



Designing financial instruments for land-based ecological restoration: A review and future research Agenda[☆]

John Garvey^{a,*}, Vasilis Grigoriadis^b, Darragh Flannery^c, Edward Knapp^c, Elizabeth Gold^d, George Hutchinson^d, Lynn J. Frewer^e, Paul Brereton^d, Kenneth A. Byrne^f

^a Department of Accounting and Finance, Kemmy Business School, University of Limerick, Ireland

^b Department of Economics, University of Ioannina, Ireland

^c Department of Economics, Kemmy Business School, University of Limerick, Ireland

^d School of Biological Sciences, Queen's University Belfast, Ireland

^e School of Natural and Environmental Sciences, University of Newcastle, Ireland

^f School of Biological Sciences, University of Limerick, Ireland

ABSTRACT

Land restoration requires innovative approaches to prevent ongoing degradation and increase the functionality of land use. While land restoration has been studied extensively from the perspective of ecologists and local communities it is a topic that remains at the periphery of the financial economics literature, despite the global financial system's centrality to the problem. This paper reviews the literature on financial instruments that are designed for land-based ecological restoration, extracts key learnings from this literature and deploys a functional perspective to better understand how financial instruments that aim to scale up land restoration activities can be mainstreamed within the global financial system. This paper presents a framework that promotes public channels to best direct public and private capital towards land restoration projects. Matching the supply of capital with a pipeline of spatially explicit and sometimes unique restoration solutions requires an architecture that can implement this coordination and aggregation function. This has the potential to mitigate transaction costs and improve transparency issues associated with monitoring and reporting. This framework is illustrated for an actual land restoration program underway in Europe.

1. Introduction

Human land-use change has caused habitat transformations that have reduced biodiversity and the functional traits of ecosystems. This in turn has influenced the services that these ecosystems provide to humanity (Cardinale et al., 2012, Newbold et al., 2015). An estimated 60% of the world's major terrestrial systems have been degraded or used unsustainably through increases in agriculture, forestry and urbanization (Kinzig et al., 2011). Examples of valuable ecosystem services include the regulating services of carbon sequestration as provisioned by healthy, biodiverse forests or natural agricultural pest regulation which occurs when a variety of natural enemies such as predators, parasites and pathogens are allowed to survive (Cardinale et al., 2012). The decline in the performance of ecosystems has caused species extinction and continues to increase extinction risk (Powers and Jetz, 2019). Without system-wide changes in human activity, the further decline in

population abundance is projected to be between 18 and 35% while extinction risk is projected to increase to between 8 and 23% of all species (Visconti et al., 2016).

The urgent need to re-direct financial flows so that the degradation of land-based ecosystems is paused, and restoration activities can be supported is a challenging task. The Global Biodiversity Framework (2022) identifies the need to reduce harmful public subsidies by \$500 billion/per year while redirecting an estimated \$600 billion of private capital per year. For this to happen, it is clear that governments have an essential role to play and can "... drive innovation, shift markets, assign costs and liabilities, incentivize important investments and behaviors, and define fiduciary responsibilities." (Sachs et al., 2023, p. 46). This is a monumental task. At its core, the global financial system is engineered to support capital owners as they seek to optimize risk-adjusted financial returns across relatively short time horizons. The efficiency of the system in identifying opportunities and developing innovative approaches

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* Corresponding author.

E-mail address: john.garvey@ul.ie (J. Garvey).

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to activating these opportunities can now be observed in all aspects of human activity. It influences patterns of consumption (Gonzalez, 2015), where people live (Walks, 2013; Savini and Aalbers), access to clean water (Lofthus et al., 2019), the production of food (Baines, 2017) and how households allocate their savings (Röper, 2021).

The flow of resources is directed by networks of financial institutions and intermediaries that deploy decision-making tools and instruments that are ill-suited to integrating the large-scale and complex risks that result from a changing climate and biodiversity depletion. This can be observed at several levels of the financial system. The financial drivers that underlie the evolution of marketplaces provide a useful context. These marketplaces rely on trading commission that is associated with transaction volume and their success relies on their capacity to match the requirements of potential buyers and sellers (Seddon, 2020). To achieve this, transactions adopt standard features that facilitate the requirements of both commercial and speculative market participants. This supports trade volume and thus contributes to efficient price discovery (Chordia et al., 2011). The emergence of a financial product potentially holds lessons for applications in biodiversity finance which currently resides at the periphery of the financial system. Former CME President, EP Harris describes the early phase of product development as follows;

Beginning in the early fifties and until the present time, Exchange members have vigorously researched, tested, and promoted many new contracts for futures trading. Most have been agricultural commodities but some nonagricultural commodities were also formulated. Some have succeeded and some have failed, but fear of failure has not impeded progress. The commodities which have fallen by the wayside in futures trading include onions, scrap iron, frozen shrimp, frozen broilers, hides, and apples. Successful markets have been established in frozen pork bellies, Idaho potatoes, live hogs, strictly fresh eggs, and the most exciting current futures — live beef cattle.

Harris (1970), p.52

The success of *live beef cattle* as a futures contract relied on the creation of clear rules around their trade and delivery as well as policy enablers – for example, agricultural subsidies, which help to maintain a sufficient volume and stable supply of the underlying asset, live beef cattle (Laborde et al., 2021).¹ As noted by Paulson (2024), the financialization of live beef cattle demonstrates how a commodity becomes ‘more physically abstract over time’ yet the physical effects on land degradation and water quality are well understood (Cesonienė et al., 2019). The mechanisms that motivate financial transactions (and thus the allocation of resources) are similarly observed in other markets. Hsu et al. (2023) demonstrate that firms producing more toxic emissions are associated with higher subsequent stock returns and that constructing investment portfolios on this basis rewards investors.

The twin crises of climate change and biodiversity loss are motivating efforts to re-engineer this system. Within the European Union, this is evidenced in the three interacting regulations that are seeking to address how sustainable finance is defined and implemented. The EU Taxonomy,² the Corporate Sustainable Reporting Directive (CSRD)³ and Sustainable Finance Disclosure Regulation (SFDR)⁴ are complementary regulatory instruments that are expected to empower

stakeholders to make more informed and responsible choices and move towards a more transparent and accountable corporate environment. These regulatory instruments and their successors are expected to prompt companies to pressure their supply chains to decarbonise and mitigate their ecological impact. In the context of land-based ecological restoration, the set of financial instruments that will be used to operationalize this change remains unclear.

The current study seeks to better understand the practical implementation of financial instruments within the setting of mainstream finance. From the perspective of local landowners and communities that implement and are directly affected by land-based ecological restoration, the review is motivated to examine financial instruments that can deliver ‘adequate, predictable and easily accessible’ as set out by the GBF. The review thus deliberately narrows the focus of the review to a product-level analysis of the design, size, and scope of the financial instruments that have been directed towards land based ecological restoration. The functional perspective is then used to frame this analysis and contextualize how these instruments align with mainstream finance. In focusing on the ‘operational, management, and transactional costs’ associated with financial instruments, this approach deepens one of the proposed research clusters recommended in Cosma et al.’s (2023) bibliometric analysis of the broader conservation finance literature. The review thus aims to be a stepping-off point from which to examine the constraints arising from financial instrument design that hinder the effective allocation of capital towards sustainable land-use change and nature restoration.

2. Financial mechanisms and land use change

The financial system can be viewed as an optimizing machine that identifies and ranks investment and lending opportunities based on their risk and return characteristics (Crane, 1995). Against this dynamic backdrop, the functional perspective provides a framework for other domains to evaluate and critique the core functions of the financial system. Within this functional perspective, financial innovation is intended to identify and exploit inefficiency and therefore it directs the system towards ‘greater economic efficiency’ in which private capital flows through several channels, via instruments (e.g. equities, bonds), financial institutions and markets (Merton and Bodie, 1995, p.4). It should be noted that while innovation in how these functions are delivered, may improve efficiency (reduce costs and aid short term price discovery), there is no theoretical basis to expect that they increase welfare (Zingales, 2000). Indeed, the prioritization of short-term gains above longer-term investments and the redirection of profits back into the financial sector can lead to reductions in welfare (Mazzucato, 2020). While the allocation of voting rights to shareholders can influence corporate decision-making on several important topics that affect firm value (e.g. capital structure, Myers (2000); executive compensation, Rajan and Zingales (2000)), its impact on mitigating the costs of corporate activity on nature remain questionable. The intention behind reformist approaches to sustainable finance is to improve how sustainable activity is defined (EU Taxonomy) and advance the transparency of corporate (CSRD) and financial (SFDR) activities. There is some (as yet sparse) evidence that attention on biodiversity loss and enhanced transparency on corporate impacts on biodiversity can influence investor decision-making (Garel et al., 2024). The functional perspective provides an operational view on how the financial system functions and is thus a useful tool to analyze the set of potential financial instruments that could be used to activate capital flows towards land-based ecological restoration. It helps us to better understand how existing financial instruments are likely to evolve if finance is to be re-directed towards the protection and restoration of biodiversity. Investing in financial instruments that directly allocate capital towards land-based ecological restoration can be part of an overall strategy that is shaped by the investors’ needs and preferences. Potential investors may be corporates mandated to direct funds towards restoration in fulfillment of planning

¹ <https://www.cmegroup.com/markets/agriculture/livestock/live-cattle.contractSpecs.html>.

² https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en.

³ https://finance.ec.europa.eu/capital-markets-union-and-financial-market/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en.

⁴ https://finance.ec.europa.eu/sustainable-finance/disclosures/sustainability-related-disclosure-financial-services-sector_en.

requirements (Environment Act, 2021) or an asset manager who is extending their investment strategy beyond exclusion criteria to evaluate financial instruments that invest in nature positive actions (Springer, 2020). Bonds or fixed-income instruments offer one of the most effective structures for financial instruments directed towards restoration activity. Their application in project finance as well as their clearly defined duration and the predictable nature of cash flows meet many of the expected requirements for providers of nature-based solutions as well as prospective investors.

The architecture of a conventional bond (Fig. 1) provides a useful starting point to evaluate proposed biodiversity-linked securities. Typically, the bond issuer (payor) is seeking capital to undertake a new project while the bond investors (beneficiary) in return for providing capital, receive periodic interest payments (coupons) over the life of the bond as well as the loan amount (principal) at the end of the bond's duration. Within the global bond markets, there are multiple variations of this basic bond structure based on the preferences of bond counterparties and they typically trade in dealer-oriented over-the-counter (OTC) search markets that are very different from other market structures, such as equity or commodity markets. The scale and efficiency of bond transactions rely on the smooth operation of several functions such as the clearing and settlement of payments, the management of risk and accurate price information. The current review aims to better understand how biodiversity linked finance addresses these functions to better understand how mainstream finance can be unlocked for protection and restoration activities.⁵

Biodiversity linked finance is frequently located in two bond structures, namely green bonds and environmental impact bonds. Environmental impact bonds (Fig. 2) establish a close relationship between the bond investor, the borrower, and the results from an investment. In contrast to the green bond, where the investor's return is only subject to conventional financial risk (non-repayment), the environmental impact bond includes risks for the investor that are linked to performance, in this case the creation of environmental benefits derived from ecosystems services (e.g. measured improvements in water quality, measured reductions in flood risk) (Herrera et al., 2019). The design principle resides in creating a set of financial incentives for the private market (bond investors) to optimally select and monitor contractors who will implement the restoration project in a timely and cost-effective way.

Green bonds and environmental impact bonds are financial instruments that treat the challenges around ownership and implementation and incentivization in different ways. In both cases, these instruments exist alongside a universe of conventional investment opportunities. Understanding their capacity to scale up investment in the protection and restoration of nature requires a better understanding of how investors rank those instruments against conventional financial securities when seeking to optimize their capital allocation decisions. Consideration of the operational aspects of these transactions is essential if biodiversity-finance is to move beyond CSR-type capital allocations and into mainstream finance. Trade execution is sensitive to several factors, including return volatility (how capital owners receive a return

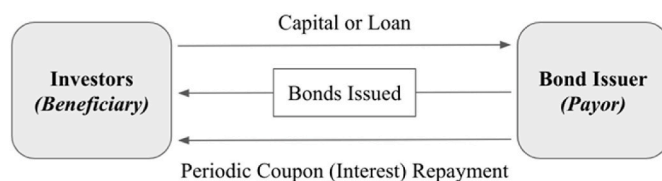


Fig. 1. Conventional bond structure.

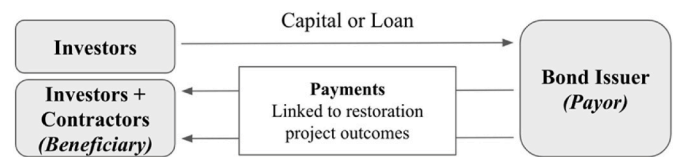


Fig. 2. Basic environmental impact bond structure.

on their investment), customer arrival rates (how quickly investors can view and transact the new financial instrument) and the likelihood of information asymmetries, that is, how simple and transparent the financial instrument is for investors and the intermediaries who effectively supply financing (see Bessembinder et al. (2020) for a review of market microstructure in fixed income securities). This has implications for the arrival rate of potential investors irrespective of the motivating force behind their investment is a regulatory imperative or client driven demand for biodiversity linked capital allocation. In the context of the issuance of sovereign bonds for biodiversity protection and restoration, these issues are relatively benign as the financial instruments are government backed and for the investor, they exhibit an architecture that is like conventional bonds, that is, the return of capital (both the principal and coupon) are not contingent on the achievement of biodiversity results.

Reviews of green bond issuance reveal that both corporate and sovereign issuers have typically used proceeds from green bonds to invest in renewable energy, clean transport and energy efficiency (Bhutta et al., 2022; Lewandowski and Smoleńska, 2023). Within the EU, after 2018 when the EU Taxonomy was first put on the table EU member states that described the use of proceeds as significantly contributing to the taxonomy and fulfilling the 'do no significant harm principle.' Lewandowski and Smoleńska (2023) note that credibility and trust in the market segment are aided by the adoption of a clear set of standards and rules, exemplified by the EU Taxonomy. Deploying green bonds for land-based ecological restoration is significantly more complex than for projects in relation to energy and transport. These complexities can be identified in the selection of restoration projects and the policy commitments that will deliver a sufficient volume of effective restoration projects so that bond proceeds are used efficiently. The availability of supportive infrastructure such as second party opinion providers who can verify the impact of the use of proceeds is likely to be more challenging in ecological restoration than in other sectors.⁶

Financing activities that protection and restore biodiversity has thus far been reduced to relatively smaller scale projects. Naeem et al. (2015) cite several projects undertaken at varying scales, including Costa Rica's PES program (national scale), New York City's water supply (regional scale), down to community-scale biodiversity conservation in Cambodia. They summarize the complexity of these projects by noting issues around the identification of 'whom to compensate, what to pay (i. e. money or other forms of incentives) and how much to pay, the mechanisms of payment and verification of service delivery' (Naeem et al., 2015). Naeem et al. (2015) note that even selecting the optimal approaches to biodiversity protection and restoration are contested from within the natural sciences. From an economic perspective, there are equivalent challenges around identifying who should pay and the channels through which capital can be allocated in an optimal way.

The current paper uses a systematic review of the literature to evaluate the contours of the research and applications of financial instruments design to protect and restore biodiversity in land-based ecosystems.

The functional perspective is used to assess the design features of

⁵ Global long-term fixed income issuance in 2022 was \$22.5 trillion. <https://www.sifma.org/resources/research/fact-book/>.

⁶ EU Member States are supporting the development of this infrastructure for example, Vigeo Eiris (France), Sustainalytics (Netherlands) and ISS ESG (Germany).

those selected financial instruments and identify their compatibility with the global financial system.⁷ Within the functional perspective, environmental impacts and the distributional effects of resource allocation are not considered, rather the research imperative relates to allocative efficiency.⁸ While Lewandowski and Smoleńska (2023) notes that this functional perspective appears to deliberately ‘depoliticize’ the global financial system it helps to assess the distance between current instruments used in private financing of land-based ecological restoration and the design features needed to unlock mainstream finance for the restoration of our biosphere. The following section provides detail on the materials and methods used in the systematic review.

3. Materials and methods

The methods employed in this systematic review are explained in detail in an a priori systematic review protocol (Grigoriadis et al., 2023). This systematic review follows the guidelines of PRISMA-P (Preferred reporting items for systematic review and meta-analysis protocols) which support the planning and documentation of review methods and act as a guard against subjective decision-making during review conduct (Moher et al., 2015). The PICO (Population, Intervention, Comparison and Outcomes) framework, the search string and the eligibility criteria can be found in Grigoriadis et al. (2023).

Following Moher et al. (2015), the following definitions and scopes were used to frame the identification of relevant studies. *Financial instruments*: “Any contract that gives rise to a financial asset of one entity and a financial liability or equity instrument of another entity” (IFRS Foundation, 2024). Excluded from our review are more recent innovations that address debt within developing countries as an opportunity to initiate improved nature governance and support restoration activities. In particular, refinancing agreements associated with tailored approaches to restoration remain such as debt-for-nature swaps or nature bonds are interesting approaches but are typically negotiated and agreed outside mainstream finance.⁹ *Land restoration* is the “process of ecological restoration of a site to a natural landscape and habitat, safe for humans, wildlife, and plant communities” (UNCCD, 2022). Moreover, ecological restoration is the “intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability” (Clewett et al., 2004). *Environmental sustainability* is defined as “responsible interaction with the environment to avoid depletion or degradation of natural resources and allow for long-term environmental quality”. The practice of environmental sustainability helps to ensure that the needs of today’s population are met without jeopardizing the ability of future generations to meet their needs” (Anes and Mohan, 2018). *Ecosystem services* are the “benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling” (MEA, 2005).

Literature searches were conducted in June 2022 using English

language search strings in Scopus (907 studies), Web of Science (646), and Agricultural & Environmental Science Collection (80) (for complete search strings, see Grigoriadis et al., 2023). Also, the first 200 studies from Google Scholar are used to identify any academic or grey literature not captured by the search of bibliographic databases. All search results (1833 studies) were downloaded and catalogued in the EndNote 20 version before removing duplicate studies.

Out of 1833 studies, 1384 remained after removing duplicate records, books or book chapters and non-English documents (Fig. 3). These studies were screened at title and abstract level: 1048 of them were excluded and 336 were included for the next screening process. As the full texts of 18 studies were inaccessible, the remaining 318 studies were screened at the full text level. 311 of them didn’t meet the inclusion criteria and were excluded as a) ecosystem restoration was not the focus of the study, b) they did not include any financial mechanism, or c) they did not aim to improve environmental sustainability and/or ecosystem services. This resulted in seven selected studies for evaluation, with Brand et al. (2021) additionally included as it was a motivating paper selected prior to the review process.

At each stage of the screening process, the articles were screened by two reviewers to assess consistency of decisions between reviewers. The Cohen’s kappa (McHugh, 2012) was estimated to test the degree of agreement between the two reviewers. An acceptable level of agreement, indicating substantial consensus among reviewers, is determined when the Cohen’s Kappa statistic is equal or greater than 0.6 (Huang et al., 2021). The review’s Cohen’s Kappa statistic for screening on title and abstract was 0.72; and for screening on full text 0.79. Studies that did not have a consensus between the two reviewers were discussed and finally agreed on inclusion or exclusion with two other members of the research team.

4. Results and discussion

4.1. Study type and geographical location

The selected eight studies detail ten projects, either underway or proposed, and their associated financial instruments. These projects relate to both national (Europe, North America) and international (Africa, Oceania, Asia) capital flows. Table 1 categorises each study by methodology as well as ecosystem and region. Following Stake’s (1995) characterisation, the studies 1–3 adopt an *intrinsic* case study, drawing on existing models to analyze or extend from conventional financial instruments to learn about the financing of ecosystems within a unique setting. The uniqueness of the phenomenon and its associated challenges are emphasized, in this case, distinguishing the protection or restoration activity from all others. In contrast, studies 4–6 seek to implement an *instrumental* approach by using a particular case (some of which may be better than others) to gain a broader appreciation of an issue or phenomenon. Studies 7 and 8 adopt a *collective* case study approach that involves the analysis of multiple cases simultaneously or sequentially in an attempt to generate a still broader appreciation of the design of a financial instrument for application in biodiversity protection and restoration.

The financial instruments in the selected studies are defined variously as green bonds, blended finance, and environmental impact bonds and attempt to link these financial instruments to mainstream financial institutions and markets. Study #1 notes ‘investor appetite for socially and environmentally responsible investment, and a willingness on the part of financial and other institutions to offer investment opportunities to meet the demand’ (Ferguson et al., 2016). While Study #2 refers to benefits such as ‘reputational value’ and they propose that they ‘will be highly attractive to impact investors and other socially responsible retail investors.’ Study #4 similarly deploy a descriptive case study noting that the proposed Forest Resilience Bond (FRB), provides an opportunity for ‘willing private investors (who) have too often been left on the sidelines.’ (Madeira and Gartner, 2018).

⁷ Published in 1995, *The Global Financial System: A Functional Perspective* is an edited monograph produced by a group of finance scholars at Harvard Business School and MIT. Despite being almost thirty years old, this book still provides a comprehensive description of how the Global Financial System functions and reflects the areas of attention for current researchers in the field. This is despite the multiple failures of the system to adequately manage risk or consider challenges relating to inequality, distribution of risk or extractive economic activity and environmental damage.

⁸ That is, how the financial system achieves risk adjusted returns while minimizing transaction costs.

⁹ <https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/nature-bonds/>.

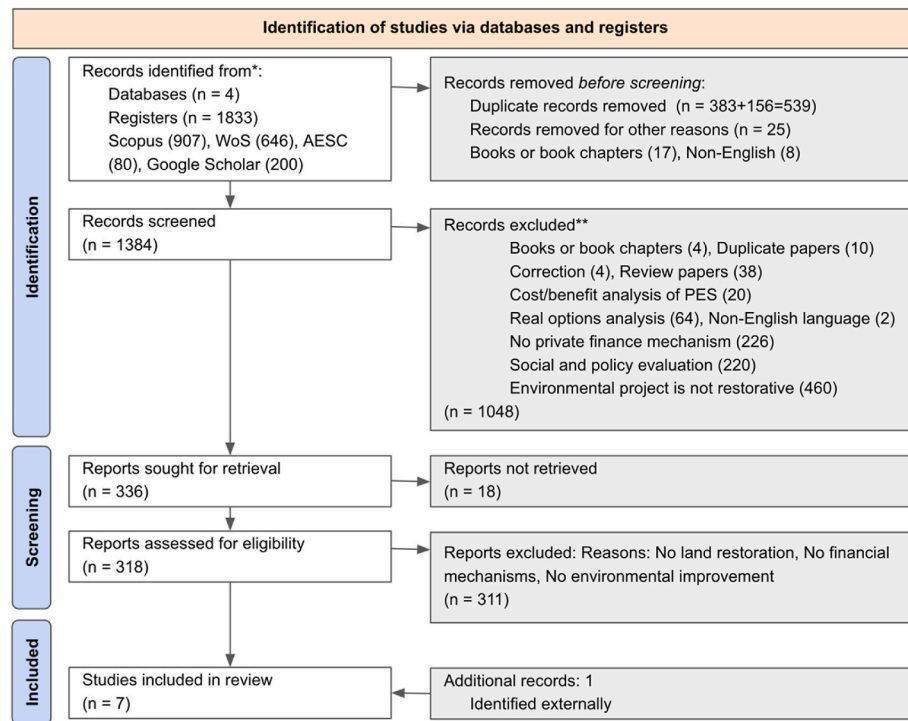


Fig. 3. PRISMA-P flowchart illustrating the systematic review process. [Page et al. \(2021\)](#)

*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

Table 1
Summary of selected studies by title, study methodology and location.

Study #	Author(s) (Year)	Study Methodology (ecosystem)	Location
1	Ferguson et al. (2016)	Intrinsic case study (forest)	Australia
2	Hall et al. (2017)	Intrinsic case study (forest)	New Zealand
3	Madeira and Gartner (2018)	Intrinsic case study (forest)	United States
4	Herrera et al. (2019)	Instrumental case study (coastal wetland)	United States
5	Bernknopf and Broadbent (2020)	Instrumental case study, Portfolio Theory (forest)	United States
6	Moxey et al. (2021)	Instrumental case study (peatland)	United Kingdom
7	Brand et al. (2021)	Collective case study (freshwater, forest)	United States
8	Thompson (2023)	Collective case study (forest, tropical landscape, species protection)	United States, Indonesia, South Africa, Kenya

The conviction of these initial, motivating statements is tempered in later sections where a more conservative tone is adopted. For example, Study #2 goes on to cite commentary from a workshop on forest finance, that indicates the need for market liquidity and a variety of risk-return profiles to attract investors. Once ‘the market deepens’ ... ‘a tranche structure within different risk/return profiles could additionally appeal to institutional investors’ ([Hall et al., 2017](#)). There is a notable absence of detailed analysis of the market and regulatory conditions necessary for these instruments to be considered alongside conventional financial instruments. Similarly Study #1 later caveats its initial enthusiasm, observing that ‘green bonds do not seem as readily applicable to biodiversity-based services, which remain complex and problematic in Australia.’ ([Ferguson et al., 2016](#)). The importance of the characteristics

of the marketplace, the requirements of investors and the primacy of informational transparency remain peripheral in all studies.

Study #5 comprises a conventional, empirical finance approach as it evaluates the projected rate of return on a bond that provides returns for both timber products and ecosystem services. The study then seeks to apply this concept to an afforestation project in the Lower Mississippi Valley (LMV) and it assigns a market value to the price of timber as well as ecosystem services (habitat development, carbon sequestration). In common with the earlier selected studies, little attention is given to empirical evidence of investor preferences, or where biodiversity-linked assets might rank among the universe of fixed income securities. The study is distinct in that it partly draws on conventional financial economics methods (portfolio theory) to validate pricing for a biodiversity-linked asset. The uncertainties associated with the production of ecosystem services creation are not easily aligned with conventional investment decisions guided by modern portfolio theory.

Study #6 examines blended finance approaches to attract private finance. Extending from an existing public finance scheme - the UK’s Peatland Code – the study acknowledges the difficulties in attracting private finance for ecosystem restoration. ‘Whilst some ecosystem service benefits are now valued through markets and offer rewards to private investors, others still take the form of public goods and externalities that are not.’ ([Moxey et al., 2021](#)). This is a frequently observed challenge within the environmental economics literature which both identifies a market failure and highlights a need for improved markets and mechanisms in the ecosystem finance literature ([Bellanger et al., 2021](#); [Bruel et al., 2016](#); [Cheng et al., 2019](#)). This critical perspective opens avenues for investigation on how to best match private funding to restoration projects. Depending on the macrofinancial regime in place, the transfer of capital to reduce negative externalities may be more effectively analyzed as a matching problem rather than a valuation problem ([Roth, 2018](#)).

The design of an environmental impact bond (EIB) (Study 4) seeks to create incentives and assurances for bond beneficiaries (investors) so

that restoration activity can be accelerated. To this point, the implementation of these bonds has been proposed in the US where adequate public finance solutions appear to be unavailable or lack performance criteria. The authors of Study 4 pay close attention to ‘aligning incentives of the investors and payors around metrics of wetland sustainability’. The EIB architecture closely ties the proposed activity to biodiversity restoration as well as a reduction in economic costs associated with coastal flooding. They note that ‘innovative financing tools that ... have a potential to attract private capital ... are needed to support coastal resilience’. (Herrera et al., 2019). The remaining two studies (#7, #8) employ a collective case study to provide a comprehensive insight into the design features of an environmental impact bond, placing a strong emphasis on addressing the incentives for investors. In common with all selected studies, the proposed size of investment is bounded by an unspecified estimation of investors’ willingness to pay for restoration projects. Less attention is given to the scale of the challenge at a landscape level and what optimal ecosystems restoration might entail and its associated costs. The following section details the financial characteristics of the instruments considered in each of the selected studies.

4.2. Transaction size, project duration, interest rates and ratings

A summary of the main characteristics of each of the bonds considered in the selected papers is provided in Table 2. The table identifies the beneficiaries of the bonds as well as the payors. Beneficiaries (benefit from investment), receive a return in various forms from the payors. This repayment can vary from an interest repayment like a conventional bond, access to sustainable rubber or timber or a specific action linked to the protection of existing landscapes. The selected studies evaluate completed and proposed transactions that range from small individual, retail investment (ticket size AUD\$5000) to corporate and institutional investments (ticket size USD\$150 million). The study examining the blended finance proposal (the Peatland Code, Study #6) is distinctive among the selected studies as it focuses on the system bottlenecks that prevent participation in biodiversity restoration. The study does not provide an aggregated estimate for a large-scale financial instrument for a national restoration program for degraded peatland, rather owners of peatland can access private capital via the European Union Emissions Trading System as part of a complementary public and private financing system. The authors point to the need for improved efficiency around implementation and monitoring, noting that the routing of private funding through public administrative systems could deliver on efficiency but this ‘would need to be balanced by consideration of other issues such as transparency, risk and probity’ (Moxey et al., 2021). Other studies included in the current review similarly focus on the design of financial instruments without quantifying the potential private funding that could be mobilized in a real-world iteration of the instrument (namely, the Sustainable Forestry Bond and the Biodiversity Investment Scheme, both S#1 and the Permanent Forest Bond, S#2). In contrast, Study #8 describes five major biodiversity related green bonds issued at a combined value of \$446m. Three of the bonds are issued for forestry management (two in the US, one in Kenya). In the case of these bonds, beneficiaries (investors) are provided with access to sustainable timber harvesting, sale of CO2 credits and agreed tiered payments for improved water quality from downstream water utilities and hydro power plants. Such benefits are subject to meeting biodiversity targets such as reestablishing continuous timber cover, reducing wildfires and soil erosion, preserving biodiversity habitat and safeguarding water quality. The Rhino Impact Bond in South Africa links bondholder payments to the achievement of a targeted increase in the net population increase over five years. The Tropical Landscape Finance Facility Sustainability Bond defines the bondholders (payors) as the managers of 88,000 ha of sustainable rubber plantations in Indonesia. Under the bond structure, half the land comprises rubber plantations while the other half is ostensibly managed for conservation. Market revenue to bondholders to be

provided from sale of sustainable rubber over the 15-year contract (Michelin, 2019).

Study #2 details an expansive proposal for an environmental impact bond (EIB) in New Zealand that will fund afforestation to “prevent annual costs to New Zealand worth hundreds of millions of dollars due to erosion damage, reduced water quality, flooding, carbon offsetting and the degradation of New Zealand’s green brand” (Hall et al., 2017). The study provides an effective exposition of the relative incentives for the prospective participants in such a bond, however less attention is given to the mechanics of payments and how they might interact with existing public administrative systems.

Similarly Study #4 provides a detailed architecture for an EIB designed to direct \$50m towards wetland restoration in Louisiana. Part funded from the Deep-Water Horizon Natural Resource Damage Assessment Award, the authors outline a program of mangrove restoration for flood risk reduction at key port facilities and for mitigation of land loss in port and industrial areas with addition benefits of habitat creation and preservation and of carbon sequestration. This nature-based solution is expected to generate economic benefits in addition to marketable carbon credits from mangrove enhancement. This is the most advanced of the three EIB projects by providing a roadmap for significantly upscaling of nature-based solutions and points to their broader application to globally significant environmental engineering and biodiversity restoration projects. The proposed EIBs in both New Zealand and the US emphasize how stacking ecosystem services is an economic imperative that facilitates the grouping of payors with specific exposures or interests so that bond beneficiaries receive an ‘adequate’ return.

From the selected studies, six bonds were successfully issued. In three cases the payors are state departments (in the United States) and/or utility companies that are seeking private funds for forest restoration activity that impacts on risk mitigation or improved water quality. The remaining three bonds were intermediated by the World Bank, Goldman Sachs, and BNP Paribas respectively and typically involve a corporate entity as at least one counterparty. The BNP Paribas intermediated bond provided Michelin Group with a funding mechanism to access rubber while undertaking a set of activities linked to conservation including the ‘setting aside’ of land area for conservation and provision of extension services to farmers. From the project description provided, it is unclear to what extent the payor is contributing a premium above the market price on rubber that was committed to it by plantation landowners as part of this transaction. The Green Bond for Working Forests (GBWF) and the IFC Forests bond were broadly similar in that they provided funds for the protection of existing forest areas in the US and Kenya respectively. In the case of the GBWF, the issuance of green bonds is for the most part dedicated to the purchase of large land areas of forest. The Conservation fund then works with local public agencies and communities to generate revenue channels to fund the bond’s coupon. The IFC Forests Bond is broadly similar but applied in the context of international development and financial deepening, particularly the World Bank’s strategic vision to extend financial services into developing economies. The IFC Forests Bond was successfully issued to institutional investors including TIAA-CREF and QBE.

The instruments in the selected studies approximate well to individual bond issuance in the municipal bond market which had an average and the median issue size of \$34.8 million and \$7.0 million, respectively in 2014 (Craig et al., 2018). The return to investors was either poorly defined in the context of competing market rates (e.g. 4% in the case of Forest Resilience Bond) or was contingent on the production of ecosystem services (e.g. Louisiana Wetland Bond). The total volume of bonds proposed and issued within the selected papers

Table 2
Summary of financial instruments and their associated characteristics.

Study No.	Project Name/Instrument Type	Financial Instrument Characteristics				
		Duration	Min. Trans. Size	Payers	Beneficiaries	Financial Intermediary
1	Biodiversity Investment Scheme/ Green Bond	5 years ^b	AUD5,000+	Conventional assets/ Biodiversity manager	Retail Investors	Bank
2	Permanent Forest Bond/EIB	5 years	Not defined	New Zealand Government	Retail & Institutional Investors	Not defined
3	Forest Resilience Bond/EIB, PPP ^a	7 years	US\$50m	USFS, State Owned Enterprises, Water Utilities	Institutional Investors ^b	Not defined
4	Louisiana wetland restoration/ Environmental Impact Bond	10–15 years	US\$30m	Oil & Gas Corporates	Institutional Investors	CPRA's Financing Corporation
5	Sustainable Forestry Bond, Green Bond	Annual	Not defined	Timber Production	Institutional Investors	Not defined
6	The Peatland Code/Blended Finance	30+ years	Not defined	Landowners	UK Government + Corporate	Not defined
7	Atlanta Flood Bond/EIB ^a	5 years	US\$14m	Atlanta DWM	The Rockefeller Foundation	Not defined
8	Green Bond for Working Forests/ Green Bond ^b	5–10 years	\$150m	Public agencies/Local Communities	The Conservation Fund	Goldman Sachs
8	IFC Forests Bond/Green Bond ^a	5 years	\$152m	Local communities and landowners	Institutional Investors	Int. Finance Corporation (IFC), part of the World Bank
8	Tropical Landscape Finance Facility Sustainability Bond/Green Bond ^a	15 years	\$95m	Rubber plantation landowners	Corporate Investors (Michelin Group, France)	BNP Paribas
8	YUBA I FRB/Green Bond ^a	4 years	\$4m	State of California, Yuba Water Agency	Impact Investors	Blue Forest (NGO)

^a Bond issued.

^b Implied in the analysis.

indicates the continued mismatch between the size of the proposed financing effort and the scale of the challenge.¹⁰

For each of the issued bonds, investment risk was relatively low and similar to that associated with a municipal bond. The design principles of the environmental impact bonds as well as the green forestry bonds, reflect a *weak derisking state*. Gabor and Braun (2023) define this weak derisking state as a form of macrofinancial regime that accedes to the voluntary and ad-hoc involvement of private finance rather than mandating a reallocation of resources (*a big Green state*). Within this regime, advocates for private finance seek to incentivize ‘impact’ investors to allocate finance towards biodiversity protection by ‘derisking’ their investment underwriting bond returns.

4.3. Financial instrument design and risk categorisation

Forest-based protection and restoration projects make up eight of the ten financial instruments considered in the selected studies. Of these, three distinct types were present: ‘afforestation/reforestation’ (projects aimed at both re-establishing forest in deforested areas and establishing new forested areas); ‘forest restoration’ (projects aimed at restoring existing forest areas, e.g. by increasing tree density, soil/water quality and biodiversity markers); and ‘forest management’ (projects aimed at ensuring existing forest does not become degraded as a result of human or corporate activity in the area). The proceeds from the TLFFSB (Study #8) are used to fund commercial rubber tree plantations, with half of the land area “ring-fenced for conservation”. The remaining two instruments finance coastal wetland and peatland restoration.

To help structure the analysis, the characteristics of each financial instrument across four risk categories are considered from the perspective of the beneficiary (bond investor providing capital) or the payor (the bond holder who must provide a financial return and/or commit effort to provide ecosystem services). These categories are; *measurement risk*, the extent to which cash flows are at risk due to contested performance metrics associated with ecosystem services; *natural risk* relates to

a defined link between cash flows and natural events that leads to the deterioration of biodiversity; *financial risk* identifies where the burden of non-payment resides; and *social-political risk* examines the extent to which either counterparty is exposed to social-political risks that jeopardize the stated objective of the financial instrument.

The qualitative approach used in reviewing the selected studies adapts the framework proposed by Aven (2017), see Table 3 within this framework, it is possible to evaluate how each of the risk categories are assessed by the authors across the dimensions of probability and impact, while taking account of the strength of knowledge that is applied by the authors to each risk domain. As many of the selected studies are prospective or are based on limited case studies, the strength of knowledge is interpreted as ‘very reasonable’ (s1), while not being in a position to analyze these risks with greater rigour due to sparse data or access to a panel of experts to provide a more formal analysis. Table 4 provides an overview of how risk categories were characterised using this approach.

The measurement of ecological improvement is identified as a challenge to implementing financial instruments in several studies. The

Table 3

Framework for risk characterisation. We adapt the risk assessment approach proposed by Aven (2017) to characterise risk across the dimensions of probability and impact. In addition we include an assessment of the strength of knowledge of the authors in relation to specific risks.

Very high risk: Potential for extreme consequences for either payor or beneficiary, relatively large associated probability of such consequences and/or significant uncertainty
High risk: The potential for extreme consequences for either payor or beneficiary, relatively small associated probability of such consequences and moderate or weak background knowledge
Moderate risk: Between low and high risk. For example, the potential for moderate consequences
Low risk: Not referenced in the selected study and thus assumed to have no potential for serious consequences

Incorporated into the characterisation is an assessment of **strength of knowledge (SoK)** demonstrated in the study can be labelled as follows; **s1**) The assumptions made are seen as very reasonable; **s2**) Large amounts of reliable and relevant data/information are available; **s3**) There is broad agreement among experts; **s4**) The phenomena involved are well understood; the models used are known to give predictions with the required accuracy; **s5**) The knowledge K has been thoroughly examined.

¹⁰ For comparison, year to 01 November 2024, US Municipal Bond issuance was \$446.5 billion with \$4.1 trillion outstanding (<https://www.sifma.org/resources/research/us-municipal-bonds-statistics/>).

Table 4

Risk characterisation and distribution by financial instrument counterparty (payor, beneficiary).

Project (Study #)	Risk Category							
	Measurement		Natural		Financial		Social-Political	
	Payor	Benef.	Payor	Benef.	Payor	Benef.	Payor	Benef.
Biodiversity Investment Scheme (#1)	s1	s1	s1	s1	s1	s1	s1	s1
Permanent Forest Bond (#2)	s1	s1	s3	s3	s3	s3	s1	s1
Forest Resilience Bond (#3)	s1	s1	s3	s3	s3	s3	s1	s1
Louisiana wetland restoration (#4)	s1	s1	s3	s3	s3	s3	s1	s1
Sustainable Forestry Bond (#5)	s1	s1	s1	s1	s1	s1	s1	s1
The Peatland Code (#6)	s1	s1	s1	s1	s1	s1	s1	s1
Atlanta Flood Bond (#7)	s1	s1	s3	s3	s3	s3	s1	s1
Green Bond for Working Forests (#8)	s1	s1	s1	s1	s1	s1	s1	s1
TLFF Sustainability Bond (#8)	s4	s4	s1	s1	s4	s4	s1	s1
IFC Forests Bond (#8)	s1	s1	s1	s1	s1	s1	s1	s1
Yuba Forest (#8)	s1	s1	s1	s1	s1	s1	s1	s1

This table characterizes the risk across the following categories (measurement risk, natural risk, financial risk and social-political risk) and across the dimensions of likelihood, impact and strength of knowledge. The risk assessment procedure uses a qualitative approach to evaluate how this risk is distributed by category and within each category (payor-beneficiary distribution). For example, Study #8 highlights how IFC Forests Bonds create local social and political issues around the allocation of funds to landowners when land owning rights are contested and frequently exclude local Indigenous communities. This risk must be managed by those receiving funds, the payors (darker shade), but it has no serious consequences for beneficiaries and does not emerge in their corporate disclosures (lighter shade). In this case the risk assessment appears to be very reasonable (s1).

recommendations provided in the selected studies increase the idiosyncratic characteristics of the proposed instruments and reduce opportunities to standardize instruments. Study #6 proposes that landowners avail of public funding to undertake restoration and then rely on private funding to pay for the marginal gain in carbon sequestration arising from those actions. Given how uncertainty around the marginal effect on carbon sequestration, the authors recommend that the instrument should include rewards for a wider range of ecosystem services – including biodiversity risk – to reduce the financial risk for the payor (landowner). EIBs (Study #2, #3, #4, #7) explicitly link the availability of bond proceeds to the ecological performance of restoration activity. In each case, the beneficiary receives a return on their investment based on environmental outcomes, e.g. ‘these impacts could include x-number of trees per hectare after five years, y-tonnes of carbon per hectare, or a z-percentage decrease in phosphorous concentrations in freshwater samples.’ (Hall et al., 2017). The sustainable forestry bond (Study #5) applies a quantitative approach to establish financial returns for a traditional forest bond that integrates with specified ecosystems (i. e. waterfowl habitat and improved water quality arising from nitrate reduction). Measurement risk is considered only from the perspective of the investor and analysis of natural and socio-political risks are examined in a reduced form using approaches adopted from portfolio theory.

In contrast, Study #1 is less concerned with measurement error and suggests the financial instrument is directed towards individual investors directing relatively small investments in forestry protection and restoration. Similarly, the TLFF bond (Study #8) secures supply of rubber, a key input for the bond beneficiary and the IFC Bond (Study #8) directs capital towards the protection of existing forest and the associated capital sequestration capacity of these forests. The authors note that the selection of project sites is problematic as they have ‘low or ambiguous threat statuses’ and acknowledge that the selection of impact metrics may be simplified. In general, the impact of the instrument’s proceeds on ecological restoration are not central to delivering the bond, are used as an un-measured additional service to complement carbon sequestration. These findings from the selected studies are summarized in Study #1 where the authors note that, ‘green bonds do not seem as

readily applicable to biodiversity-based services, which remain complex and problematic in Australia. This is partly due to their scale but also due to the difficulties of defining and measuring biodiversity-based services ...’ (Ferguson et al., 2016).

Mitigation of natural risk, specifically the risk of wildfires, motivates the forest bonds proposed in Studies #3 and #8, while flood risk is a motivating force for the bonds described in Studies #4 and #7. In each case, risk reduction is specifically linked to the use of proceeds and bond return to Government agencies and utilities based on specific protection actions such as ecological thinning or coastal protection. Social-political risks are emphasized in Study #1, #2 and #6. Study #1 identifies property rights issues when undertaking restoration on privately held forests. This is an especially important aspect in some Australian states where Indigenous communities are large landowners (63% in the Northern Territories). The Peatland Code (Study #6) similarly notes the desire of potential payors, in this case, landowners, who are being financed under the proposed scheme ‘... to continue (indeed honour) practices and landscapes inherited from previous generations rather than undertake what is perceived as radical and possibly irreversible change’ (Moxey et al., 2021). In the case of Study #2, the political concerns for the payor (New Zealand Government) when incentivising land use change from agricultural use to permanent forestry are noted.

Within conventional financial markets, the investment decisions is based on key risk and return characteristics, including the assets maturity features. In the case of the selected studies, no rationale is provided for the choice of instrument maturity, either from the investor perspective or requirements of the restoration project.¹¹ Financial return is not defined in Study #1 and investors are expected to be small-scale, philanthropic investors. The authors acknowledge that their proposal is likely to remain at the periphery of mainstream finance noting that,

¹¹ Longer maturity bonds (five years or more) are attractive for investors with long maturity liabilities, as they seek to match their assets (the bonds they invest in) and their liabilities (their outgoing cash flows, for example pension liabilities).

‘experience suggests that many investors are most likely to contemplate such an investment towards the end of the financial year, when they have otherwise under-utilized funds that they may wish to invest in a socially or environmentally responsible activity’ (Ferguson et al., 2016).

4.4. Financial instrument integration with mainstream finance

Table 5 summarises how the selected studies address the six core functions of the global financial system identified by Crane (1995). In general, the reviewed studies are vague or provides no information on the financial architecture within which these instruments function. By drawing on the functional perspective we can observe knowledge gaps in several areas. The costs of bringing the financial instruments to market are not described or benchmarked against equivalent sized financing arrangements in the mainstream market. While implementing land-based ecological restoration presents complexity, it is unclear how assessment and restoration activities are monitored during the term of the financial instrument and whether investors would continue to access and report data on ecosystem services production after maturity. From a financial perspective, important issues in relation to the clearing and settlement of trades, the need to standardize financial instruments to facilitate investment from a broader pool of investors and perhaps an expanded set of investor types (not just corporate or institutional but retail investors), increased collaboration from other stakeholders to develop insurance-type products to provide financial protection against unexpected loss of ecosystem services production (e.g. disease, wildfire). The functional perspective also highlights the need for improved analysis of how investor preferences to understand how biodiversity-linked bonds rank in the universe of investible green assets and continued attention on monitoring tools and governance frameworks to overcome incentive problems associated with financing land-based ecological restoration.

5. A future research agenda

The research agenda emerging from the current review, points towards three strands of investigation that contribute to the design of financial instruments. These include:

- *Marketplace design and the enabling conditions* to clear and settle payments for nature protection and restoration,
- Addressing *transactions costs* through standardization and unified channels for the measurement and sharing of nature information,
- Addressing *the incentive problems* associated with financing biodiversity protection and restoration activities.

Fig. 4 provides a conceptual view of the most common financial transaction that is evidenced in the selected studies. Within this view, corporate funds are directed towards a financial instrument which then contractually undertakes with a provider of nature-based solutions (NbS) to protect or restore biodiversity within a landscape. This NBS provider can undertake this restoration themselves or can contract with local communities or landowners to undertake this work. Thus, the delivery of corporate funds is motivated by an ‘impact’ or corporate social responsibility imperative or may be linked with regulatory provisions related to climate or biodiversity policy objectives.

5.1. Marketplace design and the enabling conditions

The functional perspective deployed in the current paper identifies bottlenecks that relate to marketplace design and the systems needed to clear and settle payments for protection and restoration activities. Moxey et al. (2021) point to the need for ‘purposeful, joint planning to design schemes in tandem’ so that providers of ecosystem services can more easily match capital inflows with implementation of protection and restoration activity. This reflects the language used in the market

Table 5

A functional perspective on financial instruments for land-based ecological restoration.

Clearing and settling payments to facilitate trade.	Not specified for US-based EIBs (S#2, #3 and #7) but assumed that a financial intermediary hold funds and distributes them based on the achievement of agreed targets (notified to it by a third party). S#6 recommends that private funds could be efficiently channeled through government agencies. No recommended payments procedure for transparent, efficient and timely payments for ecosystem services, and the associated reduction in transaction costs. S#8 (TLFF, IFC bonds) no detail is provided on the costs of financial intermediation activity facilitated by World Bank, BNP Paribas and Goldman Sachs respectively. No information provided on fee income paid to financial institutions (either in absolute terms or relative to benchmark costs for conventional instruments. No information provided on governance procedure for release of funds.
To provide a mechanism for the pooling of resources and subdividing of shares in various enterprises.	US-based EIBs (S#2, #3 and #7) does embed the ‘stacking’ of ecosystem services, so that multiple bond beneficiaries can enable a transaction size that is economically feasible, and benefits can be allocated to more than one counterparty (e.g. water quality/water utility, reduction in flood risk/risk management agency). Not considered in selected studies. Financial instruments facilitate cash flows between two entities with one entity acting as a conduit for funding those actively undertaking restoration activity.
To provide a way to transfer economic resources through time, across borders and among industries.	S#8 international financial transfers are facilitated by financial intermediation. The returns to beneficiaries conflate corporate benefits to investors (e.g. access to crops) and the marginal impact on ecosystem services. In all other selected studies, issuance of finance and restoration activity take place within national borders. S#6 identifies the time lag between landowners incurring costs and the availability of funds that are contingent on ES provision as problematic.
To provide ways of managing risk.	Financial instruments are seen as mitigating economic risks associated with environmental degradation (e.g. soil erosion/agricultural production; coastal erosion/damage to ports) The design features of some instruments additionally ‘de-risk’ those instruments for private finance, providing investors with opportunities for enhanced returns. Limited discussion on additional risk management features (e.g. how to improve certainty for landowners around securing payments linked to ES provision). The role of insurance covers against landscape level losses linked to wildfire and disease could be introduced in this context. No information is provided on how the financial instrument addresses financial risks or how these risks distributed between the payor and the beneficiary (e.g. are payments protected against inflation or foreign exchange risk (in the case of international transfers)).

(continued on next page)

Table 5 (continued)

To provide <i>price information</i> to help coordinate decentralized decision-making in various sectors of the economy.	While price information (as it relates to carbon pricing) does help to ground the proposals around private finance flows via the Peatland Code (S#6), use of price information is not directly considered in protection and restoration activities. Price information is inferred, based on capital committed and the associated interest return to beneficiaries. No ranking criteria for beneficiaries to allocate capital - either on a risk-reward basis or based on their expected contribution to biodiversity net gain.
To provide ways of <i>dealing with the incentive problems</i> created when one party to a transaction has information that the other party does not.	S#6 references the challenges around measuring and monitoring of ES by counterparties. S#4 identifies role of third-party verifiers needed to provide objective data on progress in agreed ES measures. Incentive problems arising from missing or asymmetric information are addressed indirectly.

emergence of agreed procedures and standardization. This can be observed in agricultural commodities as well as more recent innovations such as weather derivatives.¹³ The ecology community have recognized the importance of standardization to facilitate monitoring and financial transfers (Boyd and Banzhaf, 2007). Despite this, the role of standardization – both in the mechanisms used to measure and report on biodiversity as well as the size and scope of restoration activity – are not evaluated in the selected studies. This standardization can contribute to the aggregation of individual, site-specific restoration activities and support the development of a matching market where the characteristics of financial instruments meet the requirements of investors.

5.3. Incentive problems

Mainstreaming finance for biodiversity requires more effective tools that can effectively measure and share information on the ecological status of a landscape, its modelled future status under alternative management approaches. In Europe, projects such as the INCA platform¹⁴ may become an important building block for larger-scale deployment of private capital. The platform aims to provide a view on baseline ecosystems data at a landscape level. Meanwhile ESAP is ex-

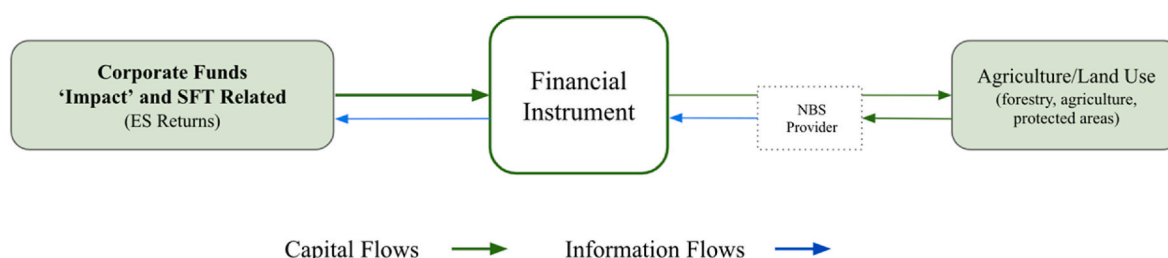


Fig. 4. Financial Architecture (current). This conceptual view shows typical instrument design for biodiversity-linked finance as evidenced in selected studies. In all cases, these instruments remain outside mainstream finance as they are not integrated with other biodiversity-linked cash flows (marketplace design), incur high transaction costs and do not adequately address incentive problems arising from no information or asymmetric information.

design literature which notes the importance of ‘a centralized clearinghouse of some sort, as in a centrally administered order book that ... arranges transactions according to a set of marketplace rules’ (Roth, 2018). Within blended finance, platforms such as Convergence Finance help to match prospective investors with potential opportunities including land-based ecological restoration. The financial instruments include the use of bonds, equity investments as well as project level investment.¹²

The design of biodiversity linked financial instruments (product level innovation) should be complementary to a marketplace, so that the arrival of capital through individual financial instruments is more efficiently matched with the disbursement of capital (activity level innovation). Implementing these design principles is more likely to deliver finance for large-scale large-scale landscape restoration. This systematic approach to nature finance would be a shift from the current reliance on the ‘charitable’ instincts of corporations indicated Study #2 which notes that ‘successful implementation depends on ... the conduct of the parties involved and the strength of their commitment to the shared goal of expanding permanent forest’ (Hall et al., 2017).

5.2. Transaction costs

The emergence of new financial instruments is made possible by the

pected to capture sustainability data for the capital markets with greater transparency ESAP.¹⁵ These platforms – and their equivalent, are likely to become important enablers for the development of financial instruments that allocate capital to nature-based solutions. Payors should seek out aggregating mechanisms that allow them to view the expected biodiversity net gain that arises from their investment and how their investment is part of a larger, coordinated effort. To operationalize this, there will need to be technologies that synchronise data gathering at the level of individual NBS projects with large-scale platforms like INCA and ESAP. Standardization of the procedures governing data capture and governance procedures for nature-based solutions will thus facilitate participation in aggregating mechanisms, allowing them to participate in mainstream finance. Accreditation programs such as Verra,¹⁶ Climate, Community, and Biodiversity Alliance standards¹⁷ are important enabling conditions that can support large-scale financing of land-based ecological restoration in the coming years. Fig. 5 below provides a conceptual view how individual NBS can be aggregated using a special purpose vehicle (SPV), green bond or a sustainability-linked bonds (SLB) are closely aligned with mainstream finance and could in

¹³ Weather derivatives are a financial instrument where a contract is agreed between two counterparties. A financial transfer is contingent on weather characteristics at a specific location.

¹⁴ <https://ecosystem-accounts.jrc.ec.europa.eu/>.

¹⁵ <https://www.consilium.europa.eu/en/press/press-releases/2023/05/23/easy-access-to-corporate-information-for-investors-provisional-agreement-reached-on-the-european-single-access-point-esap/>.

¹⁶ <https://verra.org/new-biodiversity-methodology/>.

¹⁷ <https://www.climate-standards.org/ccb-standards/>.

¹² <https://www.convergence.finance/design-funding/grant-portfolio>.

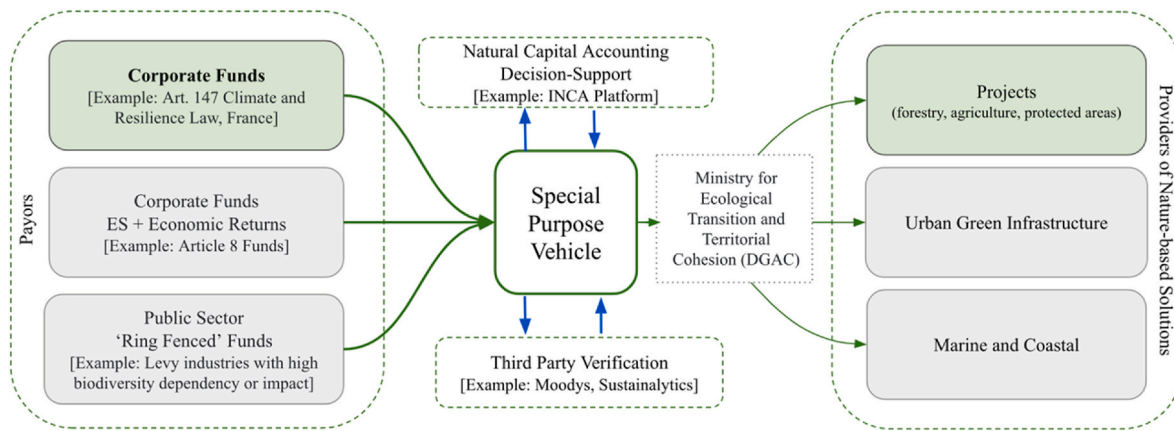


Fig. 5. Financial Architecture (proposed). This conceptual view shows how the creation of a special purpose vehicle (either by/on behalf of a government agency or by a financial intermediary) can effectively act as a centralizing mechanism to match private cash flows to the protection and restoration of biodiversity. This design allows for funds to be fungible across nature-based solutions and integrated with landscape level data monitoring. Thus, payors are provided with better information on how their funds are expected to contribute to net biodiversity gain. Transaction costs and incentive problems are also mitigated as the special purpose vehicle acts to optimally distribute funds to individual NBS projects.

the future be useful for land-based ecological restoration (Feldhütter et al., 2024)¹⁸

Fig. 5 illustrates the use of an SPV as an aggregating mechanism within which financial flows from more than one financial instrument could be efficiently allocated to a validated set of Nbs and contribute to national policy efforts in relation to nature restoration. An SPV is typically set up as a company, it can be regulated by a central supervisory authority and is designed so that functions and activities are contractually defined and limited. In the context of delivering capital to projects engaged in the protection and restoration of biodiversity, the SPV can put in place systems and procedures to ensure that there is compliance with all its contractual obligations including, such as ensuring that any investment restrictions are not breached; ensuring that the allocation of funds within biodiversity project adhere to standards in relation to ecosystems services data capture and sharing; and ensuring adequate and timely determination of liabilities and satisfaction of obligations. Importantly, the SPV can provide a regulated entity that overcomes addresses market design challenges by ensuring that there is a matching procedure between available capital and biodiversity projects, reducing the search and monitoring costs for payors and overcoming incentive problems that arise out of information asymmetry. If established on behalf of a national government the SPV will require a political governance function to support coordination and ranking on Nbs projects across government departments. For example, in France this function could be led by the Ministry for Ecological Transition and Territorial Cohesion (DGAC). Decision-support could be additionally supported (and indeed could contribute data to) nascent technologies such as the INCA platform which identify the extent of ecosystems at a regional level.

6. Conclusion

The current study undertakes a systematic review of financial instruments that are directed towards the protection and restoration of biodiversity. A product-level analysis shows that current instruments are not designed to be integrated into the global financial system but rather facilitate voluntary, one-off investment structures that are difficult to scale up. The review highlights the need for greater attention on the transparency and financial efficiency of instruments. Research in nature finance should clearly document fee and advisory income, identify the counterparties that are exposed to financial risks such as inflation or

currency fluctuations, and the governance structures around payment delivery. As noted by Zingales (2000) there is a responsibility on finance academics to help to 'curb the rent-seeking behavior of finance' and this analysis would enhance trust in the sector and begin to establish norms for the transaction costs associated with nature finance. Furthermore, there are a very particular set of challenges in scaling restoration activity that is not observed on other areas of green finance (e.g. renewable energy). It is important that restoration projects are locally led, and appropriate for local ecosystems yet conventional financial instruments are typically designed to move capital at scale to optimize financial efficiency. There is thus a need to for new research into the financial architecture that can aggregate these efforts and incorporate a governance structure that enables capital to be available in a timely way and for it to be fungible across several projects. The current study proposes that future research should address core issues around market design, transaction costs and incentive problems that are currently impeding the flow of capital towards the protection and restoration of nature. Developing and testing this architecture can support more ambitious and clearly articulated policies that re-direct mainstream finance towards nature restoration.

CRediT authorship contribution statement

John Garvey: Writing – review & editing, Writing – original draft, Visualization, Supervision, Funding acquisition, Formal analysis, Conceptualization. **Vasilis Grigoriadis:** Methodology, Investigation, Formal analysis, Data curation. **Darragh Flannery:** Writing – review & editing, Validation, Supervision. **Edward Knapp:** Writing – review & editing. **Elizabeth Gold:** Investigation, Data curation. **George Hutchinson:** Supervision, Methodology, Conceptualization. **Lynn J. Frewer:** Methodology, Conceptualization. **Paul Brereton:** Supervision. **Kenneth A. Byrne:** Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Edward Knapp reports financial support was provided by University of Limerick. Vasilis Grigoriadis, Elisabeth Gold reports financial support was provided by Queen's University Belfast. If there are other authors, they declare that they have no known competing financial interests or

¹⁸ <https://www.lse.ac.uk/granthaminstitute/explainers/what-are-sustainability-linked-bonds-and-how-can-they-help-developing-countries/>.

personal relationships that could have appeared to influence the work reported in this paper.

Appendix. Search string query

Database	Query string	Filters	No of documents
Scopus	TITLE-ABS-KEY (("sustainable finance" OR "environmental impact bond*" OR "securitization" OR "real option*" OR "municipal bond*" OR "PFP" OR "pay for performance" OR "pay-for-performance" OR "pay-for-success" OR "pay for success" OR "green bond*" OR "resilience bond*" OR "sustainability bond*" OR "green bond*" OR "climate-aligned bond*" OR "climate aligned bond*" OR "forest bond*" OR "catastrophe bond*" OR "cat bond*" OR "finance option*" OR "risk pool*" OR "agricultural grants" OR "payments for environmental services" OR "payments for ecosystem services") AND ("land restoration" OR "environmental restoration" OR "hydrologic restoration" OR "*forest*" OR "tree planting" OR "woodland*" OR "wetland*" OR "peatland*" OR "bog*" OR "carbon sequestration" OR "carbon sink*" OR "GHG sink*" OR "greenhouse gas sink*" OR "mangroves" OR "coral reef*" OR "rehabilitation") AND ("environmental sustainability" OR "climate change mitigation" OR "carbon mitigation" OR "carbon reduction" OR "GHG mitigation" OR "GHG reduction" OR "greenhouse gas mitigation" OR "greenhouse gas reduction" OR "global warming mitigation" OR "biodiversity" OR "eutrophication" OR "ecosystem service*" OR "resilience" OR "flood protection" OR "waste treatment" OR "waste management" OR "cultural" OR "aesthetic" OR "soil protection" OR "habitat protection"))	Exclude books and book chapters, Include only English	907
Web of Science	((TS=("sustainable finance" OR "environmental impact bond*" OR "securitization" OR "real option*" OR "municipal bond*" OR "PFP" OR "pay for performance" OR "pay-for-performance" OR "pay-for-success" OR "pay for success" OR "green bond*" OR "resilience bond*" OR "sustainability bond*" OR "green bond*" OR "climate-aligned bond*" OR "climate aligned bond*" OR "forest bond*" OR "catastrophe bond*" OR "cat bond*" OR "finance option*" OR "risk pool*" OR "agricultural grants" OR "payments for environmental services" OR "payments for ecosystem services")) AND TS=("land restoration" OR "environmental restoration" OR "hydrologic restoration" OR "*forest*" OR "tree planting" OR "woodland*" OR "wetland*" OR "peatland*" OR "bog*" OR "carbon sequestration" OR "carbon sink*" OR "GHG sink*" OR "greenhouse gas sink*" OR "mangroves" OR "coral reef*" OR "rehabilitation")) AND TS=("environmental sustainability" OR "climate change mitigation" OR "carbon mitigation" OR "carbon reduction" OR "GHG mitigation" OR "GHG reduction" OR "greenhouse gas mitigation" OR "greenhouse gas reduction" OR "global warming mitigation" OR "biodiversity" OR "eutrophication" OR "ecosystem service*" OR "resilience" OR "flood protection" OR "waste treatment" OR "waste management" OR "cultural" OR "aesthetic" OR "soil protection" OR "habitat protection"))	Exclude books	646
Agricultural & Environmental Science Collection	((("sustainable finance" OR "environmental impact bond*" OR "securitization" OR "real option*" OR "municipal bond*" OR "PFP" OR "pay for performance" OR "pay-for-performance" OR "pay-for-success" OR "pay for success" OR "green bond*" OR "resilience bond*" OR "sustainability bond*" OR "green bond*" OR "climate-aligned bond*" OR "climate aligned bond*" OR "forest bond*" OR "catastrophe bond*" OR "cat bond*" OR "finance option*" OR "risk pool*" OR "agricultural grants" OR "payments for environmental services" OR "payments for ecosystem services") AND ("land restoration" OR "environmental restoration" OR "hydrologic restoration" OR "*forest*" OR "tree planting" OR "woodland*" OR "wetland*" OR "peatland*" OR "bog*" OR "carbon sequestration" OR "carbon sink*" OR "GHG sink*" OR "greenhouse gas sink*" OR "mangroves" OR "coral reef*" OR "rehabilitation") AND ("environmental sustainability" OR "climate change mitigation" OR "carbon mitigation" OR "carbon reduction" OR "GHG mitigation" OR "GHG reduction" OR "greenhouse gas mitigation" OR "greenhouse gas reduction" OR "global warming mitigation" OR "biodiversity" OR "eutrophication" OR "ecosystem service*" OR "resilience" OR "flood protection" OR "waste treatment" OR "waste management" OR "cultural" OR "aesthetic" OR "soil protection" OR "habitat protection"))	Search only in titles, exclude books and book chapters, include only English	80
Google Scholar	("financial mechanism" OR "financial instruments" OR "environmental impact bond" OR "green bond") AND ("land restoration" OR "environmental restoration" OR "*forest*" OR "woodland") AND ("environmental sustainability" OR "ecosystem service"))	1987–2022	First 200 results

Data availability

Data will be made available on request.

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