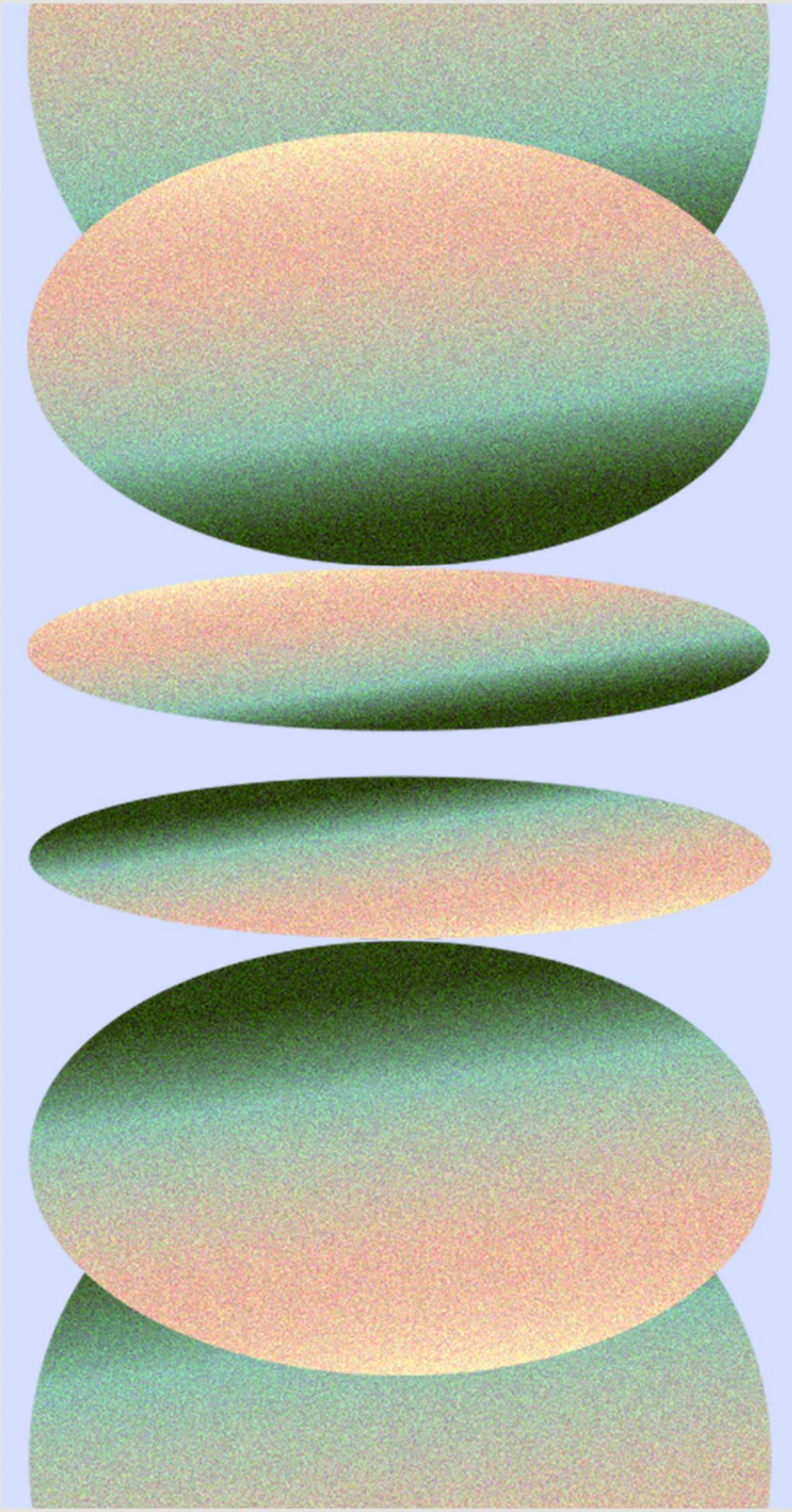
STUDY ESG LAB



FEBRUARY 2026

VALUING ECOSYSTEMS: CHALLENGES, METHODS AND LIMITS OF INTEGRATING LIFE INTO FINANCE

LABS

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They will be cited in the article: A.Cadi, C.Soulard, M.Culot-Horth, M.Delabie, O.Frings, V.De Chillaz.

OBJECTIVES OF THE STUDY

In 2025, sustainable finance is on the cusp of a major transformation. While the valuation of ecosystems is beginning to be integrated into certain financial strategies, it is still largely exploration. This article aims to shed light on this emerging theme with a dual objective: to strengthen the knowledge on the issues related to ecological valorization and to share these reflections with the network of researchers and partners.

We examine the facts, challenges, limitations, and opportunities offered by existing methods, while translating these analyses into the financial practices of the future. This synthesis is based on both technical reports and interviews.

For any questions or further exchanges, do not hesitate to contact us:

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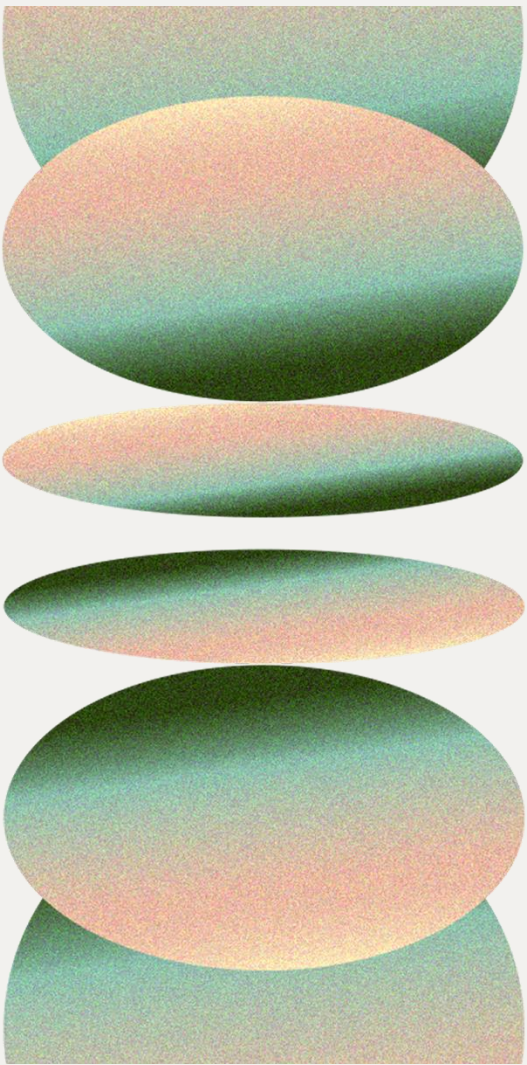

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ACRONYMS

Note: *The original article was written in French. Consequently, the definitions of some acronyms may not fully correspond to standard English usage or may be adapted for clarity in this translation.*

BBNJ	Biodiversity Beyond National Jurisdiction
CAP	Willingness to pay
CARE	Comprehensive Accounting In Respect of Ecology
CBD	Convention on Biological Diversity
CNTRL	National Centre for Textual Resources and Lexicals
COP	Convention of Parties
CSRD	Corporate Sustainability Reporting Directive
CUMA	Agricultural Equipment Use Cooperative
EIOPA	European Insurance and Occupational Pensions Authority
ENCORE	Exploring Natural Capital Opportunities, Risks and Exposure
OFB	French Office for Biodiversity
ONF	National Forestry Office
GBF	Global Biodiversity Framework
GTAP	Global Trade Analysis Project
MEA	Millennium Ecosystem Assessment
MEB	Mission of the Biodiversity Economy
IPBES	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
SEEA – EA	System of Environmental-Economic Accounting – Ecosystem Accounting
TNFD	Taskforce on Nature-related Financial Disclosures
TCFD	Task Force on Climate Related Financial Disclosures
VET	Total Economic Value
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute
WWF	World Wildlife Fund

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ABSTRACT

The accelerated degradation of ecosystems highlights the limits posed by the non-integration of a value associated with living things in economic models. Yet, more than half of the world's GDP depends directly on nature. By relying on indicators that ignore the depreciation of natural capital, financial systems perpetuate an illusion: that of growth disconnected from ecological limits.

This article explores how the valuation of ecosystems can both fill this structural gap and ensure the preservation of nature; conditions that are essential to ensure long-term economic stability. Our analysis combines a review of academic work and interviews with actors from the academic, public and private sectors.

First, we define the central concepts of the research: what ecosystems are, how they differ from biodiversity and how their valuation can be a strategic lever. Secondly, we present a state-of-the-art inventory of existing valuation approaches (quantitative, qualitative and accounting) while highlighting the main limitations. Finally, we highlight the key issues arising from the interviews, which structure the conditions for the implementation and adoption of these approaches.

The results show that there is a lack of awareness of biodiversity and ecosystem issues, which impacts possible solutions for nature protection and their integration into financial choices and strategies. Although there is a diversity of methods for the valuation of nature, their adoption remains limited. This is due to the intrinsic complexity of ecosystems, the lack of common standards, the low availability of data, the lack of private funding, as well as the temporal dissonance between ecological cycles and financial models, which hinder their integration. The analysis also reveals the risks of inaction, regulatory challenges (including Solvency II) and the lingering weight of the carbon-centric paradigm.

By providing an operational synthesis of valuation methods and their implications, this article identifies ways to account for the value of nature in financial decision-making and to support the development of strategies that enhance ecological resilience.

BACKGROUND

In December 2022, the 15th Conference of the Parties to the Convention on Biological Diversity (COP 15) marked a historic turning point: the adoption by 188 States of the Kunming-Montreal Global Biodiversity Framework, an ambitious agreement aimed at halting and reversing the decline of biodiversity. It is based on a long-term vision, broken down into four strategic objectives for 2050, and an immediate action plan composed of 23 priority targets to be achieved by 2030. These should lay the foundations for achieving the ambitions set for the middle of the century. Among the agreed targets are the protection of 30% of land and marine areas, as well as the restoration of 30% of degraded ecosystems and the mobilization of at least $200 billion per year of public and private capital annually.

This treaty echoes alarming findings: human activity has already altered 75% of land surfaces, 66% of oceans impacted and 85% of wetlands that have disappeared (IPBES, 2019). In addition, 55% of global GDP, or $42 trillion (corresponding to the combined economies of the United States, China, Japan, Germany and India) is highly dependent on biodiversity (Swiss Re Institute, 2020).

The cost of inaction, estimated at $10 trillion by 2050 (WWF, 2020), contrasts with the $200 billion pledged annually; a drop in the bucket compared to the 700-900 billion needed annually according to the Paulson Institute (2020).

It is a question of making ***the invisible visible***, which remains difficult as the economy has long relegated social and environmental impacts to the rank of externalities. These effects, which are not integrated into market mechanisms, require the adoption of interdisciplinary models combining economics, ecology and social sciences to be properly assessed and internalized. Indeed, classical economists, based on the idea that the market is self-regulating, do not consider these externalities as an integral part of their analysis (Pigou, 1920; Nordhaus, 1993; Stern, 2007).

The economist P. Dasgupta suggests in an eponymous report (Dasgupta, 2021) that we attribute an economic value to nature to reverse its treatment as a free and unlimited resource. Internalizing the costs associated with its consumption would make it possible to account for its real value and encourage a more rational use of it. Monetizing nature means creating a common unity among all stakeholders, promoting its adoption in the processes of reflection and planning. Beyond its simple economic development, the formalization of nature makes it possible to identify specific territorial components. This approach provides public

and private actors with the necessary tools to measure the benefits it provides and thus integrate them strategically into policies and business models.

But this approach is divisive: between those who see it to mobilize markets and those who fear a commodification of the commons (Kill, 2015), the debate remains lively. Financial players, who are called upon to play a key role via frameworks such as TNFD, are still struggling to integrate these risks into their models. A Banque de France blog post (2022) reveals that 42% of the value of the securities portfolio held by French financial institutions is exposed to companies that are highly or very highly dependent on at least one ecosystem service. Yet, globally, corporate adoption of these issues remains limited: only 5% of large companies measured their dependence on biodiversity in 2024, and less than 1% specifically assessed their dependence on nature (World Benchmarking Alliance, 2024).

Valuing ecosystems raises major challenges. Geographical location makes it possible to locate a specific ecosystem, but its real value lies in the functions it provides climate regulation, water purification, maintenance of biodiversity, among others. However, inaction is no longer an option, as A. Cadi, President of Restore, pointed out in an interview conducted in 2025, *"the time for free ecosystem services is behind us"*. It is in this context that the Louis Bachelier Institute wishes to address the challenges of ecosystem valuation and their implications for financial players.

BIODIVERSITY &
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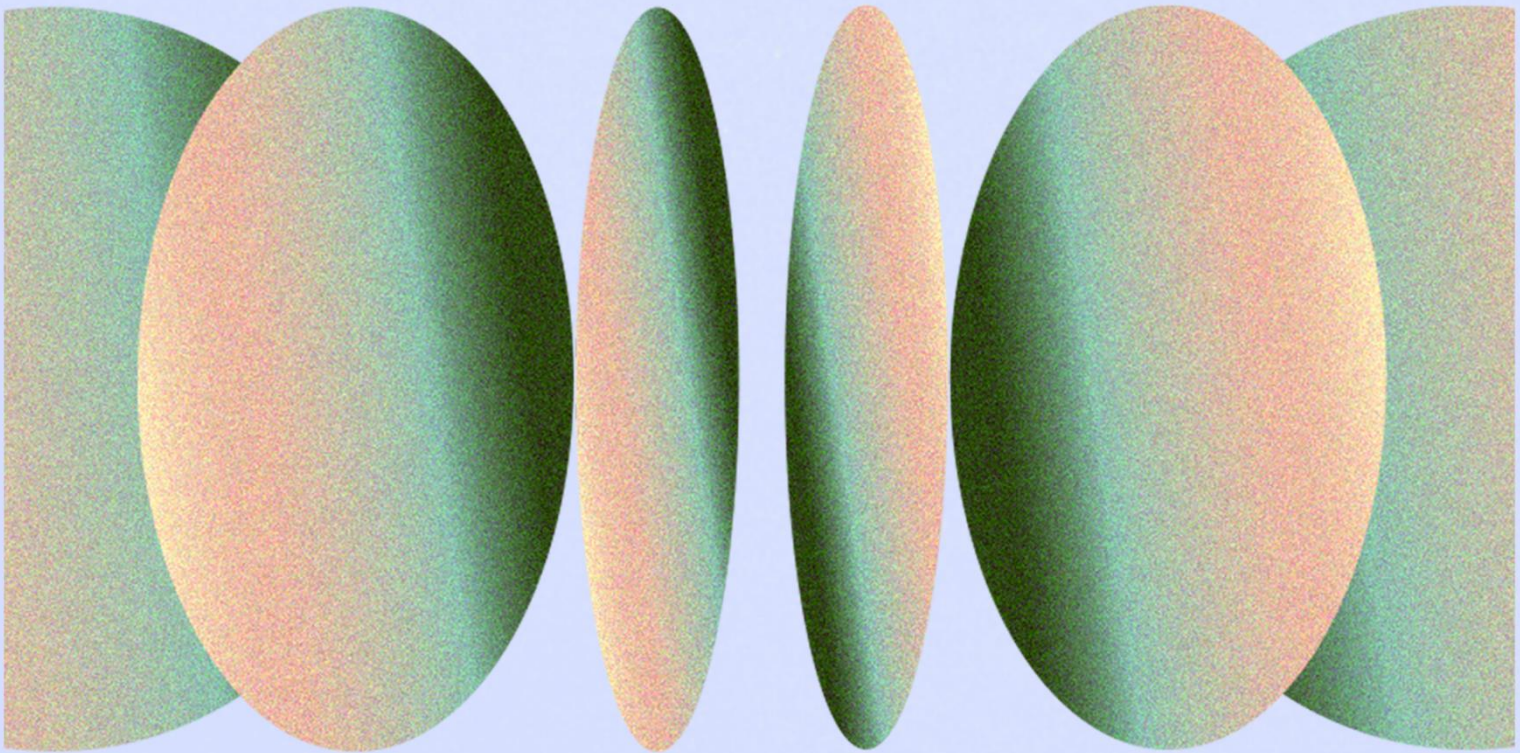


BIODIVERSITY AND ECOSYSTEM

Before going into detail about the mechanisms for valuing biodiversity in the markets, it is necessary to establish key definitions that will allow us to analyze the state of play of the valuation of ecosystem services.

Biodiversity

The notion of "*biodiversity*", a contraction of "*Biological Diversity*", was popularized in the 1980s by the entomologist Edward O. Wilson as part of the National Forum on BioDiversity. The term was officially adopted at the Rio Earth Summit in 1992 via the Convention on Biological Diversity (CBD).

"Variability of living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; This includes diversity within and between species as well as that of ecosystems." (*CBD, 1992)*

The use of this notion is recent. It does, however, encompass the ongoing evolution of life on Earth, which originated about 3.5 billion years ago. Three interdependent levels can be distinguished: ecosystems, species and genes.

Ecosystems

According to the CBD, an ecosystem is defined as the *dynamic complex formed by communities of plants, animals and microorganisms and their non-living environment which, through their interaction, form a functional unit.*

In other words, an ecosystem consists of two universes, namely the living (biocenosis) with interacting individuals and the non-living environment (the biotope).

Ecosystems are difficult to quantify. It all depends on the order of magnitude that we attribute to them. The planet is an ecosystem. A biome (tundra, savannah, mangrove, desert, oceans, etc.) can be defined as a macro-system in which hundreds of thousands of microsystems evolve. Microsystems are, strictly speaking, territories of a few centimeters.

All ecosystems are grouped together under the notion of biosphere, a term encompassing the atmosphere, the lithosphere and the hydrosphere.

The difference between biodiversity and ecosystem

The two concepts can sometimes be confusing, as they are so interdependent: a healthy ecosystem maintains biodiversity, and rich biodiversity strengthens the resilience of the ecosystem.

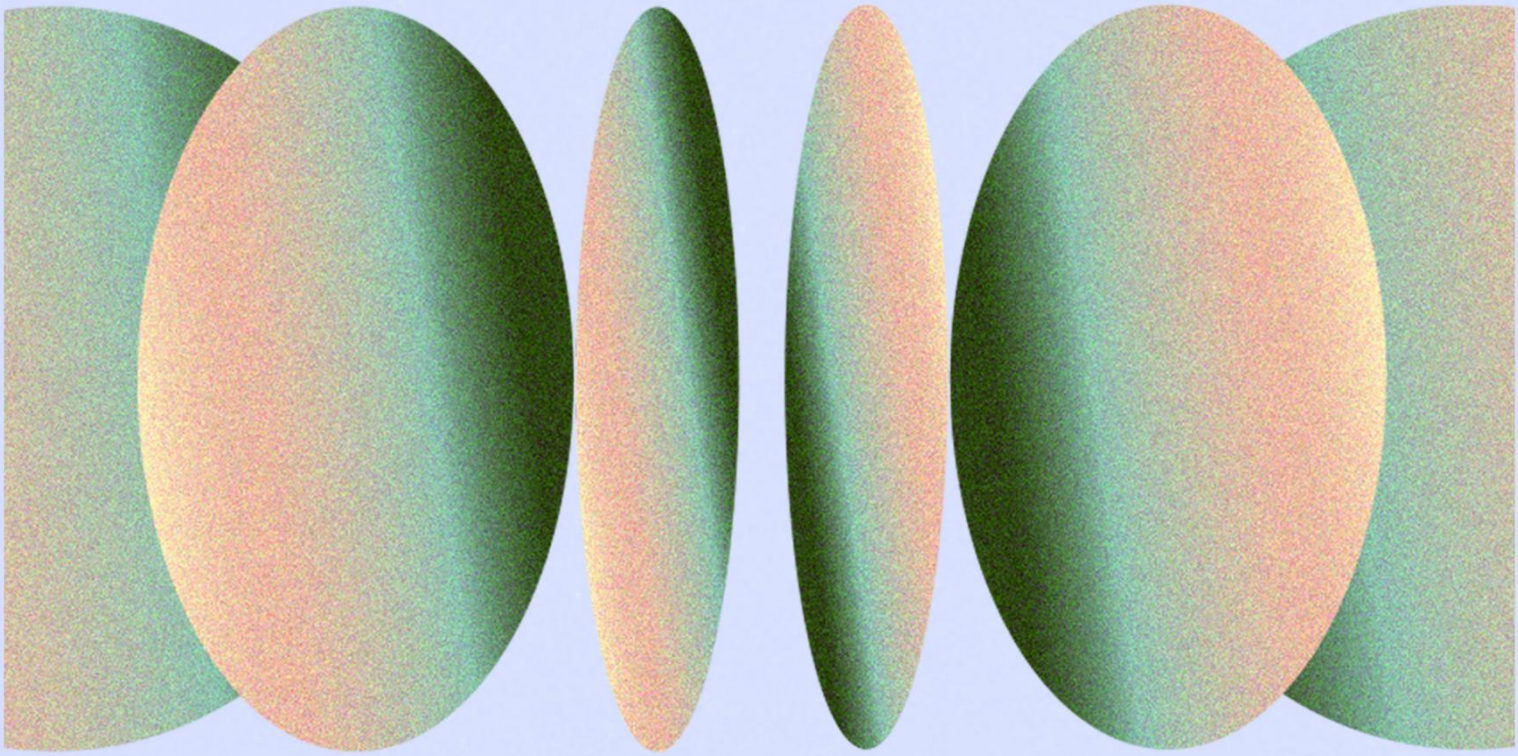
Biodiversity refers to the variety of living beings and their genetic heritage in each space, while the ecosystem encompasses the interactions between these species, their environment, and the functions that result from them.

According to Mr. Delabie, coordinator at the French Office for Biodiversity, this interaction is an essential subject that "deserves to be understood". Species act as bioindicators of the state of natural habitats. With climate change, they migrate and change their spatial distribution, which directly affects the functioning of ecosystems. Maintaining natural habitats in good condition and in sufficient quantity is therefore essential to preserve these balances.

Thus, when we talk about a " *biodiversity crisis* ", we are actually referring to a crisis that affects both biodiversity and ecosystems. However, it is less technical to communicate on the loss of species (biodiversity) than on the state or capacity of a forest to capture carbon (an aspect more related to ecosystem functioning).

For those who wish to delve deeper into these technical concepts, it is recommended to take a closer look at planetary boundaries[1], one of which directly measures biodiversity loss.

[1] Planetary boundaries - Stockholm Resilience Centre



WHY IS ECOSYSTEM VALUATION IMPORTANT?

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What does it mean to assign a value to nature?

According to the CNTRL[2], "valorizing" means *giving greater value to something, enhancing to obtain greater profitability or greater efficiency.*

In a register specific to economics, it is *to cause an increase in the market value of a product*.

Valuing ecosystems therefore means highlighting the interactions that govern living things and their environment.

On a socio-economic level, Garret Hardin illustrates the challenge of valorization in 1968 through the theory of the tragedy of the commons. The lack of regulation or separate property rights leads to the overexploitation of natural resources. Each actor acts in his own interest, depleting the resource leading to its inevitable degradation. Valuing ecosystems offers a structural response to this dilemma.

By assigning a market value to the benefits derived from nature, it is possible to internalize the costs of their degradation and create incentives to preserve them. Nature becomes a capital to be protected. However, the interview with Mr. Delabie, coordinator at the French Office for Biodiversity, points out that investors' prudential rules limit investments in the commons. Thus, a small share of capital is devoted to biodiversity, even though it generates much more value.

The European Parliament's research services evaluation (2022) on Solvency II also identifies a key problem: insurers have limited *incentives for insurers to contribute to the long-term financing and the greening of the European economy* (Girard, 2022).

Solvency II is a European directive that defines internal management, assessment and organization models for risk management, to ensure the solvency of financial players and to ensure that the insurance sector has sufficient capital to cover its liabilities. The standard formula is used to calculate the *Solvency Capital Requirement* (SCR): this is the capital needed to cover the risks and remain 99.5% solvent over a one-year horizon. This method is based on standardized risk models, defined by EIOPA, and includes volatility, correlation and stress factors.[3]

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[2] Definition of VALOR - CNRTL

[3] Calculation of the Solvency Capital Requirement - EIOPA

In this context, insurers must allocate sufficient capital to cover quantifiable risks. Biodiversity-related investments, which are often long-term, illiquid and difficult to standardize, therefore appear to be riskier. Regulatory logic and the lack of a developed secondary market tend to favor more liquid and standardized assets, creating an indirect disincentive to invest in biodiversity, despite its significant ecological and economic value.

Ecosystem services

The *Millennium Ecosystem Assessment* (MEA) defines ecosystem services as "*the benefits that humans obtain from ecosystems*" and classifies them into four categories (cultural, supply, regulation and support). Ecosystems perform economic and social functions that are essential to humans.

In 1997, Costanza et al. estimated the value of these services at $33,000 billion, twice as much as the gross world product at the time. If they were priced in to the extent of their real contribution to the global economy, the price of goods and services would be much higher. In addition to the mercantilist aspect, the monetization of ecosystems raises awareness among policymakers and reflects the importance of conservation policies. The loss of certain ecosystems is considered irreplaceable and the lack of services they provide is reflected in production costs. For example, artificial pollination to replace bee pollination is estimated to have cost American farmers more than $300 million in 2017 (USDA National Agricultural Statistics, 2017). Globally, 75% of food crops depend on animal pollination (IPBES, 2016).

However, this approach is not exempt from criticism, particularly because of its very anthropocentric character. By attributing a value that is strictly too utilitarian, man places himself as the master of the living. Indeed, only the components of nature that are of direct use to humans are valued, while essential but less visible ecological functions are often neglected, as their protection is not considered a priority. It is also to claim that we understand all the interactions of the environment, which is not the case (Duquesne, 2023). What is more, valorization requires profound legal, political and ideological transformations (Polanyi, 1944). It is difficult to conceive that an indigenous forum in the Amazon would consider valorization according to market standards.

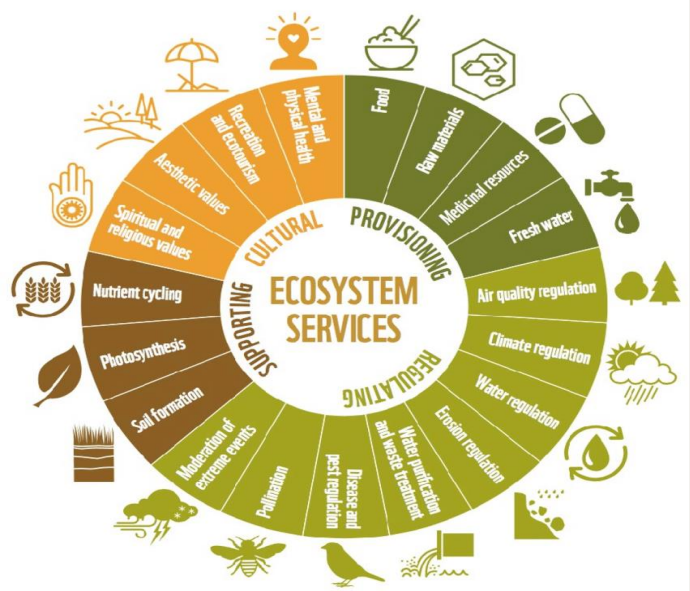

Figure 1 – Illustration of the categories of ecosystem services
Reproduced from WWF (2016)

Valorization, a strategic development issue for companies and society

Valuing ecosystems means enabling public and private actors to move from the logic of exploitation to a real collaboration with nature. By accounting for this value, we better understand what nature represents. It is within this framework that nature-based solutions (NBS) encourage restoration through natural processes and generate co-benefits for human health, ecosystem services and biodiversity. For companies, they help reduce systemic risks (supply chain disruptions, productivity losses or increased costs) while creating sustainable value, by anticipating emerging regulations and stakeholder expectations (Vidal et al., 2024). They also address the gaps in carbon-centric approaches, which neglect the complexity of ecosystems and their interdependencies.

A carbon-only approach is not enough to protect or maintain the balance of ecosystems. Monocultures or plantations set up for carbon offsetting can, for example, impoverish soils, disrupt local biodiversity and reduce the resilience of ecosystems. New Zealand encouraged the development of carbon farms with the aim of developing the timber export sector and the carbon offset market. Thus, 200,000 hectares of agricultural land have been replaced by exotic pine trees, reducing the area dedicated to food. These pines, which are more vulnerable to natural disasters due to their lack of adaptation to New Zealand's soils, pose a threat to nearby communities. With each cyclone or flood, hundreds of trunks are uprooted and damage the surrounding infrastructure and biodiversity. For farmers, these disasters lead to debt related to clean-up costs and a loss of

valuable time that could have been spent on harvesting. As for the Maori communities along the river, they suffer the destruction of essential ecosystems, sources of subsistence and cultural practices. This example illustrates how a seemingly virtuous solution, but designed in a one-dimensional way, can lead to environmental, economic and social crises (ARTE Reportage, 2023).

The interview with V. De Chillaz, Head of Methodology and Data at NEC Initiative, highlighted that the inherent limitations in the use of carbon intensity can also influence investment decisions. Indeed, the comparison of companies from different sectors is often based on emission indicators such as carbon intensity. However, some sectors, such as aviation, are inherently more CO_2 emitting than others. In the field of computing, and more particularly with the growth of artificial intelligence, debates have intensified on the consumption of water, which is necessary for cooling and the production of energy for the operation of servers. It is estimated that a "typical" data center can consume the equivalent of the daily water consumption of a city of 30,000 to 50,000 people (Veolia Water Technologies, 2023). Thus, comparing companies because of their carbon intensity alone does not reflect their true impact on resources. It therefore does not allow for a proper analysis of the state and risks related to the nature of the companies within an investment portfolio.

Climate change and biodiversity are inseparable issues

Climate policies were initially oriented towards the reduction of greenhouse gases, supported by a set of standards, measurement norms and regulatory frameworks structuring national strategies for reducing emissions. The *Greenhouse Gas Protocol*, published in 2001 by the WRI and WBCSD, has played a key role in this dynamic. It is a methodological accounting guide that allows organizations to measure and report their emissions using a standardized approach (Scopes 1, 2 and 3). This protocol is not an international regulatory instrument, but it has served as a technical basis for subsequent policy and regulatory frameworks, including for the Paris Agreement.

Conversely, biodiversity has long lacked an equivalent framework. The Kunming-Montreal Global Biodiversity Framework, adopted only in 2022, is more than twenty years behind in structuring climate policies.

There are several reasons for this difference:

- **The complexity of the measurement** : the impact on biodiversity depends on many factors (ecosystems, species, genetics), which makes it difficult to define universal indicators.

- **Lack of international consensus** : There is still no agreement on the common indicators to be measured.

- **The lack of a single global target**, unlike the climate, where the 1.5°C warming limit serves as a universal benchmark. While the 2022 global framework sets concrete targets, such as restoring 30% of land and sea by 2030, these targets are based on differentiated national commitments and do not constitute a single global benchmark comparable to that of the climate.

Nevertheless, when we talk about climate change, we include biodiversity, which is both impacted by it and constitutes a lever for climate change mitigation and adaptation.

According to the Convention on Biological Diversity (CBD), the proper management of ecosystems, such as grasslands and forests, remains one of the best strategies for climate change mitigation, due to the potential for sequestration and the current state of carbon stored in these ecosystems (Secretariat of the Convention on Biological Diversity, 2009). A relationship of resilience is established between the two notions.

Ecosystem health plays a central role in the carbon cycle: if an ecosystem is healthy, it is generally resilient. A resilient ecosystem can recover from droughts or fires, and carbon stored as biomass or in the soil can be absorbed again. On the other hand, if the level of resilience is compromised, biomass may release carbon into the air (Secretariat of the Convention on Biological Diversity, 2009).

The temporality of the markets

The valuation of ecosystems in long-term strategies has a definite advantage, but it faces a major challenge: temporality. For example, in the financial markets where investment mandates are still mainly oriented towards the search for immediate profits. However, this trend is being challenged by a growing share of institutional or insurance investors, who are seeking to reconcile long investment horizons with the risks associated with the degradation of ecosystems (CFA ESG, 2025).

This tension highlights a dual challenge: accurately assessing the value of natural resources to design effective conservation strategies and rethinking financing mechanisms to align nature's long cycles with short-term economic horizons. Without this adaptation, conservation efforts risk being marginalized, compromising the future resilience of human activities and the mobilization of the necessary funding to protect them.

APPROACHES TO ECOSYSTEM VALUATION

ECOSYSTEM VALUATION
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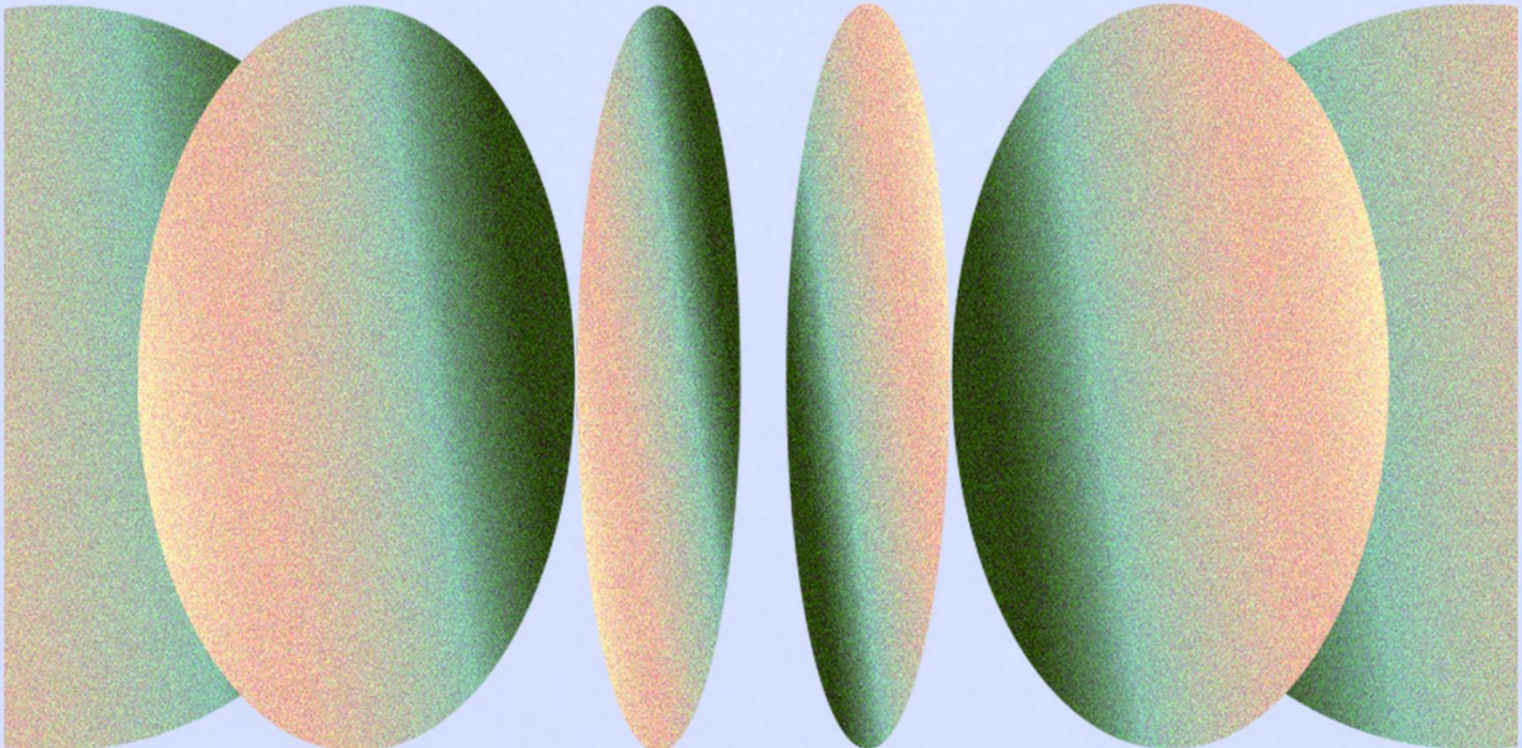

APPROACHES TO ECOSYSTEM VALUATION

Economic approaches

These approaches are the result of the popularization of environmental economics that began in the 1960s and 1980s. Without figures, it is difficult to make financial players aware of the economy's dependence on ecosystems. Moreover, values are not expressed simultaneously and appear according to the contexts and tensions of a given moment. An ecosystem service is generally recognized as a posteriori, after disasters or specific situations. However, Mr. Delabie, coordinator at the French Office for Biodiversity, suggests that natural environments in good condition are real assets for adaptation to the effects of climate change. However, these assets have no clear legal status, no codification in urban planning documents, no recognized value outside of crises. For example, after storm Xynthia, the State had to deconstruct and relocate damaged homes at a cost of €600/m², while the Conservatoire du Littoral was buying wet meadows at €0.40/m² before the disaster. These figures illustrate the consequences of inaction: healthy ecosystems prevent substantial expenditures, yet their value is revealed ex post through retrospective analyses and research.

1. Replacement or avoided cost approach

This approach involves valuing an ecosystem service based on the costs saved by its presence or the expense of artificially replacing it. The approach has been widely used to demonstrate the savings generated by ecosystems such as wetlands, forests or mangroves.

As an example, Albers and Schmitt (2023) demonstrated that a $1.1 million investment to rehabilitate mangroves in northern Vietnam avoided $7.3 million in coastal infrastructure spending.

2. Production approach

This approach values an ecosystem service according to its direct contribution to economic production. Gallai et al. (2009) used this approach to emphasize the importance of crop pollination.

As discussed earlier, the decrease in pollinating insects has led U.S. farmers to invest more than $300 million in artificial pollination solutions. Also, according to Gallai et al. (2009), nearly 39% of the world's agricultural production depends on pollinators, representing an estimated direct economic value of €153 billion per year.

3. *Preference approach*

This approach is based on the idea that observable behaviors reveal the value that people attach to ecosystem services. There are two types of preferences: recorded and declared.

Among the surveys, two methods can be applied:

- The travel cost method for which the ecosystem service is valued based on the expenditure incurred to receive that service. It is mainly linked to the recreational, tourist and educational value of environmental sites. The more time and money agents are willing to spend to get to the site, the more valuable it becomes. It is possible to use this method to evaluate the benefits/costs associated with a change in the environmental quality of the site, its creation or its disappearance (EauFrance, 2020).

$$\text{Coût total de transport} = \underbrace{\text{coût de transport}}_{(1)} + \underbrace{\text{coût d'opportunité du temps}}_{(2)} + \text{autres coûts}$$

Avec :

$$(1) = \frac{(2 * \text{distance domicile–site} * \text{coût kilométrique})}{\text{nombre de personnes}}$$

$$(2) = p * \frac{T}{60} * \frac{R}{135}$$

Où :

T	Temps en minute
R	Revenu mensuel
P	Poids du salaire (généralement compris entre $\frac{1}{3}$ et 1)
135	la durée horaire mensuelle moyenne de travail en heures

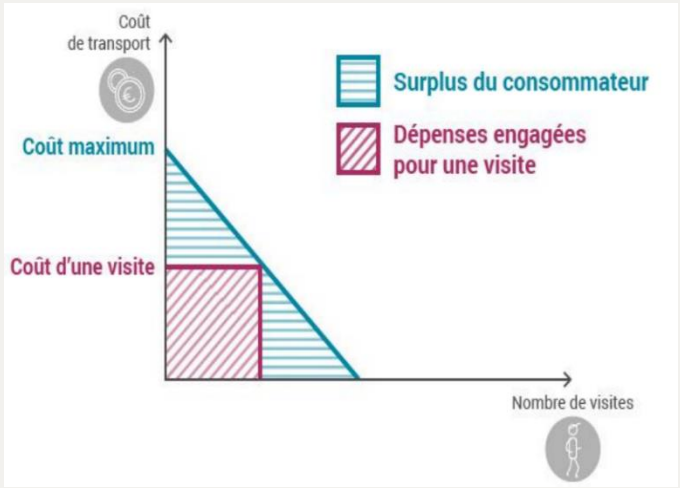

Figure 4 – Example of modelling by calculation of the travel cost method (EauFrance, 2020)

- The hedonic price approach, which assesses the monetary value of a non-market environmental characteristic by analyzing its impact on the price of a market good. It makes it possible to compare properties with identical qualities that are differentiated via an environmental attribute. The difference observed reveals the value of this environmental attribute. By this method, it is possible, for example, to determine the difference in sale price between two identical dwellings but located in different environments (one on the seafront, the other in the city center). Living on the seafront generally offers a better living environment, as the marine ecosystem provides, through its cultural properties, more benefits (relaxation and

improvement of mental health, artistic inspiration, attachment to identity,). These elements, although less tangible, contribute significantly to the perceived value of these spaces. If we take the example of insect pollination, we can imagine that the price of agricultural land located near a forest will be worth more than that located near a motorway complex; the forest allows a better proliferation of pollinating insects and therefore a higher agricultural yield.

The declared preferences include:

- The contingent valuation method. This method consists of assessing the degree of variation in an individual's well-being according to an ecosystem service. This makes it possible to determine how much an agent would be willing to pay to continue to benefit from an ecosystem service. This interest, called willingness to pay (PAC), can be used to model the preservation value of an ecosystem. For example, how much individuals would be willing to pay to save a wetland (Bonnieux, Le Goffe and Vermersch, 1995).

4. Total Economic Value (VET)

The VET is not a stand-alone approach, but a global conceptual framework that brings together all the components of the value of an ecosystem, market and non-market. Popularized by Pearce and Turner (1990), VET can be used in cost-benefit analyses, to set environmental taxes, or to develop market mechanisms and payments for ecosystem services. It provides the financial sector with a strategic tool to identify and quantify the natural assets that underpin the economic value and resilience of companies.

Use value is defined as the benefits derived from the use of a natural asset and results from two categories:

- Direct use value (VUD), representing concrete and immediate benefits.
- Indirect use value (IWV) corresponds to the benefits of ecosystems for humans.

The non-use value reflects non-consumable natural assets. There are also two categories:

- The bequest value (NAV) symbolizes the heritage preserved for future generations.
- Existence value (EV) or intrinsic value, characterized by the value that an individual, community or society places on a natural asset simply because it exists. For example, an individual may attach particular importance to an animal species or ecosystem without benefiting from its use. Its value is based on its very existence.

Finally, the option value, which is found in both use and non-use values. It refers to the value of preserving and conserving natural resources for future use.

Mathematically, the VET can be translated by the following equation:

$$VET = VUD + VUI + VO + VL + VE$$

The quantification of use and non-use values is done through evaluation methods. These methods aim to transcribe the service provided by ecosystems into a monetary unit (euros, dollars, etc.).

Illustrative example of the application of valuation methods to calculate TEV

In this scheme, a coastal wetland is threatened by an urbanization project. The local authority wishes to assess whether its conservation is economically justified using the VET method.

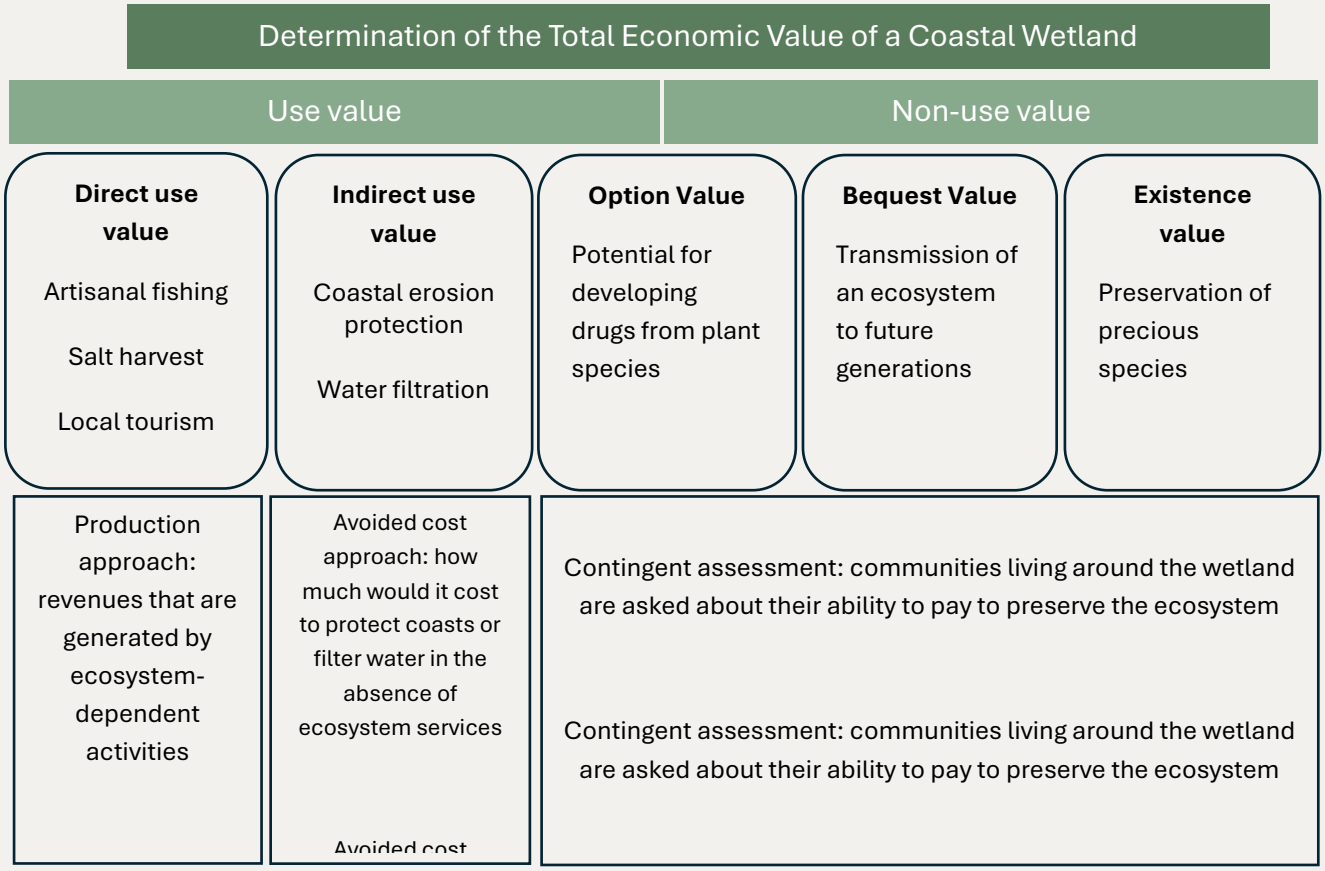

Figure 7 – Diagram illustrating the estimation of the VET for a coastal wetland (Institut Louis Bachelier, 2025)

The sum of these values makes it possible to compare the annual benefits of conservation with those of the urbanization project (land sales, property taxes, etc.).

If the expected gain from the urbanization project is €500,000/year while that of the wetland VET is €1,200,000/year (the values indicated are purely indicative), the preservation of the ecosystem will be economically justified. Either the urbanization project is cancelled, moved elsewhere, or it is remodeled to better integrate the wetland.

In short, the VET allows for a holistic assessment by capturing tangible and intangible benefits. It accounts for the exchange values and functionalities of ecosystems. Although it is recognized as a relevant modern solution, it nevertheless suffers from criticism relating to the bias of the methodologies used (sensitivity of the CAPs linked to the income and culture of the respondents, the risk of double counting of conservation benefits under several values of the VET), the difficulty of monetization (intrinsic value or legacies difficult to monetize) and structural inconsistencies (overlap between use and non-use values).

An interview with O. Frings (2025), PhD student at Chaire Economie du Climat, highlights the main limitations of survey-based methods for assessing willingness to pay (CAP). As no real monetary exchange takes place, the answers may diverge from actual payment behavior (hypothetical bias). The results also vary depending on the wording of the questions: the type of payment proposed (tax, royalty, price increase), the presentation of the scenarios or the way in which the scope of a project is described influence the amounts of the willingness to pay. For example, announcing that a project is twice as large does not always lead to a willingness to pay twice as large, especially if this magnitude is described in abstract numbers rather than simple shares (e.g., "half" rather than "all"). These effects, which are recurrent in studies of declared preferences, invite us to consider CAP figures as contextual indicators, and not as exact monetary values.

Methodological framework	Main use	Relevance to a project	Example	Limitation
Cost-based approach	Estimate the avoided costs or expenses needed in the absence of an ecosystem service.	Relevant to justify investments in the restoration or protection of ecosystems.	See article Mangrove rehabilitation in Vietnam: $1.1 million invested to save $7.3 million in artificial barriers, with additional benefits for biodiversity.	Doesn't capture non-monetary profits; depends on the availability of data on substitution costs and the uncertainty associated with the principle of additionality.
Production approach	Assess the contribution of ecosystem services to the production of marketable goods.	Useful for ecosystem-dependent sectors (agriculture, fisheries).	See article Decline of pollinators in the United States: $300 million spent on artificial pollination; 39% of global agricultural production depends on pollinators	Ignore non-market values; requires accurate data on the links between ecosystems and production.
Preference approach	Infer the value that individuals	Particularly suitable for	Studies of travel costs and hedonic prices make it	The preferences revealed mainly capture

	place on ecosystem services from their observed behaviors or survey responses.	the evaluation of non-market benefits and the social acceptability of different management or public policy options.	possible to infer the value of access to natural spaces; Contingent valuation methods and choice experiments reveal a willingness to pay for conservation measures or management changes.	use values; Reported preferences, on the other hand, are sensitive to survey design and can be affected by hypothetical biases and framing effects.
Total Economic Value (VET)	Identify and categorize the use and non-use values generated by natural assets.	Fundamental for a holistic vision of the benefits linked to ecosystems, useful upstream of a conservation or restoration project.	Calculation of the VET of a forest: VUD (wood, tourism) + VUI (water regulation) + VO (future potential) + VL (inheritance) + EV (intrinsic value).	Difficulty in quantifying non-market values (e.g. existence value); risk of double counting between categories.

Table 1 – Summary of the application of the economic approaches and the VET method

These surveys are most useful for getting the big picture: identifying patterns of general preferences, how support is distributed in society, and how individuals deal with trade-offs. Since respondents must choose between overall solutions that offer different advantages and costs, it can be seen which aspects they favor and what they are willing to give up. The results can reveal different patterns: sometimes a single, widely shared preference, sometimes a clear division into distinct groups, and sometimes a wide dispersion of opinions. Depending on the model observed, the actions to be taken differ to capitalize existing consensus, modulate communication and funding allocations in case of differences of opinion, or offer a range of options when preferences extend across a continuum.

Qualitative approaches and methods

While quantitative methods can be used to monetize ecosystem services, they can be limited by the complexity of the links between human societies and their environment, but also when data are lacking. Qualitative approaches offer essential complementarity by integrating cultural, ethical and social dimensions. These methods, which are based on interviews, stories or participatory analyses, reveal issues of environmental justice and governance, while avoiding the reduction of ecosystems to simple financial assets.

These approaches are based on the epistemological turning point that began in the 1990s. The work of Funtowicz and Ravel (1993) suggests that ecological issues cannot be dealt solely with numerical processes. They call for participatory science, where dialogue between local communities and scientists makes it possible to integrate values such as cultural attachments or traditional knowledge.

In the same vein, Martinez-Alier (2002) has shown that ecological conflicts often emerge from the confrontation between divergent value systems. For example, a forest may be perceived as an economic resource by a company, but as sacred or vital territory by an Indigenous community. Rather than privileging a single (often economic) perspective, Martinez-Alier emphasizes the need to recognize this plurality: the spiritual, identity, or social values of nature must be considered in the same way as monetary valuations.

International initiatives have since enshrined these principles. The *Millennium Ecosystem Assessment* took a first step by integrating, in its report *Ecosystems and Human Well-being (Millennium Ecosystem Assessment*, 2005), the involvement of non-utilitarian (socio-cultural) methods for assessing ecosystems. IPBES has also systematized the approach in its report *The Diverse Values and Valuation of Nature* (IPBES, 2022) by identifying and classifying methods to facilitate their application.

According to the same IPBES report, "*Over 50 different methods to assess nature's values have been applied in diverse socioecological contexts around the world (well established)*", the aim here is not to describe each method but to show an overview of their use.

1. *Semi-structured individual/group interviews and discussions*

In this approach, interviews are conducted with local agents to better understand the cultural and social importance of an ecosystem. Oral tradition, which is still very present in some societies, makes it possible to grasp intangible values such as beliefs or collective memory.

For example, the sacred forests of Ghana (such as those of Nsadwer) show how qualitative interviews reveal intangible and economic values linked to ecosystems. Local accounts attribute vital roles to these forests: protection against epidemics (such as smallpox or the Spanish flu), fertility (Nana *Abodei* wood is associated with the birth of children), or defense against invasions (*Akromapow* wood is said to have repelled enemies thanks to spiritual "miracles"). These beliefs, collected by oral tradition, show that the value of these forests goes beyond their ecological utility: they structure the collective memory (places of historical refuge), strengthen social cohesion (shared rituals) and preserve traditional knowledge (medicinal uses). In this way, the interviews transform narratives into tools for sustainable management, where the preservation of the ecosystem becomes a pillar of community identity and resilience. (Chouin, 2022)

However, this approach remains highly subjective, as it reflects individual cognitive processes, biases related to the recruitment of participants as well as the time-consuming collection and analysis process.

2. *Participatory mapping*

Another approach is to spatially visualize the importance of ecosystems according to local communities. Participants are invited to place on a map the areas they consider important, sensitive or symbolic, according to their uses, beliefs or cultural attachment. This method, which combines qualitative analysis and spatial representation, makes it possible to translate intangible values into concrete data, thus facilitating territorial planning and ecosystem conservation.

A study conducted by Baral et al. (2015) illustrates the effectiveness of this approach: members of rural communities in Nepal were able to identify, through participatory mapping, the ecosystems deemed to be priorities for the preservation of their livelihoods and natural heritage.

This approach is part of a broader dynamic where mapping is becoming a key tool for monitoring the evolution of forests and ecosystems. Platforms such as Global Forest Watch[4] illustrate this trend by providing a real-time visualization of forest change on a global scale.

3. *The DELPHI Method*

Developed by the *Rand Corporation think tank*; the Delphi method aims to collect the opinions of experts from various fields through iterative and anonymous questionnaires. The participants are carefully selected and do not communicate with each other, thus limiting mutual influences.

This approach has several advantages. It helps to compensate for the lack of quantitative data and the difficulties related to data collection in the field. Indeed, access to local communities is sometimes hindered by logistical (geographical isolation) and contextual (political, health) constraints. On the other hand, the analysis and processing of oral histories require a significant investment of time and materials. The Delphi method thus offers an alternative (sometimes complementary) that allows to reach a consensus more quickly.

In the article "*Validation of a rapid wetland ecosystem services assessment technique using the Delphi method*" (Walters et al., 2021), the authors show how

[4] *Global Forest Watch* , an initiative of the World Resources Institute (WRI), is committed to providing the best public data and tools available to monitor and protect the world's forests.

this approach has made it possible to validate an ecosystem services assessment tool (WET-Ecoservices) in a geographical area marked by a lack of empirical data.

"*The Delphi method provided a low cost but defensible approach to validating the WET-Ecoservices assessment method. In the absence of study sites where the link between ecosystem process and ecosystem services have been quantified, we used an adaptation of the Delphi method that used data from well described wetlands supplemented by expert opinion to quantify levels of ecosystem service delivery that were then compared to the results of the scientifically based WET-Ecoservices model.*(Walters *et* al., 2021)

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4. *The Photovoice method*

This technique became popular in the 1990s with the use of photography to document complex and sensitive subjects. The study by Brandt et al. (2017) illustrates how this approach can highlight the links between the environment, health and well-being, by directly involving local communities. In Orangeburg (South Carolina), about fifteen residents photographed their living environment (workplaces, leisure activities, natural spaces), revealing the elements that positively or negatively influence their health. The photos highlighted key ecosystem services (such as access to green spaces, community gardens, or the presence of pollution) while highlighting their unequal distribution.

The "*show and tell"* sessions identified recurring themes, such as:

- Leisure and nature spaces (parks, hiking trails), perceived as sources of physical and mental well-being, but sometimes degraded or inaccessible.
- Access to healthy food (community gardens, local markets), illustrating the role of ecosystems in food security and public health.
- Environmental risks (water pollution, waste, hazardous infrastructure), which threaten the quality of ecosystem services and the health of inhabitants.

By combining visual testimonies and participatory dialogues, Photovoice not only enabled the mapping of ecosystem services perceived by residents, but also to raise awareness among decision-makers of their importance. This method thus offers a powerful collaborative tool to value the services provided by ecosystems,

anchoring them in local realities and advocating for more equitable and inclusive environmental policies.

Approach	Main objective	Benefits	Limitations	Concrete example
Individual/group interviews	Understanding communities' local perceptions, values and uses of ecosystems	Direct involvement of local actors, capture of intangible values (cultural, spiritual), flexibility.	Subjectivity of responses, recruitment bias, long and time-consuming process, difficulty in generalizing.	See article Chouin (2002): interviews revealed the cultural values of Ghanaian forests.
Participatory mapping	Spatially visualize the importance of ecosystems according to local communities and territorial issues	Direct involvement of local actors, capture of cultural values and spatialization of the issues.	Representation bias, need for technical skills, time-consuming process.	See article Baral et al. (2015): Mapping priority ecosystems in Nepal.
DELPHI Method	Gather expert opinions to deal with complex topics (e.g., conservation).	Avoids mutual influences, allows topics to be dealt with with little data available.	Long and costly, depends on the selection of experts, qualitative results that are difficult to generalize.	See article Walters et al. (2021): validation of a rapid assessment technique for wetlands.
Photovoice	Documenting and raising awareness of local issues through photography and storytelling.	Gives a voice to marginalized communities reveals invisible concerns.	Subjectivity, participant selection bias, complex qualitative analysis.	See article Brandt et al. (2017): to illustrate the impacts on their health, followed by collective discussions ("show and tell").

Table 2 – Synthesis of qualitative approaches to the valuation of ecosystem services

The qualitative assessment methods that have been discussed are not exhaustive but provide an overview of the benefits for the identification of essential ecosystem services to local communities. They are an alternative or complementary to quantitative approaches, allowing to obtain more robust results but which require data. The results of a qualitative approach can nevertheless be biased by the subjectivity of the respondents, making the comparison process sometimes difficult. Moreover, these methods are generally time-consuming and expensive.

Accounting approaches

The development of these approaches emerges from a questioning of traditional accounting systems, which are considered too focused on economic production to the detriment of social and environmental dimensions. Since the post-war period, the rise of environmental concerns has gradually gained visibility in the political and economic spheres, revealing the limits of GDP as a central indicator of wealth. National accounting systems, harmonized in 1953 under the aegis of the UN, were designed to measure the creation of material value, without

considering the contribution of ecosystems or the costs of their degradation. This awareness has led to the emergence of so-called "satellite" accounting systems, aimed at supplementing national accounts by better valuing socio-environmental issues and by recognizing natural capital, a concept popularized in the book *Small is Beautiful* (Schumacher, 1973). This capital, defined as all the resources essential to the functioning of society and the economy (European Investment Bank, 2023), is nevertheless treated as a free resource by industrial systems, despite an intrinsic value accumulated over 3.8 billion years. Between 1992 and 2014, natural capital per capita declined by 40%, while capital produced per capita doubled (Dasgupta, 2021). At this rate, 1.6 Earths would be needed to maintain humanity's current way of living, a pressure aggravated by population growth, longer life expectancy and the emergence of consuming middle classes in the Global South (CFA, 2025).

In this extension, new approaches have sought to document the links between human activities and ecosystems, recognizing the latter as a capital whose state can be monitored via stock and flow measurements. This is how ecological accounting emerged.

As the *Biodiversity Economics Mission* (CDC Biodiversité, 2023) points out, this accounting fills in the gaps in financial data, which is unable to reflect the environmental performance of organizations. Where traditional accounting is limited to the inputs and outputs of business units, ecological accounting informs the interactions between organizations and nature. For investors, it is becoming a key tool for guiding decisions towards more virtuous actions, based on ecosystem valuation models.

To illustrate this dynamic, three concepts are presented:

1. The *System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA – EA)*

The SEEA–EA is an international statistical framework adopted by the United Nations Statistical Commission in 2021. It provides a standardized methodology for integrating ecosystems into national accounts, combining biophysical and economic data. The model is based on five types of ecosystem accounts, taking a spatialized approach to measuring:

- **the extent of ecosystems**, i.e. their surface area and geographical distribution.
- **their ecological status** (*ecosystem condition*), assessed via health indicators (biodiversity, water quality, etc.).

- **their ability to provide ecosystem** *services*, such as climate regulation, resource supply or recreational benefits.
- **the value of natural assets** (*ecosystem asset accounts*), which quantifies the stock of natural capital.
- **Ecosystem** *Service Flow Accounts*, which record the services consumed or beneficial over a period.

These accounts are interdependent: service flows depend directly on the status and extent of ecosystem stocks, reflecting a geospatial and functional relationship between ecosystem health and the benefits they provide to society. For example, *Extent* and *Condition* accounts track the spatial and qualitative evolution of ecosystems, while *Ecosystem Asset Accounts* value these stocks as economic assets.

For example, the EAS-EA has been applied in the Dutch North Sea to quantify the extent and state of marine ecosystems (such as circalittoral sandbanks), as well as to assess ecosystem services (climate regulation, fisheries, coastal protection) and anthropogenic pressures (trawling, offshore wind energy, pollution).
This framework has produced standardized accounts integrating biophysical and economic data, revealing for example that the monetary value of natural assets in the North Sea is around €50 billion, while identifying critical areas (such as Natura 2000 sites) that require enhanced protection to maintain their capacity to provide these services. (Bogaart et al., 2023)

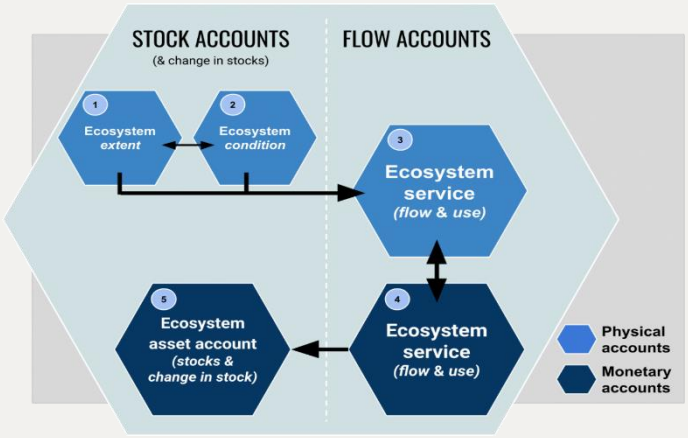


Figure 10 – Ecosystem accounts and their interactions (Source: EA SEES)

2. *Comprehensive Accounting in Respect of Ecology (CARE)*

Developed in 2013 by the Chair in Ecological Accounting, the CARE model aims to integrate the preservation of natural capital into the financial accounting of organizations.

Environmental and social capital is considered in the same way as financial capital. All of them are considered loans: loans from shareholders for finance capital, from the planet for environmental capital, and from society for human capital. Any deterioration in this capital, caused by the company's activity, is considered a debt that the company must repay.

CARE is based on a logic of active support of ecological functions, by adopting:

- double **materiality** (*inside-out* / *outside-in*),
- strong **sustainability** (ecological functions are considered non-substitutable),
- **biophysical translation** (creation of hybrid metrics and satellite accounts measuring stocks and natural flows),
- ecological **enhancement** (integration into the necessary costs for preservation and restoration).

The CARE model is not yet widely recognized or integrated by financial institutions. Its interest lies in the fact that, when evaluating projects or companies, it makes it possible to consider not only financial performance, but also environmental, social and human performance. In other words, it is about assessing how a company preserves natural and human capital, and how these dimensions can be integrated into the definition of financing conditions. This approach prioritizes the allocation of loans or grants to the most sustainable and financially robust companies over a 15- to 20-year horizon. Hence, promoting the creation of a virtuous circle between economic performance, social and environmental responsibility.

For example, the CARE/IDEA4 project utilized the CARE methodology on farms in Ille-et-Vilaine to translate environmental and social impacts into extended accounts. Carried out on a dozen farms between 2023 and 2024, the project combines the IDEA4 method, which assesses sustainability via 53 environmental, social and economic indicators, and CARE accounting, which quantifies the costs necessary to preserve natural (soil, water, biodiversity) and human capital.

The objective[5] is both to measure "ecological debts" and existing efforts, and to create a territorial dialogue between farmers, local authorities and local actors to co-construct ecological transition plans.

CARE can become a real decision-making tool but still faces challenges in terms of recognition. For the method to be fully adopted, it is essential to democratize it,

[5] *CUMA* Extended Accounting, Research Projects: CARE/IDEA4

by popularizing the concepts of natural and social capital, and by harmonizing accounting and preservation methodologies.

3. Limits and Foundation Towards Sustainability Accounting Model (LIFTS)

Developed by the Global Performance Multi-Capital research center, the *LIFTS Accounting Model* (*Limits and Foundations Towards Sustainability Accounting Model*) offers an innovative accounting framework to translate the principles of the Doughnut model (Raworth, 2017) and planetary boundaries (Rockström et al., 2009) at the organizational level.

Planetary boundaries identify nine critical environmental thresholds (climate, biodiversity, nitrogen and phosphorus cycles, land use, freshwater, etc.), the crossing of which could compromise the stability of the Earth. The Doughnut model provides LIFTS with an interpretive and steering framework: it defines a safe and fair space for human activity, located between the nine planetary boundaries that must not be exceeded and the twelve social foundations that must be reached.

LIFTS is anchored in this model by translating these boundaries and foundations into measurable organizational budgets, allowing to know for each dimension whether the organization is in a safe space, or whether it is contributing to overcoming limits or failing to meet social foundations.

For example, Danone has applied the LIFTS model to its subsidiary "Les Prés Rient Bio" to manage its sustainability. The company has translated planetary boundaries and social foundations into budgets for its production sites and products. For example, quotas have been defined for water use, CO_2 emissions and certain social dimensions such as working conditions and employee remuneration. Thanks to LIFTS[6], Danone has been able to measure the gaps between its actual activities and budgets, identify the processes contributing the most to environmental or social debt, and prioritize corrective actions such as energy optimization and waste reduction (Danone, 2023).

LIFTS therefore offers an accounting mechanism that allows each organization to manage its budgets, to measure the discrepancies between what was forecasted and the actual budget, and to react if this last one is exceeded. It goes beyond the simple traditional accounting logic and brings a perspective of sustainable and forward-looking management.

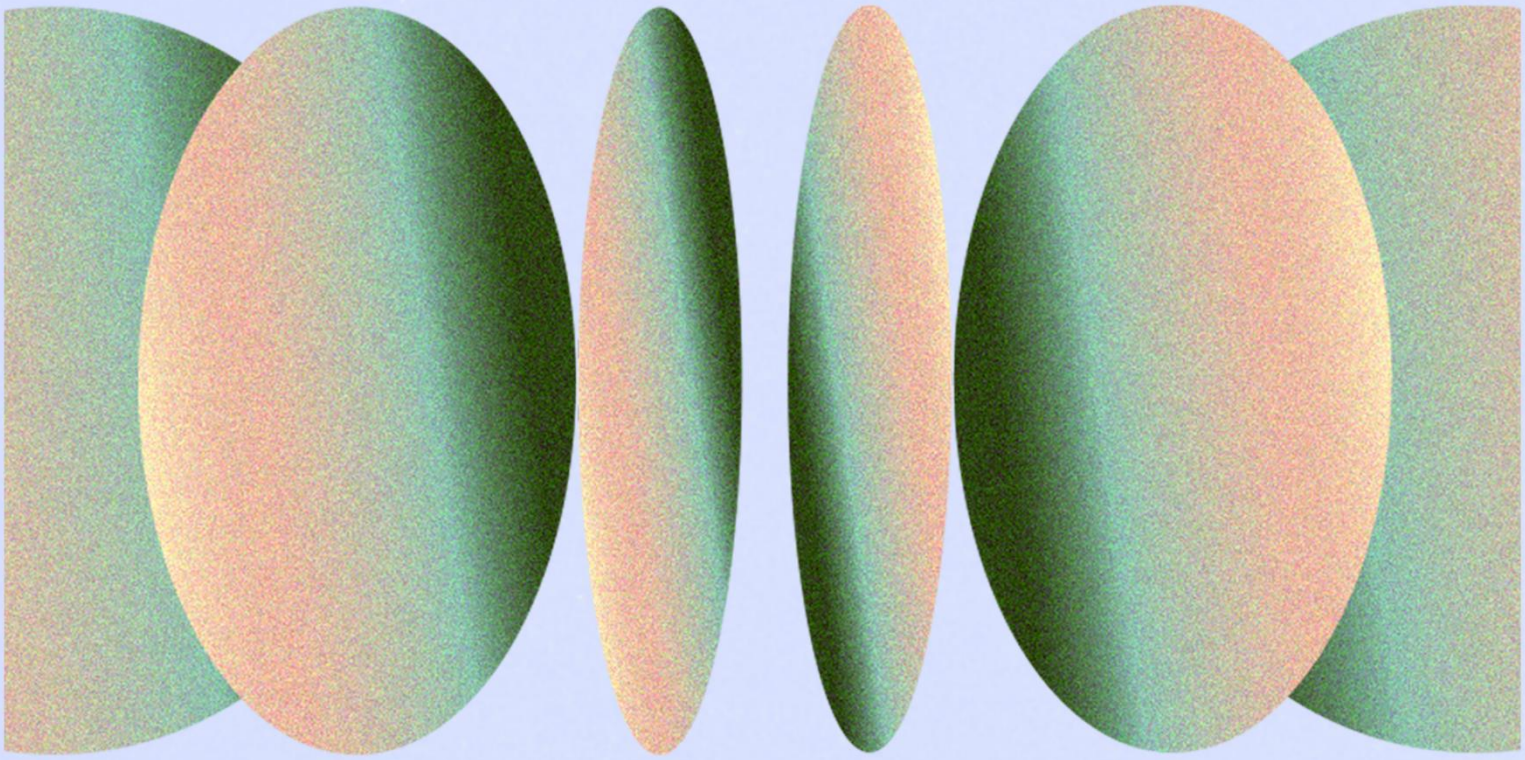
These new accounting approaches represent a shift from the traditional systems. For the financial industry, their adoption represents a major step forward: they

[6] The LIFTS Accounting Model, Danone and multi-capital accounting: feedback from PWC.

make it possible to assess systemic risks related to ecosystem degradation, to identify sustainable investment opportunities (such as natural assets or circular business models), and to meet the transparency requirements imposed by regulations such as the CSRD or the TNFD. By integrating the value of natural capital and planetary boundaries into their analyses, financial players can both secure their portfolios against climate risks and capture new markets related to the ecological transition.

Approach	Main objective	Benefits	Limitations	Concrete example / Application
SEEA – EA	Measure the area, health and value of ecosystems via standardized accounts (stocks and flows).	International framework adopted by the UN, integration into public policies, spatial approach.	Complexity of implementation, need for accurate geospatial data, dependence on countries' technical capacities.	See article Bogaart et al. (2023): Assessment of marine ecosystems in the Dutch North Sea
CARE	Integrate the preservation of natural capital into the accounting of organizations through a proactive approach.	Double materiality, strong sustainability, creation of satellite accounts for biophysical flows.	Complexity of implementation, requires an overhaul of existing accounting systems.	See website CARE/IDEA4 project: evaluation of agricultural farms in Ille-et-Vilaine.
LIFTS	Allocate biophysical budgets to organizations based on planetary boundaries and the Doughnut model.	Radical approach to framing economic activity within ecological limits, intergenerational equity.	Difficult to apply without a strong regulatory framework, risk of resistance from organizations.	See website Use by Prés Rient Bio (Danone group) to drive sustainability.

Table 3 – Synthesis of accounting approaches to the valuation of natural capital (Louis Bachelier Institute, 2025)



KEY ISSUES &
ACTION LEVERS
FOR ECOSYSTEM
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While the theoretical frameworks presented above make it possible to define the contours and foundations of ecosystem valuation, their implementation faces major challenges. Following the interviews conducted and the expected conferences, three issues were identified for a harmonization of practices: territoriality, regulation and governance as well as methodology.

1. The territorial dimension of ecosystem valuation

The question of territoriality is at the heart of the challenges of enhancing ecosystems, insofar as the services provided by nature transcend administrative and economic boundaries. As Mr. Delabie, coordinator at the French Office for Biodiversity, points out, ecosystems are understood at multiple scales (local, regional, even transborder), which makes their measurement complex. Indeed, they are not limited to human-made artificial boundaries or boundaries, which do not necessarily correspond to natural ecosystems, and require collective approaches.

Understanding the territorial dimension requires taking into account the differences between human boundaries (administrative, legal, or political), as these shape regional governance, the allocation of responsibilities, and the limits of action. This understanding is essential for evaluating and contextualizing the actions or efforts required from economic actors, whether for the protection, restoration, or study of ecosystems. It is these territorial structures and frameworks that largely determine the effectiveness of measures undertaken to preserve and manage nature. To shed light on these issues, certain studies and institutional chairs provide a valuable framework (Chair of Ecological Accounting[7], Chair of Climate Economics[8]).

The case of peatlands in the Vosges region illustrates the complexity of the involvement of multiple actors, where restoration actions mobilized : the *Office National des Forêts (*ONF), elected officials, companies and the general public on several locations well beyond the municipal or departmental boundaries (French Office for Biodiversity, 2023). Another example is the LIFE funding program, supporting the European network of protected areas LIFE (27,000 sites in 27 countries), covering 18.5% of the European Union's land surface and 8.9% of its marine surface (Ministry of Ecological Transition, 2018).

[7] Chair of Ecological Accounting

[8] Home - Climate Economics Chair | Our economic choices in the face of climate change

In the case of marine ecosystems, this territorial complexity reaches an additional level: the high seas, which are beyond national jurisdiction, require international frameworks to be protected. The BBNJ Agreement, which entered into force in September 2025, responds to this challenge by establishing marine protected areas in international waters. It requires environmental impact assessments for human activities and provides for the equitable sharing of marine genetic resources. This treaty is a major step forward for global ocean governance, where international cooperation is essential to preserve environments that "belong to no one but concern everyone" (Ministry of Ecological Transition, Biodiversity, Forestry, the Sea and Fisheries, 2025).

The territory defines the right scale of action. However, an outcome cannot be evaluated solely from the action itself. It must also consider other criteria, including the time factor. Faced with the biodiversity loss crisis, there is an emergency.

A.Cadi, president of Restore, suggests that it is sometimes necessary to take a step back and prioritize the urgency of ecosystem restoration over short-term local expectations. As he points out, more than 30% of biodiversity has been lost since the beginning of the industrial revolution, with an annual acceleration of 0.5 to 1%. Territoriality, although essential for organizing governance, requires legal agreements, administrative boundaries and consultations, which can slow down the protection processes. Faced with such pressing issues, the effectiveness of action must sometimes take precedence over the logic of division.

Nevertheless, going beyond geographical limits does not mean denying the existence of territorial scales. As Mr. Delabie, coordinator at the French Office for Biodiversity, points out, it is rather a question of recognizing that ecological interdependencies go beyond administrative borders. Moreover, the level of action remains limited by collective capacities, a factor that must be considered when developing strategies. In this regard, A. Cadi, President of Restore, stresses that ambitious policies must be thought out and designed at the international level and, as far as we are concerned, implemented at European, national and local levels.

Finance plays a role in ecosystems mainly through compensation mechanisms. According to O. Frings, a PhD student at Chaire Economie du Climat, compensating for biodiversity loss cannot be reduced to a simple numerical equivalence: the location of ecosystems is crucial, because the ecological functions and services provided by nature are inseparable from their geographical and social context. One hectare of restored forest in Europe will never replace the specificities of a coral reef in Indonesia, nor the unique interactions it harbors. These poorly designed mechanisms risk encouraging an accounting approach

that is disconnected from local ecological realities, where ecosystems are reduced to interchangeable assets.

In this context, A. Cadi, President of Restore, stresses that it is essential to recall the hierarchy of actions "Avoid, Reduce, then Compensate", which constitutes the basis of public policies in terms of biodiversity. This sequence reflects the need to avoid impacts and to remember that all projects generate a residual impact that must be compensated for: some impacts on ecosystems are irreversible or non-substitutable and therefore cannot be corrected a posteriori by compensatory mechanisms. However, in practice, finance and market tools tend to focus primarily on offsetting, to the detriment of the first two stages, which are decisive about the critical state of biodiversity. In addition, the actual effectiveness of the compensatory measures implemented is subject to documented limitations, particularly in terms of ecological outcomes, funding and duration of implementation.

Their implementation therefore requires a rigorous design, integrating not only robust scientific criteria, but also inclusive governance, capable of reconciling the imperatives of preservation with territorial dynamics. This vigilance is even more crucial because the temptation to standardize solutions could, in the long term, weaken the very effectiveness of measures intended to protect nature.

2. Regulation and governance

In France, the commitment to biodiversity is mainly driven by regulatory measures such as Article 29 of the Energy-Climate Law. It strengthens non-financial reporting for investors and asset management companies by requiring the publication of strategies aligned with climate and biodiversity objectives, as well as a double materiality analysis. The latter makes it possible to assess in part the impact of activities on ecosystems, as well as the risks they pose to financial performance. At the European level, regulation has been strengthened by the CSRD, which now requires companies to publish detailed non-financial information. However, this progress was partially weakened by the CSRD's Omnibus Directive, which reduced the number of companies subject to the reporting obligation from 50,000 to around 8,000. This revision goes against the expectations of financial players, who are calling for clear indicators and a precise definition of materiality for companies. For A. Cadi, president of Restore, the real challenge of reporting obligations is not so much the reporting itself as the understanding of the impacts and dependencies of companies regarding biodiversity. Above all, it is a question of defining the materiality of biodiversity for each sector of activity and each economic actor, to enable them to develop effective strategies for reducing risks and impacts.

Indeed, materiality, combined with demanding regulation, remains an essential lever for enhancing ecosystems, making their vulnerability visible and directing financial flows towards their preservation. All of this forms the basis for a sustainable future for many companies. However, as Mr. Delabie, coordinator at the French Office for Biodiversity, reminds us, while the objective is to allow investors to direct their flows, the sample of companies with appropriate tools remains very limited: only 1% of global companies publish biodiversity indicators. For benchmarks to be reliable and for capital to be redirected, the relevant thresholds must be defined by the financial players themselves. At the international level, initiatives such as the TNFD framework have been put in place to enable companies and financial institutions to identify and assess their impacts and dependencies on nature, as well as the associated risks and opportunities. This voluntary framework, inspired by the TCFD climate recommendations, encourages a holistic approach that includes measuring pressures on ecosystems, anticipating physical risks and seizing opportunities related to the ecological transition. Complying with the requirements of TNFD can allow financial players to better secure their portfolios, meet the expectations of certain stakeholders, but also position themselves in a rapidly evolving market.

Another subject is the proliferation of reporting standards and standards (National Biodiversity Strategy 2030, TNFD, Science Based Targets for Nature) which creates legal uncertainty. Companies face different environmental standards and regulations depending on the jurisdiction. For example, a "green investment" recognized in Europe may not be recognized in Australia or the United States, creating major complexity for companies, investors, and financial institutions. These players must navigate between sometimes contradictory frameworks, which increases compliance costs and increases the risk of error. This lack of harmonization also encourages greenwashing, by allowing divergent interpretations that undermine the credibility of environmental commitments and expose stakeholders to legal or reputational risks. As a result, companies, especially SMEs, may be discouraged from adopting ambitious sustainability actions. On the markets, this uncertainty can result in a slowdown in investment in "green" projects, explained by investors' hesitation in the face of vague and shifting criteria. Finally, adapting to several standards generates high administrative and operational costs, diverting resources that could be devoted to concrete actions for the environment.

3. Methodology

Beyond the limitations identified for each valuation approach, the interviews conducted highlighted methodological limitations that could impact financial decisions. As O. Frings, PhD student at Chaire Economie du Climat, points out, the

declared willingness to pay is influenced both by the characteristics of the survey (and the biases they may introduce) and by the actual patterns of preferences within the population. In practice, it is not always easy to distinguish between actual signals and methodological effects, so these estimates should be interpreted as scenario-specific indicators and as far as possible, cross-checked by simple methods or against additional evidence. This represents a major problem for investment decisions, as valuations based on this data can be biased, leading to inefficient capital allocations or an overestimation of ecological benefits. For example, a conservation project could be financed based on overvalued CAPs, with no guarantee that the expected benefits will materialize.

In addition, as Mr. Delabie, coordinator at the French Office for Biodiversity, points out, the valuation of ecosystems also involves mapping, i.e. the characterization of direct and indirect beneficiaries and forms of value expression, which is an essential tool for effective action. It is not enough to list the benefits of ecosystem services: it is crucial to know who benefits from them, to prioritize actions, design more precise and equitable policies and interventions, and guide communication and efforts with appropriate stakeholders. Indeed, when the balance of an ecosystem is disturbed, some populations can be affected more severely than others. Identifying direct beneficiaries also allows decision-makers to understand the importance of protecting these services.

However, this exercise remains complex and often poorly carried out, for several reasons: lack of collaboration between stakeholders, difficulties in immediately measuring certain services (e.g. flood protection), lack of data on uses (e.g. rural communities), non-monetary or cultural nature of certain benefits, widespread sharing of benefits or evolution of beneficiaries over time.

These difficulties are accentuated when the valuation relates to an ecosystem service linked to biodiversity. Unlike carbon, for which a dominant metric has been imposed, biodiversity is the subject of a plurality of measurement methods. Valuation, which aims to translate impacts on biodiversity into economic or decision-making terms, therefore depends on initial assessments that are themselves not harmonized. The measurement of biodiversity and the valuation of ecosystems are not the same, but complement each other: without reliable measurement of impacts, valuation rests on fragile foundations. In this context, tools such as the *Global Biodiversity Score* (GBS) are an important step forward in quantifying the impact of human activities on ecosystems, offering companies and institutions a standardized metric to facilitate the comparison of projects. However, their relevance remains conditioned by their ability to capture real ecological complexity.

Biodiversity depends on local dynamics (climate, soils, interactions between species), critical thresholds (ecosystem resilience) and temporal factors (delayed effects, irreversibility). An overall score, even a sophisticated one, can smooth out these specificities and obscure essential issues. Technological innovations therefore play a key role in refining measurement and obtaining more granular data. The Sonosylva project, led by the OFB[9], illustrates this dynamic by developing an acoustic memory of forest ecosystems, making it possible to assess the quality of biodiversity through the analysis of soundscapes.

The granularity of the data is a central issue for valorization, as it conditions the application of existing methods. However, this approach faces major challenges, including the difficulty of measuring impacts on a relevant scale, as C. Soulard, climate and environment expert at Crédit Agricole Assurance, points out. To address this, tools are emerging, such as collaborative mapping tools (digital twins, spatial data) and public-private partnerships, aimed at involving local populations and equitably distributing the costs and benefits of restoration projects.

Faced with these challenges, C. Soulard identifies two levers: on the one hand, the framework prescribed by the regulations and/or expected by the regulators (which can promote the production of data and its analysis by the actors) and, on the other hand, an iterative approach, favoring the development of simple and actionable solutions, based on physical, non-aggregated data, in addition to more complex models.

Ideally, improving the quality and granularity of data should be seen as a positive development. However, it may lead to the use of different methodologies than those applied in previous years, making the results difficult to compare over time when different assumptions or datasets are used.

For companies and project leaders, this situation is a major challenge. The lack of methodological continuity and stabilized performance indicators (KPIs) complicates the development, monitoring and management of robust biodiversity strategies. In addition, the improvement of data collection and processing processes can paradoxically lead to an apparent deterioration in biodiversity impact scores, insofar as more detailed data make it possible to reveal impacts that were previously underestimated.

This can be a deterrent for companies: initially more favorable outcomes, obtained from lower quality data, can be replaced by less advantageous scores, exposing

[9] The National Forestry Office

organizations to increased expectations from investors, customers, or other stakeholders.

The interpretation of these results therefore requires a rigorous methodological analysis, explicitly integrating the assumptions, limitations and scope of the methods used. It is not possible to generalize these effects without examining the suitability of the methodology to the case under study, as well as the trade-offs it implies in terms of accuracy, comparability and operational feasibility.

This phenomenon is not new and has already been observed with methodologies for measuring greenhouse gas emissions. For example, less granularity of the data, such as the use of monetary emission factors, can lead to an overestimation of impacts. These factors, often used for their simplicity, generate much higher estimates than those obtained with physical emission factors. For example, repairing a car door after a disaster can be associated with an emission of around one ton of CO_2e with a monetary method, compared to only 42 $kgCO_2e$ with a physical method.

An apparent deterioration in the results does not necessarily mean a real deterioration in environmental performance but can on the contrary indicate an improvement in the accuracy of the measurements.

This could lead one to think that measuring the biodiversity footprint is useless. Yet, unlike the Greenhouse Gas Protocol, which has been in existence since 2001, the Global Biodiversity Framework was not officially launched until 2022. In other words, the integration of metrics and the development of standards to assess ecosystem services and the impact on biodiversity is still ongoing. This process naturally leads to geographical and temporal challenges.

In addition, another major issue is that of additionality, i.e. the need to ensure that ecological gains come from projects and not from pre-existing dynamics. This underscores the importance of training teams and standardizing methodologies.

Despite these challenges, biodiversity remains a central tool for mitigation and adaptation, a real driver of sustainable finance and key to responsible and sustainable resource management.

SUMMARY AND PERSPECTIVES

The enhancement of ecosystems is now an essential lever for reconciling the economy and the preservation of living things. It offers an alternative to traditional indicators of economic performance, such as GDP, which ignores the depreciation of natural capital. Valuing nature as a strategic asset means including it in the national accounts and giving it the necessary visibility to guide the choices of economic and political decision-makers. In addition, as Mr. Delabie, coordinator at the French Office for Biodiversity, points out, the transparency introduced by the reporting systems has made it possible to highlight the individual responsibilities of economic actors, whether they are companies or financial institutions.

The approaches presented in this article already offer concrete levers to start connecting natural capital to the world of finance, but they come up against a lack of international standardization and certain structural limitations. They do not consider changes in the value of ecosystem services over time, preventing real-time monitoring. However, it is important to note that these challenges are not specific to the methodologies themselves, but stem from the available data. According to some studies, the variability in methods and data could mean that, in billions of dollars, the cost of nature loss could be much higher for the global economy (World Bank, 2021).

A notable breakthrough came in October 2025 with the publication of ISO 17298, the first international standard dedicated to biodiversity and designed to help organizations assess their impact and dependencies on ecosystems. For Mr. Delabie, coordinator at the French Office for Biodiversity, the priority lies in the establishment of shared reference systems. Today, initiatives remain fragmented, often limited to the level of companies, without a common framework to articulate financial players, territories and ecologists. We need to build bridges between the languages of life and those of finance, articulate local, national and ecosystem scales, and make collective dynamics measurable. He illustrates the current imbalance with the metaphor of the Jenga (or infernal tower): each piece removed represents a weakened ecosystem or a degraded natural service. Through this image, we understand that the economic system continues to pile up its blocks, without realizing that its stability depends on this ecological basis. When too many pieces have been removed, the tower will collapse.

However, this metaphor must be understood in a territorialized way, because the fragilities and solutions differ depending on the region: protection measures or the management of a territory are not the same from one place to another, and

strategies must be adapted. Nevertheless, the weakening of a territory, even an isolated one, can weaken the overall balance of the tower. It underlines the need to combine systemic actions, applicable to all, with better tools for territories, to avoid irreversible feedback loops leading to the permanent loss of ecosystem services. This discrepancy between the scale of the risk and the responses provided is directly reflected in financial flows, since financial actors currently allocate only 2% of investments to biodiversity[10], a level much lower than the structural dependence of the economy on living things.

Finally, this dynamic refers to the profoundly performative nature of finance: the rules of financial performance, largely homogenized on a global scale, shape a dominant representation of wealth creation, largely disconnected from the living. Changing this framework of representation is therefore a major collective lever, as finance remains, to this day, one of the most powerful performative tools for transforming economic trajectories.

According to O. Frings, PhD student at Chaire Economie du Climat, market-based mechanisms (such as biodiversity credits or payments for ecosystem services) are only one option among others, alongside regulatory and hybrid approaches. There is no intrinsically better family of instruments: their performance varies according to the context and the objectives of the policy implemented. Market-based tools often seem effective in theory, but this can minimize practical frictions: information asymmetries, transaction and monitoring costs, implementation challenges, as well as the risks of manipulation, speculation, or short-term profit-seeking in an area that requires a long-term vision. On the other hand, the so-called *"Command and Control*" regulations may offer clearer minimum standards, but they can also be rigid, complex or administratively burdensome. Beyond mere efficiency, all instruments also have redistributive effects, influencing who bears the costs and who benefits from environmental actions. In practice, the choice and combination of instruments require a case-by-case assessment of their effectiveness, efficiency and fairness, supported by a clear regulatory framework and robust governance.

According to O.Frings, environmental economist at the Economy and Climate Chair, market mechanisms (biodiversity credits, payment for ecosystem services...) are a complementary solution in contexts where the regulatory intervention of States faces obstacles such as the limited understanding and acceptance of the rules, standards or regulations necessary to respond to current environmental challenges. However, this approach also has its own limits with the risk of speculation or the search for short-term profitability to the detriment of a

[10] Climate and Biodiversity: an ambition for the planet by the AFD (The French Development Agency)

long-term problem. Their success will depend on the establishment of a clear regulatory framework and robust governance mechanisms.

As Mr. Culot-Horth, an expert in biodiversity, water and circularity at the Caisse des Dépôts Group, points out, it is essential to remember that the purpose is not to "put a price on nature", but to integrate its real costs and benefits into economic decisions, in order to reduce risks and direct financial flows towards trajectories compatible with ecological resilience. Valuing ecosystems means redefining the very notion of prosperity but also recognizing our dependence on living things. It means admitting that restoring an ecosystem is not only about restoring a service for humans, but about preserving a living system for itself. It also means aligning financial temporalities with the long cycles of nature: without this adjustment, the transition will remain incomplete.

By making ***the invisible visible***, the valuation of ecosystems goes beyond the accounting exercise: it invites us to rethink the place of living things at the heart of our economic models. If finance finally agrees to recognize nature as the basis for all value creation, it can no longer become a factor of degradation, but a vector of regeneration.

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