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Economic Assessments of Services Provided by Biodiversity

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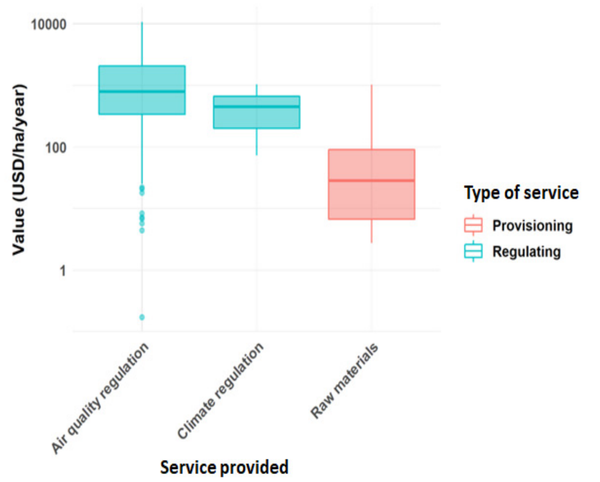
- The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has made a tworrying assessment of global biodiversity loss. Unlike with climate change, the multidimensional nature of biodiversity makes it difficult to measure its status using a single indicator.
- Recent decades have seen the development of analytical economic instruments to estimate the value of services provided by ecosystems and biodiversity. These analyses rely on indirect methods of valuation, including avoided costs and agent preferences.
- A meta-analysis of 365 studies shows a high degree of heterogeneity in the estimated unit values of ecosystem services. Estimated unit values vary due to the diversity of estimation methods and differences in the nature of the cases analysed, the ecosystem under consideration and the services provided. Regulating services (e.g. climate change mitigation), for instance, have higher unit values on average than provisioning services (e.g. supply of raw materials).
- Estimating the socio-economic value of ecosystem services contributes to raising awareness of the importance of preserving biodiversity and to improving the socio-economic evaluation of projects. Methodological difficulties imply that these values should be used with caution, especially when aggregated on a national or global scale. It should also be noted that biodiversity preservation objectives are typically established without reference to these value estimates.
- Government action must be coordinated at international, national, and local levels. The "post-2020 global biodiversity framework" is currently under negotiation and is expected to be adopted at the 15th Conference of the Parties in Kunming, China, in 2022. This international policy response should make it possible to define common commitments that will then be implemented at national level, e.g. in France's "2030 national biodiversity strategy" currently under development.

Distribution of ecosystem service values by service type for "temperate forest" ecosystems ($/ha/year, log scale)



Source: DG Trésor calculations using the TEEB database.

The horizontal lines in the rectangles represent the median value for each service, while the lower and upper boundaries of the rectangles represent the difference between the first and third quartiles. The vertical lines represent the tails of the distribution of observed values.

1. Biodiversity provides multiple services; all are under pressure

1.1 Four main categories of ecosystem services

Biodiversity, as defined by the Convention on Biological Diversity (CBD, one of the three conventions resulting from the 1992 Rio Conference), is a concept that characterises the organisation of all life in terms of three forms of diversity:

- Genetic diversity is the diversity within a species; it is directly linked to the number of individuals in a population.
- Species diversity is the diversity between species, and is related to the number of different species found in a given ecosystem.[1]
- Ecosystem diversity is the diversity between different ecosystems.

Ecosystems and biodiversity provide numerous services to socio-economic systems; these are called "ecosystem services". In 2005, the United Nations Millennium Ecosystem Assessment project to determine the impact of ecosystem change on human well-being proposed classifying ecosystem services into the following four categories: (i) provisioning services (for resources such as water, raw materials, food and medicines); (ii) regulating services (for regulation of the biosphere, e.g. climate change mitigation, moderation of extreme climate events, prevention of erosion); (iii) cultural services (e.g. aesthetic value, recreation); and (iv) supporting services (those necessary for the production of all other ecosystem services, e.g. the habitat for a species).

Ecosystem services do not always refer to services provided directly by nature; they may also arise from a combination of natural capital (ecosystems and biodiversity) with human and technical capital.[2] Their value can also vary as practices evolve (automation, settlement of uninhabited areas, etc.) or with uncertainty surrounding the potential utility of a service in the future (option value).[3]

1.2 Biodiversity is exposed to serious pressures

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), which can be considered the biodiversity equivalent of the Intergovernmental Panel on Climate Change (IPCC), has identified five direct drivers of human pressure on biodiversity that threaten the continuity of ecosystem services. In order of importance at global level, these are: (i) change in land and sea use; (ii) direct exploitation of animals, plants and other organisms; (iii) climate change; (iv) pollution; and (v) invasive species.[4]

Because of its multidimensional nature, the status of biodiversity is complicated to measure. Unlike the climate, which is often assessed in terms of global mean surface temperature change, there is no single standard indicator for biodiversity. The IPBES has identified 20 essential variables[5] to characterise the status of biodiversity; however, these variables can provide at best a partial view, if only because substantial numbers of species remain to be discovered.[6] While indicator species can be monitored to provide insight into what is occurring with other (unobservable) species and phenomena, the process is costly and labour-intensive as it can only be performed locally.

Despite these limitations, most indicators available show an acceleration in the loss of biodiversity, at both global level[7] and national level.[8] The World Wildlife Fund (WWF) composite Living Planet index, based on the evolution of the populations of several thousand vertebrate species, declined by 68% between 1970 and 2016.[9]

(1) An ecosystem is a system formed by an environment and all the species that live, feed and reproduce within it.
(2) Costanza et al. (2014).
(3) Option value refers to the economic benefits that agents could derive from potential use of a resource that they do not currently use, but that they want to preserve for future use (e.g. genetic resources, or future use of a forest for tourism and which therefore needs to be preserved).
(4) The IPBES identifies four categories of indirect drivers of change: demographic and sociocultural; economic and technological; institutions and governance; and conflicts and epidemics.
(5) Essential Biodiversity Variables, see portal.geobon.org.
(6) French Council of Economic Analysis (2020), "Mesurer la biodiversité", Focus no. 46-2020.
(7) IPBES (2019), Global Assessment Report, 2.2.5.2.
(8) CGDD ONB (2018), *Biodiversité - Les chiffres clés*.
(9) WWF (2020), Living Planet Report 2020.

In France, recent assessments[10] indicate that change in land and sea use is the main factor in the decline of biodiversity, particularly due to land artificialisation, but also to the fragmentation of natural environments and wetland drainage. Other causes include pollution, climate change and, in a more location-specific manner, the direct exploitation of organisms (particularly marine organisms). All ecosystems are under pressure, to varying degrees (see Table 1). For example, 22% of common specialist bird species, i.e. those traditionally attached to a specific habitat (forest, urban, etc.) and therefore major markers of the pressures exerted on ecosystems, disappeared between 1989 and 2017.[11] Similarly, French coral cover fell by 29% between 2011 and 2015.

Table 1: Ecosystem types in France and their exposure to pressures

Ecosystem type	Area (Mha)	Percentage of total area of mainland France	Change in land and sea use	Direct exploitation of animals, plants, other organisms	Climate change	Pollution	Invasive species
Agricultural areas	26.8	49%					
Forests	16.9	31%					
Urban areas	2.7	5%					
Other artificial areas	2.3	4%					
High mountains	1.7	2%					
Inland waters	1.7	3%					
Other wetlands	1.8	3%					
Other areas	1.3	3%					
Total: geodesic area	55.2	100%					
Marine and coastal ecosystems[a]	29.7						

	Major risk recognised, not under control		Major risk recognised, or local risks identified. Uncertainty regarding control of these risks.		Major risks under control. Local risks may remain.

a. Exclusive economic zone belonging to mainland France.

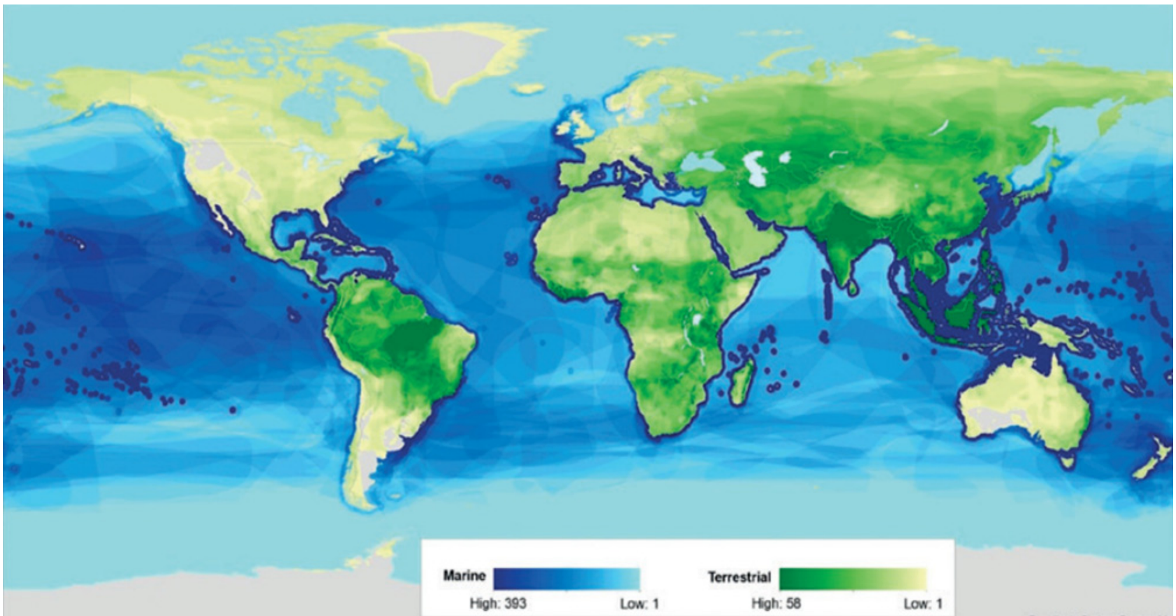
Source: DG Trésor using data from the national ecosystem assessment project (Évaluation française des écosystèmes et des services écosystémiques, EFESE) begun in 2012 and involving a large range of stakeholders (experts, users and policymakers) to provide a basis for private and public sector decision making. The level of risk associated with each pressure is estimated by the EFESE and is based, inter alia, on compliance with existing regulatory limits for each type of pressure. See EFESE (2020) "Du constat à l'action: rapport de première phase de l'évaluation française des écosystèmes et des services écosystémiques" (p. 33). The other data (on surface areas) are from the following sites: eaufrance.fr, limitesmaritimes.gouv.fr, and agreste.agriculture.gouv.fr.

1.3 Geographical effects

Compared to climate change, biodiversity loss is characterised by more location-specific effects, with greater correlation between areas subject to pressures on biodiversity and areas affected by biodiversity loss. Numbers of threatened species,[12] for example, vary considerably across the world (see Chart 1), not only because initial numbers of species differ between areas, but also due to varying degrees of pressure (e.g. differences between coastal areas can depend on the degree to which they are used by humans).

(10) French Council of Economic Analysis (2020), "Biodiversity in Danger: What Can Economics Do?" *Les notes du conseil d'analyse économique* (59); EFESE (2020), *Du constat à l'action: rapport de première phase de l'évaluation française des écosystèmes et des services écosystémiques*.
(11) CGDD ONB (2018), Biodiversité - Les chiffres clés.
(12) A threatened species is one that is at risk of extinction in the near future (i.e. vulnerable, endangered or critically endangered).

Chart 1: Numbers of threatened species per 10 km grid cell, worldwide

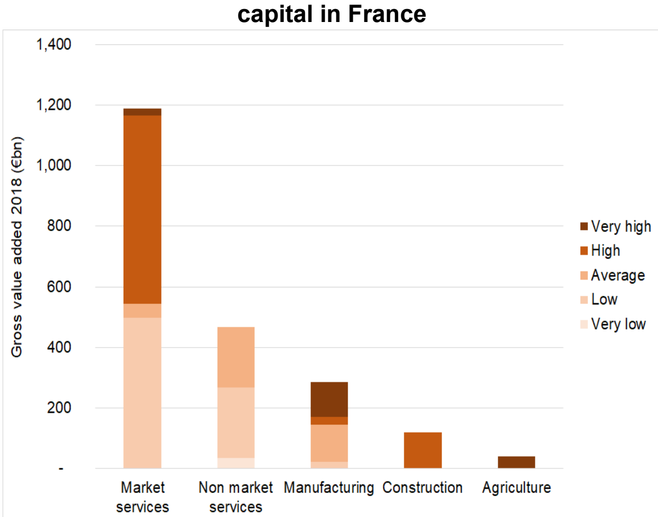


Source: IPBES (2020) Global assessment report on Biodiversity and Ecosystem Services à partir de Hoffmann et al. (2010), "The Impact of Conservation on the Status of the World's Vertebrates", Science (330)- 6010.

1.4 Sectoral effects

As with climate change, some economic sectors are more vulnerable to biodiversity loss than others, and not all sectors contribute to biodiversity loss to the same degree. Both globally and in France, agriculture is particularly sensitive to biodiversity loss (due to the effects of climate change or invasive species) and also contributes to it (increased size of cultivated lands, destruction of hedgerows, drainage, farm specialisation, crop protection products, anti-parasite treatments for livestock).[13] Based on existing literature and sectoral expertise, the United Nations Environment Programme Finance Initiative (UNEP FI) and Global Canopy have compiled a database with a five-level classification of the dependencies of 167 economic sectors on 21 ecosystem services.[14] Applying this classification to the French economy as a whole, 44% of gross value added appears to be "highly" or "very highly" dependent on natural capital. The most highly dependent sectors include agriculture and the agri-food industry, as well as construction and real estate activities (see Chart 2).

Chart 2: Dependency of economic activities on natural capital in France



Source: CDG Trésor calculations based on ENCORE database classification and INSEE gross value added data.

To take one example, France has the world's second largest exclusive economic zone, due to the country's overseas territories and *départements*, which account for 80% of France's biodiversity and 10% of the world's coral reefs. As isolated, resource-rich islands, these areas are dependent on natural capital.

(13) FAO (2019), The State of the World's Biodiversity for Food and Agriculture. For France, see also INRA (2008) *Agriculture et biodiversité. Valoriser les synergies.*
(14) Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE). See https://encore.naturalcapital.finance.

1.5 Effects on inequalities

The social consequences of biodiversity loss also vary greatly. At global level, the poorest population groups are the most highly dependent on ecosystem services (especially provisioning).[15] To measure the relationship between natural resources and poverty, World Bank economists have studied the income components of rural households from all regions of the world.[16] The analysis identified income derived from natural resources and calculated the household poverty rate (the proportion of the population living on less than $1.25 per day at the time of the analysis) following the loss of ecosystem services. For some regions (Latin America, South and East Asia), the poverty rate could double if the ecosystem services on which the population is dependent were to disappear. Moreover, from a public health standpoint, the IPBES estimates that 30% of zoonotic diseases[17] that have emerged since 1960 can be explained in part by changes in land use.[18]

In France, per capita GDP in the overseas *départements* and territories is significantly lower than the national average. Biodiversity loss could further widen these inequalities, while also increasing the vulnerability of these regions and their populations (e.g. water contamination, loss of coral reefs and their fish nursery services).

2. Estimating the value of ecosystem services provided by biodiversity

2.1 The challenge of measuring and valuing ecosystem services

Estimating the socio-economic value of the ecosystem services provided by biodiversity is fraught with methodological difficulties arising from the very nature of these services and the multidimensional, and still imperfectly understood, aspects of biodiversity.

Most ecosystem services can be considered non-excludable goods in that it is difficult to restrict their use by any category of users. This characteristic, combined with a relative abundance that makes the scarcity principle inapplicable, explains why they have not been priced into economic markets. The socio-economic value of these resources is virtually absent from market prices and consequently from the standard measures of output such as GDP. Hence, there are no quantified values for these services that can be imported directly into economic calculations.

The characteristics of biodiversity, and especially its multiple dimensions (see above), mean that assessments of the value of biodiversity services are inevitably local and specific to a given ecosystem. This makes it difficult to compare the unit values of services between different regions.

Moreover, these assessments are partial in that they address only selected ecosystem services and fail to take into account interdependencies between services. Aggregating them to estimate the total value of biodiversity services would be problematic.

These limitations are compounded by our still fragmentary understanding of certain ecosystems (e.g. deserts) and ecosystem benefits (e.g. aesthetic services), which have received scant attention from academic research. Estimates have thus varied over time as knowledge of biodiversity has evolved.

Finally, economists may choose to estimate in terms of average values or marginal values, adding a further layer of difficulty to the interpretation of available estimates. The choice of method often depends on how the valuation is to be used. The TEEB database, for instance, contains estimates of average values of ecosystem services in different regions of the world and at different dates. Taking the surface area of the ecosystems on which the estimate was made, the economists who created the database calculated a unit value per hectare for each ecosystem service. This provides comparable unit values for each service and facilitates analyses for decision-makers. Other economists use marginal value, i.e. the service provided per additional hectare, to define thresholds for ecosystem protection. The marginal value, however, is highly dependent on how ecosystems evolve, and therefore on the date of valuation. Indeed, as a service degrades, its unit value is likely to increase due to

(15) Dasgupta P (2021), *The Economics of Biodiversity: The Dasgupta Review*, HM Treasury.
(16) World Bank, *Investing in Nature Pays off for People and Biodiversity* (2020).
(17) A zoonosis is an infectious disease that has jumped from a non-human animal (typically a vertebrate) to humans.
(18) IPBES Workshop on Biodiversity and Pandemics Report (2020).

scarcity; on the other hand, the total value of the services rendered may fall due to a decline in the quantity of services provided.

2.2 Three approaches to estimating the value of ecosystem services

To address these issues, recent work by biologists, ecologists[19] and economists has proposed three categories of indirect approaches for estimating the value of ecosystem services provided by biodiversity.

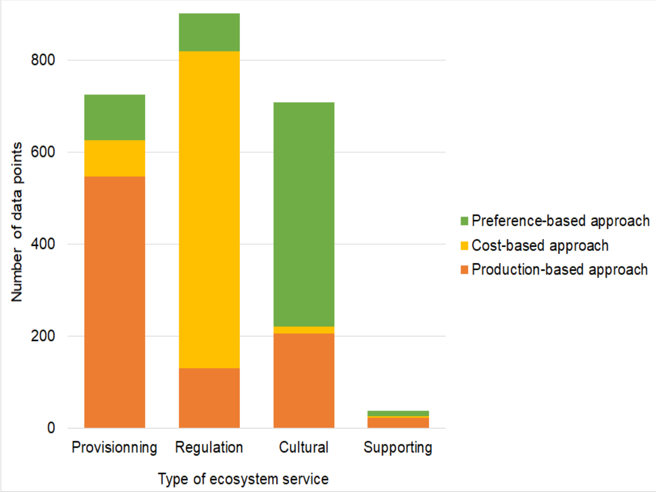
Cost-based approaches: The substitute or alternative cost approach considers the cost of a human-made alternative to an ecosystem service. Similarly, the avoided cost approach estimates the costs that would be incurred if an ecosystem service were not present. The value of an ecosystem service can also be estimated from the costs of maintaining or restoring it. In Vietnam, for example, one case study found that rehabilitating mangrove forests was less costly than building artificial barriers to protect against natural disasters.[20]

Production-based approaches: For market sector activities, the value of a service can be estimated by the market price. This is particularly appropriate in the case of a provisioning service that is commercially traded, such as the sale of wood from a forest. However, if prices are not directly observable or if they incorporate other forms of capital (human, industrial), then a production function can be estimated to assess the marginal impact of a change in natural capital on value creation.

Preference-based approaches: Value can also be estimated on the basis of revealed or stated preferences. In the case of revealed preferences, the travel cost method has been developed to value cultural services such as outdoor recreation by estimating the cost of an ecosystem service from the costs incurred to benefit from the service, including, for example, travel expenses, visitors' time, and entrance fees paid to enjoy a natural park. Similarly, the hedonic price approach identifies the value assigned to a service by comparing, all other things being equal, the price of an asset according to its proximity to an ecosystem, e.g. real estate prices according to distance to a forest. For stated preferences, the most popular approach is the contingent valuation method, in which a fictitious market is defined and users are surveyed to determine their willingness to pay for the service. An implicit price can then be derived from the stated preferences among alternatives. The stated preference approach, while sometimes the only way to evaluate a service, is fraught with many biases. Respondents may overvalue a service because of the hypothetical nature of the survey, or they may simply answer incorrectly because they lack information. Other biases are related to the representativeness of the panels surveyed, their motivations, or the way the surveys are designed.

An analysis of the case studies included in the database developed by the international organisation The Economics of Ecosystems and Biodiversity (TEEB, see Box 1) shows that the approach chosen in each case is highly dependent on the type of ecosystem service examined (see Chart 3).

Chart 3: Diversity of methods for estimating ecosystem services



Source: DG Trésor analysis of TEEB database. The number of observations corresponds to distinct monetary values for ecosystem services from the TEEB database (see Box 1).

(19) Ecologists study the relationships between organisms and their ecosystems. Among ecologists, Robert Costanza gained recognition with his first valuation of the Earth's biodiversity, "The Value of the World's Ecosystem Services and Natural Capital", published in *Nature* in 1997. Costanza asserted: "To say that we should not do valuation of ecosystems is to deny the reality that we already do, always have and cannot avoid doing so in the future". Myers and Reichert, two American ecologists contributed to these analyses, pointing out that "we do not protect what we do not value". (*Nature's Services: Societal Dependence on Natural Ecosystem*s, Island Press,1997).

(20) TEEP Interim Report, *The Economics of Ecosystems and Biodiversity* (2008).

Box 1: A database of case studies with monetary estimates of ecosystem services

TEEB (The Economics of Ecosystems and Biodiversity) is an international organisation created in 2007 at the initiative of the G8+5[a], to investigate the benefits of biodiversity and the costs of ecosystem loss or degradation. Starting in 2010, it developed the Ecosystem Services Valuation Database, which now comprises over 4,000 ecosystem service values (observations) estimated at different scales (municipality, province, country, region or world). The TEEB database was updated in December 2020; its values are now drawn from approximately 690 case studies published between 1973 and 2020. The database distinguishes 23 ecosystem services for over 16 ecosystem types. To provide for greater comparability, TEEB analyses each study and homogenises the original monetary values of the case studies by multiplying or dividing into the standard measure, that is, US dollars per hectare per year. This homogenisation process, however, introduces a bias, as the value of services provided by an ecosystem is not necessarily proportional to its surface area.

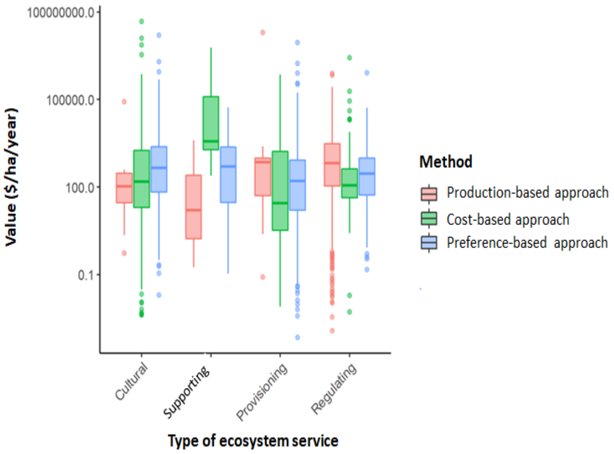
After processing, and eliminating observations with missing data, the meta-analysis reported here was conducted on the basis of 2,944 values from 365 case studies.

a. The G8+5 group was composed of the heads of government of the G8 countries (Canada, France, Germany, Italy, Japan, Russia, the United Kingdom and the United States), plus the five major emerging countries (Brazil, China, India, Mexico and South Africa).

2.3 Meta-analysis of the estimated value of ecosystem services

Analysis of the 2,944 observations from the TEEB database shows the extreme diversity of estimated values of ecosystem services, which range from 0 to over $46m/ha/year (see chart on cover page).[21] Values per hectare also vary widely for each type of ecosystem service (see Chart 4). To take one example, the wood harvested from French forests has a market value of nearly €2bn a year,[22] while the French population's willingness to pay to enjoy forests is estimated at nearly €10bn a year. Similarly, the cultural services associated with tourism provided by coral reefs can vary from $0.1/ha/year for small isolated reefs to over $1m/ha/year for the most highly visited reefs.[23]

Chart 4: Heterogeneity of ecosystem service values by type of service and methodological approach ($/ha/year, log scale)



Source: DG Trésor calculations using the TEEB database.

The horizontal lines in the rectangles represent the median value for each service, while the lower and upper boundaries of the rectangles represent the difference between the first and third quartiles. The vertical lines represent the tails of the distribution of observed values.

(21) The average of the values identified in the studies is $55,410/ha/year and the median is $245/ha/year.
(22) In addition, the value of wood that does not reach the commercial marketplace is estimated to be close to €1bn.
(23) De Groot et al. (2012), "Global Estimates of the Value of Ecosystems and Their Services in Monetary Units", *Ecosystem Services*, p. 50-61.

An econometric analysis of these data suggests that the estimated value of ecosystem services is correlated with three main factors (see Box 2):

- The nature of the service provided by an ecosystem: In comparison with raw material provisioning services, regulating services (such as moderating extreme events, pollination, or erosion prevention) have, all other things being equal, a higher value, but one that is rarely internalised in market prices. To take one example, the price of wood depends on its value as a raw material, and not as a carbon sink, i.e. as a regulating service that contributes to mitigating climate change. The value of preserving genetic diversity (a supporting service) is also found to be significantly higher than the raw material provisioning value.
- The properties of the ecosystem under consideration: All other things being equal, most ecosystems corresponding to natural areas subject to relatively low exploitation pressure (temperate forests, ocean, rivers and lakes) have significantly higher value than cultivated areas. This shows how land use change can have a negative impact on ecosystem services, and the value of preserving certain ecosystems in their natural state. Furthermore, natural ecosystems located in urban areas are valued higher than equivalent ecosystems located in other areas.
- Geographic area (continent): Ecosystem services in Asia, for example, are valued more highly on average than in Europe. This probably reflects the fact that some regions may be more economically dependent on nature than others, or place a higher cultural value on nature.

Box 2: Econometric model[a]

The value of an ecosystem type is estimated here from the multiple assessments identified in the TEEB database (Box 1), taking into account the service provided, the assessment method, and the continent. A cross-sectional regression of the annual unit value of ecosystems (Y, in logarithm) is run on ecosystem type (biome) (B, 10 categories) and type of service (SE, 16 categories), controlling for other variables that may explain differences between data points, namely the methodological approach (M, 3 categories) and the continent of the case study (C, 6 categories).

$Log(Y_{ie}) = \beta_0 + \beta_1 + \beta_{ie} + \beta_2 SE_{ie} + \beta_3 M_{ie} + \beta_4 C_{ie} + \varepsilon_{ie}$ where *i* represents an observation and *e* a case study in the TEEB database.

Chart 4 reflects the exploratory analysis of the database on which this regression is performed. It illustrates the variability of service values according to the type of service provided and the estimation method. The initial analysis suggests the absence of a direct link between the choice of estimation method and the value of the services provided. For example, while the preference approach tends to higher estimates for supporting services than the other methods, the case of provisioning services differs in that the corresponding estimates appear to be more heterogeneous but generally lower.

a. The results are available in the following document: « Results of an Econometric Model of the TEEB Database ».

2.4 Early estimates of the total value of ecosystem services

The 2014 benchmark synthesis by Costanza et al.[24] estimates the total value of ecosystem services by assigning an average unit value per hectare for each ecosystem service and each ecosystem, calculated from a literature review reflected in the TEEB database. This average unit value of a service for a given ecosystem is then multiplied by the global surface area of the ecosystem (ignoring possible variations by geographical location for example). By summing the total values thus obtained for each ecosystem service at global level (see Chart 5), the authors estimated the total value of services provided to be approximately $125tn, or 1.6 times the global GDP in 2011 (the

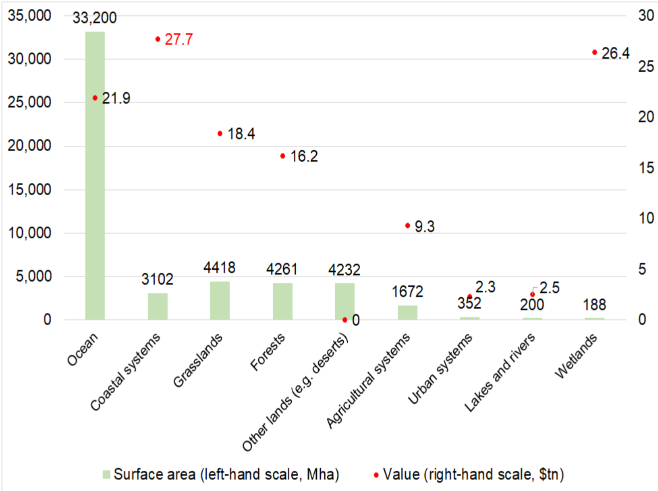
(24) Costanza et al. (2014), "Changes in the Global Value of Ecosystem Services", *Global Environmental Change* (26) p. 152-158.

reference year of the estimate). The 2014 paper updated a previous synthesis published by the same authors in 1997. While the same methodology was used for the 1997 and 2011 data, there were changes in the number of case studies used and in the surface area of each ecosystem.

To measure the impact of the changes in the surface area of each ecosystem, the authors multiplied the average unit value per hectare of each service estimated in 2011 by the area of the ecosystems in 1997 and 2011. The total aggregate value was found to have fallen by approximately 14% between the two dates, solely due to changes in land use.

These aggregate values must be treated with caution, given the methodological caveats indicated above. The studies listed in the TEEB database concern location-specific estimates for a given ecosystem service at a given valuation date. The authors note, for instance, that the estimate of the average total value of ecosystem services per unit area of mangroves increased by a factor of 13 over the value based on data available in 1997, primarily as a result of newer, more complete studies in 2011. While global estimates of this kind can indeed raise awareness among economic agents of the importance of tackling biodiversity loss, the results are subject to substantial inherent uncertainty and cannot be used directly in decision making.

Chart 5: Global distribution of ecosystems and their values, based on Costanza et al. (2014)



Source: DG Trésor based on Costanza et al. (2014).

3. Challenges for economic policy

3.1 Estimating the cost of inaction remains problematic

While it remains difficult to quantify the value of ecosystem services, there are indisputable indicators of biodiversity loss, a loss that significantly reduces the total value of ecosystem services[25] and entails socio-economic costs because humans are highly dependent on those services. Greater accuracy in estimating those costs could inform public policy in favour of biodiversity. While the cost of inaction in the area of climate change has been estimated by incorporating damage functions into conventional economic models, only a small number of models currently incorporate biodiversity value.

Building on the work of Costanza et al. (2014), Kubiszewski et al. (2017) published the initial projections of future changes in the global value of ecosystem services according to four socio-economic scenarios,[26] primarily by simulating changes in land use and management. They showed that only under ambitious reform scenarios that impose severe limits on land take would it be possible to maintain or increase the global value of ecosystem services, albeit at the cost of lower GDP growth than under a business-as-usual scenario. They estimated that continuing the current trends would result in a 30% loss in the total value of ecosystem services by 2050. A policy reform scenario based on sustainable resource use would preserve the total value of ecosystem services but would reduce global GDP by 4% in 2050 compared to business-as-usual. A more ambitious approach, focusing on ecosystem restoration and preservation, would increase the value of ecosystem services by 25% but lead to GDP 9.5% lower than under business-as-usual.

(25) The cost of losing a hectare of ecosystem should be calculated as the present value of the future annual services it would have provided had it been preserved.
(26) The economic variables in the scenarios are exogenous to the model in Kubiszewski et al. (2017). The scenarios and their related values are based on Hunt et al. (2012), "Scenario Archetypes: Converging Rather Than Diverging Themes", *Sustainability* (4) p. 740-772.

These results are very preliminary and fragmentary, since they capture only some of the pressures on biodiversity (changes in land use) and are subject to the many limitations previously mentioned regarding the valuation of ecosystem services. They call for further research on evaluating the costs of inaction. In France, the Biodiversity Research Foundation in 2010 began a project on biodiversity modelling and scenarios. In 2013, the foundation published a review of French research, reporting that very few papers were based on bio-economic models,[27] and that the existing models were generally specific to a given ecosystem and region.

3.2 Applying ecosystem service assessments to the decision-making process

Approaches to valuing ecosystem services are still incomplete and fragile, but they can nevertheless provide useful insights for economic actors and for project assessments. In the same way as the first analyses of damages linked to climate change, economic analysis quantifies the importance of preventing biodiversity loss by pointing to the monetary value of services that are often "silent and invisible".[28]

The valuation of ecosystem services could also be applied at microeconomic level as part of cost-benefit analyses to compare the cost of an activity versus the value of the environmental externalities arising from that activity, thus providing a basis for evaluating, justifying and optimizing specific projects,[29] in particular public projects. For example, by comparing the costs of removing fishing nets in the Mediterranean against the resulting increase in the value of ecosystem services (due, among other things, to the restoration of grouper (*Epinephelus marginatus*) stocks, which provide a provisioning service through fishing and a cultural service through scuba diving), the French Biodiversity Agency, Ghost Med and the Mediterranean Institute of Oceanology have shown that net removal operations have a significantly positive socio-economic benefit.[30]

Given the difficulties involved in valuation, a cost-efficiency approach is sometimes preferable to a cost-benefit approach for public policy development, when biodiversity protection objectives are quantifiable and can be controlled. In other words, once quantified policy objectives have been established (e.g. zero net land take by 2050),[31] this involves identifying the instruments that will achieve those objectives at the lowest cost to society. This approach is only suitable in cases where indicators can be routinely and reliably monitored to measure progress towards achieving objectives, which is not feasible for all biodiversity issues.

Moreover, these approaches seldom take into account the risk of the irreversibility of damages to certain ecosystems (e.g. primary forests, coral reefs), or strong complementarities between certain ecosystem services. These aspects justify strong regulatory measures in addition to measures based on cost-benefit analyses. Protected areas, natural parks, Natura 2000 areas or other standards could be defined to reflect the fragility and irreversibility of certain types of ecosystems.

3.3 A coordinated response is crucial

Government action in favour of biodiversity must be coordinated at international, European, national and local levels. This is the case, for example, of the European Union's biodiversity strategy for 2030 and its Farm to Fork Strategy. These strategies provide orientations for legislation to protect land and marine areas, and also for the new Common Agricultural Policy (CAP) for 2023-2027 adopted by the European Parliament. France's national strategic plan (PSN), the country's version of the new CAP, for instance, will promote agricultural practices to achieve the objectives of the EU strategies, including 25% of land in organic agriculture; 50% reduction in pesticide use by 2030; 3% of arable land in pro-biodiversity agro-ecological infrastructure.

(27) Economic models incorporating a biophysical component (e.g. a module to take into consideration woodland distribution and the forest generation process). See FRB (2013) *Scénarios de la biodiversité: Un état des lieux des publications scientifiques françaises*.
(28) Dasgupta P. (2021), *The Economics of Biodiversity: The Dasgupta Review*, HM Treasury.
(29) Salles J.M. (2010), "Les approches économiques de la biodiversité", press conference, Paris.
(30) See e.g. Ruitton et al. (2021), "Analyse coût-bénéfice environnemental de l'enlèvement des engins de pêche perdus", Office français de la biodiversité. Ghost Med, Institut Méditerranéen d'Océanologie.
(31) Objective set out in the 2021 Climate and Resilience Act (l*oi n° 2021-1104 du 22 août 2021 portant lutte contre le dérèglement climatique et renforcement de la résilience face à ses effets*).

Given the global nature of some ecosystem services (e.g. climate change regulation), international coordination is required to optimise efforts to preserve biodiversity. Biodiversity conservation also has many co-benefits, such as contributing to achieving other Sustainable Development Goals (SDGs), including some of the social and environmental goals adopted by the United Nations in 2015 in the 2030 Agenda, such as SDG1 (No poverty) and SDG2 (Zero hunger). The 15th Conference of the Parties (COP15) to the CBD (initially scheduled for 2020 and then rescheduled in two parts, in October 2021 and April/May 2022) to be concluded in Kunming is expected to see the adoption of the new post-2020 Global Biodiversity Framework. Negotiations are underway to define targets for biodiversity protection and the resources needed to achieve them.

At this point, however, none of the 20 global targets set for the period 2011-2020 in the context of the CBD, the so-called Aichi Biodiversity Targets, have been achieved in full, though progress has been made on six. In light of this, CBD COP15 could conclude with the adoption of a new Global Biodiversity Framework that includes a realistic number of quantifiable and actionable targets. Focuses include funding from all sources, phasing out of harmful subsidies and quantified nature protection objectives. These international ambitions will then have to be transposed into national biodiversity strategies and action plans. In France, the third national biodiversity strategy is currently under development.[32]

(32) For additional information on France's Third National Biodiversity Strategy, which is currently under development: 3ème stratégie nationale pour la biodiversité | Biodiversité (biodiversite.gouv.fr)

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