trend has mostly been driven by actors clearing land to support the expanded production of agricultural commodities (Curtis et al., 2018; Pendrill et al., 2022). In addition to the land use change driven by the conversion of forest areas for commercial purposes, significant forest degradation and value loss has also been driven by changing climatic factors such as drought, wildfires, and pests – factors which may have synergistic effects that worsen one another as further land conversion and climate change progress (Réjou-Méchain et al., 2021). On the current trajectory, one third of total forest value may be lost by 2050 (Kappen et al., 2020).

In response to these unsustainable deforestation and degradation trends, prominent global coalitions are working to mainstream recognition of the value of forests and halt their destruction. The Bonn Challenge, for example, aims to restore 350 million hectares of degraded and deforested landscapes by 2030. The New York Declaration of Forests sets out ten goals contributing to global forest conservation, such as livelihood support to local communities and improved forest governance. In addition, countries have voluntarily committed to restore over 230 million hectares of degraded forests in the next decade through Nationally Determined Contributions (NDCs) under the United Nations Framework Convention on Climate Change (UNFCCC) (Fagan et al., 2020). More recently, at the UNFCCC Conference of Parties in Glasgow (COP26), 141 countries representing over 90 percent of the world's forests committed to collectively halt and reverse forest loss and land degradation. These initiatives highlight awareness of multiple benefits of forests beyond carbon storage and sequestration[1], and that countries agree that curbing climate change must simultaneously promote the rights of indigenous peoples, gender equality, health, human rights, and more. This is also reflected through the Sustainable Development Goals (SDGs), which include multiple targets that forests contribute to such as addressing hunger, reducing poverty, and providing freshwater.

Despite the growing international recognition of the relevance of forest co-benefits for society, they remain undervalued, underpriced, and underfunded. The nature funding gap is estimated to be between US$598 and US$824 billion, meaning we need to be spending at least that much more to reverse decline in biodiversity (Deutz et al., 2020). As Costanza et al. (1997) put it, "because ecosystem services are not fully 'captured' in commercial markets or adequately quantified in terms comparable with economic services and manufactured capital, they are often given too little weight in policy decisions". Few widely accepted or implemented frameworks exist to account for them in policies and markets. The *social cost of carbon* (*SCC*), for example, omits economic impacts related to the loss of ecosystem services, essentially valuing them at zero (Druckenmiller, 2022). Meaningfully estimating the value of forest benefits can be technically and politically challenging; there are different ways to measure value, and forests hold different value for different actors (e.g., Cáceres et al., 2015). Moreover, attempting to articulate the value of forests in monetary terms can be contentious. Some critics, for example, argue that economic valuation is a distraction from a warranted focus on ending destructive and exploitative projects (Unmüßig, 2016).

In addition, the literature to date on the co-benefits of forest-based climate change mitigation activities is limited. Most such studies examine the services provided by certain forestry activities or forest types (Calvo-Rodriguez et al., 2017; Himes-Cornell et al., 2018). A global meta-analysis by Mengist & Soromessa (2019) found that co-benefits research has focused on provisioning, regulating and cultural ecosystem services, such as timber production, water supply, carbon sequestration, and recreation. Yet, while ecosystem services are essential to supporting biodiversity, research on ecosystem services does not typically include biodiversity indicators.

[1] The importance of forests to carbon storage and sequestration has also been formalized by the UNFCCC, first through the Clean Development Mechanism (CDM) under the Kyoto Protocol and later through the mechanism for Reducing Emissions from Deforestation and Forest Degradation (REDD+) under the Paris Agreement. The former made afforestation and reforestation projects in developing countries eligible for financing from developed countries because of their mitigation services, while the latter incentives countries to protect their forests through readiness and results-based payment programs.

Nevertheless, understanding the co-benefits of avoided deforestation is an essential foundation for mobilizing new investment to protect forests and the enormous value they provide (Sarira et al., 2022). They also provide an entry point for leveraging collateral investment (i.e., investment from secondary sources) for forests. Economic or social benefits shape the motivation of profit-seeking investors, public institutions, philanthropists, and impact investors to contribute funds in forest protection. The emerging carbon market, for example, highlights carbon as a primary benefit, yet buyers are increasingly focused on performance metrics beyond carbon (Goldstein, 2016). Similarly, climate finance donors, such as the Green Climate Fund, are increasingly requiring proposals to identify co-benefits. Clearer frameworks to discuss and define this valuation of forest co-benefits, and the link to social and economic outcomes, could help ease the adoption of the policies and market practices needed to bring these co-benefits the attention (social and financial) they warrant.

To advance this need, we explore how we can better reflect and communicate the full value of forest benefits in policy discussions. Specifically, we (1) bring together different concepts and provide a theoretical framework for analysis of the potential economic damages due to the loss of both forest carbon benefits and co-benefits, which we call the *social cost of deforestation* (*SCD*); (2) explore valuation of forest co-benefits in practice, focusing on high-level assessments and carbon crediting frameworks; and (3) propose some concrete ways forward that can be useful for policymakers and governments. Though we draw primarily from examples and our experiences working on tropical forests, the insights and lessons from this paper are also relevant to valuing other types of forests and ecosystems.

THEORETICAL FRAMEWORK

Defining forest co-benefits

We understand forest co-benefits as all the benefits to society provided by forest-based climate change mitigation. In most cases, these are additional benefits occurring in climate-positive activities where a primary aim is carbon sequestration. We take carbon and climate policies as our starting point because the implementation of forest activities are still occurring within a strongly carbon-centric framework, such as the REDD+ mechanism[2] and voluntary carbon market. At the same time, the emergence of co-benefits has occurred in the context of increased consensus around the need for forest carbon offsets to also provide other social and environmental benefits. Even among REDD+ stakeholders, however, there are three competing normative perspectives: carbon-centric (the primary aim should be carbon sequestration); carbon-centric with an emphasis on safeguards (the current approach adopted by the UNFCCC); and co-benefits-centric (which puts both carbon and co-benefits as primary goals of REDD+) (Vijge et al., 2016).

While there is no universally accepted classification of forest co-benefits, several scholars and institutions propose typologies of what these benefits could entail in the context of forest-based climate change mitigation. Katerere et al. (2015) propose three broad categories: social (improved economic livelihoods), environmental (ecosystem services provision), and governance (improved forest governance) benefits. Similarly, Lee et al. (2011) posit that REDD+ co-benefits can be classified according to five goals: conserving

[2] Reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries

biodiversity, protecting ecosystem services, community benefits, economic benefits, and adaptation needs. While these two typologies overlap in terms of environmental benefits, Lee et al. (2011) include adaptation needs and differentiate between economic and community benefits. They refer to economic benefit as the potential income stream that countries receive for REDD+ implementation, while community benefit refers to the direct livelihood improvement of local people and communities on the ground, where projects are implemented. Another third typology emphasizes the institutional benefits of REDD+, specifically the indirect improvement of governance (land tenure, law enforcement) and institutional capacities (Luttrell et al., 2018).

Relating valuation to monetization

Values refer to "norms that allow judging, individually or collectively, if something is good, beautiful, true, useful, moral, etc." (Salles, 2011). Valuation, the process of assigning value to goods, requires the development of frameworks for understanding how a potentially valued good should be judged against these norms. Valuation frameworks can serve as tools for rational decision making related to resource use, conservation, and the opportunity costs of one action over another. Economic valuation, and the decision frameworks that flow from it, usually have an anthropocentric focus – they are ultimately based on the impacts of choices and actions on human well-being, defined across various measures and scales.

Economic valuation is closely tied to monetization, as economic values are often expressed in monetary terms. Monetization is the estimation or conversion of the value of a good *into terms of units of currency* (Silvertown, 2015). Distinct from setting prices on a good, the process of monetization can allow the inclusion of benefits and costs in decision making frameworks that otherwise might be unable to capture them for consideration and comparison, especially frameworks considering large financial flows. Monetization can make intangible benefits more concrete for the purposes of such comparisons– in a sense, making the invisible visible on a balance sheet. But monetization, and the extent to which a monetized estimate reflects the 'true' total value of a good, is deeply shaped both by the depth of our understanding of the relevant benefits of the good in question, and by our ability to meaningfully convert these benefit streams to financial terms, through a diverse range of possible approaches.

Cost-benefit analysis has been increasingly adopted as a common framework for valuation over the last decades. Today, it often serves as a major basis for decision making within corporate finance and public policy, across many sectors and geographies. The popularity of this method may be rooted in its apparent simplicity – adding up estimates of a list of costs and benefits and then comparing. But particularly in the context of environmental decision and policy, where the benefits of a good or action may be intangible and distant compared to immediate near-term financial costs incurred by a decision-making actor, this framework can pose serious challenges. Effective cost-benefit analysis depends on comparable units of valuation; monetization is potentially useful to help bring otherwise intangible benefits into comparable units of a common currency. However, if the full value of certain environmental goods are not yet even fully understood and articulated, they cannot be adequately quantified for comparison, much less meaningfully and fairly monetized. In line with this concern, critics of the monetization of nature argue that doing so also reduces its intrinsic value (that is, perceived value in its own right) down to the insufficient monetary value.

Finally, as true market prices stem from an equilibrium between supply and demand, they are rooted in both a collective ‘willingness to pay’ for a scarce good – and in a collective *ability* to pay, which may or may not fully align with need or desire. Willingness to pay is also shaped by the information that a potential buyer has about a good, and what of that is salient to their decision-making processes. For example, an actor weighing a business decision to clear a forest and sell the timber may not be aware of the benefits of this forest to her local water supply and quality; she might value the forest more highly if she knew this– or, more importantly, if she understood the implications of the loss of these benefits for the future of her downstream aquaculture operation.

Understanding the *social cost of deforestation*

Carbon benefits, by default, currently play the role of the primary benefit justifying the core investment in forest preservation. Additional benefits justify the collateral investment, such as the positive return of transition from extensive to intensive cattle ranching (Golub et al., 2021). Over time, however, the value of individual benefits, or components, that constitute the total value of a forest may change. This can happen through various processes of land-use change, the most drastic being deforestation. As such, we introduce a new framework for capturing this change in value, which we call the *social cost of deforestatio*n.

Since the publication of a seminal article by Pearce (1990), economists have used the concept of the *total economic value* (*TEV*) of the forest to map use and non-use value derived from a range of forest co-benefits. We argue that there is rationale for a leap from just the economic value of forests to the social value of forests, which we understand as the *social cost of deforestation* as it represents the potential economic damage stemming from the loss of both carbon and other co-benefits (**Figure 1**). Similar to the *social cost of carbon*, which is defined as “the monetary value of the damage done by emitting one more ton of carbon at some point of time” (Pearce, 2003), the *SCD* reflects the net present value of the lost benefits from deforested land (damage). The concept of the *SCD*, however, is broader than the *SCC*. The *SCC* usually considers global damage, without concern for where the additional ton of CO2 was emitted. With the *SCD*, on the contrary, location plays an essential role in defining the value, which is a combination of global and site-specific losses.

Specifically, the *SCD* can be presented as a sum of three major components:

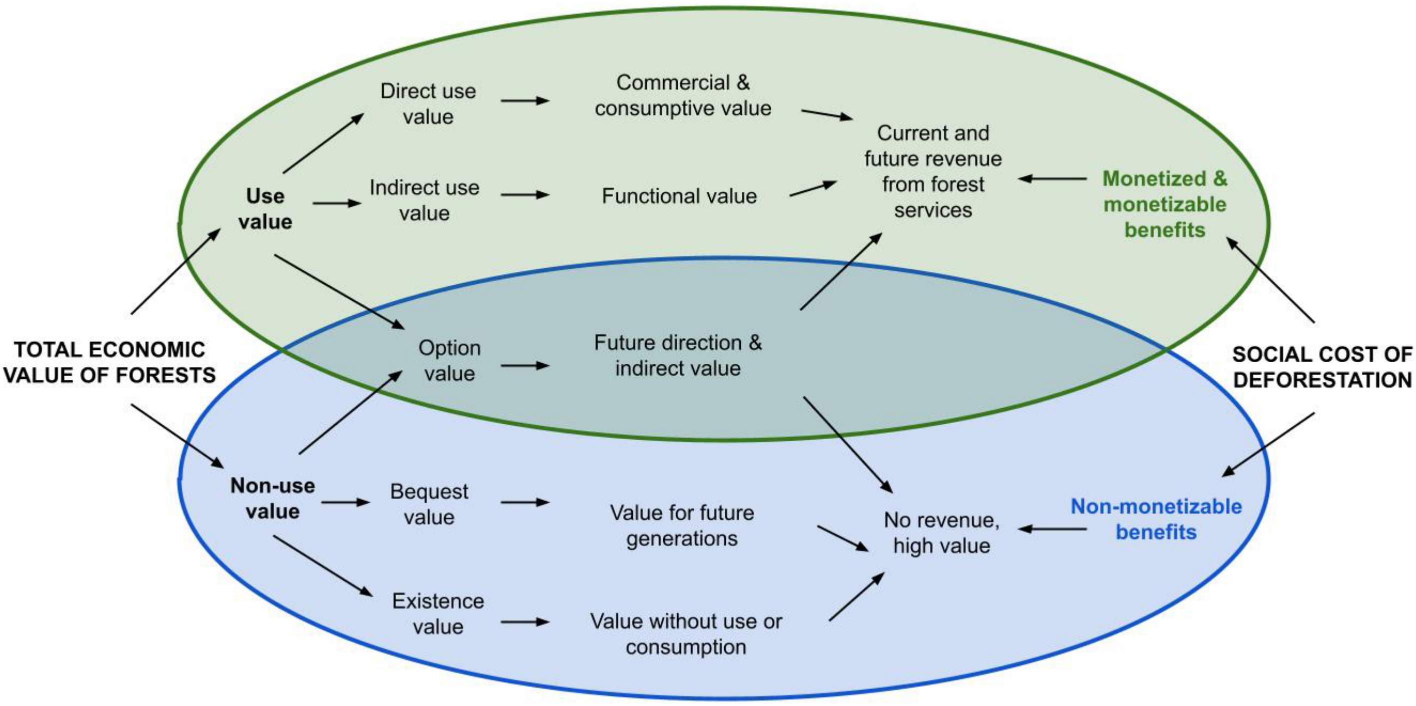
- Monetized benefits;
- monetizable benefits; and
- non-monetizable benefits that have a social value quantifiable in economic indicators

Monetized benefits reflect current revenue from ecosystem services provided by forests. These benefits create an economic barrier to deforestation that competes with other land use options that require deforestation. Examples of revenue streams created as long as the forest is preserved include sales of nontimber products, revenues from initial REDD+ intervention, philanthropic contributions, and conservation support from the government.

Monetizable benefits (but not yet monetized) include future revenues from trading high quality, high integrity emission reductions – which are likely to incentivize conservation and produce co-benefits on a large scale – for a fair market price. These include external benefits such as soil erosion prevention and watershed protection. These benefits could be monetized as a result of specific interventions targeting some or all of them.

Non-monetizable benefits may still have economic value but not be monetizable in terms of increased revenue or output. For example, health risk reduction, say, avoided mortality has a high economic value calculated as the value of statistical life but a positive economic impact on output due to preventing loss of labor is negligibly small relative to the economic value of social benefits of avoided mortality. Some benefits are intangible but should be taken into account even if their economic value cannot be calculated.

Figure 1. Expanding the *TEV* concept with the *SCD* concept. *Total economic value* separates most forest value into use or non-use values (adapted from Pearce et al., 2020). The *social cost of deforestation* provides a bridge to conceptualize the changes in forest value, and importantly, future potential value.



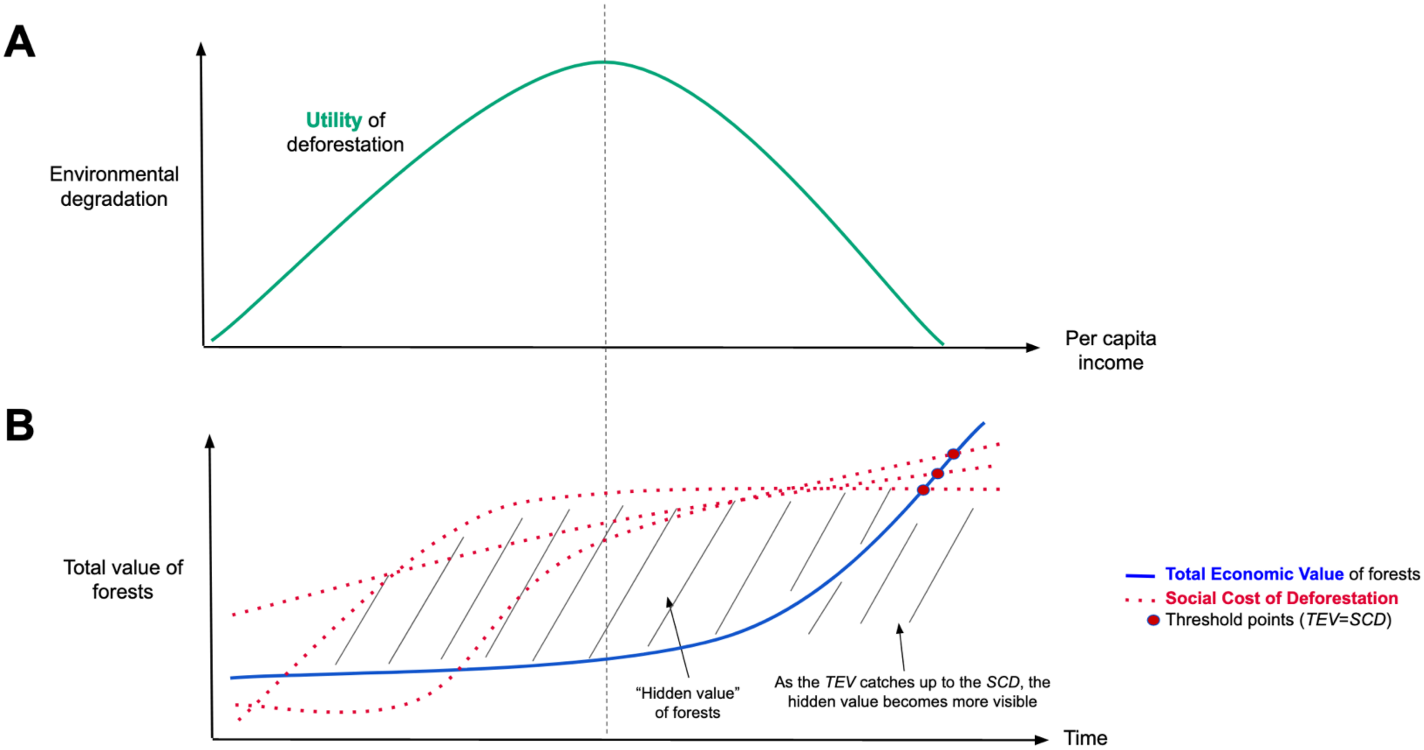
Because of the irreversibility of deforestation, taking a forward-looking analysis of benefits is essential. This allows for two complementary processes to be accounted for:

- Change in time value of different components of *TEV* of in more general terms *SCD*;
- Catchup of *TEV* with *SCD*

The literature on the Environmental Kuznets Curve (EKC) can help us to understand how these processes occur. The hypothesis of the EKC argues that an increase in per capita income first coincides with an increase in pollution but when per capita consumption reaches a certain critical level, pollution becomes a decreasing in per capita consumption function (Dinda, 2004). In other words, it postulates an inverted-U-shaped pollution dynamic – in our case the utility of deforestation – as a function of per capita income. As such, the changes in the value of *SCD* components are driven by transformations in the utility function of deforestation as the economic context evolves and transformations in the global and local ecosystems occur (**Figure 2**). For example, transformation of the utility function may lead to an increase in the relative value of the forest as a whole and changes in the relative value of individual components of ecosystem services. Different transformations take place on the global, national, and local levels.

As such, understanding local dimensions of co-benefits are essential to predict the reliability of local institutions in enforcing of forest conservation (including avoided deforestation, reforestation, and prevention of forest degradation) and realistic assessment of local participation. For example, when communities have a strong understanding of the multiple benefits of forests, and policy aligns with their values, they are more likely to comply with conservation policy and keep politicians accountable for enforcement of conservation programs and policies (Nurrochmat et al., 2019). This also suggests that region-specific *SCD* may be a good communication tool to encourage local authorities to contribute to forest preservation, as locally tailored *SCD*s can help regional institutions and decision makers understand the value of protecting their own forests.

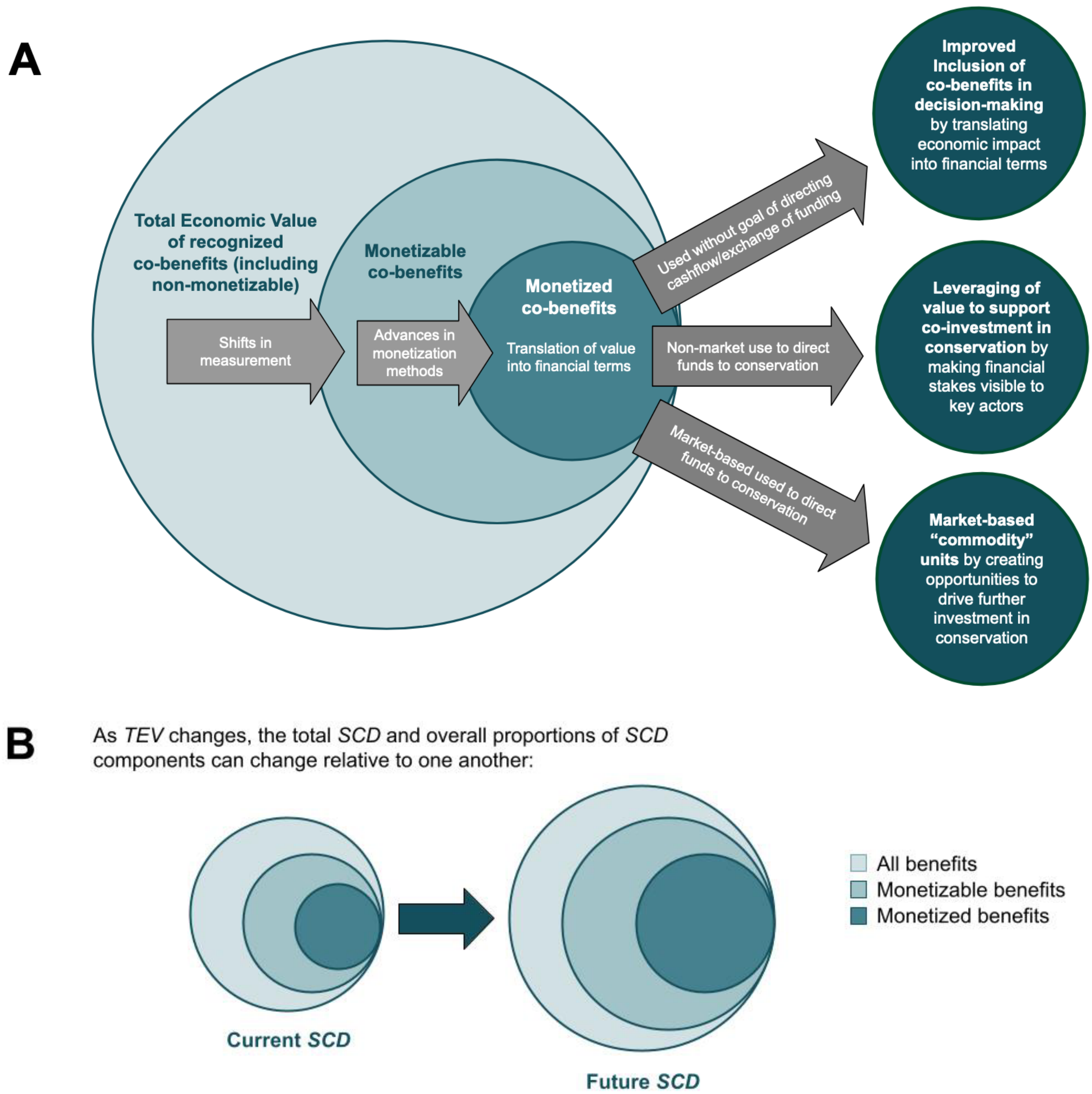
Figure 2. Illustrating *SCD* alongside the Environmental Kuznets curve framework. As deforestation increases (A), the *social cost of deforestation* increases because each unit of damage from deforestation comes at a greater cost to society (B); once deforestation peaks the *SCD* remains high because the value of forests has been recognized by society. As the gap between the *TEV* and *SCD* narrows, hidden value of forests becomes visible. The red lines illustrate potential trajectories for the *SCD*, though the possibilities are not limited to these three options; in reality, the trajectory of the *SCD* will depend on contextual conditions.



Furthermore, only a fraction of *SCD* values is monetizable or monetized, but this fraction changes over time. The social value of carbon changes over time, as does the value of biodiversity and other ecosystem services. The remaining values represent the non-monetizable benefits, in which case it may not always be necessary to assign a specific value to the benefit, but there could still be a cost associated with it. For example, with irreversible changes to the forest system such as the extinction of a species, the cost could be infinity if that species plays an important role in maintaining ecosystem functioning.

In addition, the share of different components (non-monetized benefits, monetizable benefits, and monetized benefits) also changes. For instance, the proportion of intangible/non-monetizable goods included in *SCD* is currently high. Due to changes in preferences and in response to increased scarcity of forested land, the *SCD* is likely to increase in time: advances in climate policy and building institutions to protect forests will likely increase the share of monetizable benefits; advances in the economic valuation of ecosystem services and increased demand for ecosystem services will likely also increase the share of monetizable benefits, revealing the “hidden value” of the forest. This transformation of *SCD* and changing share of its components are illustrated in **Figure 3**.

Figure 3. Transformation of *SCD* components. (A) Shifts in measurement create opportunity for forest value to be recognized as monetizable, some of which becomes monetized, or made visible in financial terms; (B) over time, overall *SCD* can change (e.g., increase) as can the individual components.



In the future, some previously unknown benefits of forests may also be revealed. This could happen if a new function or social value of forests is discovered. In this case, the process of transformation of *SCD* and its components might be more complicated. For example, imagine you have a national forest with protected upstream water resources. The total value of the resources in the forest are much larger than any economic benefit. As soon as authorities collect a fee from visitors, a fraction of the monetizable benefits becomes monetized. If authorities introduce water charges downstream, then another fraction of monetizable benefits is monetized. If, however, there is currently no monetization all external benefits are in theory, monetizable. As more benefits are socially recognized or discovered, the opportunities for monetization become endless, but this does not mean monetization will occur. In this sense, it is also possible that the gap between total value and monetizable value may never fully close and the non-monetized benefits remain; we elaborate on strategies for capturing the non-monetizable value in the **Outlook** section**.**

VALUING FOREST CO-BENEFITS IN PRACTICE

Representation in high-level assessments

Over the last two decades at least four leading scientific initiatives have attempted to compile and consolidate scientific knowledge on how ecosystems, forests, and biodiversity are valued globally (**Table 1**). Under the umbrella of the United Nations, the Millennium Ecosystem Assessment (MEA), the Economics of Ecosystems and Biodiversity (TEEB), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) all outline ways to estimate the value of nature. Similarly, the World Bank has been conducting annual assessments of natural capital accounting with their Changing Wealth of Nations (CWON) reports. These assessments are supported by international platforms for science and policy, which have potential to influence the development and trajectory of forest conservation investment globally.

Table 1. High-level assessments reviewed
[see end of manuscript]

The MEA was the first to highlight the challenges of estimating credible values for many forest services (MEA, 2005). The TEEB dedicates a full chapter to forests and proposes PES and REDD+ as measures to correct failures of markets to value biodiversity and ecosystems (TEEB, 2008). The CWON measures natural and human capital in the form of assets (World Bank, 2021). Similar to the MEA, critical services such as biodiversity habitat and species protection, cultural and/or existence values, or landscape aesthetics are not included in the CWON due to the lack of proper market equivalent values consistent with the wealth accounting methodologies. Carbon retention is another key ecosystem service not considered. Differently to MEA, IPBES recently introduced the concept of *nature's contribution to people*, which was developed to embrace a fuller and more symmetric consideration of diverse stakeholders and worldviews, and a richer evidence base for action (Díaz et al., 2018). The reporting system for *nature's contributions to people* has a gradient of complementary and overlapping approaches, ranging from a generalizing to a context-specific perspective.

These above-mentioned assessments have been picked up extensively by the mass media, reaching a broad audience and shaping global narratives. Furthermore, they have served as the theoretical foundation of environmental damage proceedings brought before the International Court of Justice (ICJ). In February 2018, for example, after Nicaragua excavated a channel on disputed territory, the ICJ ordered it to compensate Costa Rica for damage to its rainforests and protected wetlands (I.C.J., 2018). The case is significant for at least two reasons: it was the first time the ICJ decided on an environmental damage case; and the ICJ's decision explicitly recognizes that the environmental damage includes ecosystem services. The ICJ accepted Costa Rica's claim that biological diversity and ecosystem services merit valuation, and partially grounded its decision by referring to the different categories of ecosystem services developed in the MEA. In short, there was a science base that supported its claims. In the immediate future, as climate and environmental litigation continues to develop, the need for better mechanisms to value nature will become increasingly prevalent. With climate litigation cases growing exponentially in recent years, this will become increasingly important (Setzer & Higham, 2022).

Inclusion in crediting standards

A study on the emerging market of forest co-benefits found that they are often the major reason why buyers engage in forest carbon markets in the first place (Goldstein, 2016). These positive co-benefits — in particular biodiversity and community impacts — are even of equal or greater importance to some buyers of emissions reductions than the carbon credits themselves. It remains, however, difficult to track the impacts of carbon projects beyond carbon as these are not often included in assessments. This is in part because individual impacts are very context-specific, and measuring them could mean additional transaction costs for projects. Yet, there are also potential negative impacts, or trade-offs, that may occur in the implementation of carbon projects. As such, to evaluate forest co-benefits in carbon standards we must consider on the one hand, what criteria and indicators are in place to ensure positive co-benefits are accounted for in project design; and on the other hand, what environmental and social safeguards are in place to minimize adverse outcomes.

We use the forest carbon standards reported on by Ecosystem Marketplace, an initiative publishing information and reports on financing for ecosystem services, as our starting point. Specifically, we review four of the most commonly used standards for certifying forest projects in the voluntary carbon market (VCM): the Verified Carbon Standard (VCS), the Gold Standard, Plan Vivo, and the Climate Action Reserve (CAR). We also look at the newer The REDD+ Environmental Excellence Standard (TREES), which aims to provide a market pathway for high integrity emission reduction and removals credits coming from countries and sub-national jurisdictions.

Currently, most activity related to forest credits takes place in the voluntary carbon market as most compliance markets, such as the European Union Emission Trading System, have limited inclusion or exclude forests from their crediting schemes (Maguire et al., 2021). Lessons from the VCM, however, may still be applicable to compliance markets as they are expected to grow in the near future. This is indicated by recent negotiations under Article 6 of the Paris Agreement, which deemed REDD+ credits eligible for international transactions as long as they comply with the rules and meet quality criteria (Streck, 2021). The emergence of new compliance mechanisms, like the United Nation's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) program, also hints at this as they plan to accept forestry and land-use offset standards (Maguire et al., 2021).

We find that the carbon standards we evaluated vary in their scope and coverage of forest activities (see **Table 2**; **Supplemental Information**). Additionally, some capture co-benefits directly within their standard requirements, while others ensure environmental and social safeguards by partnering with complementary standards to certify co-benefits beyond carbon. The latter seems to be the case with the larger standards, like VCS and Gold Standard, while direct integration in the standard framework occurs with Plan Vivo and TREES, which both have a more specific mandate. Plan Vivo prioritizes smallholder projects, which are mostly land-based, while TREES focuses specifically on REDD+ transactions, with the aim to unlock long-term financing for forest protection and restoration.

Table 2. Forest carbon standards reviewed
[see end of manuscript]

However, there is still room for improvement. Forest projects remain a relatively small share of carbon credits, meaning the amount of certified co-benefits is likely even smaller. Furthermore, while some standards represent individual co-benefits well, few are comprehensive in their coverage of co-benefits. A report on carbon market standards for REDD+ projects came to similar conclusions. No one standard scored at least 80% across all areas of their evaluation, which included 'climate integrity', 'biodiversity conservation' and 'human and community rights, stakeholder participation and sustainable community development' categories (Schmidt & Gerber, 2016).

OUTOOK: EXAMPLES AND OPPORTUNITIES

As discussed above, there is increasing global recognition of multiple streams of benefits from forest-based mitigation activities. But emerging valuation approaches in practice currently are diverse, and many assessments still do not consider the full potential of forests. Examining methods and frameworks currently in use for valuing co-benefits can help identify new opportunities to mobilize increasing funds for forest preservation. To this end, we discuss some practical ideas that could be extended to capture a more complete valuation of forests in decision-making.

In the **Theoretical Framework** section, we defined total forest value as consisting of monetized benefits, potentially monetizable benefits, and non-monetizable benefits. Here, we first consider tools for shifting potentially monetizable benefits towards monetized, primarily by extending existing markets and finance tools. We then discuss non-market opportunities to leverage previously uncaptured value from non-monetizable benefits. Some of these approaches have implications for both market- and non-market-based mobilization of funds; we discuss the example of jurisdictional REDD+ to illustrate this (see **Box 2**).

Market-based strategies for capturing monetizable benefits

There is currently a high proportion of unmonetized benefits in the *SCD*. We discuss market-based strategies for leveraging these benefits that build on the success of carbon markets and of existing financing mechanisms for ecosystem services. We also consider opportunities for driving new investment using a *green alpha* methodology, a novel approach for estimating the hidden benefits of avoided deforestation and assessment of these benefits in monetary terms.

Further embed valuation of co-benefits into existing carbon markets

Interest in "high-quality" carbon credits is rising, particularly given increasing public scrutiny and media conversations highlighting the potential dangers of insufficiently rigorous forest carbon crediting frameworks (see, for example, discussion in Nasi & Pham 2023). This demand is already beginning to translate into increased prices, and therefore increased potential for financial support of well-implemented REDD+ activities credited under high integrity frameworks; for example, a 2015 study found that voluntary credit purchasers, particularly nonprofit or government buyers, were willing to pay a significant price premium for Gold Standard credits, used within the study as a proxy for quality (Parnphumeesup and Kerr, 2015).

A 2016 study suggests that credits generated under standards with a co-benefits emphasis were more likely to be successfully sold to a buyer (Lee et al., 2016). Within the voluntary carbon market, this protection and enhancement of forest co-benefits within crediting standards aligns with reported motivations for some classes of credit purchasers (Goldstein 2015). As illustrated in **Table 2**, many major forest-based emissions crediting standards already incorporate requirements for environmental and social safeguards that protect and maintain key forest co-benefits. Other standards are beginning to elevate formal recognition of these co-benefits; for example, Architecture for REDD+ Transactions (ART) has recently launched a process to develop a formal co-benefits certification option as part of its jurisdiction-scale TREES crediting framework (ART, 2023b).

This emerging trend could be further leveraged by promoting standards and rules privileging high-quality forest carbon standards – including those that protect and enhance forest co-benefits—within compliance markets and common voluntary emissions target-setting frameworks. In alignment with this, third-party efforts to define credit quality increasingly highlight the inclusion of environmental and social safeguards that align with the enhancement of ecosystem services and other co-benefits, particularly as they relate to impacts on indigenous and local stakeholders. Recent and ongoing nonprofit efforts to define carbon credit quality include the Tropical Forest Crediting Integrity Guide (COICA et al., 2023), the Integrity Council for the Voluntary Carbon Market (ICVCM) Core Carbon Principles guidance and Assessment Framework development process (ICVCM 2023), and the Carbon Credit Quality Initiative (CCQI). Credit rating efforts from for-profit companies are also emerging as the value of traded credits continues to rise. To the extent co-benefits are included, whether explicitly or implicitly, such emerging frameworks for assessing the quality of forest-based credits generally associate credit generation efforts that enhance aspects of forest co-benefits with preferential ratings. Expanding the association of these co-benefits with definitions of higher carbon credit quality may in turn open the door for higher future prices and increasing flows of forest finance.

Target nature-related financial risks to leverage emerging finance mechanisms

Recent innovations in finance to support ecosystem services are beginning to unlock funds to incentivize forest conservation specifically on the basis of their monetized co-benefits. One illustrative example of relevant innovation in this space is the Cloud Forest Blue Energy Mechanism (CFBEM) (Narvaez et al., 2017). The CFBEM relies on the ability to model and monetize particular co-benefits of forest conservation and restoration, enabling beneficiaries to *"pay for success*" of direct financial benefits provided by the conservation and enhancement of forests. Specifically, a major co-benefit of restored and protected cloud forests is the prevention soil erosion; these benefits are in turn monetized based on their impact to the operating costs of hydropower companies (i.e., reductions in expenses related to reservoir sediment dredging, due to enhanced conservation and restoration within the watershed). These reduced hydropower operating costs also translate into cost savings for hydropower consumers, who may also be charged some of the cost difference to support forest protection and restoration.

Mechanisms like this example rely on the ability to meaningfully quantify and translate ecosystem services into estimates of tangible costs avoided by the financing actors (in this case, estimates of the dredging costs avoided by participating hydropower companies). Expanding such mechanisms to other as-yet-unmonetized co-benefits may require work to articulate, quantify, and monetize the impacts of these benefits through the lens of "nature-based solutions" – that is, with a focus on specific financial damages and risks that the conservation of forests can help avoid. In line with this, efforts such as the Taskforce for Nature-related Financial Disclosures (TNFD) may prove particularly valuable; this UN-supported working group is developing a framework to drive increased reporting and disclosure of nature-related financial risks and dependencies by corporations and other actors (TNFD, 2022). Such reporting would likely expand the awareness and salience of tangible impacts of forest conservation on business operations – setting the stage for increasing monetization and subsequent financing to reduce the risks created by forest loss. Similarly, the insurance industry is also considering opportunities in the nature-based solutions space, with forest insurance currently being the most advanced (Swiss Re Institute, 2021; Li, 2022).

Adopt a green alpha paradigm

While some of the tangible value that forests provide can be identified and quantified as discussed above, some value provided by forests have likely not yet been identified. Moreover, as discussed in the **Theoretical Framework** section, the total economic value per unit of forest is expected to increase over time, especially as additional forested land is lost. A methodology to estimate the scale of these yet-unrecognized and/or future value components could help incorporate them into market-based transactions and decision making. The *green alpha* methodology provides an estimation of the value of preserving forests for future use – that is, an option value enabling investors to account for this likely future appreciation of the total value of forests (see **Box 1**). Based on the *climate alpha* methodology explored in Golub et al., 2022, it provides a potential pathway for actors to monetize and internalize yet-unrecognized ecosystem-linked externalities of deforestation. This framework could also help investors assess the monetizable co-benefits of avoided deforestation to calculate future return on investment.

Box 1. The *green alpha* methodology

The *green alpha* methodology is an extension of what is presented in Golub et al. (2022) as the *climate alpha* valuation paradigm. Climate alpha reflects the extent to which the current market value of emissions reductions do not reflect the future appreciation (and monetization) of these assets. *Green alpha* describes a similar mismatch between current and future valuations of forest assets, and the potential gain from investing in forests prior to this future materialization of value. By nature, both *climate alpha* and *green alpha* formation are rooted in uncertainty regarding future climate policy. For example, strong signals of near-future strengthening of global climate policy would likely result in rapid appreciation of assets that help meet climate mitigation needs (and thereby comply with newly strengthened policies), including assets based on REDD+ activities. As current global emissions and deforestation trends are known to be at odds with global decarbonization goals, such shifts in climate policy could potentially occur at any moment. But the sequence of any policy course corrections, their timing, and the actual resulting increase of the shadow price of carbon are unknown. This suggests that investment in assets that will gain value in the face of future climate policy shifts could be lucrative, but the specific scale and timing of this expected jump in value can only be described using (at best) a probability distribution or event tree. By creating a long position on high-integrity REDD+ backed emission reductions, an investor could be positively exposed to future known risk premia up to the probability distribution. The economic value of this risk premium could be calculated as an option value, as detailed in Golub et al., 2022. The same logic applied to calculating *climate alpha* potentially applies to calculating *green alpha*, in that appreciation of main and co-benefits and resulting financial valuation could be estimated as a probability distribution.

Non-market-based opportunities for capturing additional co-benefits

Beyond the sphere of market-based mechanisms described above, a range of opportunities exist to leverage the co-benefits of forests to drive both investment and decision making in support of increased conservation. The diversity of forest co-benefits, and their potential impacts on human health, wealth, and welfare, create opportunities for alignment with unconventional sectors and stakeholders. Below, we discuss pathways to raise the effective valuation and visibility of forest co-benefits on policy agendas, focusing on the agricultural commodity and health sectors as two illustrative examples.

Promotion of deforestation due diligence within agricultural supply chains

While new means of measuring the tangible impacts of forest conversion to business operations may drive new financing mechanisms, emerging policies could create additional incentives for these companies to support forest protection. For example, compliance rules regarding deforestation in agricultural commodity supply chains are emerging in major export markets such as the European Union (EU Commission, 2022). Such rules could drive new corporate interest in supporting financial or programmatic mechanisms that protect forests from agricultural conversion. The Science Based Targets initiative (SBTi) also recently issued a new methodology to align forest, land, and agriculture related goals with their framework (SBTi, 2022). Setting targets under this initiative is becoming an increasingly common standard against which corporate actors are judged; moreover, policy signals suggest that setting standards under SBTi may eventually be functionally or literally mandated for some sectors or countries in the future (for example, US federal regulatory rulemaking initiated in late 2022, which proposes to require climate goals aligned with the SBTi framework for US federal suppliers and contractors above a certain contract size (OFCSO 2023).

Alignment of forest conservation goals with holistic health policy

As links between the natural world and human health outcomes become increasingly clear, policy-relevant definition of “health” are expanding. Strategically designed initiatives can help create willingness to avoid deforestation and indirectly compensate for opportunity loss of avoided deforestation by highlighting potential health implications of forests and their co-benefits. For example, the BC Parks Foundation in Canada recently launched PaRx, an initiative that aims to promote both conservation and healthcare savings by partnering with healthcare providers to issue “nature prescriptions” (PaRx, 2023). The prescriptions reduce barriers to nature access for patients (e.g., providing passes to parks), while highlighting the many health improvements linked to time spent in nature. Similarly, Japan has a long history of forest therapy programs, with evidence supporting positive economic and physical and mental health outcomes (Zhang et al., 2022). In addition to being supported by widespread local policy, these programs are embedded in the national health framework via the Ministry of Health, Labor, & Welfare and Ministry of Agriculture, Forestry & Fisheries.

At a broader level, the Health in All Policies (HiAP) concept, endorsed by United Nations Member States, provides an example of a framework for incorporating health implications into policies and decision making across all sectors – including, by extension, health impacts related to forest co-benefits. HiAP "takes into account the health implications of decisions, seeks synergies, and avoids harmful health impacts in order to improve population health and health equity" (WHO, 2013), and has been used at local, state, and national levels to enable the insertion of health priorities into policy actions at each. While such a framework provides a potential opportunity to advance forest conservation on the basis of its links to human health, it could also serve as a model for driving attention to a topic with implications that touch a diversity of sectors. For example, efforts might be made to promote a "Forests in All Policies" model, requiring the specific consideration of ecosystem impacts in a broader suite of policy decisions.

Box 2. Mobilizing funds for forests: The case for jurisdictional REDD+

Jurisdictional REDD+ is a good example of collateral investment. Backed by public funds, institution building that allows a jurisdiction to scale up REDD+ supply in the future is probably one of the best ways to leverage private investment in emission reductions. The jurisdiction may use its resources to leverage this by directing REDD+ activities in areas where forest preservation, reforestation or prevention of forest degradation generates higher co-benefits (monetizable and non-monetizable). Accurate calculation of benefits at each implementation stage and by each stakeholder is necessary for cross leveraging and maximizing REDD+ benefits.

For practical reasons, there is still a need to draw the line between primary and collateral benefits. For example, corporations seeking high-quality high, integrity emission reductions (ERs) for compliance or as a part of voluntary actions could be willing to invest in JREDD+ to scale up ERs production. Understanding of co-benefits and EKC-like mechanisms and its monetization at the local level creates confidence in the permanence of ERs. This is because at some point, the direct incentives attributed to JREDD+ investment for ERs production will weaken and fade. When this happens, collateral benefits will play a major motivational role. For example, by estimating the co-benefits and assessing the chances that the local community and the host country will continue forest preservation in the future motivated by local benefits, the JREDD+ investor (e.g. corporation or investment fund) is better able to evaluate the risk of reversal.

CONCLUSION

The gaps between total value, monetized value, and market prices create room for enormous losses of economic value (and total value) in the context of forest conservation, particularly when forests are viewed solely through the lens of their potential carbon benefits. Estimates of the *social cost of carbo*n are generally far higher than current global market prices of carbon, including those prices used in the context of carbon-based forest finance. If forest conservation is priced on the basis of its carbon impacts alone, the enormous value provided by forests through ecosystem services is excluded from decision frameworks that estimate value based on this pricing – which itself already elides the true social benefits of the carbon value itself. As such, under a carbon-only framework, the monetization of forest conservation programs, projects, and initiatives vastly undervalues the true benefits of these forests to society.

A global transition toward green growth will ultimately result in a reevaluation of the value of the environment and natural resources. To avoid future stranded assets and minimize regrets about the irreversible loss of ecosystem services, forward-looking analysis of ecosystem value is essential. The future increase in the value of ecosystem services relative to conventional consumer goods must be considered, as well as other transformations potentially triggered by the shift toward green growth.

Moreover, to attract collateral investment, such forward-looking analysis must detect monetized and monetizable value in the investment, expressed in monetary terms. It is not just enough to compute environmental indicators: Investors are interested in what their potential monetary return may be on invested capital, as well as the risks. It remains difficult to measure, monitor, and verify many co-benefits. But the *social cost of deforestation* framework captures not only various components of economic and social benefits of forests, but also helps describe synergies and nonlinear responses of unit value to scale. Subsequently, the adoption of methodologies like green alpha valuation may help fill the gap in our near-term ability to monetize this complete value.

Using these approaches, we can assign financial weight to forest co-benefits, allowing them to be compared more easily to other goods. The goal is not to advance financial gain, but to elevate and leverage an expanded suite of forest co-benefits, across decision making frameworks and policy discussions that might otherwise eclipse what can't be represented in currency. A vital outcome of monetizing of forest co-benefits and connecting them to financial markets is the potential to unlock investment needed to support forest-positive actions. This can lay the groundwork for the collection of immediately available bridge funding resources from across sectors to complement REDD+ support, on the pathway toward a more all-encompassing framework and larger funding streams for health, biodiversity, and so on. The practical examples we discussed are already pushing the needle in the right direction.

Finally, we need to stop unsustainable nature-exploitative activities and capture true value of forests in decision making – not one or the other, but both. We must transform our value systems (held values) in societies, and policy and markets are an important political signal to catalyze this shift. However, even if a focus on co-benefits helps to accelerate investment in avoided deforestation, it still may be not enough to secure ambitious environmental targets. As such, the expansion of monetizable solutions must be reinforced by strengthening regulations. Future research should explore additional governance considerations and conditions for supporting increasing efforts to recognize forest co-benefits.

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Author contributions

SF, AG, and CD conceived of the study. IS, AG, CG, CD, and SF conceptualized the research. AG led the development of the theoretical framework. IS led the development and writing of the manuscript. All co-authors contributed to the development of the theoretical framework and manuscript, including writing and editing. IS led the reviewing and editing process. SF supervised the project.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

TABLES

Table 1. High-level assessments reviewed

Initiative/ Assessment	Last report	Relevance	Insights/method for valuation
Millennium Ecosystem Assessment (MEA)	2005	First international initiative measuring the value of ecosystem services for human wellbeing	• Argues Market approaches can only be used to estimate the value of few forest services, mostly the ones related to provisioning services and that enter formal markets • Acknowledges that there is no consistent methodology, and usually insufficient and incompatible information, to estimate credible values for many other forest services, such as habitats for biodiversity • Acknowledges that researchers have successfully applied monetary methods to “non-market” and often “non-traditional” services • Identifies *Total Economic Value* as the most widely used framework for identifying and categorizing forest benefits

The Economics of Ecosystems and Biodiversity (TEEB)	2008	Highlighted growing costs of biodiversity loss and ecosystem degradation; a motive of the study was to establish an objective global standard basis for natural capital accounting	• Proposed a three-step method for valuing poorly or undervalued ecosystem services
			  • Identify and assess the full range of co-benefits to be valued (recognize them)
			  • Estimate and demonstrate their value
			  • Capture value and seek solutions to overcome under-valuation, using economically informed policy instruments

Changing Wealth of Nations (CWON)/ The System of Environmental Economic Accounting (SEEA)	2021	CWON uses the SEEA, which is the official international framework for natural capital accounting; SEEA Ecosystem Accounting (EA) is the first internationally agreed-upon statistical framework for ecosystem accounting	• A framework of five core accounts make up the building blocks of the SEEA EA: Ecosystem extent, ecosystem condition, ecosystem services, ecosystem monetary asset and thematic accounts • Accounts constitute an accounting system which presents a comprehensive and coherent view of ecosystems • To value forests, the CWON report uses international forest statistics from FAO and its metric is U$S

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)	2022	Introduced the concept of *nature’s contribution to people*, which embraces a wide range of descriptions of human-nature interactions, including the concept of ecosystem services and other descriptions, ranging from utilitarian to relational	• Offers a systematic assessment of over 50 different methods found in the literature for valuing nature
			• Groups methods into four non-disciplinary ‘method families’
			  • Nature-based valuation gathers, measures or analyses information about the properties of nature and its contributions to people
			  • Statement-based valuation directly asks people to express their values
			  • Behavior-based valuation identifies how people value nature by observing their behavior and practices
			  • Integrated valuation brings together various types of values assessed with different information sources

Table 2. Forest carbon standards reviewed

Carbon standard*	Year established	Categories of forest use certified (as described by the carbon standard)	Co-benefit standards	Co-benefit considerations	Register-ed forest projects†	Forest projects as % of total†
Verified Carbon Standard (VCS)	2005	• Afforestation • Reforestation and revegetation (ARR) • Improved forest management (IFM) • Reduced emissions from deforestation and degradation (REDD)	• Climate, Community, and Biodiversity (CCB) program	• Must demonstrate contribution to at least three SDGs • Can certify with additional standards (e.g., CCB, SDVista) to recognize non-greenhouse gas (GHG) social and environmental benefits	225	11% (out of 2022 projects)
Gold Standard	2003 (Clean Development Mechanism) 2006 (voluntary market)	• Afforestation / Reforestation (A/R)	• Fairtrade Climate Standard	• Can certify additional SDG impacts (e.g., via SustainCERT) such as renewable energy certificate labels; water benefit certificates; gender equality impacts; improved health outcomes; black carbon reductions	32	2% (out of 1984 projects)
Plan Vivo	1994	• Protection (Reducing deforestation and/or degradation of forests) • Restoration (tree planting, assisted natural regeneration, and management to restore ecological function) • Improved management (Improving forest management practices to increase carbon stocks and/or reduce greenhouse gas emissions)	• No complementary co-benefit standard	• Requires "positive impacts on local livelihoods and ecosystems" • Requires a benefit-sharing mechanism (at least 60% of carbon sale must go to community or smallholder) • Requires setting of a livelihood and ecosystem baseline • Requires the provision of long-term livelihoods benefits that are additional to the sale of certificate of employment in projects	25	89% (out of 28 projects)
Climate Action Reserve (CAR)	2001 (began as California Climate Action Registry)	• Improved forest management • Avoided conversion (forestland to non-forest use)	• No complementary co-benefit standard	• Not reported on	115	61% (out of 188 projects)
The REDD+ Environmental Excellence Standard (TREES)	2021	• All Reduced emissions from deforestation and degradation (REDD+) activities except removals from forests remaining forest	• Announced a co-benefit certification under develop-ment in 2023	• Sets its environmental, social, and governance requirements in line with the Cancún Safeguards	17	100% (out of 17 projects)

* Information on standards sourced from documents on organization websites (ART, 2023c; CAR, 2023; Gold Standard, 2023; Plan Vivo, 2023; Verra, 2023)

† Data for VCS, Gold Standard, Plan Vivo, and CAR was accessed January 11, 2023 on the Voluntary Carbon Market Dashboard (Climate Focus, 2023); data for TREES was accessed February 13, 2023 on the Architecture for REDD+ Transactions registry (ART, 2023a)

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