Biodiversity as an Asset: A Critical Analysis of Investor Narratives and Their Justice Implications

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Short Abstract

Biodiversity is increasingly framed as an asset within the financial system, yet little is known about how this assetization process is unfolding, who is shaping it, and what its implications are for justice. Responding to calls for more transparent and justice-oriented biodiversity finance, this paper examines how nature is being turned into an asset across sectors and investors, which assetization narratives shape this process, and how such assetization processes enable or constrain just outcomes. We integrate perspectives from sustainable finance and economic geography to develop a framework based on three financial asset characteristics: fundamental value, market value, and ownership. Using AI-assisted textual analysis, implemented through large language models (LLMs) with systematic human validation and supervision, we examine investor disclosures between 2020–2024 from signatories of biodiversity initiatives: PRI Spring, Nature Action 100, and the Finance for Biodiversity Foundation. Results show that assetization narratives are dominated by market value and risk–return considerations, rather than focusing on fundamental value and ownership. Biodiversity is framed both as a component of existing real asset classes and as a standalone investable asset, with land-based biodiversity types more prone to assetization. We critically assess our results through a justice lens and propose four transformations for integrating biodiversity into financial markets in a just manner: revising valuation processes, reinterpreting fiduciary duty, expanding (steward) ownership models, and strengthening public-sector coordination.

1. Introduction

Nature losses are increasingly threatening the productivity and stability of the global economic system (Ceglar et al., 2025; European Central Bank, 2022; Giglio et al., 2023). Consequently, there is increasing pressure on both public and private actors to halt biodiversity-harming practices (Boldrini et al., 2023; DNB, 2020) and to close the biodiversity investment gap[1] (Deutz et al., 2020).

Historically, biodiversity is addressed through public financing and regulation (Cosma et al., 2023). However, persistent challenges such as weak governance for integrating and protecting biodiversity (Dorst et al., 2022; Droste et al., 2019; Fenichel & Dean, 2024), underinvestment, and an inability to fairly distribute conservation benefits and costs (Clements et al., 2010; Hadji-Lazaro et al., 2024; López & Toman, 2006) have constrained the effectiveness of public-sector-led efforts. Simultaneously, to address biodiversity loss through finance, the focus is not only on investment *in* biodiversity, but also on the impact of investments *on* biodiversity (Dempsey, 2025). The failure to adequately regulate biodiversity-harming private (finance) activities has revealed forms of government failure (Dempsey, 2013; Mazzucato, 2024).

Given the urgency of biodiversity loss and public financing efforts falling short, calls to draw in private finance for biodiversity have never been louder, with NGO's and multilateral actors in the driving seat. This momentum coincides with rising physical and transition risks for investors as biodiversity degradation disrupts supply chains, undermines firms' licenses to operate (D'Amato et al., 2024; Karolyi & Tobin-de La Puente, 2023), and exposes sectors to stranded-asset risks and cascading financial impacts (Ceglar et al., 2025; Giglio et al., 2024; Ranger et al., 2024). In response, biodiversity has been reframed as an investable asset (Kedward et al., 2022; Knijp et al., 2024) capable of generating returns or mitigating risks, or both, thereby aligning with investment frameworks (Gurney et al., 2021; Bose et al., 2019; Dempsey, 2013). This reframing is opening pathways for private capital to support nature-based interventions and enhance long-term portfolio resilience and diversification (Papari et al., 2024; Hudson, 2024; Toxopeus & Polzin, 2021)

While this market-based approach may address the biodiversity investment gap, it also raises fundamental concerns. Standardized, narrowly quantifiable outcomes traded in financial

[1] A key issue at COP negotiations was closing the funding gap, the difference between current funding and what's needed for Global Biodiversity Framework (GBF) targets. Protecting 30% of land and marine areas (Target 3) requires $103-$178 billion annually ($121-$210 billion in 2023). Broader CBD actions, including invasive species control and sector transformation, need $706-$971 billion in 2023 (CBD, 2022). Various computing and prediction methods make it difficult to precisely define the funding gap.

markets may undermine place-based ecological integrity (Arjaliès & Banerjee, 2024; Chiapello, 2020; Fransen & Bulkeley, 2025; Golka, 2021; Golka et al., 2024a). Biodiversity assetization processes risk disempowering local communities, leading to uneven development or displacement (Corbera, 2015; Theesfeld, 2018; Wade & Ellis, 2022) while shifting decision-making power towards capital-rich actors (Büscher & Fletcher, 2015; Vardon et al., 2025). However, framing biodiversity as an asset that holds value or reduces risk does not always require turning it into a narrow financial product designed to extract returns (Birch & Muniesa, 2020): some biodiversity assetization processes purposefully include community voices and steward-based governance models (Arjaliès & Banerjee, 2024),

Despite the significance of what is essentially a paradigm shift in practices of natural resource valuation and financing, we are currently in the dark on how biodiversity is being shaped as an asset, who is driving this process, through which mechanisms, and with what consequences for justice outcomes, equity and governance. Responding to earlier calls in this journal to build more structural, just, and transparent approaches to biodiversity finance (Cousins, 2021, Fenichel & Dean, 2024), this paper addresses the following questions: (1) To what extent, and by what mechanisms, is biodiversity currently being transformed into an asset class within the financial system? (2) What justice and power implications are embedded in biodiversity assetization processes? (3) How might biodiversity assetization narratives enable or hinder justice outcomes?

To answer these questions, we connect insights from sustainable finance, ecology and economic geography to construct a framework based on the three key characteristics of an asset: fundamental value[2] (Bressan et al., 2022; Chami et al., 2022), market value[3] (Chausson et al., 2023; Smessaert et al., 2020; Wunder et al., 2024), and ownership (Birch & Muniesa, 2020; Birch & Ward, 2024; Golka, 2021). We apply this framework to analyze investor narratives using AI-assisted textual analysis with human supervision and validation on a dataset of 5000 annual reports and sustainability disclosures between 2020–2024, focusing on 180 actors who pledged commitments through the initiatives PRI Spring, Nature Action 100, and

[2] The *theoretical or intrinsic worth* of an asset based on its characteristics: biodiversity's role in sustaining ecosystems, or future ecosystem service value: e.g. A wetland has value due to its flood protection, water purification, and habitat functions.

[3] The *actual price* at which the asset can be traded or transacted in the market, influenced by current investor appetite, policies, risks, and incentives: e.g. That same wetland's value on a biodiversity credit market (e.g., price per credit for conserving wetland) or as part of a real asset investment - influenced by buyers, policy incentives, or market demand.

the Finance for Biodiversity Foundation (Berg et al., 2024; Friedman & Heinle, 2016; Healy & Palepu, 2001; Rezaee & Tuo, 2017; Schimanski et al., 2023).

Our findings show that biodiversity is framed both as an integrated element within existing asset classes (e.g., real estate, regenerative agriculture) and as a standalone asset (e.g., conservation or forestry investments). Most investor narratives emphasize biodiversity's risk-return profiles and market value, guided by monetary valuation processes (Flammer et al., 2023; Garel et al., 2023). A minority of investor narratives suggest evolving ideas of ownership toward shared or community-based governance models. Based on our results we suggest four transformation interventions that could help practitioners to follow a justice-oriented approach of biodiversity inclusion into emerging market practices and to advance an equitable biodiversity assetization: pluralistic valuation, broadened fiduciary duty, stewardship-based models, and a more coordinated action of the public sector.

2. Turning Biodiversity into an Asset

The language of "*biodiversity as an asset*" is increasingly being used colloquially in the NGO and investment community, but often without reference to the core theoretical characteristics that define an asset class (Whitton & Waterford, 2023). The idea of framing biodiversity as an asset class has emerged more formally in both the finance and economic geography literature, which explore how biodiversity characteristics can be aligned with financial frameworks to attract private capital for conservation and restoration (Birch & Ward, 2024; Golka et al., 2024b; Tellmann et al., 2024; Bulkeley et al., 2023; Golka, 2021; Kedward et al., 2022; Langley, 2020).

The evolving discourse around integrating biodiversity into financial systems has been shaped by three financial logics: commodification, financialization, and assetization (Table 1). *Commodification* represents the earliest and most extractive logic, treating nature as ownable units traded for short-term gain with little regard for regeneration (Barbier, 2011; Heal, 1999; Smessaert et al., 2020). *Financialization* abstracts nature into instruments (e.g., carbon credits/offsets, green bonds etc.) whose value hinges on market expectations and proxy metrics, with emphasis on liquidity and portfolio performance (Birch & Ward, 2024; Deutz et al., 2020; Golka et al., 2024a; Wade & Ellis, 2022). *Assetization*[4] reframes biodiversity as an investible

[4] Transforming biodiversity into a financial asset is different from it being referred to as a real (natural) asset. Biodiversity as a real asset is non-fungible, place-based, and complex to monetize (Bockarjova et al., 2020; Markanday et al., 2024), while as (part of) a financial asset it is often simplified into standardized, tradable units that fit market logics (Chausson et al., 2023).

object built around its fundamental value, market value, and ownership (Birch & Muniesa, 2020; Birch & Ward, 2024; Wade & Ellis, 2022).

Commodification, financialization, and assetization share market-based features but differ in their temporal orientation, ownership structures, and value creation assumptions (Birch & Muniesa, 2020; Heal, 2003; Tellmann et al., 2024). Clarifying these distinctions is essential to assessing whether biodiversity finance tools advance ecological sustainability or simply repackage extractive logics (Table 1).

Table 1. Conceptual differences between commodification, financialization, and assetization of biodiversity

PHENOMENON	CONCEPTUAL DIFFERENCES	EXAMPLE	LITERATURE
COMMODIFICATION	**Market Exchange Focus** enabling exchange through pricing and trade, often without altering the function or control structure of the commodified object. **Tangible Output Orientation:** standardized, divisible units (e.g., timber, biodiversity credits) that can be traded as goods or services.	A forest is cut down and its timber is sold in the market for a short term-return. While it yields quick returns, this depletes resources and causes lasting ecological damage.	(Bakker, 2007; Bermejo, 2014; Martin-Ortega et al., 2019; Robertson, 2006; Smessaert et al., 2020; Heal, 1999)
FINANCIALIZATION	**Instrumentalization of Value:** Financialization abstracts value into financial instruments (e.g., green bonds, derivatives), often decoupled from the physical asset. **Short-to-Medium-Term Focus:** The logic is often about portfolio management, liquidity, and yield, usually with a depreciative value over time. Investments are held temporarily, not necessarily requiring control over the underlying resource.	A forest financed via green bond for nature regeneration; in this example once the bond matures and is repaid, neither the investors nor the issuing company necessarily retain ownership or control over the forest itself (short to medium-term holdings).	(Dempsey & Suarez, 2016; Flammer et al., 2023; Garel et al., 2023; Heal, 2003, 2004; Hudson, 2024; Löfqvist et al., 2023; Mulder, 2021; Sawyer, 2013)
ASSETIZATION	**Long-Term Value**: Assetization emphasizes future cashflow potential and capital appreciation, treating nature as a long-term asset. **Active Ownership and Control** via a governance framework to define who owns, manages, and benefits from the asset, often through property rights or financial contracts.	A forest as an asset that is owned, controlled, or managed either directly by investors or indirectly through the companies they invest in. For example, a forest managed through a timberland fund generates returns through sustainable harvesting and carbon credits. Ownership is retained by the fund, with long-term control over land use and ecological services.	(Birch & Muniesa, 2020; Birch & Ward, 2024; Golka, 2021, 2023; Heal, 2001; Kedward et al., 2022; Wade & Ellis, 2022)

2.1. Three core characteristics of an asset: fundamental value, market value, and ownership

Biodiversity assetization processes can be unpacked into three core characteristics of an asset: (1) fundamental value is captured through a recognized valuation methods, (2) market value is reflected in risk-return and cost-reduction logics, and (3) ownership and control are formalized through legal and governance structures. We discuss each characteristic in turn.

Biodiversity is defined as an ecological stock[5] *"[…] that can accumulate or decline over time*" (Costanza et al., 2023, p. 24) holding **fundamental value** (Langley, 2020; Birch & Ward, 2018)—sustaining ecosystem functions such as provisioning, regulating and supporting (Maechler & Boisvert, 2024; Perrings et al., 2009)—that could be represented in monetary[6] and non-monetary[7] terms (Barbier, 2011; Birch & Muniesa, 2020; Bockarjova et al., 2020). To attract financing, biodiversity is translated into quantifiable economic units via valuation (Löfqvist et al., 2023; Wauchope et al., 2024), being gradually reframed from a public or common good (Keeler et al., 2026) embedded in complex socio-ecological systems (Spangenberg, 2007) to a private or club good, subject to measurement, monetization, and market appropriation (Kedward et al., 2022).

The second formal characteristic of assetization is **market value**, that emerges when biodiversity's stocks are integrated into financial transactions (Chami et al., 2022; Heal, 2004) either by being treated as assets that reduce the costs of future risks or by being structured directly into investment products as an opportunity to generate profits (Table 2). In some cases, biodiversity assets may enter the market through both mechanisms simultaneously. Therefore, biodiversity shifts from a stock to a flow when integrated into productive systems, enabling the creation of tradable private goods (Epstein, 2005; Heal, 2003). Transactions enable liquidity and cash flow generation, positioning biodiversity within a risk-return logic familiar to financial markets (Markowitz & Blay, 2013; Palley, 2008). As a result, biodiversity becomes legible as a potential investable asset, not solely based on its ecological stock, but through market-based mechanisms (Chausson et al., 2023; Gurney et al., 2021; Palley, 2008), that treat it, at least partially, as a private good (Vatn, 2018).

[5] ecological components such as forests, species, or ecosystem services

[6] Purely monetary metrics captured via formalized methods (Farnsworth et al., 2015; Spangenberg, 2007) such as ecosystem service assessment, replacement cost estimates (Winfree et al., 2011), or natural capital accounting, True Cost Accounting (Baker et al., 2020; Michalke et al., 2023) etc.

[7] Non-monetary valuation methods offer important alternatives to purely monetary metrics by emphasizing ecological, social, and cultural dimensions of value (Maechler & Boisvert, 2024; Perrings et al., 2009), such as assessing ecological integrity and species richness, mapping ecosystem service hotspots and degradation levels, co-defining value with local stakeholders, and applying Multi-Criteria Decision Analysis (MCDA) to navigate trade-offs (Daily et al., 2000)

Table 2. Mechanisms of integrating biodiversity on financial markets

Purpose		Mechanism	How Biodiversity Enters the Market	Key References
PROFIT GENERATION	*Enhancing returns*	**Bundling biodiversity benefits into productive services**	Biodiversity generates and support profits through the continuous delivery of ecosystem services (pollination, water purification, carbon sequestration). Biodiversity enhances returns of real estate, regenerative agriculture, or other natural resource assets	(Heal, 2003; Kosoy et al., 2007; Bremer et al., 2016; Johnson et al., 2021; Garel et al., 2024; Croeser et al., 2024; Seidl et al., 2024; Bello et al., 2024)
	Trading products	**Embedding biodiversity into structured financial products**	Conversion of nature into financial instruments — biodiversity funds, green/sustainability-linked bonds, blended finance vehicles, biodiversity credits/offsets.	(Koziell & Swingland, 2002; Apostolopoulou, 2020; Lankes, 2021; Den Heijer & Coppens, 2023; Swinfield et al., 2024; Fenichel & Dean, 2024; Garel et al., 2024; Flammer et al., 2025)
RISK REDUCTION	*Avoiding stranded assets & Protecting operations*	**Biodiversity as a physical risk mitigator**	Biodiversity investments serve as a climate risk-reduction strategy, helping firms avoid disruptions in natural-capital inputs and production functions, while strengthening supply-chain resilience against soil degradation, water scarcity, and species loss.	(Bressan et al., 2022; Chaplin-Kramer et al., 2023; Dempsey, 2013; Giglio et al., 2024; Spangenberg, 2007; Tilman et al., 2017)
	Complying to, macro-prudential supervision and regulatory frameworks	**Biodiversity as a systemic and transition risks mitigator**	Systemic risk to economic activities and financial stability, motivates biodiversity-positive investment for long-term resilience Compliance to requirements from biodiversity protection laws and disclosure (deforestation laws, disclosure mandates under EU Taxonomy etc.) reshape market behaviour and encourage biodiversity investment.	(DNB, 2020; Quattrone, 2021; European Central Bank, 2022; Kedward, Ryan-Collins, et al., 2023; Giglio et al., 2023; Kedward, zu Ermgassen, et al., 2023; Boldrini et al., 2023; Knijp et al., 2024; Papari et al., 2024; Vanderlugt et al., 2025; Garel et al., 2025; Ceglar et al., 2025)

The third core characteristic of assetization is **ownership,** which further shapes market integration by formalizing its governance structures. The public-good logics of biodiversity (Herrmann-Pillath, 2023; Hodgson, 2015; Kedward et al., 2022) shift toward private ownership and market-based control, framing of biodiversity as a rivalrous, privately appropriable good[8], as private investors increasingly develop biodiversity markets, driven by policies addressing underfunding and externalities (Bulkeley et al., 2023; Ermgassen et al., 2024). However, biodiversity governance involves a diverse set of stewards such as conservation NGOs and

[8] particularly among organizations with large non-operational landholdings that engage in environmental markets as a revenue-generating strategy (Hardy et al., 2018; Matilainen & Lahdesmaki, 2020). This is particularly the case for land (Arjaliès & Banerjee, 2024; Bergstrom et al., 1985; Rissman et al., 2019), but also for water-related ecosystems (Bakker, 2007; Barton, 2002; Scharin et al., 2016; Theesfeld, 2018).

local communities, who hold shared or customary rights over ecosystems (Cosma et al., 2023; Kareiva et al., 2014). Recognizing this plurality of actors helps clarify the institutional logic underlying biodiversity governance, which can be interpreted as a second-best model, relative to a fully public governance ideal, in which all beneficiaries share responsibility for managing risks and preventing further degradation, relying on collective action as a central mechanism (Chausson et al., 2023; Golka, 2021). This perspective draws on the economic theory of property rights, particularly the "bundle of rights and benefits" approach (Heal, 2003), which differentiates among access, withdrawal, management, exclusion, and alienation rights (Schlager & Ostrom, 1992).

2.2. Tensions between assetization characteristics and justice concerns

Transforming biodiversity from a public good into an investable asset is not a value-neutral exercise; it raises critical justice concerns. Monetary valuation of nature raises long-standing questions around who defines that value, who benefits, and who bears the risks (Cousins, 2021). These concerns intersect across multiple dimensions of justice (Perera et al., 2024) such as ecological, distributional, recognition, and procedural justice (Table 3).

Firstly, financial models that monetize biodiversity's fundamental value, grounded in managerial and market-based logics, often neglect relational and non-market understandings of nature (Grabowski et al., 2022; Matulis, 2014). This creates tensions with ecological and recognition justice as Indigenous, cultural, and spiritual values (IPBES, 2022) are sidelined in favor of standardized metrics that translate ecosystems into cash flows (Arjaliès & Banerjee, 2024; Martin-Ortega et al., 2019). Investors participating in biodiversity markets may inadvertently reproduce this extractive dynamic—even if for the genuine purpose of conservation and reducing the biodiversity finance gap—neglecting the fact that biodiversity is an emergent outcome of natural systems, shaped by the interactions of living organisms within ecosystems (Goff et al., 2017; Smessaert et al., 2020).

Second, distributional (including intergenerational) justice concerns arise when biodiversity is assessed through market value and risk–return models (Clark, 2021; Corbera, 2015). Current investment approaches fail to account for unequal distributions of risks and benefits (Chabba et al., 2022; Kind et al., 2017), discounting the future regenerative value of biodiversity (Millner & Heal, 2023), and delaying action despite biodiversity loss being irreversible and disproportionately harmful to vulnerable communities (Farina et al., 2024; Mutlu et al., 2023; Tilman et al., 2017).

Third, ownership and governance structures underpinning environmental markets often rely on formal legal frameworks that exclude those with customary or non-titled land relationships (Higgins et al., 2014; Lockie & Tennent, 2009; Pascual et al., 2014), undermining procedural and territorial justice as decisions become more aligned with Western, market-oriented institutions (Arjaliès & Banerjee, 2024; Toxopeus et al., 2020) and risking dispossession. In response, stewardship and rightsholder approaches emphasize care, accountability, and relational governance of biodiversity, recognizing non-human actors (Cai et al., 2020; Hafferty et al., 2024) and reimagining value creation beyond commodified or assetized models (Díaz et al., 2018; Muradian & Gómez-Baggethun, 2021; Scharin et al., 2016; Spash, 2000).

Table 3. OVERVIEW ASSETIZATION CHARACTERISTICS AND RELATED JUSTICE ELEMENTS

ASSETIZATION CHARACTERISTICS	Operational meaning	Justice -related concerns			
		Ecological justice	**Recognition justice**	**Distributional justice**:	**Procedural justice**:
(1) FUNDAMENTAL VALUE AND VALUATION	Biodiversity is valued and represented in standardized units and monetary terms.	Standardized value of nature amplifying managerial, anthropocentric perspectives while marginalizing more-than-human ethics (Juhola et al., 2022; Maller, 2021; Pineda-Pinto et al., 2022). Symbolic violence through commodification of non-human life forms (Washington & Maloney, 2020). Replacing superior ethical norms with market-based reasoning (Bliss & Egler, 2020).	Reduction of nature to exchangeable units ignores Indigenous, cultural, and non-utilitarian values (Grabowski et al., 2022). Failure to acknowledge diverse cultural, historical, and identity-based perspectives on nature (Daily et al., 2000; Seddon et al., 2020). Reproduces the society/nature divide rooted in colonial and racialized capitalist systems amplifying the Global North – Global South divide (Bell, 2004; Matthew McConnachie & Shackleton, 2010)	Insufficient traceability of genetic resources and Indigenous knowledge hampering implementation of Access and Benefit-Sharing (ABS). Current valuation methods overlooking how costs and benefits should be allocated or discounted across stakeholders (Barton, 2002; Carvalho Ribeiro et al., 2024; Maechler & Boisvert, 2024).	Misalignment across different valuation of biodiversity shared benefits and costs often misaligned with international justice-based environmental policies or legislation, such as implementation of Nagoya Protocol–compliant obligations in private standards (e.g., TNFD, VERRA, IFC) (Suiseeya, 2014).
(2) MARKET VALUE AND RISK-RETURN	Ecological performance is modelled to fit long-term financial risk-return frameworks and instruments, which prioritize predictable returns.	Financialized futures shaped by technocratic projections excluding relational and more-than-human futures (Maller, 2021).	Failure to acknowledge the importance and the role of other stakeholders than investors in market transactions and defining the fiduciary duty (Chausson et al., 2023; Golka et al., 2024a).	Access to biodiversity-rich spaces is often unequal, disproportionately limited for marginalized groups based on race, income, age, gender, or disability (Pineda-Pinto et al., 2022), exposing them to greater environmental risks (Cousins, 2021; Perera et al., 2024). Delayed investment in biodiversity causes irreversible ecological loss, unfairly shifting risks to future generations, creating both social and intergenerational injustice (Clark, 2021; Kaplan et al., 2017; Norton, 1989).	The modelling of biodiversity within risk-return frameworks reflecting investor interests and financial norms, with limited transparency or stakeholder participation in defining risk typologies or investment priorities. Formal decision-making policies rarely accounting for ecological complexity or the lived realities of communities (Arjaliès & Banerjee, 2024).
(3) OWNERSHIP AND CONTROL	Rights to access, manage, and benefit from nature are typically defined through formal governance structures, such as legal titles over land, water, or biodiversity-linked financial assets. Ownership grants financial control - allowing the holder to extract rents from biodiversity via private markets (e.g. biodiversity credits).	Claim ownership of private actors over aspects of nature that inherently resist enclosure, such as migratory species or shared river systems, and over ecosystems traditionally stewarded by Indigenous peoples, fragmenting ecosystems and undermining relational land connections	Reinforcement of Western legal norms of private property tied to anthropocentric superiority (Hardy et al., 2018; Wade & Ellis, 2022) Landless and indigenous groups are often excluded from mechanisms like biodiversity credits or payments for ecosystem services, despite their stewardship roles (Corbera, 2015; Martin et al., 2016; Pascual et al., 2014).	Accumulation by dispossession - risk of land grabbing for conservation (Theesfeld, 2018). Ownership shifting from local stewards to global investors or private entities (Cooke & Moon, 2015; Fichtner & Heemskerk, 2020; Golden et al., 2022)	Fair participation and transparent decision-making processes are often absent , especially for communities most affected such as rightholders; control usually attributed to investors and not local communities (Arjaliès & Banerjee, 2024; Leach et al., 2019; Ortiz-Riomalo et al., 2023).

3. Methodology

This study proposes an AI-assisted textual analysis, implemented through large language models (LLMs) with systematic human validation to examine, whether and in what ways, the three theoretical characteristics of assetization are reflected in private self-disclosed biodiversity information produced by investors. We choose self-disclosure as empirical lens because it is often the earliest site where processes like assetization becomes visible and codified, and because it enables systematic, cross-institutional comparison (Azizi et al., 2025). Moreover, investors shape norms through voluntary reporting frameworks and new concepts like biodiversity assetization are legitimated through repeated disclosure (Blanco-Zaitegi et al., 2022; Papari et al., 2024).

We draw on a purposive sample of asset managers and investors that are signatories or members of the three leading biodiversity finance initiatives, collectively managing over USD 70 trillion[9]: the Finance for Biodiversity Foundation, the UNPRI Spring Initiative, and Nature Action 100. Rather than including all signatories and members, we select a subset of 180 asset managers and investors based on their typology, disclosure activity, and the availability of biodiversity-related reporting. This purposive selection aims to capture early movers that play a key role in shaping norms and practices in emerging biodiversity finance markets and in influencing both market expectations and future regulatory developments (Kedward et al., 2022; zu Ermgassen et al., 2022; Schimanski et al., 2023; Garel et al., 2024; TNFD, 2024). Given the large volume of textual data and the conceptual complexity of biodiversity assetization, we adopt a four-level analytical process (detailed in Figure 1) that progressively reduces the dataset while increasing analytical depth.

At Level 1, we construct the textual corpus. From the purposive sample of 180 asset managers and institutional investors, we collect 5,000 publicly available reports, selecting only the sustainability, ESG, climate, annual, and stewardship reports published between 2020 and 2024. To enable systematic analysis, all documents are broken down into individual paragraphs, which serve as the basic unit of analysis in subsequent steps. Paragraph-level segmentation allows the identification of specific statements and narratives that would be difficult to isolate at the document level. This process yields approximately 0.5 million textual paragraphs.

[9] The *Finance for Biodiversity Foundation* (177 signatories, €22.1 trillion AUM), *UNPRI Spring Initiative* (200+ investors, $28 trillion AUM), and *Nature Action 100* (190 investors, $24 trillion AUM).

In Level 2, we aim to reduce the large corpus of general text generated in Level 1 to a subset of biodiversity-related paragraphs. Given the volume of text, this step prioritizes speed and coverage and we first apply the biodiversity-focused text classifier developed by Schimanski et al. (2023), which is a computational tool that estimates whether a paragraph is related to biodiversity based on patterns learned from previously labelled biodiversity texts. To further reduce the risk of missing relevant content, we complement this step with an expert-curated list of biodiversity keywords (Appendix A, Table A1). This list draws on the IUCN Global Ecosystem Typology (Keith, 2020) and the natural capital asset classification list developed by Leach et al. (2019).

In Level 3 we focus on identifying paragraphs that describe concrete biodiversity investment-related activities. After the substantial reduction of text in Level 2, the remaining dataset is sufficiently small to allow the use of more computationally intensive but more accurate interpretive methods. At this stage, we use a general-purpose large language model (GPT-4o mini) accessed via the OpenAI API (Open Ai, 2024). Large language models are text analysis tools trained on extensive collections of written language, which enables them to interpret sentences in context rather than relying solely on predefined keywords or statistical similarity (Tamkin et al., 2021). This capability is particularly important for identifying biodiversity investment activities, which are often described indirectly, embedded in broader narratives, or framed using financial rather than ecological terminology.

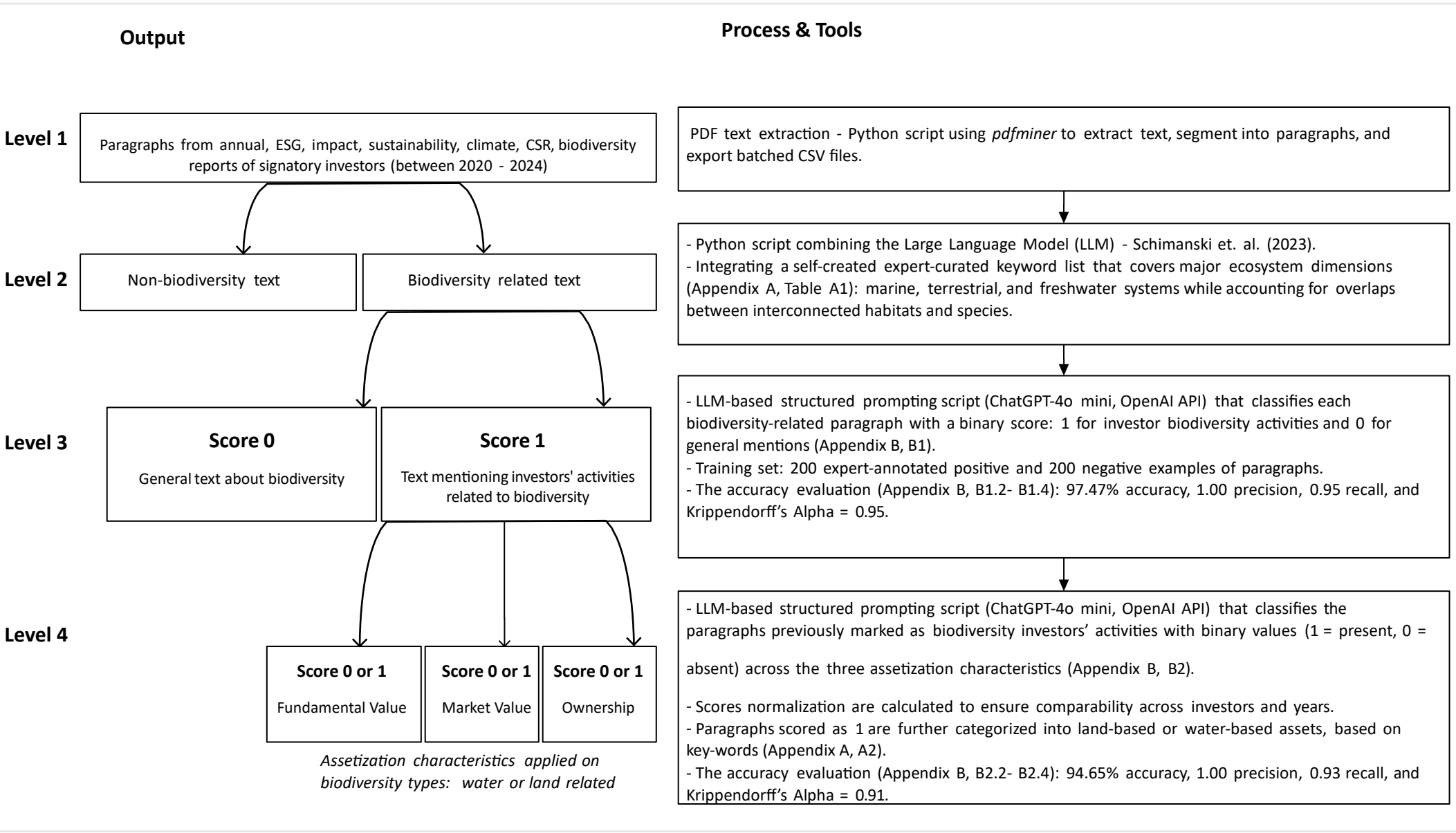
We apply the model through structured, role-based prompting (He et al., 2024; Hou et al., 2024; Kim et al., 2023). This means that, for each paragraph, the model is explicitly instructed to act as an expert reader and to evaluate the text based on definitions and examples drawn from the academic and policy literature on biodiversity finance. The prompt specifies what constitutes a biodiversity investment activity and provides clear inclusion and exclusion criteria, including illustrative examples of paragraphs that should receive a score of 1 (presence of a biodiversity investment activity) and those that should receive a score of 0 (absence of such activity). The model is then asked to return a structured binary output indicating whether the paragraph meets these criteria (Appendix B, Table B1).

This approach differs from the classifier used in Level 2 in two key ways. First, it relies on explicit conceptual definitions rather than pattern recognition alone. Second, it allows the model to assess meaning at the paragraph level by considering context, intent, and implied actions.

Lastly, in Level 4 we apply the same LLM-based procedure used in Level 3, but with a different expert-designed prompt (Appendix B, Table B2). Instead of identifying biodiversity investment activities, the model is instructed to assess whether each paragraph reflects one or more of the three theoretical assetization characteristics—fundamental value, market value, or ownership. For each characteristic, the model assigns a value of 1 when relevant references are present and 0 otherwise. As in Level 3, all outputs are subject to systematic human validation to ensure consistency with the conceptual framework.

Both in Level 3 and Level 4, all outputs are subject to systematic human validation, ensuring consistency with the conceptual framework and reducing the risk of misclassification or over-interpretation (Fang et al., 2025; Ito et al., 2023). Specifically, model classifications are evaluated against a set of expert-annotated paragraphs coded by researchers with expertise in biodiversity finance. Model outputs are cross-checked against these manual annotations using standard performance metrics—including accuracy, precision, F1 score, and confusion matrices (Schimanski et al., 2023, 2024)—to assess classification robustness. All validation procedures and results are reported in the appendices (B1 and B2).

Figure 1. The four level sequential approach of textual analysis using LLMs



4. Results

The outcome of this analysis quantifies the percentage of biodiversity-related disclosures that reflect assetization narratives. Of all biodiversity investment-related texts, 22.8% exhibit all three assetization characteristics- fundamental value, market value, and ownership - indicating a fully assetized narrative. About 50% exhibit two characteristics, and 27% only one. This distribution suggests that while assetization narratives exist, few disclosures present a fully developed framing of biodiversity as an asset (Figure 2.1).

We complement the quantitative results with a qualitative examination of the selected paragraphs, and within level 4 we differentiate between land-based and water-based biodiversity assets (Appendix A, Table A2). While both are crucial, they differ in governance, materiality, and market visibility. Land assets, being fixed and tradable, fit more easily within logics of private ownership and cashflow generation (Liao et al., 2024; Liao & Agrawal, 2025; Nilsson & Persson, 2012; Wang et al., 2016), even serving as collateral for biodiversity-linked instruments (Kaas et al., 2016). Water assets, by contrast, are harder to be included in markets due to shared use, regulatory complexity, and fluid boundaries (Pittman & Armitage, 2019; Theesfeld, 2018; Vardon et al., 2025).

4.1 Biodiversity assetization narratives

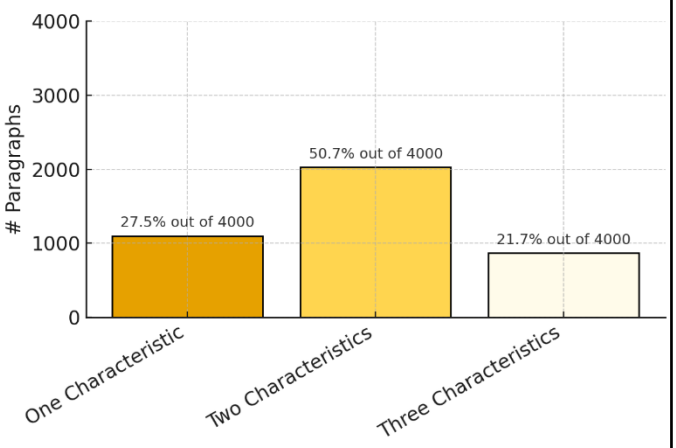
Across the three characteristics (Figure 2.2.), fundamental value is the most frequently mentioned, appearing in the majority of paragraphs. Market value is referenced in about half the cases, while ownership and control is the least discussed (approx. 14% of the sample).

We qualitatively observed a higher representation of narratives related to land-based assets versus water-based assets. When comparing all the labelled references, land dominates across ownership and fundamental value narratives, while water scores higher in market value narratives, accounting for 58.3% of the total labelled paragraphs in Level 4 (Figure 2.2). This result is driven by a high prevalence of blue bonds and conservation funds related to fisheries, sustainable sea transportation, coral reefs protection and wetlands conservation, as well as direct funding for water management in cities: "*Understanding biodiversity's materiality helps us manage risks and engage more effectively with portfolio companies. [Investors X], on behalf of the pension fund, invested in [Company Y]'s 5-year blue bond, supporting marine ecosystem restoration, sustainable fishery, and sustainable sea transport, aligning with our clients' responsible investment goals"* (Pension Fund Investment Management, Stewardship report, 2023). While land-based biodiversity remains most present in investor disclosures, covering

many related production sectors, water-related risks are recognized for both the fundamental market value and embedded in private markets as a new investment frontier: "*We use tools like ENCORE to assess water-related risks across high-impact sectors in our portfolio. This new approach helps us engage companies on reducing freshwater and marine ecosystem pressures, including through regenerative solutions"* (Asset Manager, Sustainability Report, 2024).

Figure 2. Aggregated results on biodiversity assetization narratives

Figure 2.1. Degree of assetization narratives



1 characteristic present - Non-assetized narrative
2 characteristics present - Partial assetization narrative
3 characteristics present - Full assetization narrative (fully assetized)

Figure 2.3. Degree of partial and full assetization narratives per sectors/ biodiversity activity

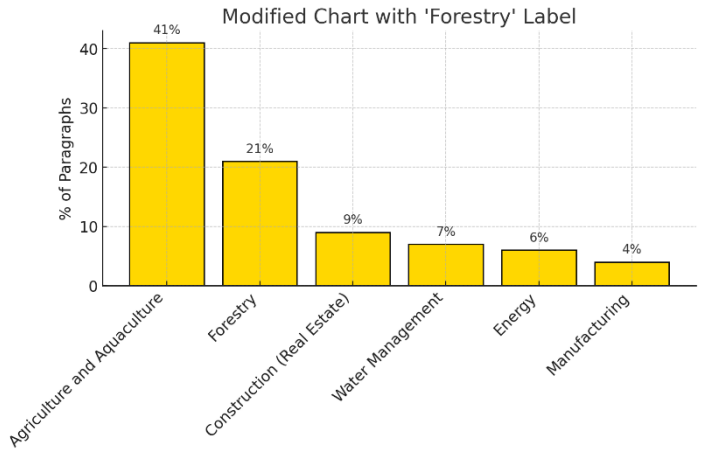
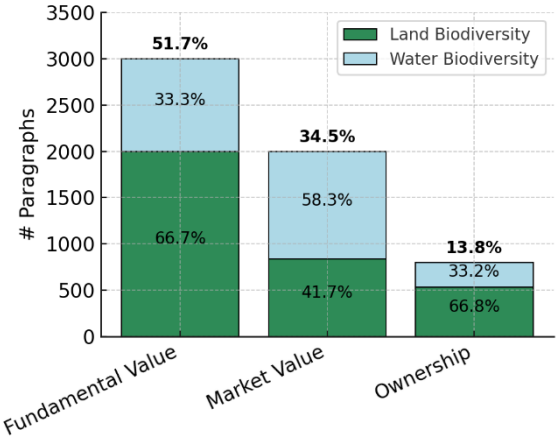
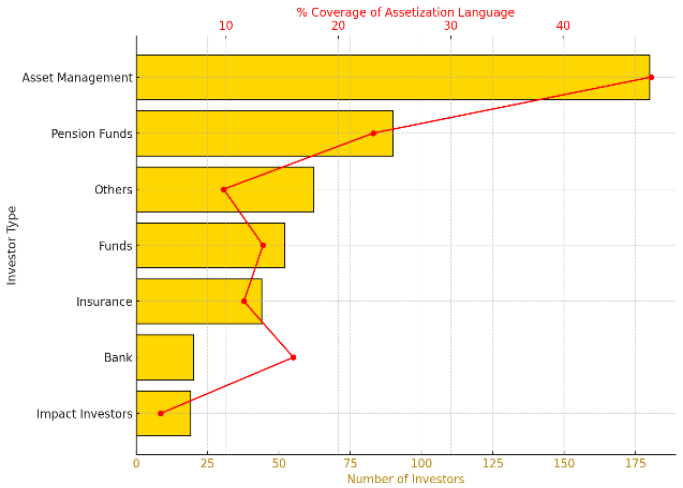


Figure 2.2. Assetization characteristics by biodiversity types



Land-based - References to terrestrial ecosystems (e.g., forests, agriculture, real estate, conservation land)
Water-based - References to aquatic ecosystems (e.g., oceans, rivers, wetlands, water management projects)

Figure 2.4. Degrees of full and partial assetization narratives per investor type



Across sectors, biodiversity assetization appears most in agriculture (41%) and forestry (21%), where it is framed as a productive resource to be utilized for (extractive) production and consumption: *"Our investments follow a landscape approach with support sustainable timber production in some regions and the expansion of agricultural land dedicated to healthy food systems, by reducing chemical use and protect biodiversity to contribute to long-term resource availability for protein transition"* (Institutional Investor, Sustainability Report 2023). Other consistently mentioned sectors are real estate (approximately 10%), energy and manufacturing (both less than 7%).

Across financial actor types, asset management firms stand out for both the volume and depth of biodiversity assetization language (Figure 2.4), followed by pension funds. While banks are less prominent in the overall sample, their disclosures exhibit a relatively higher proportion (15%) of assetization language (Figure 2.4), consistent with their traditional investment logic that emphasizes market-based valuation and control, particularly through the structuring of lending products and the use of collateral.

Across report types, biodiversity assetization narratives vary. Climate reports frame biodiversity as a mitigation and adaptation tool, signaling both fundamental and market value via cost reduction in response to climate-related risks such as environmental hazards and extreme weather events. However, it's value is often quantified through narrow, single-dimensional metrics, particularly carbon units, with an emphasis on its carbon sequestration potential, reflecting evidence for both fundamental and market value characteristics: "*Our reforestation investments enhance carbon capture while strengthening resilience against flood risks in high-exposure regions*" (Asset Manager, Climate report, 2022).

Stewardship and engagement reports explicitly reference ownership and control, portraying biodiversity as a relational governance catalyst across client supply chains. Assetization narratives shift toward ownership and fundamental value, emphasizing co-responsibility and dialogue: "*Through our forestry engagement program, we encourage clients to preserve high-biodiversity zones and transition from extractive models to long-term value creation through protection*" (Asset manager, Engagement report, 2024). Impact, CSR, and integrated reports further acknowledge the role and rights of local communities and their importance in ensuring responsible biodiversity outcomes, with more inclusive ownership and control characteristics[10].

[10] *"Our impact strategy includes participatory conservation initiatives with Indigenous communities in biodiversity hotspots impacted by infrastructure development*" (Insurance Provider, Impact report, 2023)

Table 3. Illustrative examples of assetization narratives from the data

Characteristics	Examples	Explanation
Full assetization narrative ***(three characteristics)***	*"The [X] Impact Bond Fund supports The Conservation Fund, which acquires and manages U.S. forests with the end goal of conservation and regeneration. By balancing sustainable timber harvesting with environmental protection, climate mitigation and regulatory offset services, the Fund integrates ecological preservation with long-term land management, fair valuation of ecosystem services, and revenue-generating activities."* (Asset Management Organization, Impact report, 2022)	This paragraph reflects all assetization characteristics by recognizing biodiversity value through ecosystem service pricing and environmental protection principles, linking revenue generation to regulatory offsets, framing conservation as climate risk mitigation, and ensuring long-term value and ownership via impact bonds and direct land management.
Partial Assetization ***(two characteristics)***		
Fundamental Value + Market-based value	*"The blue bond proceeds are allocated to projects that support marine ecosystem restoration and sustainable shipping, in line with the IFC Blue Finance Guidelines. These investments aim to develop and scale innovative ocean-based renewable energy solutions while actively contributing to ocean health through targeted, company-led initiatives*." (Institutional Investor, Engagement Report, 2023)	This paragraph reflects fundamental value by emphasizing biodiversity's role in sustaining ocean health and market-based value through investment in scalable, innovative ocean-based renewable energy solutions. However, it lacks reference to ownership or control over the marine ecosystems or explicit long-term governance structures, which is why it does not reflect full assetization narrative.
Fundamental Value + Ownership	*"An initial natural capital acquisition involved acquiring 6,300 hectares of Scottish moorland in Glen Dye, West Aberdeenshire, aimed at long-term stewardship through afforestation and peatland restoration."* (Insurance provider, Biodiversity report, 2022)	This paragraph reflects only fundamental value of nature, as it emphasizes long-term ecological restoration through afforestation and peatland recovery. While the investor owns the land, the framing lacks references to monetary valuation, revenue generation, or risk-return logic, which are necessary to indicate full assetization
Market-value + Ownership	*"Farmers on [Investor X]'s agricultural land in Kockengen are actively encouraged to manage the land sustainably, which has a positive effect on agricultural products. To make room for these efforts, [Investor X] offers a rent reduction scheme, 10% in the first three years and 5% thereafter, for farmers who enter additional sustainability agreements. While the scheme supports improved land management, the land is primarily valued for its agricultural productivity"* (Asset Manager, Climate report, 2023)	This paragraph reflects market-oriented value and ownership, as the investor retains control over the agricultural land and uses financial incentives (rent reductions) to promote sustainability. However, biodiversity is framed as a by-product of improved productivity rather than as a valued outcome in itself, indicating that the land's primary value remains tied to agricultural returns.
Non-assetization narrative ***(one characteristic)***		
Fundamental Value	*"Any land near our forest assets that is not suitable for acquisition will be restored or rewilded to maximize its biodiversity benefits, rather than being used for commercial purposes*." (Insurance provider, Annual Report, 2023)	This paragraph reflects a focus on biodiversity's fundamental value**,** the land is restored purely to enhance ecological benefits, without requiring ownership or generating profit and explicitly mentioning there is no commercial interest, hence lacking market-value.
Market- value	Rephrased: *[Bank X]'s green and thematic bond investments delivered measurable environmental outcomes, including 1,056 MWh of renewable energy, 1.6 million litres of water saved, and 717 tons of CO_2 avoided. These results are equivalent to powering 293 European citizens, filling one Olympic pool, and offsetting emissions from 3.4 km² of forest annually. Additional impact includes recycling 4,930 tons of waste and saving energy through sustainable transport solutions. These are all translated in more than €1 million investment value.* (Bank, Climate Report, 2024)	This paragraph reflects only market-based value, as biodiversity and environmental impacts are quantified solely through measurable outputs tied to financial investment. The focus is on return per euro invested, with no references to long-term stewardship, ecological interconnectedness, or ownership, positioning nature purely as a source of monetizable impact metrics.
Ownership	*Investor Y has secured a €24 million budsget to expand its land stock in the UK. Using this financing, it has acquired 9,000 hectares in Scotland, comprising 4,600 hectares of Langholm Moor and a 4,700-hectare estate at Invergeldie near Comrie in Perthshire*.(Pension Fund, Stewardship report, 2023)	This paragraph highlights ownership as evident, as the investor holds legal rights to the land. There's no sign of valuation or control, making it a static asset with no broader ecological or governance integration.

While dedicated biodiversity or natural capital reports remain rare, our data shows they have start to emerge as a distinct reporting trend starting in 2023. These documents contain more explicit biodiversity assetization narratives, detailing both commitments and concrete

implementation steps, such as the creation of financial instruments linked to biodiversity outcomes and the establishment of co-governance structures, highlighting market value and ownership dimensions.

4.2. Stand-alone and integrated biodiversity assets

By qualitatively exploring the paragraphs with full and partial assetization narratives, we observe two emerging trends: biodiversity positioned as (1) a standalone asset class and (2) integrated within existing classes (Figure 2.5). These two categories capture varying degrees of autonomy versus integration of biodiversity within the investment universe and in how it can be incorporated into portfolios. Since this relates merely to the type of biodiversity, we distinguish between green (land-based) and blue (water-based) categories[11], using the same approach as for in Figure 2.2 (the keyword list in Appendix 1B), to qualitatively group the asset types in Figure 2.5.

Standalone asset classes refer to nature-based investible objects as independent investment categories. These typically include agricultural land, forests, and freshwater bodies, where biodiversity is positioned as the primary source of value. Our dataset also showcases stand-alone assets in the form of conservation or landscape restoration projects[12] (Fig. 2.5), whose assetization logic rests on land ownership, conservation leasing, or stewardship models. Freshwater ecosystems- such as wetlands or river streams conservation, fisheries, or aquaculture initiatives - also appear in our data, indicating an emerging recognition of aquatic systems as discrete investment opportunities, but within more complex governance or co-financing arrangements.[13].

Within these standalone assets, two distinct narratives emerge. The first positions biodiversity within "do no harm" principles, emphasizing reduced pressures through FSC-certified forestry, biodiversity-positive agriculture, or pesticide-reduction practices, aiming to preserve nature while maintaining long-term financial returns. The second narrative centers on conservation-

[11] The physical characteristics of land and water shape their assetization differently: land, as a fixed and territorially bounded resource, aligns more readily with fundamental and market valuation methods and supports clearer ownership and control rights, while water - fluid, mobile, and collectively used - poses challenges for defining boundaries, assigning ownership, and translating its ecological value into market-based or tradable forms.

[12] For example: *"Our forestry portfolio is designed not only for long-term timber yield but also to deliver measurable biodiversity net-gain. Each forest asset is assessed for its ecological potential, with restoration plans integrated into the investment strategy to enhance habitat quality and native species richness over time."* (Asset Manager, Sustainable Forestry Report, 2024)

[13] *"Our clients focus on sustainable fisheries that contribute to restoring marine ecosystems while supporting local livelihoods with access to long-term food supply. By investing in regenerative aquaculture and fishery improvement projects, we align biodiversity recovery with sustainable food production."*(Asset Manager, Sustainability Report, 2024)

oriented investments, such as conserving forests, prioritizing ecological integrity and long-term protection over short-term market value generation.

Integrated asset classes refer to biodiversity themes that are embedded within, or attached to, existing asset classes. These appear most prominently on land, in particular within real estate - green roofs and pollinator gardens – and in conjunction with large infrastructure, such as biodiversity corridors. Biodiversity elements are incorporated into traditional assets, providing ecological value while increasing the market value of the underlying asset. Integrated categories such as regenerative agriculture, agroforestry, and natural water-retention systems further blur the boundaries between fundamental value and market instruments. They embed biodiversity outcomes into existing land or infrastructure projects, that function as blue-green infrastructure for risk mitigation or regulatory compliance[14]. Water-related biodiversity can be also integrated into land-based assets, such as rain gardens, swales and constructed wetlands. Introducing biodiversity additionality into traditional asset classes allows fundamental value, often overlooked, to be captured without altering the core financial structure of the underlying investment. [15]

Finally, we observe a distinct narrative emerging around biodiversity credits and carbon offsets. Although typically rooted in land-use practices like forestry or conservation actions such as natural parks, they occupy a distinct position in biodiversity assetization narratives. Their legitimacy is primarily drawn from climate finance practices such as carbon markets and the growing regulatory landscape of nature credit markets, highlighting them as innovative financial products with their own market infrastructure[16]. Our data sample indicates a narrative that begins with biodiversity framed as an integrated asset class but, through an intensified

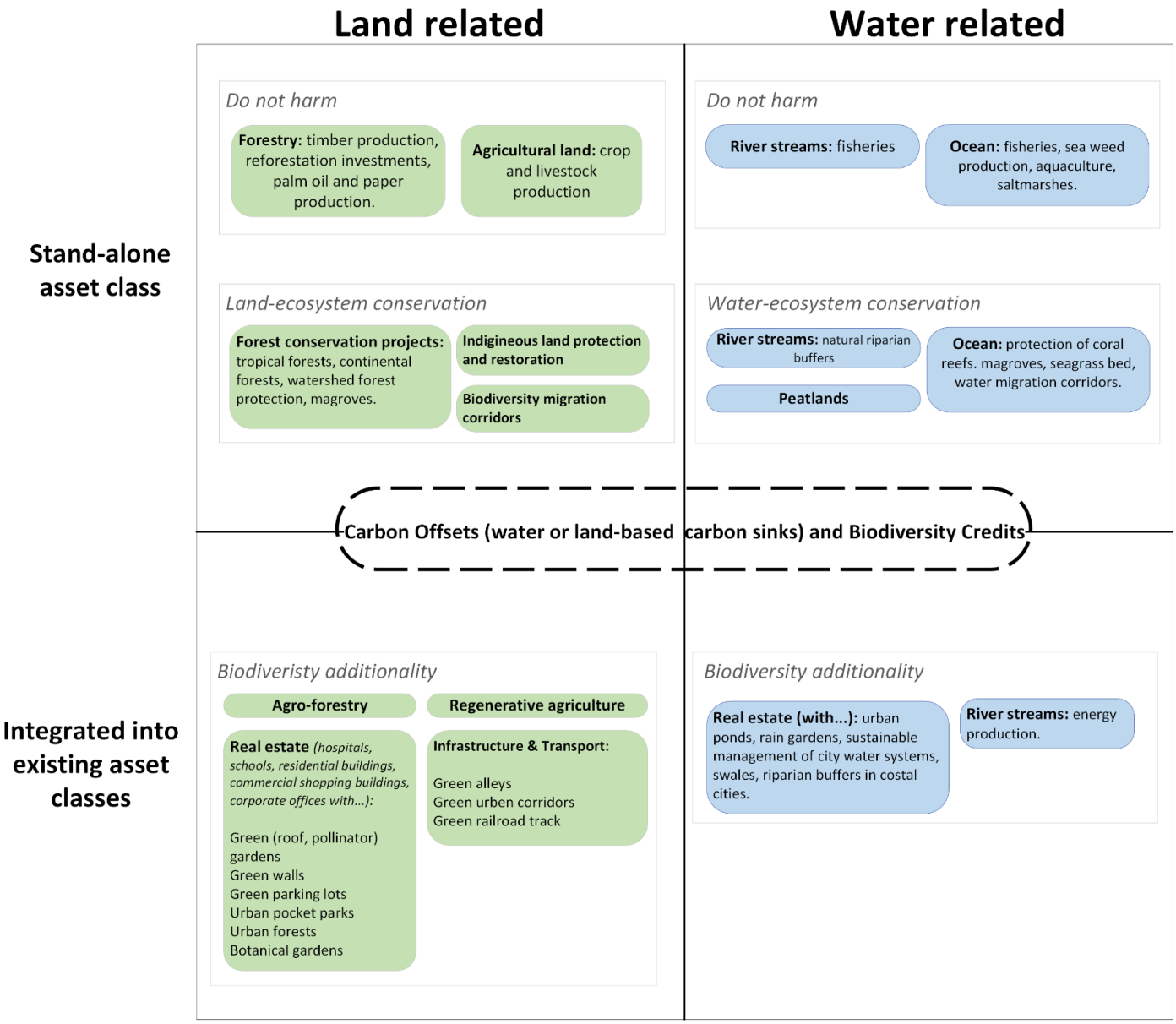
[14] *"We see features like green roofs and rain gardens not just as environmental add-ons, but as value enhancers. They improve stormwater management, lower cooling costs, and increase tenant appeal—which in turn supports higher occupancy rates and rental yields."(*Investment management, Biodiversity Report, 2023)

[15] *" At the same time, the latest sustainability and ecological features were incorporated, increasing the value of our real estate portfolio while enhancing biodiversity. For example, the semi-passive building design includes 100 photovoltaic panels and five 5,000-litre cisterns to collect rainwater for toilets and landscaping. The building also features a controlled air and humidity system for optimal energy efficiency, as well as six electric vehicle charging stations available for public use. A landscaped garden with a pond further supports local biodiversity around the structure."*(Institutional Investor, Climate Report, 2024)

[16] *"Carbon credits can help channel private capital towards nature-based solutions, such as reforestation, avoided deforestation, and sustainable agriculture that may both help address climate change and preserve nature and biodiversity. In general, these projects find it challenging to receive financing in the absence of a carbon credit project. As such, nearly half of the voluntary carbon markets consist In 2023, RBC Capital Markets created its Environmental Markets Solutions Group to help corporate and institutional clients operationalize their climate strategies, which includes crafting bespoke carbon credit procurement strategies. The group is supporting both clients who want access to carbon credits and clients that are generating credits".* (Asset Manager, ESG Report, 2023).

focus on market-based valuation, has gradually evolved into a standalone asset class[17]. This duality reveals how biodiversity is being translated into financial value, either through direct ownership and classification as standalone assets, or via functional integration with traditional investment vehicles. The findings also suggest that the integrated model may enable faster adoption, as it leverages existing asset structures and financing mechanisms to monetize biodiversity benefits while offering some degree of control over natural elements.

Figure 2.5. Stand-alone and integrated biodiversity assets



[17] *"Initially developed through a carbon quantification pilot supporting farmer-led, nature-based solutions, the project aims to establish a marketplace for ecosystem credits tied to regenerative agriculture. This mirrors developments in the UK, where Biodiversity Net Gain (BNG), once piloted, has now become a legal requirement, actively driving demand for biodiversity credits as compliance assets".* (Asset Manager, Climate Report, 2024).

4.3. Justice elements in biodiversity assetization narratives

We observe that justice considerations occasionally and increasingly appear alongside traditional assetization characteristics, particularly in reports published form 2023 onwards. These narratives arise primarily among a subset of financial actors, such as impact investors and asset managers, when they report on contributions to ecological restoration and community well-being. (Table 4).

Table 4. *Summary Results*. How justice elements surface in biodiversity assetization narratives

Assetization Characteristics	Traditional Financial narrative *Biodiversity as a…*	Justice-related narrative *Biodiversity as a…*
Fundamental Value	• natural buffer and monetized in cost-reduction terms (e.g. flood risk reduction, carbon sequestration) • singular investor-driven metric (e.g. MSA, number of trees/ha, captured CO2 tons, etc.)	• relational good, facilitating interaction across stakeholders especially in stewardship and engagement reports • ethical commitment or moral obligation for multiple stakeholders (e.g. community well-being, Indigenous stewardship) • life-support system, providing multiple co-benefits ([18])
Market value	• quantified environmental outcomes per euro invested (e.g. MWh saved, water saved, emissions avoided) • source of regulatory compliance or short-term reputational value • tool for enhancing property values, especially in adjacent asset classes like real estate • tradable traditional financial objects (credits, offsets, funds, bonds) solely by actors on the financial market (asset managers, banks, insurance companies) • underlying collateral for financial instruments • source of risk mitigation and profit increased via integration on productive sectors	• social co-benefit alongside financial return, influencing investment decision-making and legitimacy • long-term regenerative solutions, enhancing systems 'financial value focus on long-term ecological value' (prioritizing ecosystem regeneration over short-term liquidity) • inclusive and participatory biodiversity finance instruments; tools that embed local participation, shared governance, and equitable benefit-sharing in biodiversity-related financial flows. • re-imagined asset classes with diverse approaches to risk-return distribution.
Ownership	• assets held solely by financial institutions • instruments for exercising financial power and influence over financial markets • natural capital centralized by investors and embedded in financial products	• assets co-owned or stewarded by communities and indigenous peoples • mechanisms enabling shared governance and local custodianship • legal and financial structures supporting decentralized ownership models

[18] e.g. water filtration, flood control, carbon sequestration, and critical habitats for birds and fish, supports ecosystem productivity, ensures agricultural yields, and safeguards food security for future generations, regulates urban temperatures, manages stormwater, reduces noise pollution, reduces costs on real estate and increase value of buildings, etc.

The narratives from later years in the sample indicate a shift from traditional ownership toward stewardship, emphasizing local knowledge and participation. Some investors describe their work as "*supporting Indigenous women rangers in the West and Central part of the country that protect and restore the land*", highlighting gender equity and land-based knowledge (Asset manager, Trust Fund, Stewardship Report, 2023). Others exclude companies that violate Indigenous rights or degrade forests, calling for "*just choices*[19]" grounded in equity and transparency (Impact Investor, Impact Report, 2024). Biodiversity regeneration is also framed as enhancing fundamental value and social co-benefits, and although secondary to financial returns, community access to biodiversity remains an explicit consideration[20].

In regenerative agriculture, some banks move beyond transactional lending—"*[we] not only focus on carbon sequestration but primarily improve biodiversity and promote a just society*"—by working closely with loan beneficiaries. A smaller subset designs financial instruments through participatory processes with local communities and landowners[21], implying a shift from viewing biodiversity as an extractable asset to financing an ecological and cultural commons.

Initiatives such as Nature Action 100 pressure asset managers to revise governance structures and integrate biodiversity-specific indicators[22]. Some actors adopt co-governance models: "*The Collective supports and invests in mangrove conservation and blue carbon projects… through 42 partnerships including governments, private actors, and NGOs*", aiming to "*offer control and financial benefits to all the affected stakeholders*" (Insurance company, sustainability report, 2024). Yet many disclosures still position biodiversity into existing financial logics, using metrics like Mean Species Abundance (MSA) to "*aggregate the dynamic and static impacts… to support our risk-return adjustments*", while partnerships with NGOs often remain limited to data-sharing rather than deeper shifts in governance[23].

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[19] "*We invest only in companies that do not solely want to operate a little more sustainably, but genuinely stop deforestation and want to protect local communities and biodiversity making just choices*" (Impact Investor, Impact Report, 2024).

[20] "*we pushed our clients and now they prioritize biodiversity offset deals that provide the highest net-gain to biodiversity and facilitate the communities' access to water."* (Asset management, Impact report, 2023)

[21] *"we speak with every farm manager and landowners to assess the use of regenerative practices... providing an annual inventory and case studies of exceptional management"* (Sustainable Investing Report, 2023).

[22] "*At the start of 2024 we met with the World Wildlife Fund to discuss nature and biodiversity metrics for our portfolios. Within the International Corporate Social Responsibility covenant for the insurance sector, we collaborated in a broad sense with NGOs and government ministries on implementing OECD guidelines*." (Asset manager, Annual Report, 2024).

[23] *"We talk to NGOs to exchange knowledge and insights, building better metrics on measuring the land quality and land-based biosidveristy in landscape close to cities. We solely engage in improving valuation metrics and developing data opportunities"* (Asset manager, Stewardship Report, 2022).

5. Discussion: Just Reconfiguration of Biodiversity Assetization

While previous studies have explored if and how biodiversity can function as a private investible object (Chaplin-Kramer et al., 2023; Flammer et al., 2025; Hudson, 2024; Kedward et al., 2022; Seidl et al., 2024), this paper asks how biodiversity is being shaped into a financial asset and how this impacts -and might uphold- justice outcomes. We carried out an analysis of investor disclosures through the lens of the three core characteristics of an asset to understand assetization processes that are currently integrating biodiversity into financial markets, showcasing a prominent emphasis on market-value and risk–return narratives. We also find emerging evidence of justice-oriented investor narratives—including references to decentralized ownership arrangements and long-term regenerative solutions that seek to extend the financial value horizon toward ecosystem regeneration rather than short-term liquidity and rethink ownership structures.

Building on our analysis, we propose a justice-oriented reconfiguration of the assetization of biodiversity, addressing growing concerns on how to redirect private finance toward biodiversity in ways that uphold ecological integrity and social fairness (Arjaliès & Banerjee, 2024; Chausson et al., 2023; Clark, 2021; Folke, 2006). We critically assess how the shift from biodiversity as a public good to a private asset (Heal, 2004) in financial markets reshapes incentives, ownership, and the distribution of ecological and financial benefits (Heal, 1999; Kallis et al., 2015). We thereby respond to calls for frameworks that move beyond evaluative criteria of efficiency and amount of mobilized capital and instead also include equity and long-term ecological sustainability (Bull & Strange, 2018; Kedward, zu Ermgassen, et al., 2023; Maron et al., 2023; Timmers et al., 2022).

5.1. Inclusive valuation methods

How value is defined and by whom (Corbera, 2015; Matulis, 2014; Schaafsma et al., 2023; Strange et al., 2024) is crucial in determining which aspects of biodiversity become visible to markets and transactable (Bartkowski et al., 2015). Reflecting on our results regarding fundamental value approaches, we suggest that biodiversity valuation methods by investors should embed participatory processes involving local stake- and rightsholders such as local communities, Indigenous actors, and NGOs (Gibson et al., 2000; Treichel et al., 2025) to determine which ecological and cultural values are accounted for - including the indirect representation of non-human species (Matulis, 2014), and how (Arjaliès & Banerjee, 2024). Echoing prior research (Goff et al., 2017; Markanday et al., 2024; Pascual et al., 2023;

Termansen et al., 2023), we recommend that quantitative valuation models be complemented with place-based and scenario-based approaches that include qualitative, context-specific dimensions, rather than relying solely on standardized financial metrics in line with climate scenario analyses (Ceglar et al., 2025; Hafner et al., 2021; Ranger et al., 2024).

We further argue that valuation must incorporate the time value of biodiversity (Meyer et al., 2016) and recognize intergenerational considerations(Clark, 2021; Kaplan et al., 2017). The value of nature is dynamic, shaped by feedback loops, thresholds, and cumulative effects: when managed well, biodiversity's benefits grow over time, which mismatches the short-term, discounting logics of mainstream investment (Kedward, zu Ermgassen, et al., 2023). Short-term investment decisions that neglect key ecological interconnections can lead to irreversible losses (Strange et al., 2024; Turner et al., 2003; Voltaire, 2017) and intergenerational (distributional) injustice.

Finally, taking stock of the different types of biodiversity assets that we found such as blue/green and integrated/ stand-alone, we emphasize the need to tailor valuation methods to biodiversity type and scale (Aguiar et al., 2018; Cooke & Moon, 2015; Papari et al., 2024). From large-scale stand-alone conservation parks to smaller interventions like rain gardens or green roofs on real estate, impacts, risks and therefore 'ways to value' differ significantly. Investors must report transparent about these differences to avoid simplistic valuations and prevent greenwashing, especially when biodiversity is integrated within existing asset classes and assessed through narrow ESG metrics (Kopnina et al., 2024).

5.2. Market-value of biodiversity: from short-term to systemic

Although we take stock of some references to stewardship and long-term value in our results, the more dominant narrative is a narrow focus on market value and risk–return profiles of biodiversity in supporting productive sectors. This indicates that portfolio management practices often perceive biodiversity's market value through a short-term cash flow lens, ignoring the wider interdependencies between ecosystems and economic activities, and the links between climate change and biodiversity loss (Garel et al., 2024; Reguero et al., 2020).

A systemic approach to biodiversity finance requires rethinking assetization and moving beyond siloed, short-term financial metrics that underrate biodiversity's fundamental value in economic stability and portfolio resilience. When acknowledging that biodiversity loss generates systemic risks that threaten whole-portfolio performance, addressing those risks becomes not only consistent with fiduciary duty but potentially a prerequisite for investment—

even when doing so may reduce returns (Gosling, 2024). Considering the systemic risks they are exposed to, Universal Owners (Fichtner & and Heemsker and vulnerabilities of specific regions k, 2020; Mankikar, 2010) are particularly well positioned to drive this shift by aligning fiduciary goals (Johnston et al., 2022) with biodiversity's broader benefits (Cousins, 2021).

These shifts carry macroprudential implications: as biodiversity becomes an asset class, central banks should embed ecological risks and vulnerabilities of specific locations into supervision and capital frameworks (Boldrini et al., 2023; Ceglar et al., 2025; Knijp et al., 2024). Nature-based assets may eventually replace carbon-intensive stranded assets, supporting long-term stability, while categorizing assetization narratives enables nature-related scenario analysis and stress testing ((Kedward et al., 2022; Kedward, Ryan-Collins, et al., 2023; Ranger et al., 2024). Such tools can help anticipate spillovers and guide responses to ecological tipping points (Kedward & Poupard, 2024).

5.3. From Ownership to Stewardship based models and the role of Rightsholders and Universal Owners

Results show that ownership is largely absent from assetization narratives, despite being central to determining who benefits, decides, and captures value from biodiversity investments (Herrmann-Pillath, 2023). Asset managers and banks dominate biodiversity assetization where ownership is formalized and rights are clear such as land-based urban gardens and forests, whereas impact investors engage with less monetizable, harder-to-control assets such as water bodies and communal forests. This divide reflects the financial sector's established preference for enclosed, legible, and securitizable assets (Golka et al., 2024a; Gosling, 2024; Hardy et al., 2018; Holmstrom & Milgrom, 1991), which are more often greener than blue.

Current practices show limited attention to procedural justice, suggesting that narrow financial return logics are prioritized over relational values, territorial rights, and ecological integrity (Arjaliès & Gibassier, 2023; Theesfeld, 2018), while risk models shift ecological burdens to marginalized communities (Farina et al., 2024; Molina et al., 2024; Mutlu et al., 2023). Integrating local knowledge into financial decisions (Hahn et al., 2023; Quaas et al., 2019) and co-designing financial instruments - such as biodiversity-linked bonds in partnership with affected communities (Arjaliès & Banerjee, 2024), could act as a coordination mechanism across all affected parties, facilitating a landscape level investment model (Lindahl, 2012).

Traditional assetization logics conflict with Indigenous and community-based understandings of land and ecosystems, where stewardship is exercised without formal ownership through

relational governance grounded in kinship and reciprocity (Arjaliès & Banerjee, 2024). Financial instruments that rely on exclusive ownership risk perpetuating dispossession and colonial legacies, especially in economically vulnerable regions (Lockie & Tennent, 2009; Pascual et al., 2014). This concern is especially salient on land but appears equally acute for water-based biodiversity, where property rights are scarce, governance is fragmented, and markets are far less developed than for land. As our results show, weak ownership-focused narratives limit the assetization of water assets despite their acknowledged market and fundamental value. Without stewardship mechanisms, investors default to land-based biodiversity, reinforcing structural injustices in how nature is capitalized.

We argue that investors have the moral obligation to embed justice considerations into their engagement and stewardship policies. Especially large investors, such as Universal Owners (UOs) should promote alternative ownership models because their vast, cross-sectoral holdings give them structural power over how biodiversity is governed and valued. Concentrated ownership among a small group of global investors may reinforce patterns of enclosure and exclusion, where financial interests determine access to and control over natural resources (Fichtner & and Heemskerk, 2020) and higher exposure to systemic risks (Hudson, 2024). By advancing shared, custodial, or community-based ownership models, UOs can counteract power accumulation, distribute decision-making more equitably, and ensure that biodiversity governance aligns with collective stewardship rather than market dominance (Apostolopoulou, 2020; Arjaliès & Banerjee, 2024).

5.4. The active role of public governments in just assetization

Our result reflect the current practices in the broader sustainable finance domain: prioritizing disclosure, market-value framing, and singular metrics, while overlooking the structural conditions and supply-demand dynamics needed to make biodiversity investable. As a result, capital fails to reach areas where biodiversity loss is acute. And more fundamentally, capital through mainstream investors might do more harm than good if not carefully guided by justice considerations.

Public demand driven by governmental actors at all levels can generate the signals needed for privately owned biodiversity assets, including regenerative agriculture and sustainable agroforestry, to attract private investment. A justice-oriented reconfiguration requires governments to reassert their economic and coordinating role (Cooke & Moon, 2015; Kedward et al., 2022), ensuring that public finance, concessional tools, and risk-sharing mechanisms

support communities and ecosystems that markets alone would overlook. Also, public actors' interventions could reduce the large cost-of-capital disparities between advanced and emerging economies. Systemic or coordination goods, such as ecological corridors, restoration supply chains, and data systems (Molina et al., 2024), require governments, DFIs, and philanthropies to act as conveners and risk absorbers, shaping the enabling environment and coordinating collective action that markets cannot create alone.

To ensure biodiversity finance advances justice rather than deepening inequality, three interventions from public actors are essential. First, governments must create durable demand for high-integrity biodiversity outcomes through regulation, procurement, and public investment (Duffus et al., 2025; Kedward, zu Ermgassen, et al., 2023; Swinfield et al., 2024). Second, fiduciary duty should be extended to nature and vulnerable stakeholders, requiring transparent benefit-sharing, participatory governance, and safeguards against dispossession (Garel et al., 2023; Heal, 2001; Lambooy et al., 2018; Ortiz-Riomalo et al., 2023). Finally, distributional justice considerations must guide profit- and risk-sharing, protecting Indigenous and local landholders who bear disproportionate ecological burdens (Cousins, 2021; Matulis, 2014; Suiseeya, 2014).

6. Conclusions and future research

This paper provides the first comprehensive, theoretically grounded classification of biodiversity assetization narratives within investor disclosures across the three core characteristics of an asset – fundamental value, market value and ownership. Our results show that assetization processes are most often shaped through the market and fundamental value of biodiversity, while narratives on ownership remain underrepresented. Our exploratory analysis reveals multiple assetization pathways for biodiversity—stand-alone assets, integrated asset classes, and distinct patterns across land and water. Assetization narratives cluster in agriculture, forestry, and real estate, led largely by asset managers. The analysis reveals varying degrees of assetization across sectors and biodiversity types, while justice considerations receive only peripheral recognition.

We offer three key contributions. First, we advance our understanding of emerging natural resource valuation processes by private finance by empirically examining how biodiversity is being financed and disclosed upon as an asset by private investors (Birch & Muniesa, 2020; Hafferty et al., 2024). Secondly, we bridge finance and justice frameworks to engage in a structured reflection on the (different) justice concerns associated with assetizing biodiversity,

proposing a justice-oriented reconfigurations of such assetization processes (Chausson et al., 2023; Cousins, 2021). This includes reconceptualizing the roles of financiers to include stewardship responsibilities, fostering participatory governance structures, integrating time-sensitive, intergenerational valuation approaches, and integrating plural, non-monetary values. Our final contribution is methodological: we created a biodiversity assetization domain-specific pipeline for analyzing investor biodiversity disclosure using large language models and prompting techniques. This provides an open-source, scalable tool that future AI applications can build upon to analyze how financial actors articulate, translate, and report in the emergent biodiversity investment space (Blanco-Zaitegi et al., 2022; Keckel et al., 2025; Lambooy et al., 2018).

However, within our analysis, investor disclosures may reflect strategic framing or greenwashing rather than substantive changes in practices (Kopnina et al., 2024; Oinonen et al., 2025). Accordingly, we do not interpret investor narratives as direct evidence of actual biodiversity impacts; we analyze disclosures as discursive sites where financial meanings are constructed, legitimated, and normalized (Papari et al., 2024). This focus is particularly relevant in early-stage fields such as biodiversity finance, where narratives often precede formal market instruments, investment flows, and regulatory frameworks. Future research should therefore start from our study and examine how biodiversity assetization narratives translate into capital allocation, financial performance, governance arrangements, and ecological outcomes, and extend this framework to firm-level disclosures. Studying co-governance models, stewardship practices, and the time value of biodiversity, together with their justice implications, would further strengthen the evidence base for designing just and long-term-oriented biodiversity finance.

Lastly, the study faces methodological limitations related to data and model design. Larger datasets may reveal imbalanced distributions (Colesanti Senni et al., 2024; Vaghefi et al., 2023)), while keyword-based pre-filtering and reliance on self-reported disclosures may limit coverage of biodiversity finance activities (Schimanski et al., 2023, 2024). As biodiversity finance remains an emerging field, dedicated biodiversity-trained models are not yet available and should be developed to reduce bias and improve robustness (Zhou et al., 2024). Future research should advance and cross-test biodiversity-specific AI models and prompting approaches.

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Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

Statement: During the preparation of this work, the corresponding author, Cătălina Papari, used OpenAI's ChatGPT to support text editing and rephrasing for clarity and conciseness, and to assist in structuring and documenting the analytical pipeline described in the methodology. After using this tool, the authoring team reviewed and edited all content as needed and takes full responsibility for the content of the published article.

Appendix A. Keywords lists

A1. Keywords for taxonomy of biodiversity used in Level 2

Adapted explanation from IUCN (Keith, 2020)***:*** Ecosystems are defined by convergent ecological functions, while lower levels differentiate between distinct species performing those functions. This framework covers all dimensions of natural capital: marine, terrestrial, and freshwater systems, including both abiotic and biotic components. While clear boundaries are defined where possible, some overlap is acknowledged due to the interconnected nature of ecosystems, especially between species and habitats.

Table A1. List of biodiversity related keywords used in the Python script

```
Biodiversity_keywords = [
    "biodiversity", "species", "land use", "forest conservation", "reforestation", "afforestation", "savanna conservation", "tiger reserves", "elephant corridors", "pollinator habitats", "wildflower meadows", "wildlife corridors", "flora regeneration", "fauna conservation", "tree planting", "native species planting", "habitat protection", "nature conservation projects", "terrestrial ecosystems", "forest biodiversity", rare species protection", "natural habitat restoration", "invasive species control", "amphibian habitats", "beetle biodiversity", "honeybee conservation", "butterfly gardens", "forest habitat corridors", urban biodiversity hotspots", "nature into cities", "large urban parks", "urban forests", "pocket parks", "neighborhood green spaces", "botanical gardens", "alleys and street greens", "green corridors", "green belts", "railroad bank and track green", "nature on real estate", "atrium and courtyards", "green walls", "green roofs", "balcony green", "roof gardens", "green parking lots", "school gardens", "community gardens", "recreational green space", "shared ecological spaces", "living green walls", "accessible urban parks", urban greening", "urban pollinator support", "sustainable agriculture", "regenerative agriculture", "horticulture", "urban farming", "agroforestry", "permaculture", "sustainable forestry", "wildlife-friendly farming", "ecological garden maintenance", "organic gardening", "invasive species removal", "low-impact food systems", "responsible plant cultivation", "biodegradable materials", "large community gardens", "freshwater", "river", "stream", "wetland", "peatland", "stormwater retention basins", "sustainable urban drainage system (SuDS)", "natural drainage", "water control", "rainwater harvesting", riparian buffers", "clean rivers", "re-meandered streams", "stormwater storage", "aquatic habitats", "wetland conservation", "water filtration systems", "flood prevention schemes", "wetland creation", "rain gardens", "ocean", "coral reefs", "marine biodiversity", "marine ecosystems", "marine conservation", "marine life preservation", "marine protected areas", "fisheries", "seagrass conservation", "reef-building organisms", "coral bleaching prevention", "shark conservation", "dolphin habitats", "whale migration corridors", "sustainable fisheries", "overfishing mitigation", "marine mammals", "blue infrastructure", "coastline resilience", "mangroves", "sustainable aquaculture"
]
```

A2. Keywords for land versus water used in Level 4

The IUCN Global Ecosystem Typology is organised hierarchically, and each level of taxonomy provides a different degree of ecological detail. At the top are the five realms, which separate the biosphere into its broadest ecological divisions—terrestrial, subterranean, freshwater, marine, and transitional systems. Within each realm, the typology identifies a set of biomes, which group ecosystems by shared functional traits, dominant life forms, and major ecological drivers. Under each biome, the typology further identifies Ecosystem Functional Groups (EFGs), which are finer, functionally coherent units representing distinct ecological processes, trophic structures, or environmental conditions.

Building on the IUCN Global Ecosystem Typology, we collapse the REALM–BIOME–EFG hierarchy into two operational classes that are relevant for investor-focused reporting: land-based ecosystems (terrestrial and subterranean realms) and water-based ecosystems (freshwater and marine realms). We then construct two keyword lists that reflect typical ecosystem terms, habitats, and species associated with each class. These lists are implemented in the Python script used for text analysis and are applied to the already biodiversity-filtered paragraphs to mark them as land-related or water-related biodiversity assetization paragraphs.

Figure A2.1. ***Ecosystems typologies -5 realms from the IUCN report (Keith, 2020, p. 9)***

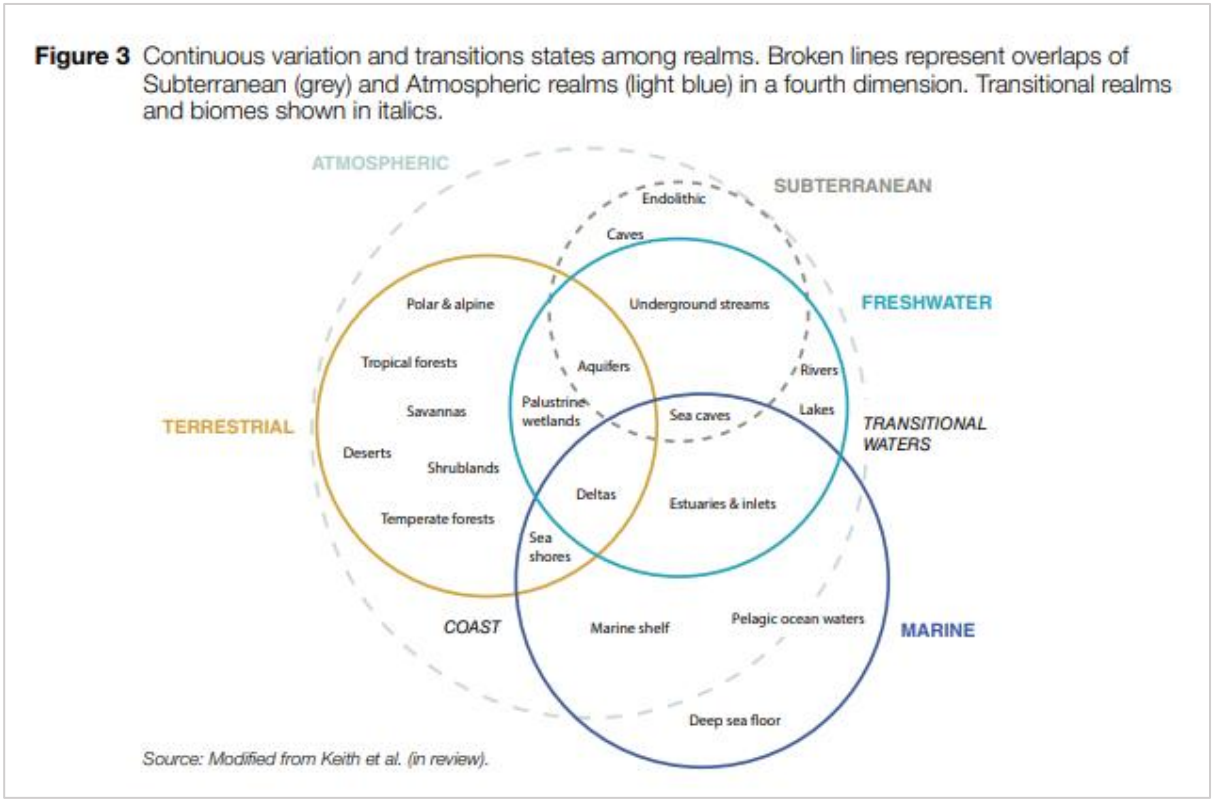


Table A2. List of land-based vs water-based biodiversity related keywords used in the Python script

```
Biodiversity_keywords = [
# CLASS LABELS
LAND = 1        # Terrestrial + Subterranean
WATER = 0       # Freshwater + Marine

# KEYWORD LISTS

land_keywords = [

    # LAND ECOSYSTEM / HABITAT TERMS
     "soil", "vegetation", "forest", "grassland", "savanna", "shrubland", "desert", "mountain", "alpine", "tundra","fire", "wildfire", "canopy", "roots", "rooting depth","dryland", "land use", "agriculture", "cropland", "pasture","peatland", "cave", "karst", "limestone", "subterranean","rock", "substrate", "permafrost", "terrestrial",

    # LAND BIODIVERSITY / CONSERVATION (allowed subset)
     "forest conservation", "reforestation", "afforestation", "savanna conservation", "tiger reserves","elephant corridors", "pollinator habitats","wildflower meadows", "wildlife corridors","beetle biodiversity","honeybee conservation", "butterfly gardens", "forest habitat corridors","urban forests", "pocket parks", "neighborhood green spaces","botanical gardens", "alleys and street greens", "green corridors", "green belts", "railroad bank and track green", "nature on real estate", "atrium and courtyards", "green walls", "green roofs", "balcony green", "roof gardens", "green parking lots", "school gardens", "community gardens", "recreational green space", "living green walls","accessible urban parks", "urban greening", "urban pollinator support",

    # LAND USE / FOOD SYSTEMS / FORESTRY / FARMING
     "sustainable agriculture", "regenerative agriculture","horticulture", "urban farming", "agroforestry","permaculture", "sustainable forestry", "wildlife-friendly farming", "ecological garden maintenance", "organic gardening", "low-impact food systems", "responsible plant cultivation", "palm oil reduction", "coffee production", "sustainable land-use",

    # LAND-RELATED ADDITIONS
    "land biodiversity", "land conservation", "land habitats", "land-based nature regeneration", "green real estate", "green buildings",

    # TERRESTRIAL SPECIES (common names only)
    "wolf", "lion", "elephant", "fox", "deer", "ant", "eagle", "falcon", "ostrich", "magpie", "blackbird", "bat", "olm"
]

water_keywords = [

    # FRESHWATER TERMS
    "freshwater", "river", "stream", "wetland", "lake", "pond",
    "stormwater retention basins", "sustainable urban drainage system",
    "natural drainage", "water control", "rainwater harvesting",
    "riparian buffers", "clean rivers", "re-meandered streams",
    "stormwater storage", "aquatic habitats", "wetland conservation",
    "water filtration systems", "flood prevention schemes",
    "wetland creation", "rain gardens",

    # MARINE TERMS
    "ocean", "sea", "marine", "coral reefs", "marine biodiversity",
    "marine ecosystems", "marine conservation",
    "marine life preservation", "marine protected areas",
    "fisheries", "fishery", "fishing",
    "seagrass conservation", "reef-building organisms",
    "coral bleaching prevention", "shark conservation",
    "dolphin habitats", "whale migration corridors",
    "sustainable fisheries", "overfishing mitigation",
    "marine mammals", "blue infrastructure",
    "coastline resilience", "mangroves", "sustainable aquaculture", "ocean plastic pollution",

    # MARINE & COASTAL HABITAT WORDS
    "salinity", "upwelling", "currents", "waves","plankton", "phytoplankton", "zooplankton","seagrass", "coastal",
    # WATER SPECIES (common names)  "dolphin", "whale", "crab", "tuna"
] ]
```

Appendix B. Prompts for GPT-4-mini

B1. Prompting Script for Level 3 and accuracy tests

To differentiate between generic references to biodiversity and actionable investor strategies (e.g., developing biodiversity-linked financial instruments, setting quantifiable biodiversity targets, or engaging portfolio companies on nature-related performance), we developed a classification prompt through an iterative, literature-informed process. The initial prompt was constructed based on the most frequently documented biodiversity investment activities identified in the academic and practitioner literature.

Following this, we iteratively refined the prompt by systematically reviewing paragraphs extracted from the corpus. Paragraphs that described investment-relevant biodiversity actions omitted from the literature-derived prompt—and therefore incorrectly labelled as non-actionable (class 0)—were incorporated into updated prompt formulations. This iterative process was complemented by a structured manual annotation exercise in which 200 paragraphs were labelled as actionable (class 1) and 200 as non-actionable (class 0). These annotations provided insight into how the large language model (LLM) interpreted textual nuances and where misalignments with expert judgement occurred, thereby informing further improvements to both the prompt and the classification script.

Across five refinement rounds, we progressively aligned the model output with expert intent. Notably, in the final iteration, the LLM's explanations for 15 of the annotated samples demonstrated greater conceptual precision than the initial human-written rationales. After careful review, we accepted the LLM's interpretation and updated the corresponding labels in the gold-standard annotation set. This ensured that the final prompt captured the full range of biodiversity investment activities represented in the corpus and supported a clean, unambiguous prediction boundary between the two classes.

Model validation results (Tables B1.2–B1.4) indicate strong and balanced classification performance. Out of 396 expert-validated paragraphs, only 10 were misclassified, confirming the robustness and consistency of the final prompt and prediction pipeline.

```
You are an expert in sustainable finance, biodiversity investments, and sustainability transitions. You deeply understand how biodiversity can be conserved, restored, and enhanced by using private capital, public finance, and blended financing structures. You also know how to set biodiversity targets, assess metrics, conduct research, and engage with companies to reduce negative and increase positive impacts on biodiversity.

I will give you text extracted from reports of financial institutions.
Your task is to evaluate whether the paragraph describes biodiversity related activities conducted by private investors and businesses OR whether it only contains generic references not related to theirs activities in relation to biodiversity.
Biodiversity related activities refer to any strategic, financial, operational, or governance activities undertaken by investors or businesses with the aim of assessing, protecting, restoring, or sustainably managing biodiversity and ecosystems, either directly or indirectly. These activities go beyond general statements and involve concrete contributions and measurable processes or at least mentioning future plans and goals that impact biodiversity outcomes.

Return only valid JSON with:
{
"score": 0 or 1,
"explanation": "short but precise reason for the score"
}

## SCORING RULES ##
```

Score = 1 if the paragraph contains at least one **biodiversity-related activity** undertaken by private investors or businesses, such as:
- Allocating capital through financial instruments (e.g. green bonds, biodiversity credits, blended finance structures, impact investing, loans, funds, offset instruments and biodiversity credits, philanthropic biodiversity finance, real assets such as land, forests, lakes etc.) that support biodiversity conservation, restoration and reduce negative impact on biodiversity.
- Channeling direct funding for biodiversity conservation or restoration (e.g. specifying amounts of money, hectares, ecosystem assets, biodiversity regions).
- Including biodiversity in decision making, on future action agenda, political agenda etc.
- Including biodiversity topics in investment, engagement, and voting policies, and engaging with firms on enhancing biodiversity positive impact and reducing biodiversity negative impact.
- Excluding firms that harm biodiversity from their portfolios.
- Engaging with firms on biodiversity loss and opportunities.
- Building the business case to invest in nature and biodiversity.
- Setting clear biodiversity-related goals, science-based targets, future commitments, or strategic intentions.
- Implementing a timeline to tackle biodiversity loss and regeneration and conducting scenario planning on biodiversity loss and regenerations.
- Designing or conducting due diligence on biodiversity-related investments or financial mechanisms.
- Assessing biodiversity-related risks, vulnerabilities, opportunities, and returns of investments (e.g. portfolio risk-return assessments).
- Conducting biodiversity materiality assessments by classifying economic sectors based on their impacts and dependencies on nature, using third-party data, internal expertise, and NGO guidance
- Restoring biodiversity via operational activities on owned or managed assets (e.g. restoring habitats, sustainably managing land, supporting regenerative agriculture, greening own offices etc.).
- Using executive remuneration and other internal governance structures to integrate biodiversity within a firm or investment.
- Conducting or funding research to develop biodiversity-related metrics and monitoring tools, biodiversity foot printing, or biodiversity impact methodologies.
- Calculate biodiversity foot printing and biodiversity impact.
- Obtaining third-party certifications or undergoing biodiversity-focused audits for biodiversity portfolios, financial instruments, or supply chains.
- Conducting business or investment activities in ways that explicitly reduce pressure on biodiversity (e.g. low-impact agriculture, biodiversity-positive supply chains, ecosystem restoration).
- Integrating ESG consideration with biodiversity metrics within investment and operations.
- Finding solutions for climate change mitigation and adaptation using biodiversity as a solution for climate issues (e.g. Nature-based solutions, flood risk reduction).
- Excluding biodiversity-rich regions used as sourcing regions of raw materials of firms in their portfolios.
- Reducing CO2 emissions and achieving carbon targets by using biodiversity (for example along their supply chain in transportation, manufacturing, delivery).
- Conducting procurement processes in relation to biodiversity.
- Recognizing the role of indigenous groups and local communities in stewardship of nature and protecting, restoring, and enhancing biodiversity.
- Collaborating together with third parties to tackle biodiversity loss - such as academic sector, NGOs or networks like Worldwide Foundation (WWF), Finance for Biodiversity Foundation, UN PRI, Nature 100 etc.

Score = 0 if the paragraph only includes **general, indirect references** to biodiversity, such as:
- Mentions of attending or participating in global biodiversity-related events or platforms (e.g. COP15, COP16, TNFD taskforce) with no follow-up.
- References to international frameworks or regulations (e.g. EU Taxonomy, SFDR, GBF, TNFD).
- Broad statements about the importance of biodiversity, ecosystem degradation, or the nature crisis.
- Citations and quotes of scientific bodies or reports (e.g. IPBES, IPCC, planetary boundaries) without linking them to decisions, targets, or implementation by the actor.
- References to increased transparency, reporting intentions, or future alignment with disclosure standards (e.g. TNFD), without describing steps taken towards implementation.
- Pledging or making commitments to protect nature or biodiversity with no plans, targets, or implementation.
Example 1
Input:
Althelia Funds, one of the private sector pioneers of natural capital investing, which is now owned by French asset manager Mirova, has adopted the blended finance approach. Althelia's approach is to help farmers and fishing communities develop additional sources of revenue, arising from 'environmental assets', such as carbon credits generated from the restoration and protection of forests, ecotourism, the provision of clean water, sustainable fisheries, and crop pollination.
Output:
{
  "score": 1,
  "explanation": "Describes Althelia’s blended finance approach in relation to carbon credits, ecotourism, sustainable fisheries, and water provision. It shows stewardship with local communities."
}

Example 2
Input:
Through AP7's green bond portfolio, AP7 invests in initiatives such as: The World Bank Sustainable Development Bonds that promote sustainability and biodiversity integrations in developing countries. The capital is invested in water purification, adaptation of communities to climate change, and biodiversity restoration.
Output:
{
"score": 1,
"explanation": "The paragraph mentions investment activity of AP7 via World Bank Sustainable Development Bonds in water purification, climate adaptation, and biodiversity restoration.",
}

Example 3
Input:
Measuring the loss of biodiversity is a complex task and it will take time to develop measurement methods. The TNFD framework is thus a good starting point for mapping risks in a systematic and uniform manner. We will also continue to be active in the TNFD taskforce.
Output:
{
"score": 0,
"explanation": "Mentions general policy and global framework of TNFD participation and reflections on measurement"
}

Example 4
Input:
The loss of nature and biodiversity is very much an economic issue that affects business and investors. Degraded ecosystems lead to increased costs, revenue loss, raw material shortages and social unrest. Decreasing biodiversity also exacerbates the effects of climate change.
Output:
{
"score": 0,
"explanation": "It discusses only general economic risks of biodiversity loss"
}

Example 5
Input:
{
"score": 0,
"explanation": "It mentions IPBES as a policy body and sector-level commentary; no link is mentioned to biodiversity-related activities of investors or businesses."
}

Example 6
Input: Achmea attaches great value to a liveable environment in which present and future generations can live and work healthily, safely and comfortably. This is why we believe it
important to devote attention to the Nature & the
environment theme in our investment policy. In this theme, we focus on aspects such as preserving and improving biodiversity. Robust biodiversity means clean air, fresh water,
good soil quality and crop pollination.
{
"score": 1,
"explanation": "The paragraph discusses the importance of a liveable environment and mentions preserving and improving biodiversity within Achmea's investment policy, indirectly referring to the inclusion of biodiversity in investment decisions."
}

Table B1.2. **Overall classification performance**

Metric	***Value***
Number of samples (N)	396
Accuracy	0.9747
Precision (pos = 1)	1.0000
Recall (pos = 1)	0.9500
F1 Score (pos = 1)	0.9744
Krippendorff's Alpha	0.9495

Table B1.3. **Per-class performance**

Class	*Precision*	*Recall*	*F1-Score*	*Support*
0	0.95	1.00	0.98	196
1	1.00	0.95	0.97	200
Accuracy (overall)			**0.97**	396
Macro Avg	0.98	0.97	0.97	396
Weighted Avg	0.98	0.97	0.97	396

Table B1.4. **Confusion matrix**

	Pred = 0	***Pred = 1***
Gold = 0	**196**	**0**
Gold = 1	**10**	**190**

B2. Prompting Script for Level 4 and accuracy tests

A similar iterative approach as in Level 3 was applied in Level 4, where the prompt was designed to classify paragraphs according to the three defining characteristics of assetization. Each paragraph received a binary score (1 = present, 0 = absent) for each characteristic. To refine the prompt and ensure conceptual alignment, we manually annotated 100 positive (1) and 100 negative (0) examples for each of the three characteristics. These expert-labelled samples served as a calibration set that allowed us to iteratively adjust the prompt, improve the decision criteria, and validate the model's interpretation of assetization-related language. The prompt was refined across successive iterations until the classification outputs and explanatory rationales consistently aligned with expert judgement, after which accuracy tests were conducted following the same validation procedure used in Level 3.

You are an expert in finance and investments for biodiversity. You are updated to all the biodiversity financing trends. You deeply understand how biodiversity could be conserved, restored, and enhanced by using pure private capital and blended financing structures. You also know how to mobilize private capital to reduce the negative impact on biodiversity.

Task
Your task is to evaluate a given text with regard to the presence of three characteristics of biodiversity assetization: **fundamental value**, **market value**, **ownership and control**.
For each text, you will allocate a score 1 for each of the three characteristics if a respective characteristic is present and 0 otherwise. Use the definitions, indicators and examples below to justify each assignment.

Return only valid JSON with:
{
"score fundamental value": 0 or 1 ,
"score market value":0 or 1,
"score ownership": 0 or 1
"explanation": "short but precise reason for the score"
}

Definition of Assetization in the context of biodiversity ##:
Assetization refers to the transformation of biodiversity into an asset asset class, financial or real. This is distinct from commodification or speculative financialization.
Assetization emphasizes **long-term ownership**, **control**, and **revenue extraction** over time.
Assets are made to keep, they generate **durable economic rents** through **control of access, usage rights**, and **future monetization and economic value**.

FUNDAMENTAL VALUE = 1 if the text contains at least one indicator or it covers the definition:
definition fundamental value: Biodiversity is framed as an ecological stock that accumulates or declines over time. This stock holds intrinsic ecological value, which can be captured through valuation methodologies and linked to broader economic and social value.
To assign economic value, private actors abstract biodiversity into comparable units with other economic assets. However, intrinsic value also emphasizes the non-substitutable, long-term, and multi-dimensional character of biodiversity.
Indicators for **Fundamental Value** include:
- References to biodiversity as a source of value
- Valuation of ecosystem services and use of payment for ecosystem services (PES) schemes
- Use of standardized methodologies, data, and tools to monitor and assign monetary value to biodiversity (e.g. natural capital accounting, internal valuation processes)
- Application of ecological, social, and cultural indicators in biodiversity valuation—e.g., species richness mapping, stakeholder co-definition of value, or Multi-Criteria Decision Analysis (MCDA)—without reducing value to a single monetary unit
- Estimation of the hypothetical cost of biodiversity loss, using avoidance cost approaches (e.g. cost of climate adaptation/mitigation in absence of biodiversity)
- Inclusion of biodiversity conservation and regeneration initiatives in investment activities
- Acquisition of land or ecological assets for restoration purposes (e.g. afforestation, peatland or wetland restoration)
- Framing biodiversity as irreplaceable or non-substitutable. Use of terms like "critical natural capital" or "irreplaceable ecosystems".
- Consideration of ecological thresholds or tipping points
- Integration of planetary boundaries or limits to biodiversity loss in financial decision-making
- Recognition of intergenerational value of biodiveristy as an asset that provides value for future generations (e.g. through long-term stewardship models)

- References to multimple benefits from biodiveristy beyond the monetary value such as nature's cultural, spiritual, or Indigenous values, particularly in stakeholder-driven valuation frameworks, provision and support via natural elements (benefits of resilience of infrastructure in facing natural hazards)
- Framing biodiversity as "insurance capital" or essential for system-wide resilience to climate or economic shock ##

MARKET VALUE = 1 if the text contains at least one indicator or it covers the definition:
definition market value: Biodiversity is integrated in the financial market and it is framed as a source of financial value, reducing costs, generating cash flow, returns on investment, or quantifiable economic benefits. It is positioned within the logic of risk–return analysis, as used in financial decision-making. The market value of biodiversity emerges when natural stocks — such as forests, species, or ecosystems — are transformed into flows via integration in financial instruments:
Indicators for **Market value** include:
- Risk-return framing and references to biodiversity as part of a financial return strategy
- Biodiversity integration into portfolios: biodiversity-positive or nature-aligned assets in multi-asset or ESG portfolios, or allocation, hedging, diversification of benefits linked to biodiversity
- References to financial instruments: Green bonds, sustainability bonds, climate bonds, climate investment, blended finance, debt, equity, biodiversity credits, carbon offsets based on natural ecosystems services, Issuance or structuring of conservation finance, impact investing, biodiversity-linked debt instruments or other green financial instruments with returns.
- Quantified financial benefits (e.g., avoided damage costs, reduce negative impact and capital loss, rents from biodiversity, etc.)
- Revenue generation and profit potential via statements about earning income from ecosystem services, nature-based offsets, conservation leases, etc. Examples: "credits sold to generate income", "landholders receiving payments for restoration", "nature as a source of yield"
- Future economic potential of biodiversity assets such as projections of revenue from future market developments (e.g., biodiversity credit markets, eco-tourism, conservation-linked debt)
- Forward-looking statements about unlocking biodiversity value or financial innovation in nature markets - e.g. biodiversity credits ##
- Cost reduction or financial risk mitigation, reducing exposure to biodiversity-related financial risks
- Biodiversity framed as a carbon sink, on carbon markets and offsets
- Lowering insurance premiums or financing costs via investments in biodiversity-friendly infrastructure (e.g., wetlands for flood control)
- References on biodiversity loss, stranded assets and systemic loss (Central banks level) ##

OWNERSHIP = 1 if the text contains at least one indicator or it covers the definition:
definition ownership: Ownership and control of biodiversity refer to who holds legal rights to access, manage, and benefit from nature.
While traditionally seen as a public good, biodiversity is increasingly governed through private, collective, or hybrid models, including land ownership, conservation easements, and biodiversity credits, allowing investors to monetize ecological assets while retaining or sharing control via financial assets linked to biodiversity.
Indicators for **Ownership** include:
- Land or water rights or project-level governance and decision making power over the natural resources and financial rents distribution
- Stewardship or co-ownership models
- Governance structure around biodiveristy projects or financial instruments
- Delegation of biodiversity management to third parties - e.g., local NGOs, impact fund managers, or stewardship trusts
- Reference to fiduciary responsibility or duty of care over biodiversity outcomes (e.g., pension funds or asset managers acknowledging their responsibility for long-term ecological value)
- Mentioning indigenous communities or other stakeholders involved in their activities or decision process
- Voting rights used explicitly to influence biodiversity governance (e.g., shareholder resolutions or proxy voting related to biodiversity impact)
- Language of exclusion/inclusion criteria tied to control mechanisms (e.g., "We exclude companies that negatively impact biodiversity" indicates portfolio control based on biodiversity criteria)
- Influence over how biodiversity is managed, conserved, or monetized
- Control and power attributed to financial instruments used for biodiveristy such as equity, bonds, loans
- Investment, engagement, and voting policies in relation to biodiversity for companies ##

EXAMPLES:
Example 1:
Paragraph: "Althelia Funds, one of the private sector pioneers of natural capital investing and accounting, which is now owned by French asset manager Mirova, has adopted the blended finance approach. Althelia's approach is to help farmers and fishing communities develop additional sources of revenue, arising from 'environmental assets', such as carbon credits generated from the restoration and protection of forests, ecotourism, the provision of clean water, sustainable fisheries, and crop pollination."
Explanation: The paragraph discusses natural capital investing, which reflects the valuation of nature's future benefits. It also refers to additional revenue streams from environmental assets, indicating the financial instruments capturing the market value of biodiversity. The mention of Althelia being owned by Mirova and offering support to local communities through investment projects suggests a degree of control and direct engagement, implying ownership.

{
"FundamentalValue": 1,
"MarketValue": 1,
"Ownership": 1
}

Example 2:
Paragraph: "In addition to the role of asset owners, there is also the opportunity to invest to contribute to biodiversity. Through AP7's green bond portfolio, AP7 invests in projects such as: The World Bank Sustainable Development Bonds that promote sustainable projects in developing countries. Through these bonds, AP7 enables investments in sustainable agriculture, renewable energy, and infrastructure that is more resilient to extreme weather. The capital is invested in projects such as water purification and water supply, adaptation of communities to climate change, and in projects aimed at restoring biodiversity."
Explanation: The paragraph highlights biodiversity restoration as an objective, linking to fundamental environmental value. It discusses green bonds and capital investment, which reflects the market value of biodiversity. However, AP7 acts as a bond investor with no evidence of direct ownership or control over biodiversity assets.
{
"FundamentalValue": 1,
"MarketValue": 1,
"Ownership": 0
}

Example 3:
Paragraph: "As investors, who have a fiduciary duty to act in the best long-term interests of our beneficiaries, we recognise the crucial role that tropical forests play in tackling climate change, protecting biodiversity and ensuring ecosystem services. As investors, we see deforestation and the associated impacts on biodiversity and climate change as systemic risks to our portfolios and see the reduction of deforestation as a key solution to managing these risks."
Explanation: The paragraph expresses recognition of biodiversity's fundamental value, especially tropical forests, in supporting climate and ecosystem stability. It makes reference to the systemic risk and relation to portfolio management depending on biodiveristy loss which is a direct mention of market value. However there's no evidence of ownership or control.
{
"FundamentalValue": 1,
"MarketValue": 1,
"Ownership": 0
}

Example 4:
Paragraph: "Germany's NRW Bank is a leader in this area, having raised a total of EUR4.6 billion from eight green bonds, of which 30 percent is earmarked for climate change adaptation projects, including restoration of the river Emscher. Key performance indicators for these bonds include: number of species in the river, prevented flooding damages (in EUR), areas of (re-) created floodplains and adjacent land (real wetlands) (in m^2)."
Explanation: The paragraph shows valuation through biodiversity-linked KPIs (e.g., species count, wetlands), indicating an effort to quantify ecosystem fundamental value. It also includes financial indicators (e.g., prevented damage in EUR), pointing to measurable cashflow from market value. Yet, there's no evidence of NRW Bank owning or controlling these ecosystems directly—its role is as financier via bond issuance.
{
"FundamentalValue": 1,
"MarketValue": 1,
"Ownership": 0
}

Example 5:
Paragraph: "In September 2023, a consortium including APG, the British Pension Protection Fund, and the Australian pension fund UniSuper acquired Forico, a forestry company in Tasmania, along with 170,000 hectares of forest. These forests contribute significantly to the production of forestry products. Forico was also the first forestry company in Australia to receive FSC Ecosystem Services certification, recognizing its biodiversity protection practices. Sustainably managed forests are highlighted as important for CO_2 storage and removal. On behalf of ABP, APG acquired a 33% stake in Forico and the forestry land."
Explanation: The paragraph emphasizes both ecological and financial dimensions. It highlights the fundamental value of biodiversity through FSC certification and carbon sequestration. It refers to forestry products, indicating the biodiveristy market value. The mention of a 33% ownership stake demonstrates direct control and investment in natural assets.
{
"FundamentalValue": 1,
"MarketValue": 1,
"Ownership": 1
}

Example 6:
Paragraph: "Investment Highlight: Domini International Opportunities Fund and Domini Impact International Equity Fund Kering S.A. is a French luxury goods conglomerate that houses brands such as Gucci and Saint Laurent. Kering's biodiversity strategy recognizes how any degradation of ecosystems can affect its global supply chain. Some of its initiatives include support for conservation programs, the development of rigorous standards for the sourcing of raw materials, and consideration of animal welfare in the manufacturing process. Kering aims to have positive systemic impacts through the development of projects that can be replicated by others in the industry. For example, it has committed to restoring and regenerating a million hectares of its supply chain and to protect one million hectares of critical habitat by 2025."
Explanation: The paragraph frames biodiversity primarily in terms of its importance to Kering's supply chain, which is a market value perspective rather than fundamenal ecological value. The commitments to habitat restoration and standards for sourcing suggest financial relevance and cashflow impacts. Ownership and control are implied through Kering's direct management of sourcing practices and large-scale restoration commitments.
{
"FundamentalValue": 0,
"MarketValue": 1,
"Ownership": 1
}

Example 7:
Paragraph: "[Bank X]'s green and thematic bond investments delivered measurable environmental outcomes, including 1,056 MWh of renewable energy, 1.6 million litres of water saved, and 717 tons of CO_2 avoided. These results are equivalent to powering 293 European citizens, filling one Olympic pool, and offsetting emissions from 3.4 km^2 of forest annually. Additional impact includes recycling 4,930 tons of waste and saving energy through sustainable transport solutions. These are all translated in more than €1 million investment value."
Explanation: This paragraph reflects only market-based value, as biodiversity and environmental impacts are quantified solely through measurable outputs tied to financial investment. The focus is on return per euro invested, with no references to long-term stewardship, ecological interconnectedness, or ownership, positioning nature purely as a source of monetizable impact metrics.
{
"FundamentalValue": 0,
"MarketValue": 1,
"Ownership": 0
}

Example 8:
Paragraph: "“Any land near our forest assets that is not suitable for acquisition will be restored or rewilded to maximize its biodiversity benefits, rather than being used for commercial purposes."
Explanation: This paragraph reflects a focus on biodiversity's fundamental value, the land is restored purely to enhance ecological benefits, without requiring ownership or generating profit and explicitly mentioning there is no commercial interest, hence lacking market-value.
{
"FundamentalValue": 1,
"MarketValue": 0,
"Ownership": 0
}

Table B2.1. Overall classification performance (Prompt assetization characteristics)

Characteristics/ Number of samples (N)	Fundamental Value/ 200	Market Value/ 200	Ownership/ 200
Accuracy	0.9600	0.9800	0.9250
Precision (pos = 1)	0.9796	0.9898	0.9474
Recall (pos = 1)	0.9400	0.9700	0.9000
F1 Score (pos = 1)	0.9594	0.9798	0.9231
Krippendorff's Alpha	0.9200	0.9500	0.8800