



## Review

## Biodiversity credits schemes: a comparative analysis

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## A B S T R A C T

Biodiversity underpins essential ecosystem services such as food security, water purification, and climate regulation, thus contributing fundamentally to human wellbeing. Yet, it faces growing threats from overexploitation, habitat loss, pollution, and climate change, which jeopardize these services. Biodiversity credits (BCs) have emerged as innovative financial instruments designed to incentivize and fund measurable conservation and restoration outcomes, offering a mechanism to align economic activities with ecological sustainability. This paper presents the first systematic comparative analysis of 15 biodiversity credit schemes (BCSs) globally, assessing their definitions, methodologies, and market dynamics. The analysis includes a review of scheme characteristics, project design requirements, and credit issuance practices, complemented by an evaluation of current market trends and challenges. The market is recent but expanding rapidly, with 49 projects across the schemes covering nearly 1 million hectares. Credit prices vary widely—from USD 7 to 68,000 per hectare/year—depending on factors such as habitat type, project location, and scheme design. While outcome-based and ex-post issuance methods dominate, ensuring results-based credibility, benefit-sharing remains uneven and governance structures vary significantly. Private-led initiatives dominate, but public schemes offer more stringent compliance mechanisms. Notably, few schemes incorporate advanced features like credit stacking or bundling. By identifying key design features and institutional configurations across existing BCSs, this paper contributes to the development of robust standards and governance models capable of supporting effective and accountable biodiversity markets. It provides an empirical basis to inform the integration of biodiversity crediting mechanisms into national and international policy frameworks, including emerging nature finance instruments and regulatory approaches. In doing so, it offers practical insights for decision-makers aiming to reconcile ecological integrity with socio-economic objectives in the implementation of biodiversity commitments. Further research should investigate enabling conditions and barriers for mainstreaming these mechanisms in global biodiversity governance.

## 1. Introduction

Biodiversity refers to the variety of living organisms originating from all sources, including terrestrial, marine, and other aquatic ecosystems, as well as the ecological complexes they form. It encompasses diversity at multiple levels: within species, between species, and across ecosystems (CBD, 1992). Biodiversity is a crucial component for natural capital and ecosystems stability allowing their regeneration and resilience to external disruptions (De Groot et al., 2003; EEA, 2015; Dasgupta, 2021; Capitals Coalition, 2021).

Functioning ecosystems are of pivotal importance for human wellbeing and socio-economic systems ensuring the flow of different goods and services, called ecosystem services - ES (Costanza et al., 2014; MA, 2005; Dasgupta, 2021). For instance, ES include provision services producing essential goods e.g. food, fuel, and clean water; cultural services including recreation and spiritual significance; as well as regulatory such as climate regulation, and natural hazard protection; and supporting services like pollination or nutrient cycling (Folke et al., 2004; MA, 2005; Turner et al., 2007; IPBES, 2019). The status of

biodiversity influences all categories of ES. For provisioning services, diverse ecosystems provide a stable supply of essential resources, such as food, water, and raw materials. For example, agricultural systems with high plant diversity improve pollination and pest control, leading to increased yields and resilience against diseases (Isbell et al., 2011). Similarly, fisheries with diverse species are more productive and resilient to environmental changes, ensuring sustainable fish stocks (Cardinale et al., 2012). For regulating services, biodiversity plays a critical role in maintaining ecological processes. Functional diversity—the range of different functional traits—ensures that multiple species can perform similar roles, which enhances the stability and efficiency of processes such as nutrient cycling and carbon sequestration (Hooper et al., 2005). Diverse forest ecosystems can sequester more carbon, mitigating climate change impacts (Griscom et al., 2017; Seddon et al., 2020; IPCC, 2022). Water purification and flood regulation are improved by increases in community diversity and the expansion of habitat areas (Harrison et al., 2014; Yao et al., 2017). Cultural services, which encompass aesthetic, recreational, and spiritual values, are also influenced by biodiversity. Richly biodiverse landscapes offer unique

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recreational opportunities and support cultural identities (Diaz et al., 2006; MA, 2005). The loss of biodiversity diminishes these cultural benefits, reducing both intrinsic and economic values. Lastly, biodiversity contributes to supporting services, such as soil formation and nutrient cycling. Diverse species interactions promote decomposition and nutrient recycling, maintaining ecosystem productivity and resilience (Isbell et al., 2011; Hooper et al., 2005; Barbier, 2021).

In the last decade, resources overexploitation, climate change, pollution, invasive species, and habitat loss (IPBES, 2023) caused biodiversity degradation compromising ecosystems and posing significant risks to global economies and societies (Hoekstra et al., 2005; Duffy, 2009; Schindler et al., 2010; Treml et al., 2015; Kalkuhl and Wenz, 2020). Recent data show that monitored wildlife populations have decreased by an average of 69 % over the past 50 years (Leung et al., 2023; World Wide Fund for Nature (WWF), 2024; World Economic Forum, 2024). The costs of inaction on biodiversity loss are significant and are projected to increase. The financial consequences of biodiversity loss are increasingly recognized as systemic risks. Approximately US\$44 trillion of economic value generation—over half of global GDP—is moderately or highly dependent on nature and its services (WEF, 2020). This dependency extends beyond industries to national economies. For instance, China, the European Union, and the United States have the highest absolute economic value in nature-dependent sectors, with \$2.7 trillion, \$2.4 trillion, and \$2.1 trillion respectively. Emerging economies are particularly vulnerable, as they often rely more heavily on nature-dependent sectors (WEF, 2020). Consequently, biodiversity decline poses a direct threat to macroeconomic stability and financial resilience worldwide. Biodiversity protection remains severely underfunded, with recent research showing upwards of a \$700 billion gap between current annual funding and what's needed by 2030 to maintain ecosystem integrity (CBD, 2021).

Halting and reversing biodiversity loss will require the adoption of holistic strategies to restore biodiversity by switching to a nature-positive economy. According to the Nature Positive Initiative (2023) nature-positive means “Halt and reverse loss by 2030 on a 2020 baseline and achieve full recovery by 2050”. This entails three fundamental transformations. First, economic performance metrics must be refined to incorporate natural capital, thereby capturing the full value of ecosystems in assessments of economic progress. Second, fiscal and economic policy frameworks should be restructured to internalize the intrinsic value of nature within public and private decision-making processes. Third, the financial system must be reoriented to systematically integrate biodiversity-related impacts, dependencies, and risks into its standards, disclosures, and investment practices. (Leclère et al., 2020; Dasgupta, 2021). At this purpose, different policy instruments can be adopted, (Michaelis, 1996; Gunningham and Young, 1997; Jordan et al., 2003; Sterner, 2003), among which economic instruments play a crucial role in protecting biodiversity by providing financial incentives and mechanisms that encourage conservation and restoration efforts (TEEB, 2011; Dasgupta, 2021; International Advisory Panel on Biodiversity Credits – IAPBC, 2024). The Kunming-Montreal Global Biodiversity Framework (GBF), adopted at COP15 in 2022, represents a strategic turning point in international biodiversity governance by placing “nature-positive” outcomes at the center of its vision. Article 19 explicitly calls for the alignment of financial flows with biodiversity objectives and the scaling of positive economic incentives for conservation and restoration. In this context, biodiversity credit schemes (BCSs) have been increasingly recognized as a potential instrument to channel private capital towards verified ecological outcomes. Recent discussions held during the GBF implementation consultations in Rome (2024) further reinforced this perspective, with several Parties and stakeholders identifying BCSs as complementary instruments to public finance within the broader resource mobilization strategy. These exchanges emphasized the necessity of establishing robust methodological standards and safeguards to ensure that BCSs contribute effectively to the GBF's targets, particularly by delivering additional, measurable, and

enduring biodiversity gains.

BC is an economic instrument that allows to finance activities, such as forest conservation or restoration, that deliver net positive biodiversity gains. BCs have been defined as units intended to finance measurable gains in biodiversity through conservation or restoration (Ducros and Steele, 2022; WEF, 2023; GEF, 2024). This mechanism stems from the evolution of carbon credits, which have been applied in both voluntary and regulated markets, water credits, and as well as broader markets for local ES (Biodiversity Consultancy, 2022). Proponents see their great potential to mobilize private conservation finance incentivizing different stakeholders to participate actively in preserving natural habitats and species. (TBC, 2022; GEF, 2023; Ducros and Steele, 2022; NatureFinance, 2023; WEF, 2022; Pollination, 2023). According to Antonelli et al. (2024), BCs could become one of the most important funding sources for the implementation of the GBF. The recourse to these innovative market instruments is intended to decouple economic growth from resources overconsumption and environmental degradation, thereby promoting long-term biodiversity conservation. Thus, interest in BCs is growing rapidly, with numerous initiatives exploring the potential for developing global credits markets. However, the swift expansion of these markets has not been accompanied by sufficient conceptual clarity regarding the definition, scope, and functioning of BCs. These aspects need to be assessed and standardized since poorly designed and implemented economic instruments can lead to counterproductive outcomes and trade-offs (Larrosa et al., 2016). High integrity BCs will have to tackle the same issues of additionality, leakage and permanence as carbon credits, but with additional complexity due to the multi-dimensional and place-specific nature of biodiversity (Burns, 2023). A gap in the existing literature on Biodiversity Credit Schemes (BCSs) lies in the lack of systematic comparative analyses, particularly concerning the distinctions between privately led and publicly governed schemes. Differences in governance models, pricing methodologies, and levels of transparency are rarely assessed in a structured and comparative manner, limiting the potential to derive generalizable insights and policy-relevant lessons. Recent reports, including IPBES (2023), emphasize the urgency of establishing consistent standards and evaluation criteria to enhance the credibility and scalability of BCSs.

The objective of this paper is twofold. First it aims to analyze existing biodiversity credits schemes (BCSs) assessing and comparing their characteristics to understand which the main elements are selected to design BCs, and secondly to evaluate the market development considering the different peculiarities of the analyzed schemes. The paper is structured in 5 sections: i) section 1 frames the topic, ii) section 2 focuses on the definition of BC and its functioning; iii) section 3 describes the methodology and the sample; iv) section 4 summarizes the main results; finally, v) section 5 highlights possible barriers and shortcomings for BCSs upscaling and replication.

## 2. Biodiversity credits definition and characteristics

Despite the growing interest on BCs, a standard definition is still missing. Different international and national organizations have elaborated their own. BCs in literature can have different names and characteristics. In addition to “biodiversity credit”, which is exactly the name used in the GBF, other terms have been proposed, like “nature credit”, “nature token”, “nature certificate” (GEF, 2024), “biodiversity certificate”, “voluntary biodiversity credit” (Biodiversity Credit Alliance definition, GEF, 2024), “biocredit” (Ducros and Steele, 2022). In this paper BCs are defined as: quantifiable, verifiable and tradeable units of biodiversity restored or preserved over a specific period through a scientific methodology, generated to fulfil nature-positive aspirations and assertions without being used for compliance purposes or offsetting biodiversity loss elsewhere (WEF, 2023; GEF, 2024; International Advisory Panel on Biodiversity Credits – IAPBC, 2024).

It is important to differentiate biodiversity credits (BCs) from biodiversity offsets, although some broad definitions of BCs, such as

"nature-specific credits" (Taskforce on Nature Markets, 2022), also encompass biodiversity offsets. While both may appear similar in structure, the purpose of their use is distinct (WEF, 2022). Biodiversity offsets are specifically designed to compensate for negative environmental impacts by creating equivalent positive impacts elsewhere. They are intended to be applied as part of the mitigation hierarchy—Avoid, Minimize, Restore, Offset (Arlidge et al., 2018)—and should only be used to address residual environmental damage that remains after all efforts have been made to avoid, reduce, and restore the losses directly caused by a project or activity. In contrast, BCs are primarily aimed at enhancing or protecting biodiversity in general, without necessarily being tied to compensating for specific damages. BCs, instead, are intended to finance biodiversity net-gains. Therefore, they represent a further step in the mitigation hierarchy, directly targeting the nature-positive objective (Taskforce on Nature Markets & Pollination, 2023). This objective becomes even more relevant considering the difficulty of precisely measuring the environmental improvements underlying credit issuance, and the consequent soundness of the related offsetting claims. This problem has already emerged in the carbon market, where recent analyses have shown that in many projects, in particular related to forestation and land use, significantly more credits were issued than the actual emissions reductions, revealing the groundlessness of many companies' net-zero statements (Haya et al., 2023; Stanley et al., 2023). Biodiversity poses an even greater challenge than carbon dioxide when it comes to compensation efforts, because it cannot be easily replaced or exchanged between different locations. Unlike carbon, which has the same impact on the atmosphere regardless of where emissions occur, biodiversity is tied to specific ecosystems, making it much less interchangeable. Additionally, BCs are distinct from carbon credits that incorporate biodiversity metrics, though both aim to address environmental challenges. Instruments such as "biodiversity-enhanced credits" or "nature-related voluntary carbon credits" are primarily carbon credits with added biodiversity components. These credits integrate specific management actions focused on biodiversity enhancement, conservation, or restoration while still targeting carbon reduction goals. The distinction between BCs and these hybrid instruments lies in their foundational purpose and market positioning. BCs are developed as a direct mechanism to value and finance biodiversity improvements, often without a carbon emissions reduction component (Mace et al., 2018). In contrast, instruments like "biodiversity-enhanced credits" or "nature-related voluntary carbon credits" integrate biodiversity improvements into the carbon market, but their primary purpose remains carbon sequestration. These credits are typically used within the voluntary carbon market, where carbon reduction is the main goal, and biodiversity benefits are considered co-benefits (Bull et al., 2018). For instance, a biodiversity-enhanced credit might result from reforestation projects designed to sequester carbon while restoring local ecosystems and biodiversity, but the primary metric remains CO<sub>2</sub> reduction (Caldecott, 2021). The terminology used to describe these instruments, such as "Biodiversity-Positive Carbon Credits" (GEF, 2024), emphasizes this dual benefit, highlighting that carbon credits can be structured to deliver additional biodiversity gains. However, these gains are secondary to carbon sequestration, and their measurement is often more qualitative than the biodiversity outcomes in standalone BCs (Spurgeon et al., 2019).

A final clarification is necessary as biodiversity credits, even when their primary focus is the enhancement and protection of biodiversity, exhibit distinct characteristics based on how the benefits included in the credit calculation are structured. In the literature, two main types of BCs are identified: bundled and stacked credits. Bundled credits refer to the combination of multiple benefits generated by a single project within a specific area into one unified credit type, which is then sold as a single product (GEF, 2024). In this approach, a single credit encompasses various environmental outcomes, such as climate and biodiversity improvements, all originating from the same project (Gradeckas, 2024). For example, a project focused on ecosystem restoration could release

bundled credits that represent both carbon sequestration and biodiversity conservation benefits in one credit package. On the other hand, credit stacking involves separately quantifying different ecosystem services provided by a project and creating distinct credit types or trade units for each service. These credits can be sold individually to different buyers, allowing the project to receive separate payments for each service provided (von Hase and Cassin, 2018). In this case, a single project might generate both carbon credits and biodiversity credits, which can be sold independently, offering flexibility in addressing diverse market demands (Gradeckas, 2024). This differentiation between bundled and stacked credits highlights the complexity and versatility of biodiversity credit markets, where projects can be designed to maximize the range of ecosystem services they provide, either through integrated or separate credit offerings.

### 2.1. Biodiversity credits' schemes

BCs have been introduced in the market by different organizations adopting different set of rules. These rules can vary across organizations, and they can be defined as Biodiversity Credits Scheme (BCS). In this paper they are defined as a set of rules regulating stakeholders' roles, project requirements, biodiversity measurement methodology, reporting and verification, credits' issuance approach and price. A BCS operates by assessing and certifying projects, which are then assigned BCs based on their positive impact. Projects for BCs generation focus on ecosystem restoration or preservation activities, conducted over specific areas and time frames, with impacts measured against predefined baselines (Ducros and Steele, 2022). The adoption of BCs is complicated by various biodiversity measurement methodologies, which range from single metrics to comprehensive baskets of metrics (WEF, 2024).

Due to the multiple dimensions of biodiversity (related to genetic, taxonomic, functional, evolutionary, ecosystem diversity), more than 570 different biodiversity metrics exist (Antonelli et al., 2024). Key principles, such as additionality, permanence, and non-leakage, are critical to maintaining the integrity of BCs (HCA, 2014; GEF, 2024). The involvement of indigenous peoples and local communities (IPLCs) is highlighted, ensuring fair compensation and benefit-sharing in these projects (GEF, 2024; Taskforce on Nature Markets, 2022). BCs can be generated based on predefined activities or outcomes, with verification occurring either ex-ante or ex-post (Pollination, 2023). At this purpose, for credits issuance, projects must be included in a register and undergo MRV to ensure that they deliver the promised biodiversity benefits over time. The registry is the database that tracks the ownership, transfer, and retirement of BCs, as well as the details of the projects that generated them (International carbon registry, 2024); and it can be directly managed by the scheme administrator or outsourced to a third party. Once certified, BCs are sold on a marketplace to businesses, governments, or individuals aiming to offset their biodiversity impacts, meet regulatory requirements, or achieve corporate social responsibility goals.

The primary actors involved in a BCS include scheme developers, who are organizations responsible for defining the rules for generating BCs. Scheme administrators certify projects for BC generation, issue BCs, and maintain a registry of certified projects. These tasks can be managed by a single entity or multiple entities (UNEP, 2022). Auditors play a critical role by validating and verifying the projects for BC generation. The same entity can handle both validation and verification, or these activities can be carried out by different entities. Project developers, who can be landowners, consultants, specialized service providers, or land stewards, are responsible for developing the project. This involves scoping out the project, design and implement it, filing necessary documents for registration and certification, obtaining funding, defining monitoring and reporting approach, and potentially selling the project to landowners (Chen et al., 2021). Landowners are the individuals or organizations that own the area where the BC generation project is implemented. End buyers are the people or organizations that purchase

BCs. Indigenous People and Local Communities (IPLCs) are those affected by the projects or actions implemented for BC generation and can also be involved in the project (WEF, 2023). Additionally, other actors can be involved in BCSs. Local partners for project implementation are individuals or organizations that execute the project. Market facilitators help attract more end buyers without being buyers themselves. They include brokers, exchanges, traders, and retailers. Exchanges are preferred for frequent trades or large volumes of standardized contracts or products, while brokers handle non-standardized products, occasional trades, and small volumes. Traders buy and sell credits to exploit market-price distortions and arbitrage opportunities. Retailers offer a convenient way for consumers and businesses to access credits, sourcing them from brokers or directly from project developers (Gradeckas, 2024; Chen et al., 2021). Consultants provide expertise to support project developers. Project funders, which include banks, private equity firms, private investors, non-profit organizations, and other entities, lend or invest equity to fund BC generation projects (Chen et al., 2021). Fig. 1 summarizes the general structure of BCSs.

### 3. Methodology

The methodology adopted for analysing existing BCSs involves the application of a structured analytical framework designed to systematically identify and compare the key characteristics of BCSs and delineate specific criteria that projects must fulfil to generate BCs. At the same time, a specific analysis has been carried out to assess the current market landscape. The analytical framework and the market analysis were applied to a selected sample of BCSs, which were identified through a comprehensive review of various sources.

#### 3.1. BCSs comparative assessment – analytical framework

The analytical framework was developed based on the foundational elements and prerequisites essential defined by BCSs for the generation of credits. Consequently, the framework is organized into four distinct categories: scheme, project, credit, and market. This distinction is made to more effectively highlight and evaluate these aspects within the assessment process. Each category encompasses multiple analytical components, resulting in a comprehensive total of 28 elements. All categories and elements are summarized in Table 1.

The “Scheme” category summarizes the general features of the scheme. In addition to the descriptive elements such as “Scheme name,” “Scheme developer,” and “Scheme administrator,” which are critical for identifying the key stakeholders, the category incorporates additional elements. These include “Launch status,” which verifies whether the foundational documentation for implementing the scheme has been completed, along with the corresponding year of release. The “Geographical coverage” element specifies the spatial scope of the scheme, indicating whether it is intended for global or national implementation. Furthermore, the framework includes an assessment of “Offsetting,” “Credit stacking,” and “Credit bundling” to determine whether the scheme is explicitly designed to support these practices.

The “Project” category analyses the design, maintenance, and integrity requirements that projects must meet to issue BC. This category includes “Ecosystem type,” which identifies the ecosystem realm affected by BCs generation, following the IUCN classification (2020). It also considers “Activity type,” to identify if activities undertaken for BCs generation include restoration and/or preservation. The “Project duration” addressing the number of years for which the continuation of project activities is assured. Additionally, the category encompasses “MRV”, which clarifies approaches adopted for MRV of project implementation and maintenance. Furthermore, elements that assess integrity are included. Specifically, the elements “Additionality requirement”, “Permanence requirement”, and “Non-Leakage requirement” are focused on evaluating environmental integrity. The social integrity is addressed

through the elements “Benefit sharing”, and “Local stakeholder engagement”.

The “Credit” category aims at analysing BCs methodology calculation, characteristics and management. Indeed, this category comprises “Credit unit and calculation approach”, which allows to identify how biodiversity improvements are quantified, and the area size where they occur with the purchase of one BC. The “Credit” category includes “Credit issuance approach”, “Credit issuance timing”, and “Registry”. The first and the second allows to outline how BCs are released (activity-based or outcome-based). The third is related instead to BCs transactions and retirements and permits to look at registry management.

#### 3.2. Biodiversity credits market

To assess the current state of the BCs market, several key elements were considered. First, the number of projects implemented or currently in progress under various BCSs included in the sample was analyzed. This allows for an understanding of the total number of projects adopting a BCS and identifies the countries where these projects are being developed. Second, the number of issued and sold credits for each project and scheme was identified, providing insights into BC supply and demand. Additionally, where possible, the sale price of each credit was calculated, enabling an analysis of the value attributed to BCs across different schemes. Some BCSs can also include transaction fees which reflect the percentage of the BC sale price allocated to the scheme administrator in each transaction. This factor can influence the overall credit’s cost. Furthermore, as BCs can be resold in secondary markets, we analyzed whether each scheme allows for this feature, referring credits as “tradable.” Secondary markets for BCs provide liquidity and flexibility by enabling the resale or trade of previously issued credits, which can impact market dynamics and pricing.

In the BC market, trading can occur through exchanges or over-the-counter (OTC) transactions. Exchange-based trading is conducted on centralized, regulated platforms, providing transparency, liquidity, and standardized pricing, which makes BCs accessible to a broader range of investors. On the other hand, OTC trading occurs directly between parties, offering more flexibility and customization but with less transparency. OTC trades are typically used for large or complex deals, and while they provide more bespoke transaction terms, they lack the visibility of exchange-based trades. Both mechanisms play crucial roles in the BC market by offering different levels of transparency and flexibility. For this analysis, data was primarily sourced from exchanges, which provided standardized and transparent insights into the market. However, it was not possible to analyze OTC data due to its private and less accessible nature, limiting the visibility of those transactions.

In summary, the market analysis includes the number of implemented projects, issued and sold BCs, BC prices, fees for scheme administrators, and the tradability of credits (Table 2), with the distinction that exchange data was analyzed due to the unavailability of OTC information.

#### 3.3. Biodiversity credits sample of analysis

To assess the current state of BCSs definition and implementation, global data from a rapidly growing number of biodiversity related initiatives using different sources have been gathered. Most existing schemes have been identified using an online repository<sup>1</sup> that includes different typologies of BCS.) at different stages of development (approved or under development). Additionally, other schemes retrieved from grey literature have been included to complete the sample (WEF, 2022; Climate Focus, 2023a, Climate Focus, 2023b; Pollination, 2023; Taskforce on Nature Markets & Pollination, 2023;

<sup>1</sup> <https://airtable.com/appQsAybbCZy9PW08/shrrjW0SpAL0vVdZx/tblMxMzKrnq2pgIHR/viwE5BnaimUBQGioF>.

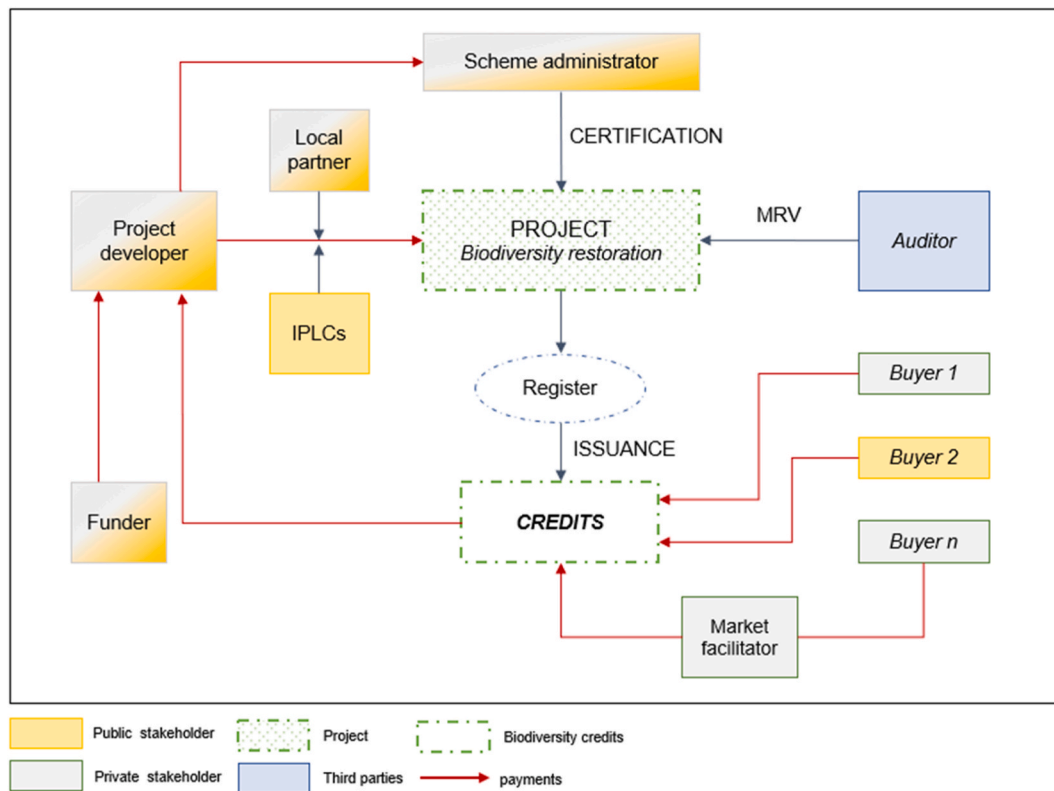


Fig. 1. Biodiversity credit schemes functioning.

Table 1  
BCSs analytical framework.

SCHEME	Scheme name	/
	Scheme developer	Private/Public
	Scheme administrator	Private/Public/Mixed
	Launch status (year)	Approved (year)/Under approval
	Geographical coverage	Global/National
	Offsetting	Allowed/Not allowed/N.A.
	Credit stacking	Allowed/Not allowed/N.A.
	Credit bundling	Allowed/Not allowed/N.A.
PROJECT	Ecosystem type	Terrestrial/Marine/Freshwater
	Activity type	Restoration/Preservation
	Project duration	Years/N.A.
	Additionality requirement	Yes/No
	Permanence requirement	Yes/No
	Non-leakage requirement	Yes/No
	Benefit sharing	Benefit sharing/N.A.
	Local stakeholder engagement	Local stakeholder engagement/N.A.
	Monitoring Reporting	/
	Verification	/
CREDIT	Credit name	/
	Credit unit and calculation approach	Index/Indicator/Mosaic/N.A.; Species/Habitat/Species and Habitat/N.A.
	Credit issuance approach	Outcome-based/Practice-based/Mixed
	Credit issuance timing	Ex-post/Ex-ante/Mixed
	Registry	Name/N.A.; Directly managed/Outsourced

Tedersoo et al., 2023; Zynobia Newman et al., 2023). In total, 68 schemes have been identified<sup>2</sup> and included in the sample. Within the sample, only BCSs focused on biodiversity net positive gain have been

Table 2  
Market analysis elements.

MARKET	# of projects	/
	# of issued credits	/
	# of sold credits	/
	Price per credit	/
	Fee for scheme administrator	Yes (quantity)/No
	Tradable	Yes/No

analyzed. Indeed, selections criteria applied are based on the BC definition: units of biodiversity restored or preserved, quantifiable, verifiable and tradeable units, and nature-positive aspirations. More specifically, schemes that have been excluded from the sample are those that: i) have *secondary focus on biodiversity* (2): schemes that have as main objective another environmental benefit and that affect biodiversity only indirectly, thereby restricting the analysis to schemes with well-identified units of biodiversity; ii) are *offset scheme* (2): schemes that are designed only for compensating negative impacts on biodiversity. Instead, schemes that are designed to contribute to the nature-positive objective, but with credits that can be used also for compensating own negative impacts have been included; iii) *bundled credits* (10): schemes with credits that include and account biodiversity and other environmental benefits, such as CO<sub>2</sub> reduction thus narrowing to those with a clear focus on biodiversity improvements. Instead, that are primarily focused on biodiversity but also include guidelines and methodologies for considering other environmental benefits, have been included. After a preliminary assessment of available information also schemes under development (23) have been excluded. Schemes that did not disclose their documentation (16) were contacted for follow-up.<sup>3</sup>

<sup>3</sup> Scheme developers have been contacted twice through various channels, including e-mail, online contact forms, and LinkedIn, in order to gather detailed information on the design and implementation of BCSs.

<sup>2</sup> Last sample update June 2024.

However, due to the lack of response or insufficient information provided, they were subsequently excluded from the sample. Table 3 summarizes the criteria, and the number of schemes excluded per each criterion.

The final sample on which the analysis has been conducted comprises fifteen schemes (Table 4). For each scheme, the scheme developer, the proper name of the scheme used to promote it and its status has been indicated.

#### 4. BCs comparative assessment results

The section outlines the main results that emerged regarding the BCs structure and peculiarities. Results are grouped following the analytical framework structure: i) schemes; ii) projects; iii) credits.

##### 4.1. Scheme

Identified schemes are both private-led (designed by private organization) and public-led (designed by governments). They were approved between 2022 and 2024 (Fig. 2a). The majority (12) have been developed by private organizations, while in three cases, national governments (UK, Australia, India) have developed the schemes. Generally, private-led schemes are administered by the same developer, whereas public-led schemes are always administered, solely or complementarily, by public organizations. Scheme developers' headquarters are concentrated in Australia (3), Colombia (3), United States (3), and UK (2). The remaining headquarters are in Brazil, Germany, India, and Mexico. Most schemes (10) have a global scope (Fig. 2b).

Among the schemes with national coverage are all three developed by public organizations, applying to the developers' jurisdictions: Australia, India, and UK. Additionally, both schemes with national coverage developed by private organizations are applicable to Australia, highlighting Australia's pioneering role, with three schemes developed and applicable there.

Finally, some schemes included in the sample are designed not only to generate positive biodiversity impacts. Indeed, some of them also foresee the possibility to generate offset, or to combine the generated biodiversity benefits with other environmental ones (i.e. bundling or stacking). Although offsetting schemes were excluded from the analysis, three analyzed schemes allow offsetting. This means that, despite being designed for nature-positive objectives, sold credits can also be used to offset impacts. For instance, in the Government of India scheme, credits can be used for compliance with compensatory afforestation; the Government of UK scheme includes credits for achieving the 10 % net gain and offsetting; and the LIFE Institute allows credits for compensating performance in their certification process. However, for most schemes (11), this possibility is explicitly forbidden, and for one scheme (ases), it is not specified (Fig. 3). Credit stacking is allowed by the majority (10) of the schemes. Only in two cases (BioCarbon, Terrasos) is it forbidden, and in three cases (LIFE Institute, Regen Network Development, Wilderlands), stacking is not specified (Fig. 3). Although schemes with bundled credits were excluded, the possibility of bundling issued "pure" BCs was explored. In almost all schemes (13), bundling is not addressed. Bundling is explicitly allowed by one scheme (Savimbo) and forbidden by another (Cercarbono) (Fig. 3).

**Table 3**  
Exclusion criteria and related BCs.

Criterion	BCs excluded
Secondary focus on biodiversity	2
Offset schemes	2
Bundled credits	10
Schemes under development	23
Missing documentation	16
<b>Final sample</b>	<b>15</b>

**Table 4**

Sample of existing BCs with launch status. \* Scheme documents have been finalized and consolidated by the scheme developer. \*\* Scheme documents are at the final stage of development; only minimal modifications could be applied.

SCHEME DEVELOPER	SCHEME NAME	STATUS
ases	ases On-Chain Protocol - Methodology for the issuance of Verified Biodiversity Credits	Approved* (2023)
BioCarbon Cert	Biodiversity Crediting Program	Approved (2022)
Cercarbono	Cercarbono Biodiversity Certification Programme (CBCP)	Approved (2024)
Government of Australia	Nature Repair Market	Approved (2023)
Government of UK	Biodiversity Net Gain	Approved (2024)
Government of India	Green Credit programme	Approved (2023)
GreenCollar	NaturePlus™ Scheme	Approved (2023)
LIFE Institute	LIFE Biodiversity Credits	Approved (2023)
Plan Vivo Foundation	Plan Vivo Biodiversity Standard (PV Nature)	Approved (2023)
Regen Network Development, PBC	Regen Registry Program - ERA Brazil Biodiversity Stewardship Credit Methodology	Approved (2024)
Savimbo	Biodiversity Program	Approved (2023)
Terrascope	Protocol for Nature Credits	Under approval**
Terrasos	Protocol for the Issuance of Voluntary Biodiversity Credits	Approved (2022)
Verra	Verra Sustainable Development Verified Impact Standard (SD VISta) - Nature Framework	Under approval
Wilderlands	Biological Diversity Unit	Approved (2022)

##### 4.2. Project

Projects for BCs generation can be implemented in different ecosystem types (terrestrial, marine, freshwater) adopting different activity types (restoration and/or preservation). Looking at the ecosystem type, the greatest share (7) in the sample is the one of the schemes that allow projects in any ecosystem type. It is followed by the one of schemes (6) focusing only on terrestrial ecosystems (BioCarbon, Government of India, Regen Network Development, Savimbo, Terrascope, Terrasos). One scheme (ases) allows projects both in the terrestrial and in the freshwater realm, and another one (Verra) in the terrestrial and the marine one (Fig. 4a).

Therefore, all the schemes apply to at least terrestrial ecosystems and nine of them also to another ecosystem type. It is interesting to highlight that only scheme designed by ases, Cercarbono, and Government of UK explicitly consider urban ecosystems. Regarding the activity type foreseen by the scheme, the vast majority (12) include both restoration-related and preservation-related activities.<sup>4</sup> In two cases (Regen Network Development, Savimbo) the scheme focuses only on preservation, while the remaining one (Government of India) focuses on restoration (Fig. 4b). Indeed, for the Government of India, despite different activity types are foreseen, including mangrove conservation and restoration, currently only the methodology for tree plantation has been developed. Concerning project duration, in three cases (Government of Australia, Government of India, GreenCollar) a minimum

<sup>4</sup> Among them, in some cases (e.g. GreenCollar) the two types of activities cannot be undertaken together (because different calculation formulas are foreseen for restoration and preservation projects). In addition, Cercarbono also includes among eligible activities, climate adaptation ones.

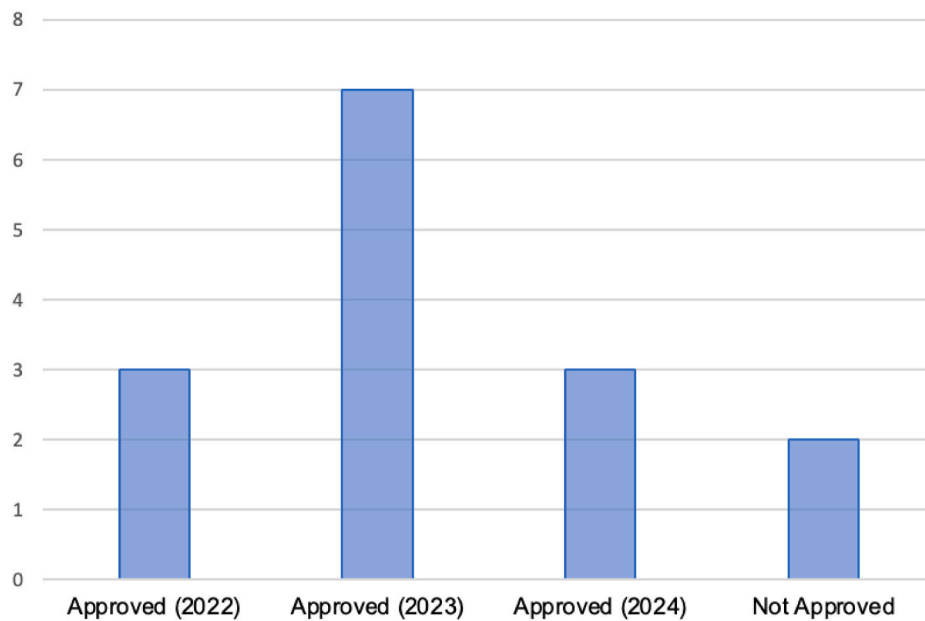


Fig. 2a. Schemes' launch status.

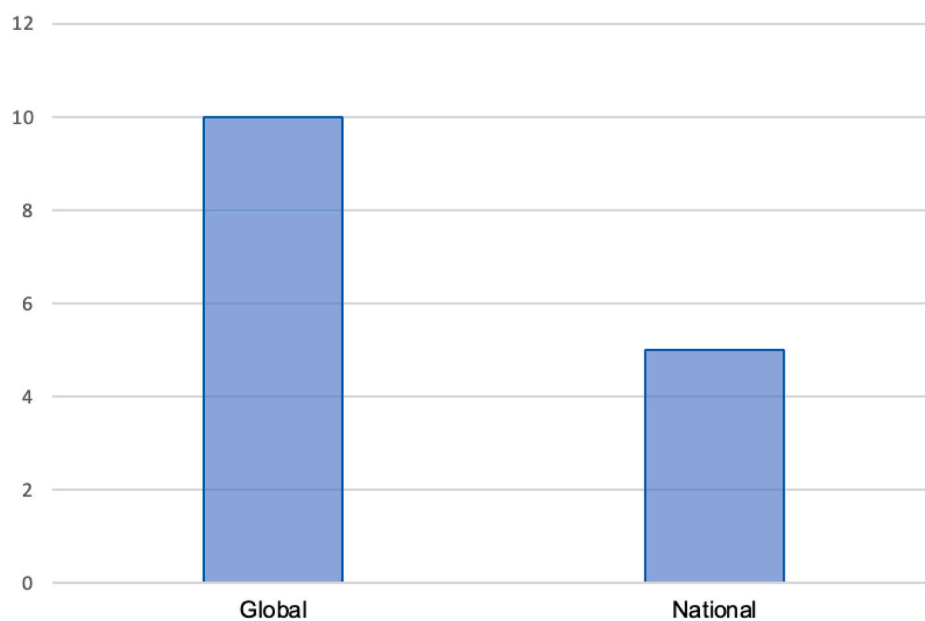


Fig. 2b. Schemes' geographical coverage.

requirement is not specified. When it is specified, instead, most cases (9) have a minimum duration of at least 10 years. Specifically, for four schemes the minimum requirement is precisely 10 years; for the other five schemes it is greater than ten years. It is twenty years for Terrasos, Verra, and Wilderlands; thirty years for Government of UK and LIFE Institute. The remaining three schemes have instead a minimum duration requirement of less than 10 years<sup>5</sup> (Fig. 5).

It is one year for Savimbo (for IPLC proponents), five years for Regen Network Development, 9 years for Terrascope. To ensure transparency

<sup>5</sup> For BioCarbon, Cercarbono, Plan Vivo Foundation, Regen Network Development, Terrascope the minimum project duration has been indirectly recovered from the crediting period, i.e. the period during which credits can be issued.

and avoid negative effects, most schemes include requirements for additionality, permanence, and non-leakage, though the level of detail and compulsoriness varies widely. Ten schemes address additionality (Fig. 6), either in general terms (Government of Australia) or through specific steps or provisions for demonstration by project developers (ases, BioCarbon, Cercarbono, GreenCollar, Plan Vivo Foundation, Savimbo, Terrasos, Terrascope, Verra). Demonstration can pertain to ecological aspects (e.g., whether net gains are generated by the project), financial aspects (e.g., resources provided by selling credits are essential to carry out the interventions), and the regulatory context (e.g., interventions are not already required by law in force). Permanence is addressed in thirteen schemes. Among these, eight schemes (ases, Cercarbono, GreenCollar, LIFE Institute, Plan Vivo Foundation, Terrascope, Verra, Wilderlands) adopt a reversal buffer to guarantee permanence. The buffer's value can be fixed or variable, with a maximum of 30 % of

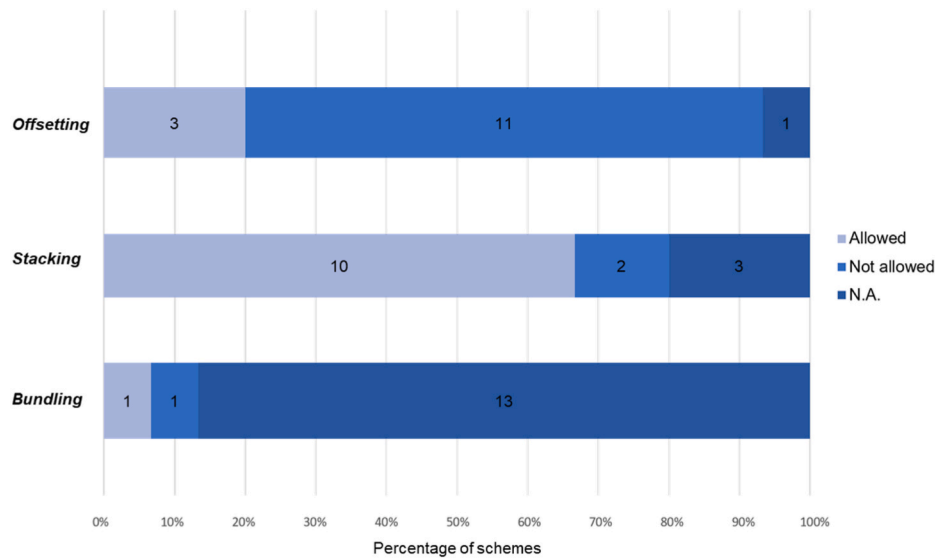


Fig. 3. Schemes' offsetting, credit stacking and credit bundling.

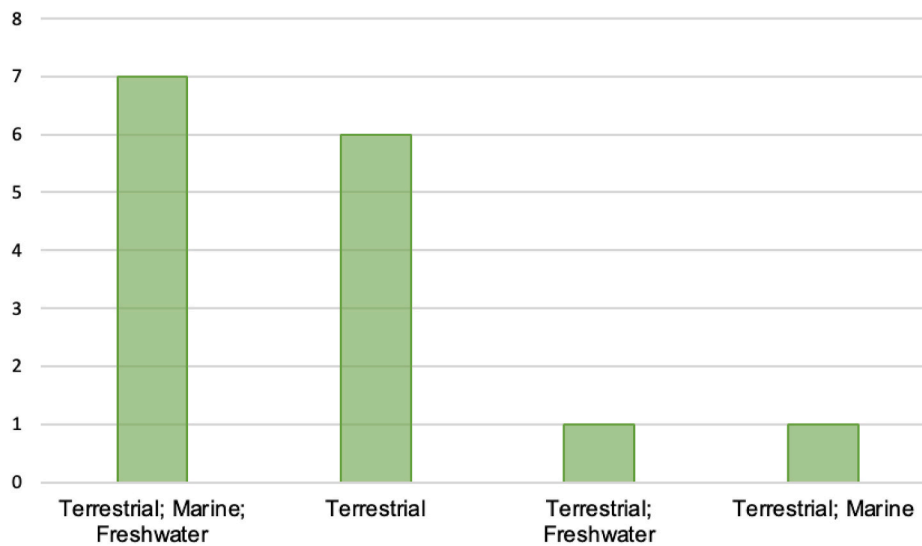


Fig. 4a. Schemes' ecosystem type.

total issued credits. In addition, permanence can be guaranteed with the requirement of: binding legal agreements (e.g., Government of UK, Wilderlands); demonstration of legal and financial conditions (Bio-Carbon); economic resources saved for the long-term conservation objective (Terrascope). Lastly, non-leakage is adopted in ten schemes. Four schemes (GreenCollar, LIFE Institute, Plan Vivo Foundation, Verra) include it in the formula for computing the total number of BCs. Others foresee assessments (Cercarbono), monitoring (Savimbo), and mitigation measures (Government of UK, Plan Vivo Foundation, Verra).

Looking at MRV, what emerges is that most schemes Monitoring and Reporting are carried out by the project developer itself, while Verification by a third party. In addition, Monitoring activities usually are carried out during the whole project duration, according to a monitoring plan; Reporting, with certain specific frequencies that varies based on schemes requirements; and Verification, before the issuance of BCs and can be based on the monitoring report. The literature underscores the importance of local stakeholder involvement in enhancing the efficacy of BCs. Accordingly, the analyzed BCs include requirements for benefit sharing and local stakeholder engagement. Specifically, benefit sharing is addressed in seven schemes, with three stipulating minimum

shares. For the LIFE Institute, if the community is involved, it must receive at least 30 % of revenues derived from credits; for the Plan Vivo Foundation, a minimum of 60 % must go to project participants; and for Terrascope, a minimum of 75 % must go to conservation, which includes the remuneration of IPLCs. The remaining schemes outline guidelines such as equitable sharing of advantages with local participants (Bio-Carbon), defining benefit-sharing agreements and mechanisms (Cercarbono, Verra), and transparent disclosure of remuneration for IPLCs (Savimbo). Local stakeholder engagement is required by twelve schemes, with varying levels of detail. For instance, Cercarbono and Plan Vivo Foundation have comprehensive requirements, ranging from stakeholder identification to consultation. Regen Network Development includes social engagement as a factor in the credit issuance calculations. Additionally, Plan Vivo Foundation and Wilderlands incentivize the involvement of IPLCs in project development. Moreover, Green-Collar, Plan Vivo Foundation, Savimbo, Terrascope, and Verra explicitly require Free Prior Informed Consent (FPIC) from IPLCs. Finally, the knowledge of IPLCs is explicitly considered in the schemes of the Government of Australia, Savimbo, Verra, and Wilderlands.

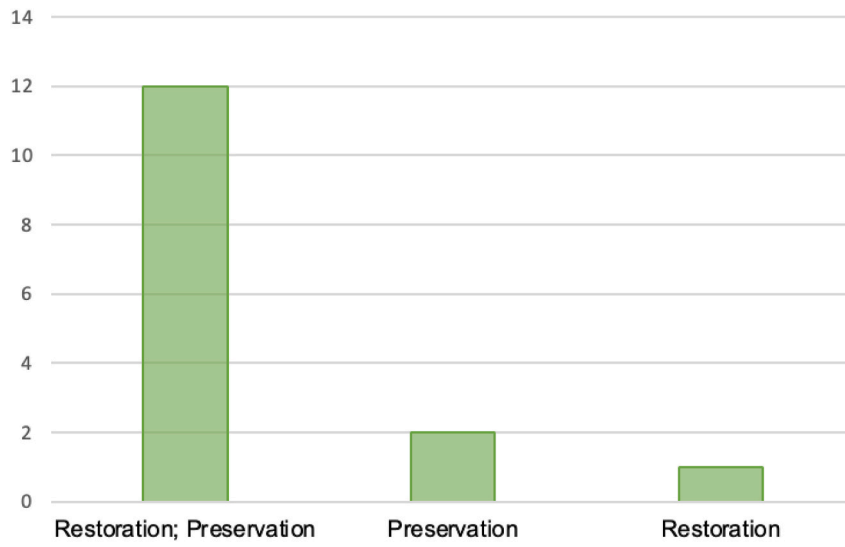


Fig. 4b. Schemes' activity type.

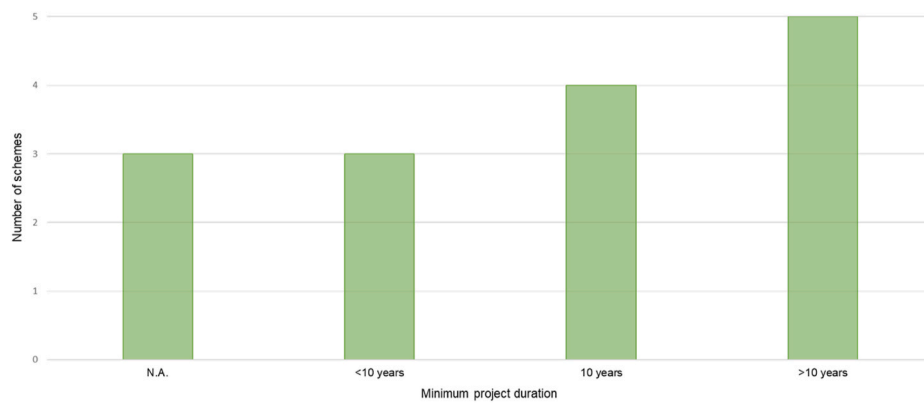


Fig. 5. Schemes' minimum project duration.

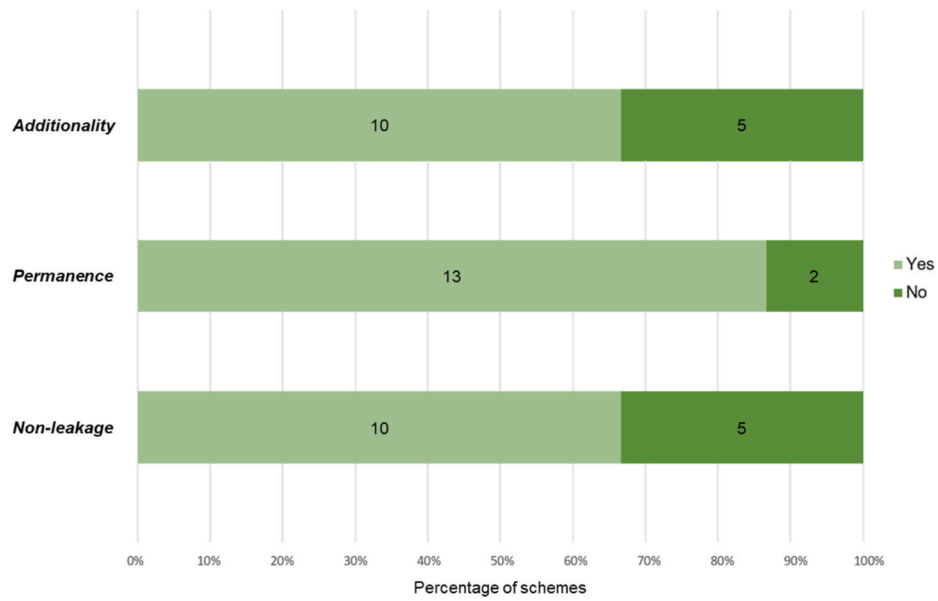


Fig. 6. Schemes' additionality, permanence and non-leakage.

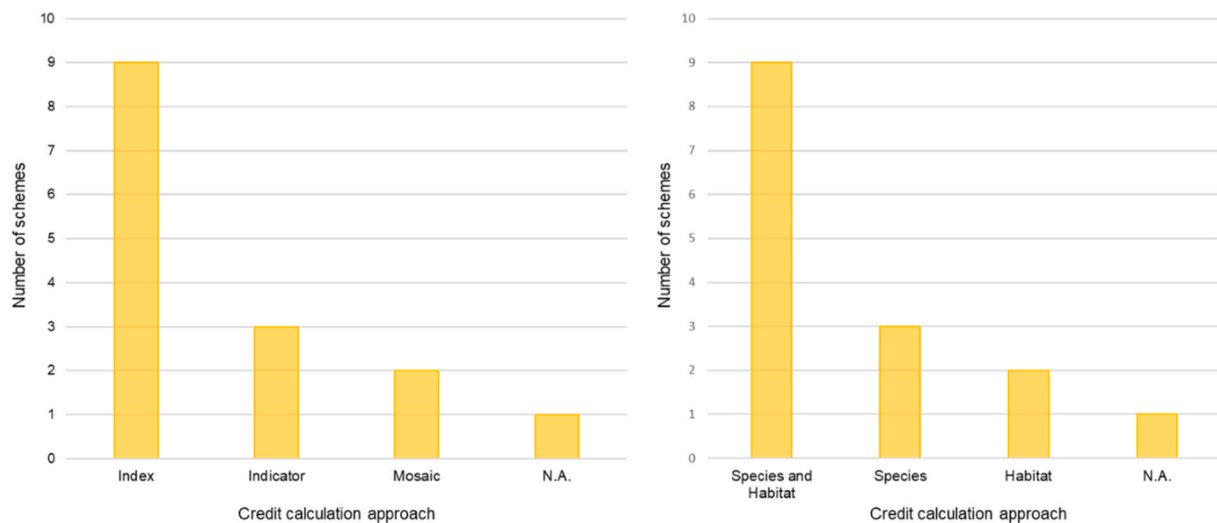


Fig. 7. Schemes' credit calculation approach.

#### 4.3. Credit

The characteristics of credits show the highest level of heterogeneity among the elements analyzed, starting from the nomenclature adopted by each scheme. The most frequently used terms are "Biodiversity" (11) and "Credit" (11). Other terms include "Nature" (3) and "Green" (1) for biodiversity, and "Certificate" (2), "Unit" (1), and both "Credit" and "Unit" (1). The Government of UK uses the terms "Statutory biodiversity credits" and "Off-site biodiversity unit". Regarding credit units and calculation approaches, most schemes (11) define each credit as corresponding to a specific project area or this information can be retrieved (Government of UK). In eight cases, this area is measured in hectares, while in three cases, it is measured in square meters. Instead, some schemes adopted different approaches. In particular, in the case of Government of UK, each hectare of the project area can generate between two and six units, the Government of Australia assigns each credit to a different project, and the Government of India equates each credit to a tree planted. For the remaining two schemes (LIFE Institute, Regen Network Development), the unit is not clearly specified. The methodologies for BCs calculation are in general different across the schemes. The only exceptions regard Cercarbono, which adopts the methodology of Savimbo; and Regen Network Development, which can apply the methodologies of GreenCollar and Terrasos in addition to the one developed by ERA Brazil. Biodiversity can be measured using a single metric or multiple metrics. In most cases (9), the calculation is based on an index. Two cases (LIFE Institute, Regen Network Development) employ a mosaic approach, while one case (Government of Australia) has not yet defined this aspect (Fig. 7). The approach to credit calculation also varies significantly, reflecting the complexity of biodiversity compared to carbon credits. Biodiversity enhancement can be measured through species attributes such as variety, number of individuals, and degree of threat, or through habitat features. More than half of schemes (9) include both species-related and habitat-related metrics in their formulas for computing the total number of credits. Three schemes (Cercarbono, Government of India, Savimbo) focus on species, while two (Government of UK, Terrasos) emphasize habitats. The Government of Australia scheme does not specify this aspect.

Regarding credit issuance, for more than half of schemes (8) it is outcome-based and ex-post. In two cases (Government of Australia, Government of UK) it is outcome-based and mixed; in one (Wilderlands) outcome-based and ex-ante; in two (Government of India, LIFE Institute) practice-based and ex-post; in one (Regen Network Development) respectively mixed and ex-post and in another one (Terrasos) mixed and mixed (Fig. 8a). Therefore, outcome-based (11) and ex-post (11)

issuances are the most common ones. Indeed, only in two cases issuance is purely based on practice and only in one case it is solely ex-ante. For the remaining cases, respectively two and three, it is mixed. Regarding the registry, most schemes (10) directly manage the registry in which the project and the credits issued are listed. Only in five cases<sup>6</sup> the registry is outsourced to a third party (Fig. 8b).

Finally, it is interesting to highlight that some schemes foresee the possibility of differentiating credits, attributing either different prices to them or a label highlighting specific features to orientate investors in their purchases. Differentiation is based on the typology of project that is implemented and in particular on the typology of habitat that is restored. Among the schemes that differentiate BCs also with prices, there are the Cercarbono's and Government of UK's ones. Cercarbono proposes (not compulsory) differentiation based on existing international frameworks or conventions on biodiversity<sup>7</sup> for prioritizing more urgent action for biodiversity. The Government of UK has developed different types of credits, differentiating hedgerows and watercourses from habitat areas and considering rarity of habitat and species richness. For Plan Vivo Foundation's scheme, instead, BCs are only differentiated with labels, which are metadata associated to the project, highlighting the global significance of the biodiversity supported (i.e. threat status or protected area status).

#### 5. Biodiversity credits' market analysis results

Currently, ten schemes have been adopted by project developers for BCs generation. Only one of these schemes has been developed by a public organization, specifically the Government of UK. This scheme is analyzed separately due to its unique compliance nature, and because, for the moment, only UK stakeholders can purchase BCs generated under this scheme. Among remaining nine schemes, a total of 50 projects have been initiated. Nineteen of these projects (17 by GreenCollar and 2 by Terrascope) are still under development. Analyzing the geographical distribution of these projects, the majority are located in Australia (24 projects) and Brazil (15 projects). The rest are distributed across Colombia (2), Ecuador (1), France (2), Laos (1), Malaysia (1), Mexico

<sup>6</sup> Cercarbono and Savimbo to EcoRegistry; Terrasos to Regen Registry System and Biotrust; Wilderlands to Vegetation Link.

<sup>7</sup> IUCN Red List of Ecosystems categories; Biodiversity Hotspot; Irreplaceable biodiversity and irreplaceable carbon; CBD National targets; IUCN Global Ecosystem Typology; UNEP Forest Biodiversity Intactness Index; Ramsar Wetland Classification; World Heritage List UNESCO.

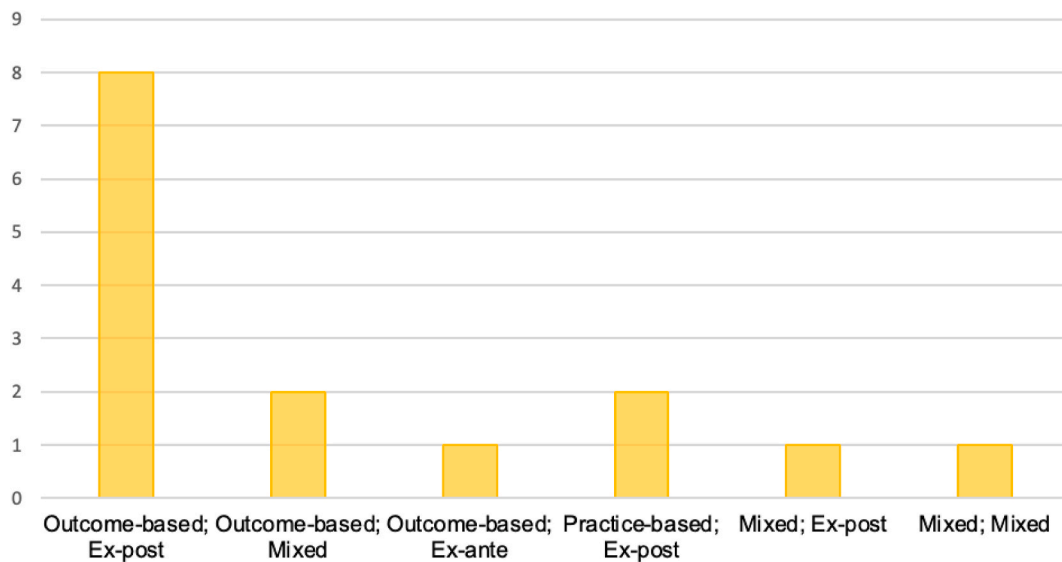


Fig. 8a. Schemes' credit issuance approach.

(1), Portugal (2), and Spain (1) (Fig. 9a). In terms of spatial extension, Brazil encompasses the largest total area with 809,360 ha, followed by Colombia with 74,540 ha, Australia with 51,929 ha, and Ecuador with 10,000 ha. Smaller areas are in Mexico (200 ha), Portugal (103.48 ha), Spain (38 ha), and France (0.32 ha). For Laos and Malaysia, the information is not available (Fig. 9b). Consequently, BC issuance projects cover nearly 1 million hectares in total.

Additional information regarding the BCs market has been obtained from the websites of schemes' developers, registries, and market facilitators, as well as through interviews with these entities. Table 5 presents these findings, detailing for each scheme developer the number of issued, retired, and sold BCs, along with credit prices. The table also includes the number of projects, their total area, and the type of activity involved. For issued BCs, actual numbers are provided where available; otherwise, projected figures are given. To facilitate price comparison both across and within schemes, values have been converted to dollars and calculated on a per-ha, per-year basis. Data reveal considerable heterogeneity among the schemes, with frequent gaps in information, particularly regarding sold BCs and their prices.

Among the schemes, the majority (seven) have already issued BCs. In total, 11,661,887.05 BCs have been issued or are projected to be issued, with the actual issued BCs totalling 5,789,664. Information on the number of sold BCs is rarely available, with only three schemes publicly disclosing this data. In total, 124,183 BCs have been sold of which 1285 retired. BC prices vary widely across schemes and even within the same scheme. Despite efforts to standardize these prices by converting them to dollars per hectare per year, significant differences remain, with prices ranging from \$7 to \$68,000. This heterogeneity can be attributed to three main factors: (i) the type of credit (depending on the habitat considered); (ii) the type of project (based on the activities carried out); and (iii) the type of seller. Notably, the lowest prices are associated with schemes focusing solely on preservation activities. Regarding the secondary market, four schemes (ases, BioCarbon, LIFE Institute, Regen Network Development) allow it, while three schemes (GreenCollar, Terrasos, Wilderlands) do not, and information is not available for the remaining two. A trading fee in favor of the scheme administrator is explicitly stated by one scheme (LIFE Institute), while for the others, this information is not available.

Overall, schemes differ in their geographic focus, project proponents, pricing mechanisms, and registry functionalities, with varying degrees of transparency and market facilitation. Looking more in detail at each scheme, ases includes two projects in France, two in Portugal, and one in Spain, all managed by Life Terra Foundation. A unique aspect of this

scheme is that prices are listed in bitcoins (MATIC) and transactions are conducted on the Polygon Mainnet blockchain platform, although USD values are also provided. Royalties are designated for the credit owner. BioCarbon scheme has recently listed its first project, developed by CarbonPlus, in Mexico. Regen Network Development has projects in Ecuador and Brazil, focusing on jaguar monitoring. These projects offer pre-sale BCs, with one project having 200,000 BCs available out of a projected 1,400,000. Savimbo's project is in Colombia, possibly consisting of several smaller projects. The scheme offers two types of BCs: "Biodiversity credit" (pre-certified) and "Biodiversity + Impact credit" (MRV), priced at \$7.50 and \$5 per hectare per month, respectively. These BCs can be sold through platforms such as DOVU, Boosterra, Xpansive, Emsurge, and Senken. Terrasos's project is located in Colombia. BCs are priced based on land extension (\$25 for 10 m<sup>2</sup>, \$70 for 30 m<sup>2</sup>, and \$110 for 50 m<sup>2</sup>) and are sold through the Boosterra platform. They are listed in Biotrust and Regen Registry System, with transactions facilitated by Climate Trade and Regen marketplace, involving either a fee or cryptocurrency requirements. Wilderlands has projects in Australia, with BCs sold in packages based on land coverage and activity duration. All projects are listed in the Vegetation Link registry and sold through the Boosterra Marketplace. GreenCollar's projects are all based in Australia, despite plans for global expansion, with further developments needed to apply outside Australian borders. No public registry for GreenCollar was found. LIFE Institute's projects are located in Brazil. While the registry is not public, a document provides details on projects, including area, status, estimated credits, and contact information. Buyers do not need an account on the platform, and transactions must be reported to LIFE Institute. No information on issued or sold credits or their prices was found. Terrascape has two projects under development, one in Malaysia and another in Laos, although the scheme's documents are not yet finalized.

Since the UK Biodiversity Net Gain (BNG) scheme is mandatory and BC generated can be sold only within national boundaries, market have been described separately from other BCs. BNG scheme allows for BCs to be obtained onsite, offsite, or through statutory biodiversity credits.<sup>8</sup> A national registry, operated by Natural England, records offsite gain sites. Statutory credits are sold only by Natural England on behalf of DEFRA, while offsite biodiversity units can be sold by different stakeholders (e.g.: landowners, habitat bank operators, brokers, trading

<sup>8</sup> Statutory credits are a last resort for this reason prices include a markup to prevent undercutting the offsite market.

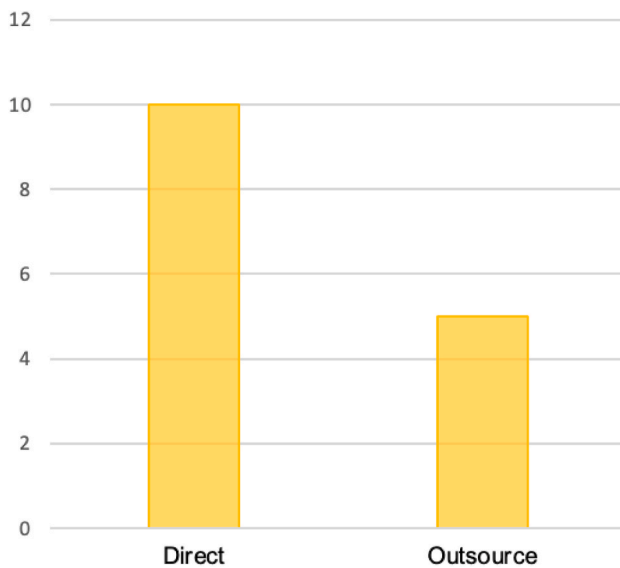


Fig. 8b. Schemes' registry management.

platforms, local authorities). Market facilitators (e.g.: Gaia, Environment Bank, Ground Control, and Wild Capital) connect developers to buy/sell offsite credits on their platforms, with prices negotiated among contracting parties. Price standardization for the UK scheme is challenging due to the lack of a direct link between units and area size. Calculations were made assuming that 1-ha project can release between 2 and 6 units, and one offsite unit is equivalent to two statutory credits. Statutory credit prices range between £42,000 (\$54,180) and £625,000 (\$806,250), but information on sold credits is not available. For offsite biodiversity units, sold credit data comes from allocated units in the registry for one project, while prices are not publicly available except for one the market facilitator, Gaia. Gaia's revenue includes £604,747,140 (\$780,123,811) for area habitat, £46,040,520 (\$59,392,271) for hedgerow, and £11,790,250 (\$15,209,423) for watercourse habitats. Gaia's projects include a minimum of 1338 km of hedgerows and 666 km of watercourses. Overall, information on sold credits and prices is rarely available for the UK scheme. All available information is summarized in Table 6.

## 6. Discussion and conclusions

The paper analysis 15 BCSs focused on achieving net positive biodiversity gains, examining their characteristics in terms of structure, involved stakeholders and approach adopted for credit calculation and issuance. Results indicate significant structural variation among BCSs, with most being private-led and fewer developed by national governments. The dominance of privately led biodiversity credit schemes raises important concerns related to regulatory oversight, environmental integrity, and cost-efficiency. In the absence of standardized rules and third-party verification, there is a risk of greenwashing and inconsistent definitions of additionality and permanence (CBD, 2022; Green Finance Observatory, 2021). High transaction costs further limit accessibility, particularly for smaller actors (Pascual et al., 2022). These challenges point to the need for stronger governance frameworks to ensure credibility and effectiveness. Nevertheless, with appropriate safeguards, privately led schemes have the potential to play a complementary role in mobilizing capital for biodiversity conservation at scale. Schemes encompass diverse ecosystems, including terrestrial, marine, and freshwater environments, and involve activities like restoration and/or preservation. Ensuring additionality, permanence, and non-leakage is crucial, with different schemes adopting varied approaches. Among schemes, ten have initiated 49 projects (19 of which are under development), that are mainly located in Australia and Brazil. In these countries, BCSs have developed more rapidly, due to specific geographical and institutional conditions. Both countries have extensive areas of high biodiversity and have experienced significant land-use change, which increases the importance of instruments designed to compensate for biodiversity loss. Regulatory frameworks—such as biodiversity offset schemes in Australia and the Forest Code in Brazil—provide a legal foundation for the development of credit-based mechanisms. Biodiversity offset schemes are formal policies that require developers to compensate for residual impacts on biodiversity by ensuring equivalent gains elsewhere, following principles of 'no net loss' or 'net gain' of biodiversity (BBOP, 2012; IUCN, 2020). In Brazil, the Forest Code mandates the maintenance and restoration of native vegetation on rural properties, serving as the legal basis for mechanisms such as Environmental Reserve Quotas (CRA), which enable biodiversity credit trading (Soares-Filho et al., 2014; Rajão et al., 2020). Their federal systems allow subnational governments to design and implement context-specific schemes. Moreover, both countries possess technical

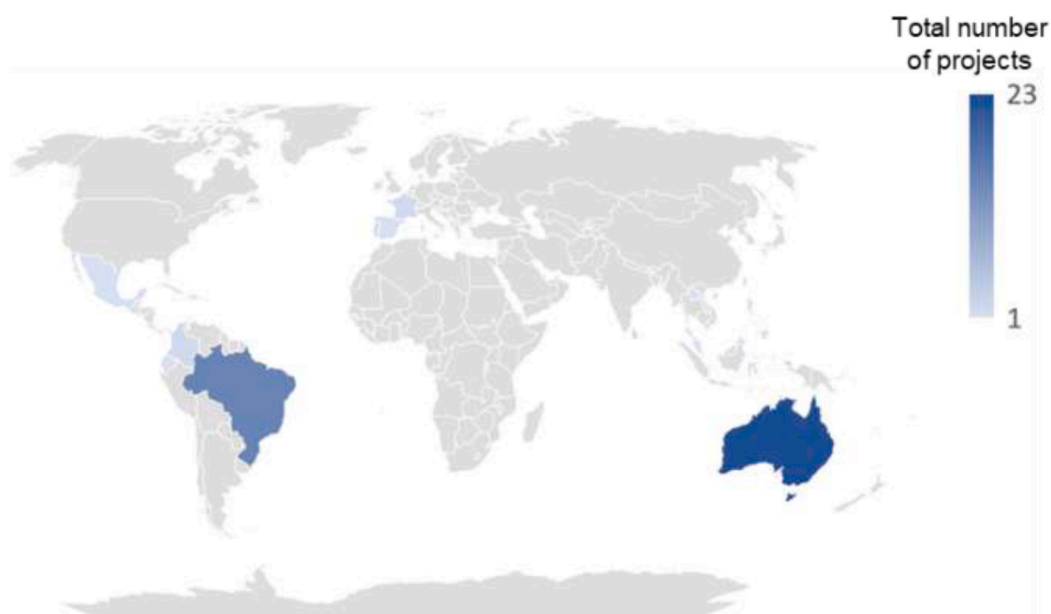


Fig. 9a. Total number of projects.

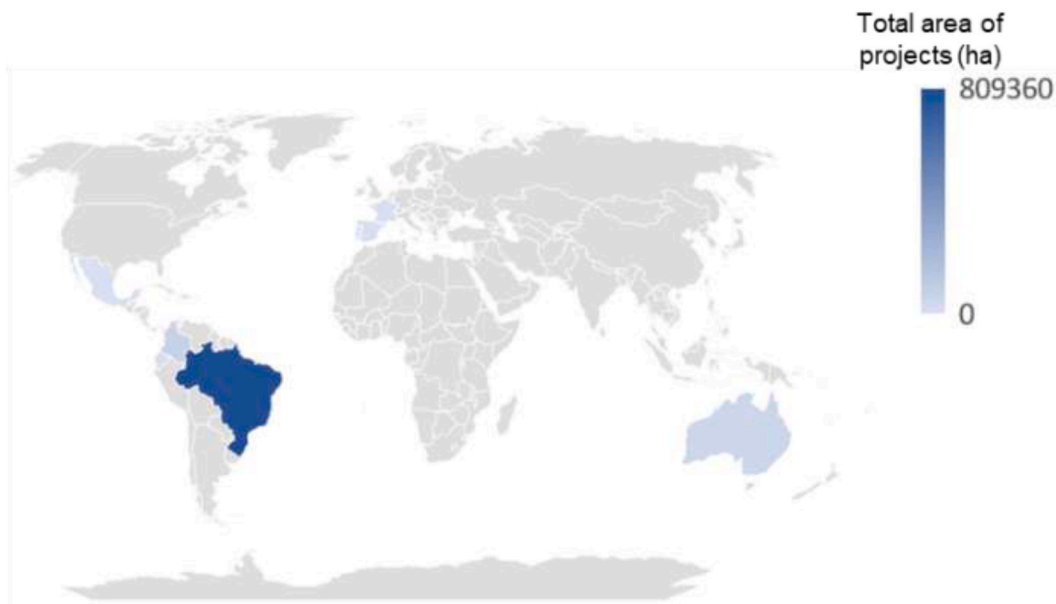


Fig. 9b. Total area of projects (ha).

**Table 5**  
Schemes' market. \*Values based on own calculations. \*\*Values sent via mail.

Scheme developer	# of projects	Area (ha)	Activity type	# credits issued (estimated)	# credits sold (retired)	Price (\$/ha/y)
ases	5	142	Both	3086	N.A. (0)	94–233
BioCarbon	1	200	Both	N.A.	N.A.	N.A.
GreenCollar	20	51,233	Restoration	60,435	N.A.	N.A.
LIFE Institute	14	758,760	Both	(4,396,923)	N.A.	N.A.
Regen Network Development	2	60,600	Preservation	(1,475,300)	N.A.	7–18*
Savimbo	1	74,200	Preservation	94,000	2030*	60–90
Terrascape	2	N.A.	N.A.	N.A.	N.A.	N.A.
Terrasos	1	340	Both	62,063	1543* (1285)	733–1052
Wilderlands	4	696	Both	5,570,080**	120,610**	20,400–68,000**

**Table 6**  
Government of UK scheme. \*Values based on own calculations. \*\*Values retrieved from interview.

Credit type	Source	# of projects	Total area (ha)	# of issued credits	# of sold credits	Mean price (\$/ha/y)
Statutory credit	Government website	N.A.	N.A.	N.A.	N.A.	21,543–64,629*
Offsite unit	National registry	9	266	532–1597*	13	N.A.
	Gaia	233**	3762**	22,621**	N.A.	6460*
	Environment Bank	46	529	1057–3171*	N.A.	N.A.
	Ground Control	2	160	514	N.A.	N.A.
	Wild Capital	2	32	260	N.A.	N.A.

capacity in environmental assessment and land monitoring, which facilitates the operationalization of BCs. Seven schemes have issued or plan to issue a total of 11,661,887.05 credits, with 5,789,664 already issued, 124,183 sold, and 1285 retired. Credit calculation and issuance methods differ significantly, with a preference for outcome-based and ex-post issuance. Market shows considerable variability in issued/sold credits and their prices. Finally, findings underscore the critical role of transparency, stakeholder engagement (specifically IPLCs), and metrics in enhancing the effectiveness and credibility of BCs. To fully exploit the demand potential while maintaining high integrity, developments are necessary across three key facets: metrics, governance, and market.

The methodologies and metrics adopted to measure biodiversity are crucial for balancing standardization with context-specificity to facilitate market development (NatureFinance & Carbone 4, 2023; Climate Focus, 2023a, Climate Focus, 2023b). Currently, methodologies for biodiversity accounting in BCs are highly varied, leading to significant difficulties in comparing credits across different schemes. Some

initiatives focus solely on species or habitat metrics, while others attempt to combine both. The absence of comprehensive metrics that account for the complexity of biodiversity can undermine the effectiveness of the credits. Ensuring the accuracy and reliability of biodiversity measurements is challenging. The diversity in the methodologies complicate the assessment and comparability between credits, with some incorporating different ES (e.g.: habitat connectivity) and others considering solely metrics referred to species conservation and/or restoration. Standardization in biodiversity metrics is essential for comparability, credibility, additionality, and permanence in BC schemes (WEF, 2020). The endeavour to establish a unified metric for biodiversity appears inherently problematic. The ecological value of individual components of nature is highly context-dependent, and the vast diversity of life results in numerous exceptions to any standardized rule. Consequently, any “basket of metrics” approach is prone to cherry-picking, compromising its robustness and validity (Mace et al., 2018; Purvis, 2020; Sutherland et al., 2013). The methodological

heterogeneity observed across BCSs reflects the current developmental stage of these instruments, where no dominant standards have yet been consolidated. This fragmentation is not unexpected in emerging environmental markets and mirrors the early evolution of carbon credit systems. In the voluntary carbon market, initial diversity in metrics and protocols gradually gave way to greater standardization, as actors converged around a limited number of robust and credible schemes (e. g.: Verra and Gold Standard). In contrast, BCSs remain characterized by diverse evaluation criteria, indicators, and verification procedures, which hinders consistency across schemes. As Mace et al. (2018) have noted, the reliance on multi-dimensional indicators, while ecologically appropriate, introduces substantial complexity and limits cross-scheme comparability. Advancing toward standardized biodiversity metrics will therefore require coordinated efforts across scientific, regulatory, and standard setting actors to identify common rules and indicators that are both ecologically meaningful and operationally feasible within crediting systems.

Governance is another crucial aspect for the efficacy of BCSs. The heterogeneity observed in current schemes leads to inconsistencies in how BCs are issued and managed. Some schemes suffer from regulatory gaps, lacking robust frameworks to ensure compliance and enforce standards, which can compromise credits integrity. The roles of stakeholders in the execution of BCSs are varied and include project developers, investors, regulatory bodies, and local communities. Project developers are responsible for the implementation and monitoring of biodiversity projects, investors provide necessary capital, regulatory bodies ensure compliance with environmental standards, and local communities, particularly IPLCs, are integral to the sustainability and social integrity of the projects. IPLCs engagement is often insufficient, posing significant challenges in ensuring equitable benefit-sharing. It is imperative to implement mechanisms for equitable benefit-sharing between IPLCs and project developers, with active IPLC involvement in market design and development (Zynobia Newman et al., 2023). Examples of effective engagement include projects by Savimbo and Terrasos. National governments and international organizations can play a pivotal role in enhancing the integrity of BCSs by enforcing environmental regulations to limit leakage risk and instituting property laws that clarify IPLCs' land rights and ownership of credits on public or community land (WEF, 2023). Additionally, by developing and enforcing standardized guidelines and frameworks, regulators can help ensure that all stakeholders adhere to best practices, thereby enhancing the overall credibility and effectiveness of BCSs. In this case the scheme developed by UK represents a guidance. The governance of BCSs must include well-defined roles for all stakeholders, robust and transparent frameworks, and active involvement of IPLCs. Addressing these aspects will lead to greater consistency, accountability, and integrity, ultimately resulting in more effective and sustainable biodiversity conservation outcomes.

The BCs market faces several critical issues that hinder its development and scalability. One of the main challenges is the significant variability in the pricing of BCs, influenced by factors such as habitat type, project activities, and the seller. Price volatility constitutes a critical structural barrier to the development of credible and investable BCSs. As observed in other emergent environmental markets, including early carbon trading systems, the combination of limited liquidity, heterogeneous credit quality, and the absence of robust price benchmarks often results in thin markets characterized by significant valuation uncertainty (Piris-Cabezas and Lubowski, 2018; Liang et al., 2016). In the context of BCSs, where the ecological and financial value of credits remains subject to evolving methodologies and standards, this uncertainty can hinder both supply-side participation and demand-side confidence. Addressing this challenge may require the introduction of price stabilization mechanisms - such as government-backed minimum purchase guarantees, public reserve facilities, or market-making functions - that can provide price stabilization, enhance investor assurance, and support orderly market development (World Bank, 2022). Such

instruments are particularly relevant during the initial phases of market formation, when volatility is highest and price signals are most fragile. Additionally, improving efficiency and lowering project development costs are necessary steps to meet the potential demand (WEF, 2023; International Advisory Panel on Biodiversity Credits – IAPBC, 2024). Overcoming the barrier of postponed payments in outcome-based credits is crucial, as delays between project initiation and credit issuance can impede supply growth, particularly in the absence of development finance (Pollination, 2023). This variability complicates investors' ability to consistently assess the value of credits. Furthermore, the infrastructure for trading BCs is still underdeveloped, with some schemes lacking efficient platforms for buying and selling credits, and secondary markets not always available. Another critical issue is the difficulty in retrieving information on available projects and credits, which complicates decision-making for investors and other stakeholders. The presence of intermediaries or market facilitators can help bridge gaps in the biodiversity credits market, but their roles and impact must be clearly defined and managed to avoid potential conflicts of interest or additional costs. Facilitators play a crucial role in enhancing market transparency by providing valuable information and expertise to both buyers and sellers and helping to standardize processes (Mandel et al., 2010; Narloch et al., 2011). They can also improve market liquidity and accessibility by developing efficient trading platforms and secondary markets, thereby increasing investor confidence (Ecosystem Marketplace, 2020). However, if their roles and fees are not transparently managed, they could introduce additional costs and reduce overall market efficiency. Proper regulation is essential to ensure that facilitators contribute positively to the market without driving up transaction costs (Bull et al., 2013). High transaction costs, including administrative fees, compliance costs, and the expenses associated with monitoring and verification, can be significant barriers to market efficiency and participation (Wunder, 2007). Finally, to improve the supply of BCs, it is essential to ensure integrity (WEF, 2023). Integrity is crucial for ensuring that positive impacts on biodiversity and communities are effective, requiring the development of high-integrity credits at a sufficient scale (NatureFinance & Carbone 4, 2023). Several key elements ensure the integrity of biodiversity credits. Firstly, additionality is necessary; projects must demonstrate that their activities result in net positive gains in biodiversity that would not have occurred without the project. Permanence involves ensuring long-lasting benefits through measures like legal agreements or conservation easements to maintain biodiversity gains over time. Non-leakage ensures that biodiversity benefits in one area do not lead to negative impacts in another. Robust monitoring and verification are essential, requiring regular scientific monitoring and independent third-party verification to track progress and validate results. Transparency is also crucial, with project documents, methodologies, and outcomes made publicly available to allow for validation by stakeholders.

All in all, achieving a balance between high integrity, rigorous MRV, fair pricing, and public willingness to pay is necessary for sustainable market growth (Pollination, 2023). Robust governance and regulatory support are vital for expanding market size and preserving integrity. Establishing transparent institutional arrangements and robust governance frameworks is essential (NatureFinance, 2023; Pollination, 2023). This is further underscored by the fact that BCSs have so far emerged only in a limited number of contexts, typically those characterised by advanced institutional capacity and relatively mature environmental markets. Their absence in other countries reflects the demanding governance and market conditions these mechanisms require to function effectively. Future research can play a transformative role in clarifying the financial and management implications of biodiversity loss. In finance, there is a pressing need for methodologies to quantify and integrate biodiversity-related risks into asset pricing, sovereign credit ratings, and investment decisions (Dasgupta, 2021; Aglietta and Espagne, 2016). Regulatory developments - such as emerging sustainability reporting obligations and nature-related disclosure frameworks

(e.g., CSRD and TNFD) - also offer empirical opportunities to investigate how policy shapes market practices and investor responses. In management, further studies should examine how firms internalize biodiversity considerations within strategic planning, risk management, and supply chain governance. Comparative research on organizational responses to biodiversity-related risks can offer valuable insights into the institutional determinants of adaptive capacity and long-term value creation, thereby informing strategies that support both ecological resilience and corporate sustainability. Standardized guidelines and frameworks can help address these issues by providing clear and consistent protocols for the issuance, management, and verification of biodiversity credits.

### CRedit authorship contribution statement

**Edoardo Croci:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Benedetta Lucchitta:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Marta Cusa:** Writing – original draft, Visualization, Investigation, Data curation.

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### Declaration of competing 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.

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### Data availability

Data will be made available on request.

### References

- Aglietta, M., Espagne, E., 2016. Climate and Finance Systemic Risks, More than an Analogy? the Climate Fragility Hypothesis. CEPII Policy Brief.
- Antonelli, A., Rueda, X., Calcagno, R., Nantongo Kalunda, P., 2024. How biodiversity credits could help to conserve and restore nature. *Nature* 634 (8036), 1045–1049.
- Arlidge, W.N.S., Bull, J.W., Addison, P.F.E., Burgass, M.J., Gianuca, D., Gorham, T.M., Jacob, Shumway, C.N., Sinclair, S.P.P., Watson, J.E.M., Wilcox, C., Milner-Gulland, E.J., 2018. A global mitigation hierarchy for nature conservation. *Bioscience*.
- Barbier, E.B., 2021. Habitat loss and the risk of disease outbreak. *J. Environ. Econ. Manag.* 108, 102451. <https://doi.org/10.1016/j.jeem.2021.102451>.
- BBOP, 2012. Standard on Biodiversity Offsets. Business and Biodiversity Offsets Programme.
- Biodiversity Consultancy, 2022. Exploring Design Principles for High Integrity and Scalable Voluntary Biodiversity Credits. The Biodiversity Consultancy Ltd, Cambridge, U.K.
- Bull, J.W., Hardy, M.J., Moilanen, A., Gordon, A., 2018. Categories of flexibility in biodiversity offsetting, and their implications for conservation. *Biol. Conserv.* 227, 152–160. <https://doi.org/10.1016/j.biocon.2018.09.022>.
- Bull, J.W., Suttle, K.B., Gordon, A., Singh, N.J., Milner-Gulland, E.J., 2013. Biodiversity offsets in theory and practice. *Oryx* 47 (3), 369–380.
- Caldecott, B., 2021. Nature-based solutions: financing natural climate solutions and biodiversity conservation. *Journal of Environmental Investing* 12 (1), 45–59. <https://doi.org/10.2139/ssrn.3873656>.
- Capitals Coalition, 2021. Natural capital for biodiversity policies. <https://capitalscoalition.org/wp-content/uploads/2021/04/Natural-capital-for-biodiversity-policy—FINAL-1.pdf>.
- Cardinale, B.J., et al., 2012. Biodiversity loss and its impact on humanity. *Nature* 486 (7401), 59–67.
- CBD, 2022. Decision 15/4: Kunming-Montreal Global Biodiversity Framework (CBD/COP/DEC/15/4). Convention on Biological Diversity. <https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf>.
- Chen, X., et al., 2021b. Biodiversity credits: a new approach to conservation finance. <https://www.ecosystemmarketplace.com>.
- Climate Focus, 2023a. Definition of Biodiversity Credits issue paper n.3.
- Climate Focus, 2023b. Bcs Markets. Charting Pathways for Early Investment and Sustainable Market Growth.
- Costanza, R., et al., 2014. Changes in the global value of ecosystem services. *Glob. Environ. Change.* <https://doi.org/10.1016/j.gloenvcha.2014.04.002>.
- Dasgupta, P., 2021. The Economics of Biodiversity: the Dasgupta Review. HM Treasury.
- De Groot, R., Van der Perk, J., Chiesura, A., van Vliet, A., 2003. Importance and threat as determining factors for criticality of natural capital. *Ecol. Econ.* 44 (2–3), 187–204. [https://doi.org/10.1016/S0921-8009\(02\)00273-2](https://doi.org/10.1016/S0921-8009(02)00273-2).
- Diaz, S., et al., 2006. Biodiversity loss threatens human well-being. *PLoS Biol.* 4 (8), e277.
- Dovu. Savimbo biodiversity credits. <https://app.dovu.market/projects/savimbo-biodiversity-credits>.
- Ducros, A., Steele, P., 2022. Biocredits to Finance Nature and People. International Institute for Environment and Development, London.
- Duffy, J.E., 2009. Why biodiversity is important to the functioning of real-world ecosystems. *Front. Ecol. Environ.* 7 (8), 437–444. <https://doi.org/10.1890/070195>.
- Ecosystem Marketplace, 2020. State of biodiversity markets: offset and compensation programs worldwide. *Forest Trends*.
- European Environment Agency (EEA), 2015. The European Environment – State and Outlook 2015: Synthesis Report. European Environment Agency, Copenhagen. <https://www.eea.europa.eu/soer/2015/synthesis/report>.
- Global Environment Facility (GEF), 2023. Innovative finance for nature and people. [https://www.thegef.org/sites/default/files/documents/2023-03/GEF\\_IIED\\_innovative\\_Finance\\_Nature\\_People\\_2023\\_03\\_1.pdf](https://www.thegef.org/sites/default/files/documents/2023-03/GEF_IIED_innovative_Finance_Nature_People_2023_03_1.pdf).
- Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., Holling, C.S., 2004. Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology, Evolution, and Systematics* 35, 557–581. <https://doi.org/10.1146/annurev.ecolsys.35.021103.105711>.
- Global Environment Facility (GEF), 2024. Innovative Finance for Nature and People: Opportunities and Challenges for biodiversity-positive Carbon Credits and Nature Certificates (Advance Unedited Version).
- Gradeckas, S., 2024a. Voluntary biodiversity market, visualized. Bloom labs. 17 January. <https://sgradeckas.substack.com/p/voluntary-biodiversity-market-visualized?r=2j49nh>.
- Gradeckas, T., 2024. Market Facilitation in Biodiversity Credit Schemes.
- Griscom, B.W., et al., 2017. Natural climate solutions. *Proc. Natl. Acad. Sci.* 114 (44), 11645–11650.
- Gunningham, N., Young, M.D., 1997. Toward optimal environmental policy: The case of biodiversity conservation. *Ecology Law Quarterly* 24 (2), 243–298. <https://doi.org/10.15779/Z38BN7K>.
- Harrison, P. A., Berry, P. M., Simpson, G., Haslett, J. R., Blicharska, M., Bucur, M., Dunford, R., Ego, B., Garcia-Llorente, M., Geamăna, N., Geertsema, W., Lommelen, E., Meiresonne, L., Turkelboom, F., 2014. Linkages between biodiversity attributes and ecosystem services: A systematic review. *Ecosystem Services* 9, 191–203. <https://doi.org/10.1016/j.ecoser.2014.05.006>.
- Haya, B.K., Alford-Jones, K., Anderegg, W.R.L., Beymer-Farris, B., Blanchard, L., Bomfim, B., Chin, D., Evans, S., Hogan, M., Holm, J.A., McAfee, K., So, I.S., West, T. A.P., Withey, L., 2023. Quality Assessment of REDD+ Carbon Credit Projects. Berkeley Carbon Trading Project.
- HCA, 2014. Additionality guide. In: *Forest Trends*, fourth ed. <https://www.forest-trends.org/publications/additionality-guide-4th-edition/>
- Hoekstra, J.M., Boucher, T.M., Ricketts, T.H., Roberts, C., 2005. Confronting a biome crisis: global disparities of habitat loss and protection. *Ecol. Lett.* 8 (1), 23–29.
- Hooper, D.U., et al., 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecol. Monogr.* 75 (1), 3–35. [https://doi.org/10.1016/S0921-8009\(02\)00273-2](https://doi.org/10.1016/S0921-8009(02)00273-2). <https://capitalscoalition.org/wp-content/uploads/2021/04/Natural-capital-for-biodiversity-policy—FINAL-1.pdf>.
- International Advisory Panel on Biodiversity Credits – IAPBC, 2024. Framework for High Integrity Biodiversity Credit Markets.
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2019. In: Brondízio, E.S., Settele, J., Díaz, S., Ngo, H.T. (Eds.), *Global Assessment Report on Biodiversity and Ecosystem Services*. IPBES Secretariat. <https://doi.org/10.5281/zenodo.3831673>.
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2023. *Global Assessment Report on Biodiversity and Ecosystem Services*. IPBES Secretariat.
- Intergovernmental Panel on Climate Change (IPCC), 2022. *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. <https://doi.org/10.1017/9781009325844>.
- International Union for Conservation of Nature (IUCN), 2020. Global standard for nature-based solutions: a user-friendly framework for the verification, design and scaling up of NbS. <https://portals.iucn.org/library/node/49070>.
- Isbell, F., Calcagno, V., Hector, A., Connolly, J., Harpole, W.S., Reich, P.B., Scherer-Lorenzen, M., van Ruijven, J., 2011. High plant diversity is needed to

- maintain ecosystem services. *Nature* 477 (7363), 199–202. <https://doi.org/10.1038/nature10282>.
- Jordan, A., Wurzel, R.K.W., Zito, A.R., 2003. Comparative conclusions - “new” environmental policy instruments: an evolution or a revolution in environmental policy? *Environ. Polit.* 12 (1), 201–224. <https://doi.org/10.1080/714000667>.
- Kalkuhl, M., Wenz, L., 2020. The impact of climate conditions on economic production: evidence from a global panel of regions. *J. Environ. Econ. Manag.* 103, 102360. <https://doi.org/10.1016/j.jeem.2020.102360>.
- Larrosa, C., Carrasco, L.R., Milner-Gulland, E.J., 2016. Unintended feedbacks: Challenges and opportunities for improving conservation effectiveness. *Conservation Letters* 9 (5), 316–326. <https://doi.org/10.1111/conl.12240>.
- Leclère, D., Obersteiner, M., Barrett, M., et al., 2020. Bending the curve of terrestrial biodiversity needs an integrated strategy. *Nature* 585, 552–556. <https://doi.org/10.1038/s41586-020-2705-y>.
- Leung, B., Hargreaves, A.L., Greenberg, D.A., McGill, B., Dornelas, M., Freeman, R., 2023. Clustered versus catastrophic global vertebrate declines. *Nature* 603 (7900), 241–245.
- Mace, G.M., Norris, K., Fitter, A.H., 2018. Biodiversity and ecosystem services: a multilayered relationship. *Trends Ecol. Evol.* 27 (1), 19–26.
- Mandel, J.T., Donlan, C.J., Wilcox, C., Cudney-Bueno, R., 2010. Debt investment as a tool for value transfer in biodiversity conservation. *Conserv. Lett.* 3 (5), 289–297.
- Millennium Ecosystem Assessment, 2005. *Ecosystems and human well-being: Synthesis*. Island Press; World Resources Institute.
- Narloch, U., Pascual, U., Drucker, A.G., 2011. Cost-effectiveness targeting under multiple conservation goals and equity considerations in the andes. *Environ. Conserv.* 38 (4), 417–425.
- NatureFinance, 2023. *The future of biodiversity credit markets*. Taskforce on Nature Markets [Consultation paper]. <https://www.naturefinance.net/wp-content/uploads/2023/02/TheFutureOfBiodiversityCreditMarkets.pdf>
- NatureFinance & Carbone 4, 2023. *Harnessing biodiversity credits for people and planet* [Report prepared for the Summit for a New Global Financing Pact, in collaborazione con il Global Environment Facility su richiesta del governo francese]. NatureFinance & Carbone 4. <https://www.naturefinance.net/wp>.
- Pascual, U., Balvanera Levy, P., Christie, M., Baptiste, B., 2022. Summary for policymakers of the methodological assessment of the diverse values and valuation of nature of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). IPBES Secretariat.
- Piris-Cabezas, P., Lubowski, R.N., 2018. Catalyzing carbon markets globally to realize the promise of Paris: The power of markets to increase ambition [Manuscript]. Environmental Defense Fund.
- Purvis, A., 2020. The future of biodiversity. *Science* 348 (6234), 227–229.
- Rajão, R., Soares-Filho, B., et al., 2020. The rotten apples of Brazil’s agribusiness. *Science* 369 (6501), 246–248.
- Schindler, D.E., Hilborn, R., Chasco, B., Boatright, C.P., Quinn, T.P., Rogers, L.A., Webster, M.S., 2010. Population diversity and the portfolio effect in an exploited species. *Nature* 465 (7298), 609–612.
- Seddon, N., Turner, B., Berry, P., Chausson, A., Girardin, C.A.J., 2020. Grounding nature-based climate solutions in sound biodiversity science. *Nat. Clim. Change* 10 (10), 800–802.
- Soares-Filho, B., et al., 2014. Cracking Brazil’s forest code. *Science* 344 (6182), 363–364.
- Spurgeon, J., Meyers, D., Ledley, T., Turner, G., 2019. Quantifying biodiversity outcomes in nature-based solutions for climate mitigation. *Conserv. Lett.* 12 (2), e12635. <https://doi.org/10.1111/conl.12635>.
- Stanley, P., Spertus, J., Chiartas, J., Stark, P.B., Bowles, T., 2023. Valid inferences about soil carbon in heterogeneous landscapes. *Geoderma*. <https://doi.org/10.1016/j.geoderma.2022.116323>.
- Sterner, T., 2003. Policy instruments for environmental and natural resource management. Resources for the Future. World Bank.
- Sutherland, W.J., et al., 2013. Identification of 100 fundamental ecological questions. *J. Ecol.* 101 (1), 58–67.
- Taskforce on Nature Markets & Pollination, 2023. *Biodiversity Credit Markets. the Role of Law, Regulation and Policy*.
- Taskforce on Nature Markets, 2022. *Nature-Related Voluntary Carbon Credits: Building Biodiversity into Carbon Markets*. Taskforce on Nature Markets Report. Retrieved from <https://www.naturemarkets.org>.
- The Biodiversity Consultancy (TBC), 2022. *Exploring Design Principles for High Integrity and Scalable Voluntary Biodiversity Credits*. The Biodiversity Consultancy, Cambridge, UK. [https://www.thebiodiversityconsultancy.com/fileadmin/uploads/tbc/Documents/Resources/Exploring\\_design\\_principles\\_for\\_high\\_integrity\\_and\\_scalable\\_voluntary\\_biodiversity\\_credits\\_The\\_Biodiversity\\_Consultancy\\_1\\_.pdf](https://www.thebiodiversityconsultancy.com/fileadmin/uploads/tbc/Documents/Resources/Exploring_design_principles_for_high_integrity_and_scalable_voluntary_biodiversity_credits_The_Biodiversity_Consultancy_1_.pdf).
- Tederso, L., Sepping, J., Morgunov, A.S., Kiik, M., Esop, K., Rosenvald, R., Hardwick, K., Breman, E., Purdon, R., Groom, B., Venmans, F., Kiers, E.T., Antonelli, A., 2023. Towards a co-crediting system for carbon and biodiversity. *Plants, People, Planet* 5 (4), 287–297 <https://doi.org/10.1002/pp>.
- Tremblay, E.A., Fidelman, P.I.J., Kininmonth, S., Ekstrom, J., Bodin, O., 2015. Analyzing the (Mis)fit between the institutional and ecological networks of the Indo-West Pacific. *Glob. Environ. Change* 31, 263–271.
- Turner, W.R., Brandon, K., Brooks, T.M., Costanza, R., Da Fonseca, G.A.B., Portela, R., 2007. Global conservation of biodiversity and ecosystem services. *Bioscience* 57 (10), 868–873. <https://doi.org/10.1641/B571009>.
- United Nations Environment Programme (UNEP), 2022a. *Guidelines for biodiversity credit schemes*. <https://www.unep.org/resources/report/guidelines-biodiversity-credit-schemes>.
- World Economic Forum (WEF). High-level governance and integrity principles for emerging voluntary biodiversity credit markets. [https://www3.weforum.org/docs/WEF\\_Biodiversity\\_Credits\\_Markets\\_Integrity\\_and\\_Governance\\_Principles\\_Consultation.pdf](https://www3.weforum.org/docs/WEF_Biodiversity_Credits_Markets_Integrity_and_Governance_Principles_Consultation.pdf).
- World Economic Forum (WEF). Biodiversity credits: Demand analysis and market outlook – Insight Report. [https://www3.weforum.org/docs/WEF\\_2023\\_Biodiversity\\_Credits\\_Demand\\_Analysis\\_and\\_Market\\_Outlook.pdf](https://www3.weforum.org/docs/WEF_2023_Biodiversity_Credits_Demand_Analysis_and_Market_Outlook.pdf).
- World Economic Forum (WEF). How biodiversity credits can finance nature-positive outcomes. <https://www.weforum.org/agenda/2024/01/how-biodiversity-credits-can-finance-nature-positive-outcomes/>.
- World Economic Forum (WEF), 2022a. High-level governance and integrity principles for emerging voluntary biodiversity credit markets. [https://www3.weforum.org/docs/WEF\\_Biodiversity\\_Credits\\_Markets\\_Integrity\\_and\\_Governance\\_Principles\\_Consultation.pdf](https://www3.weforum.org/docs/WEF_Biodiversity_Credits_Markets_Integrity_and_Governance_Principles_Consultation.pdf).
- von Hase, A., Cassin, J., 2018. Theory and Practice of ‘Stacking’ and ‘Bundling’ Ecosystem Goods and Services: A Resource Paper. Business and Biodiversity Offsets Programme (BBOP). Forest Trends, Washington, D.C.
- World Economic Forum (WEF), 2020. Nature risk rising: Why the crisis engulfing nature matters for business and the economy. <https://www.weforum.org/publications/nature-risk-rising-why-the-crisis-engulfing-nature-matters-for-business-and-the-economy/>.
- World Economic Forum (WEF), 2022b. Biodiversity Credits: Unlocking Financial Markets for nature-positive Outcomes.
- World Economic Forum (WEF), 2023. Biodiversity credits: demand analysis and market outlook – insight report. [https://www3.weforum.org/docs/WEF\\_2023\\_Biodiversity\\_Credits\\_Demand\\_Analysis\\_and\\_Market\\_Outlook.pdf](https://www3.weforum.org/docs/WEF_2023_Biodiversity_Credits_Demand_Analysis_and_Market_Outlook.pdf).
- World Economic Forum (WEF), 2024. How biodiversity credits can finance nature-positive outcomes. <https://www.weforum.org/agenda/2024/01/how-biodiversity-credits-can-finance-nature-positive-outcomes/>.
- World Economic Forum (WEF), 2020. Nature risk rising: why the crisis engulfing nature matters for business and the economy. <https://www.weforum.org/publications/nature-risk-rising-why-the-crisis-engulfing-nature-matters-for-business-and-the-economy/>.
- Wunder, S., 2007. The efficiency of payments for environmental services in tropical conservation. *Conserv. Biol.* 21 (1), 48–58.
- World Wide Fund for Nature (WWF), 2024. *Living Planet Report 2024: Bending the Curve of Biodiversity Loss*. WWF International.
- Zynobia Newman, E., Steele, P., Ducros, A., 2023. *Biocredit Catalogue: a Collection of Biocredit Developers and Schemes*. IIED, London.
- Burns, F. et al. 2023. State of nature 2023. – The State of Nature Partnership. Convention on Biological Diversity. (1992). Convention on Biological Diversity (Art. 2). Secretariat of the Convention on Biological Diversity. Retrieved August 18, 2025, from <https://www.cbd.int/convention/articles/?a=cbd-02>.
- Convention on Biological Diversity. (2021, July 12). First detailed draft of the Global Biodiversity Framework. Secretariat of the Convention on Biological Diversity. Retrieved August 18, 2025, from <https://www.cbd.int/doc/press/2021/pr-2021-07-12-gbf-en.pdf>.
- Green Finance Observatory. (2021, October 15). Three decades of climate mitigation: Why haven’t we bent the global emissions curve? Green Finance Observatory. Retrieved August 18, 2025, from <https://greenfinanceobservatory.org/2021/>.
- Liang, J., Watson, J.V., Zhou, M., & Lei, X. (2016). Effects of productivity on biodiversity in forest ecosystems across the United States and China. *Conservation Biology*, 30(2), Article e12636. <https://doi.org/10.1111/cobi.12636>.
- Michaelis, P., 1996. *Economic instruments in environmental policy: A practice-oriented introduction* (Physica Textbook). Physica-Verlag Heidelberg. <https://doi.org/10.1007/978-3-642-61206-0>.
- Pollination. (2023). State of voluntary biodiversity credit markets: A global review of biodiversity credit schemes. Pollination. Retrieved from <https://pollinationgroup.com/wp-content/uploads/2023/10/Global-Review-of-Biodiversity-Credit-Schemes-Pollination-October-2023.pdf>.
- Nature Positive Initiative. (2023). *Nature-positive: Halt and reverse nature loss by 2030 on a 2020 baseline, and achieve full recovery by 2050*. Nature Positive Initiative. 2011 TEEB. (2011). *The Economics of Ecosystems and Biodiversity in National and International Policy Making* (a cura di P. ten Brink). Earthscan: London and Washington.