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Completing national accounts to see the wood for the trees

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Preserving natural capital is a major challenge in the fight against global warming. To effectively guide public action, decision-makers must be provided with reliable information on the environmental consequences of economic activities. Despite recent progress, important gaps remain. Using forests as a case study, this Note pursues two objectives: first, to propose a method for valuing the various services provided by forests within national accounts; and second, to inform public policy by making explicit the costs and benefits of forest-related actions that have so far remained largely implicit. Although the approach is intended to be extended to other ecosystems (such as agricultural land and wetlands) and resources (including water and biodiversity), forests constitute a particularly relevant case given their central role in national carbon neutrality strategies and the wide range of services they provide.

Forests are significant carbon sinks, absorbing around 10% of French greenhouse gas emissions. Maintaining their sequestration capacity—and enhancing that of wood products—is therefore essential. Yet the capacity of these carbon sinks has halved over the past decade. This raises important policy questions: should priority be given to planting trees and reducing timber harvests? Or should harvesting be increased while subsidising wood energy or encouraging the use of wood in long-lived products? To inform such trade-offs, valuing environmental capital in monetary terms is essential. Doing so not only improves our understanding of the macroeconomic value of forests but can also provide meaningful guidance for public policy. Using an original method to value carbon sequestration services, this Note proposes a new estimate of the value added by the forestry and timber sector, amounting to €11.2 billion in 2018—3.5 times its market value. Moreover, while the market value of the forestry sector in mainland France is estimated at €139 billion, the social value of the carbon stored in forest biomass is estimated at around €380 billion. This is complemented by an estimated €270 billion corresponding to the net present value of future benefits associated with other ecosystem services, including hydrological regulation, biodiversity conservation, and recreational amenities.

Taking into account the non-permanent nature of carbon storage in forests, the findings of this Note shed new light on the carbon footprint of policies promoting the use of wood for energy. Although wood energy currently accounts for the majority of public support to the sector, its climate impact is at best marginally positive and, moreover, highly uncertain. We therefore recommend prioritising the cascading use of wood—giving preference to long-lived applications such as construction and furniture—and integrating the wood sector into CO_2 quota markets in order to internalise the social costs and benefits of forest management.

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Introduction

The urgent need for large-scale climate action is now well established, as highlighted in the report by Jean Pisani-Ferry and Selma Mahfouz[1]. This requires providing decision-makers and economic agents with informed facts on these issues. National accounting aggregates cannot meet this need because they do not take environmental damages into account and do not yet fully capture the costs and benefits of environmental protection measures. This prevents incorporating natural capital into economic and financial decision-making: without a common metric, how can we integrate the benefits of investing in natural assets and shed light on the trade-offs and interactions between investments in different assets?

This shortcoming, which has been identified for years, led to the creation of environmental economic accounts in the early 1990s, governed by international standards (UN and Eurostat). Much progress has already been made, particularly in the physical measurement of physical stocks and flows, for example through the national natural heritage inventory or greenhouse gas emissions accounts. This progress is essential for quantifying depletion of natural assets and assessing the risks to future natural heritage. The programme launched in 2013 on the French assessment of ecosystems and ecosystem services (Efese) also represents a remarkable step forward. Finally, the publication in 2024 of carbon accounts with a dual approach based on production (carbon emissions) and final demand (carbon footprint), accompanied by an assessment of adjusted net savings, is essential[2].

However, efforts must continue to better value the environment within national accounts. Forests provide an interesting case study as they provide many services: wood production, CO2 capture and sequestration from the atmosphere, flood control, preservation of biodiversity, etc. However, only so-called market services are currently valued in national accounts: forestry (the activity of maintaining forests for commercial exploitation) accounted for €3.9 billion of gross value added in 2022[3], i.e. 0.15% of GDP. However, this estimate remains incomplete as it does not take into account the social and economic value associated with the many other services provided.

Based on the case of French forests, which have been damaged by the effects of climate change, this Note develops an original method for measuring the value of non-market forest services – particularly carbon sequestration – within an enhanced national accounting framework. This work remains crucial for informing the public debate and guiding climate policy choices. Its findings could be used to evaluate policy measures based on the capacity of forests to remove CO_2 from the atmosphere, such as reforestation plans, and policies to support the timber industry – including wood energy – notably implemented as part of the France Relance plan.

Forests: an underestimated ally in climate policy

Forests have expanded significantly since the mid-19th century. They have more than doubled in France since 1850 and now cover 25 million hectares, divided between mainland France (17.5 million hectares), where they account for around 31% of the territory, and overseas territories, where they cover 97% of French Guiana and 42% of other regions[4]. Metropolitan France has the fourth largest forested area in Europe[5].

Climate change is causing a slowdown in French forests' carbon sink

Forests play a central role in climate regulation by capturing and storing atmospheric CO_2, mainly in the form of biomass (see **Box 1**). In metropolitan France[6], living and dead forest trees, litter and organic matter in the soil's top 30 centimetres represent a stock of 2.8 billion tonnes of carbon in 2023[7].This carbon stock is still growing: between 2014 and 2022, forests absorbed on average 39 million tonnes of CO_2 per year. This is why forests are referred to as «carbon sinks». They play an important role in achieving carbon neutrality: to date, forests are the main driver of large-scale CO_2 sequestration in France[8]. Without their contribution, net greenhouse gas (GHG) emissions would be, on average, 10% higher each year[9].

[*] **The authors would like to thank the CAE's permanent team for their help on this Note, in particular Claudine Desrieux, scientific advisor, Lucie Huang, policy analyst, and Mariane Modena, research assistant.**

[1] Pisani-Ferry J., Mahfouz S. (2022) : « L'action climatique : un enjeu macroéconomique », France Stratégie, *Note d'Analyse* n° 114.

[2] Larrieu S., Roux S. (2024) : « Peut-on prendre en compte le climat dans les comptes nationaux ? », *Insee Analyses* n°98.

[3] CGDD (2025) : Panorama des comptes de la forêt métropolitaine de 2007 à 2022, Datalab, septembre (à paraître).

[4] Institut national de l'information géographique et forestière (2024) : « Inventaire forestier national. Mémento. Édition 2024 ».

[5] Ministère de l'Agriculture et de la Souveraineté alimentaire (2025) : « La forêt française en chiffres », Info+.

[6] Overseas forests are not included in forest satellite accounts. Indeed, they are often less consistently documented, rendering their analysis more difficult. Furthermore, the specific characteristics of overseas forests, which are often tropical and dense, hinder their direct economic exploitation, whether due to their remoteness or stricter regulations governing their exploitation (this is the case, for example, of the Amazonian park in French Guiana). This is why this Note focuses solely on metropolitan France.

[7] IGN (2023) : « Inventaire forestier national. Mémento Édition 2023 », Institut national de l'information géographique et forestière.

[8] Forests represent the bulk of France's terrestrial carbon sink. Grasslands and wood products also contribute to capturing CO2, but to a lesser extent, while other types of land use are, on the whole, net carbon emitters. Service de la donnée et des études statistiques (2024) : Chiffres clés du climat – France, Europe et Monde – Édition 2024, ministère de la Transition écologique.

[9] Baude, M., Larrieu S. (2024) : « Emissions de gaz à effet de serre et empreinte carbone de la France en 2023 », *Insee Première* n°2023.

Box 1. Carbon sequestration mechanisms in forests

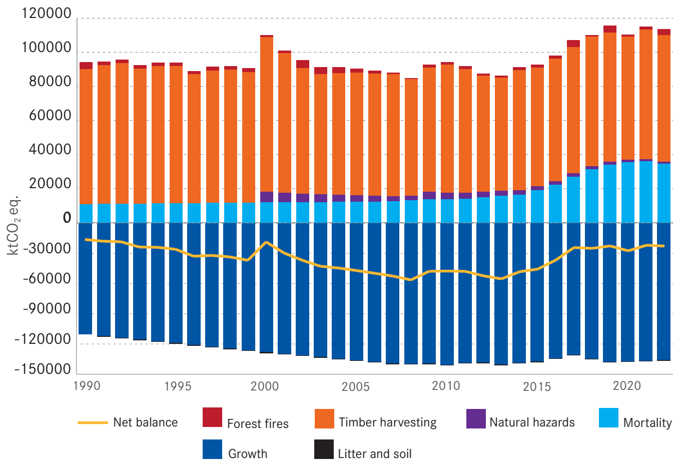
Through photosynthesis, trees remove carbon from the atmosphere and store it in the form of biomass (trunks, branches, leaves, roots). Some of this carbon is then transferred to the soil via litter, dead roots and exudates, contributing to carbon storage in soil organic matter.

The rate at which carbon is stored in forest ecosystems depends on many factors: the type of soil and the microorganisms it harbours, the climate (temperature, rainfall, humidity), which influences both tree growth and organic matter decomposition, tree species (coniferous, deciduous), tree age and forest structure (an old, dense forest generally generates more litter than a young and/ or sparse forest). Management practices, such as rotation periods and limiting clear-cutting or tillage, can also alter the forest's capacity to store carbon by affecting both biomass growth dynamics and the preservation of soil stocks.

The carbon stored in a tree remains there when it is transformed into a wood product. However, when the tree dies and decomposes, the stored carbon is gradually released into the atmosphere. When the tree is used as wood energy, this carbon is emitted immediately during combustion.

However, the effects of climate change have damaged forests' health and weakened their role as carbon sinks over the last decade. Although forests still absorb more carbon than they emit, this capacity has halved in ten years[10]. This decline can be explained in particular by the dual impact of climate change. On the one hand, the increase in hazards (droughts, storms) and health crises, such as bark beetle infestations, has doubled tree mortality between the periods 2005-2013 and 2014-2022. On the other hand, average tree growth slowed by 4% over the same period, largely due to water stress. At the same time, timber harvest[11] has not decreased; it has even increased slightly (see **Figure 1**).

Figure 1. Evolution of forest carbon sink components in mainland France



Interpretation: Negative figures represent carbon absorption. After rising sharply until the early 2000s, the net carbon sink balance has declined significantly since then, reaching -21,000 kt CO2 eq. in 2023.

Source: Citepa.

The situation is sometimes more alarming abroad: in Germany, forests became a net source of CO_2 emissions between 2017 and 2022[12]. In France, in some regions such as the north-east, forests are becoming net sources of emissions, mortality and harvesting exceeding growth. In 2023, the French Academy of Sciences warned against the deterioration of French forests, which could lose their capacity to absorb CO_2 in the medium term[13], even though forest areas keep increasing.

Prospective models show that climate change is likely to deeply alter forest productivity, available resources and the economic balance of forestry (see Focus No. 119). The predicted increase in extreme weather events (storms, droughts, fires) is likely to cause massive releases of carbon into the atmosphere. This is referred to as the risk of impermanence of carbon storage[14]. However, these events, which are unlikely but have a significant impact, remain little integrated into climate policies, which leads to an over-estimation of the future capacity of forests to sequester carbon. As a result, having failed to anticipate the collapse of the forest carbon sink, France did not meet the net emissions target set by the National Low-Carbon Strategy (SNBC 2) for 2019-2023[15]. The draft National Low-Carbon Strategy for 2030 (SNBC 3) acknowledges this fact and marks a change in approach: it now sets gross emission targets, i.e. excluding sequestration

[10] Source : Observatoire des forêts françaises.

[11] The term «logging» refers to the volume of timber extracted voluntarily as part of planned felling operations. It differs from «harvest», which also includes timber from sanitary felling, salvage felling or exceptional climatic events. Harvesting therefore corresponds to the total volume of timber actually removed from the forest, regardless of its origin.

[12] Bundesministerium für Landwirtschaft, Ernährung und Heimat (2024), Der Wald in Deutschland - ausgewählte Ergebnisse der vierten Bundeswaldinventur.

[13] Rapport du Comité des sciences de l'environnement de l'Académie des sciences et points de vue d'Académiciens de l'Académie d'agriculture de France (2023) : « Les forêts françaises face au changement climatique ».

[14] Bastit F., Riviere M., Lobianco A. et al. (2024) : « Prospective impacts of windstorm risk on carbon sinks and the forestry sector: an integrated assessment with Monte-Carlo simulations », *Environmental Research Letters*, vol. 19.

[15] If the forest sink had followed the planned trajectory, the SNBC 2 carbon budget would probably have been met, even though some sectors exceeded their limits while others compensated for it.

linked to land use and forestry, reflecting the growing uncertainties about the future contribution of the forest sink to carbon neutrality.

Finding 1. French forests capture on average 10% of national greenhouse gas emissions. However, they are currently experiencing a significant crisis in terms of mortality and growth, their carbon sink having halved in ten years. The future contribution of forests to achieving national net CO_2 emissions targets now appears uncertain.

Which levers to strengthen the climate role of forests and the timber industry?

Public policy faces a sensitive trade-off. On the one hand, increased carbon sequestration in forests argues for reducing harvesting and increasing planting. On the other hand, promoting the use of wood which allows carbon to be stored in wood products and reduces emissions by substituting fossil fuels or materials, implies an increase in harvesting, at the risk of degrading the forest sink in situ. SNBC 2 thus aimed to increase harvesting while redirecting uses towards products that reduce emissions through the substitution effect[16].

Maintaining the carbon sink in situ

The government supports the forest carbon sink through various public policies. For instance, the forest section of the French low-carbon label enables forestry projects (reforestation, sustainable management) leaders to receive funding through the sale of carbon credits.

Above all, the French major reforestation plan launched in 2020[17] aims to protect the resilience of forests by planting 45,000 hectares designed to capture an additional 150,000 tonnes of CO_2 per year. This plan now takes the form of a forest renewal aid scheme[18]. However, a Terra Nova publication of April 2025[19] warns about the massive funding of clear-cutting by these policies[20], which consist of cutting down all the trees on a plot of land before replanting on a large scale. While these interventions may sometimes be justified locally[21], they threaten biodiversity and ecosystem resilience, and do not always offer a positive carbon balance in the short or medium term, until the young forest captures more carbon than the one it replaced.

Substitution effects

Assessing the overall impact of forest on GHG emissions is not only about observing changes in the carbon sink in situ, it is as well about downstream uses of wood. This latter can indeed replace all sort of materials and energy sources that are more CO_2 intensive: wood energy can replace fossil fuels, while the use of wood products in construction, insulation, packaging and furniture reduces demand for more highly carbon-intensive materials such as concrete, steel and plastics. For example, replacing concrete by wood in structural work can reduce emissions by up to 60%. This is solely due to the substitution effect of materials, i.e. without even taking into account the future carbon sequestration associated with the regrowth of harvested wood[22]. The France 2030 plan as well as the new environmental regulations for buildings support this logic by promoting carbon storage in wood products. However, the main public support measures remain focused on wood energy: the Fonds Chaleur, MaPrimeRénov', energy saving certificates (Certificats d'Economie d'Energie, CEE) and Éco-PTZ promote the purchase of wood-fired domestic heating equipment[23].This sector is often presented as carbon neutral, on the grounds that the CO_2 emitted during combustion is offset by tree regrowth. However, this neutrality is based on the assumption of rapid forest regeneration, which does not always match reality. In fact, if we consider only direct emissions, wood energy emits more CO_2 than natural gas (at least 340 gCO_2 /kWh for wood compared to 200 gCO_2 /kWh for gas)[24]. The climate benefit therefore depends on a carbon recapture cycle that can span several decades and becomes uncertain in the context of droughts, diseases and storms. Long-term uses of wood that enable sustainable storage or significant material substitutions (particularly as a replacement for steel or concrete) appear, at first sight, to be more robust in terms of climate neutrality than the use of wood for energy.

The challenge of choosing uses is even more acute in the case of crisis wood, resulting from climatic or health hazards. In these situations, harvesting is often unavoidable: the question is no longer whether to harvest, but what to use it for. It then becomes essential to quickly redirect these volumes towards the most relevant uses, favouring those that guarantee

[16] Grimault J., Tronquet C., Bellassen V., Bonvillain T., Foucherot C. (2022) : « Puits de carbone : l'ambition de la France est-elle réaliste ? Analyse de la Stratégie nationale bas-carbone 2 », I4CE.

[17] France Relance (2020) : « Le renouvellement des forêts françaises »

[18] See the forest renewal aid scheme.

[19] Terra Nova (2025) : « Pour un nouveau paradigme forestier ».

[20] See Canopée (2024) : « Plan de renouvellement des forêts, un risque majeur de financer des coupes rases injustifiées ».

[21] According to the official method for restoring forest stands, plots with 20% mortality may be eligible for clear-cutting. Source : Gleizes O. (2025) : « Méthode de reconstitution de peuplements forestiers dégradés (version 3) », CNPF, 121 p.

[22] Carbone4 (2025) : « Sauver le climat avec nos forêts ? La construction touche du bois ! ».

[23] After an initial 30% reduction in subsidies for the installation of wood-burning heating appliances applied on 1 April 2024, the energy renovation subsidy scale was revised again on 1 January 2025: subsidies for domestic wood heating were reduced.

[24] IPCC (2006) : 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2: Energy, Chapter 2: Stationary Combustion.

long-term storage or high substitution effects. This requires dynamic and forward-looking management of the forest-wood sector, based on anticipation and better coordination of outlets to optimise the use of harvested wood.

> Recommendation 1. To preserve ecosystems resilience and the carbon sequestration capacity of forests, stop subsidising clear-cutting and prioritise long-term uses of wood (construction, furniture) and promote cascading uses where wood energy comes second, after wood construction.

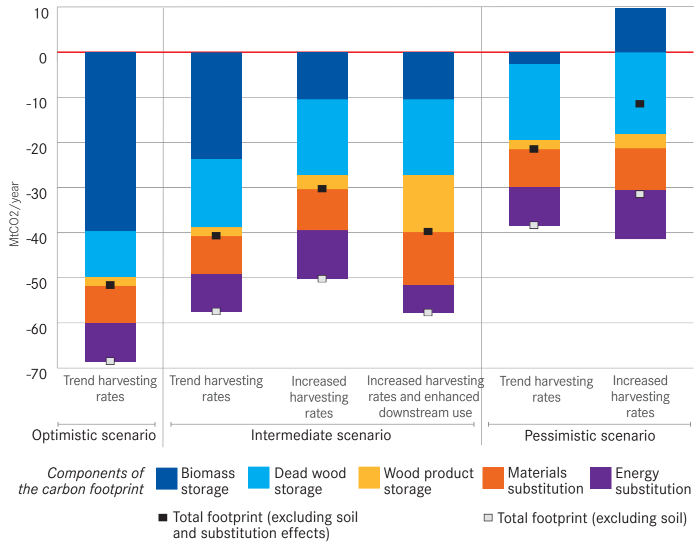
Forests, emissions and downstream uses: what impact on the total sink?

What is the overall carbon footprint of the forestry and timber industry? Various forward-looking scenarios have been established jointly by the IGN and the FCBA (Forêt cellulose bois-construction ameublement) for 2024[25] (**Figure 2**). In an optimistic climate scenario, where the current forest crisis is only temporary, the annual carbon footprint could return to a high level thanks to the forest sink. In the intermediate climate scenario, the intensity of the forest sink depends on the harvesting levels. However, the total carbon balance could be improved by a strong focus on the «materials» sector and an increase in domestic recycling. If the crisis in forest mortality and growth persists (third scenario), the forest carbon sink will shrink significantly, becoming even negative if the harvest rate increases by around 20% from its current level.

In all scenarios, an increase in the harvesting rate worsens the average carbon balance, even when substitution effects are taken into account, except in the case of a net shift in use towards long-life wood products rather than wood energy. However, this would require demand from the sectors concerned to increase sufficiently to absorb this increase in harvests. As highlighted in an I4CE report[26], such an increase seems unrealistic without the introduction of appropriate incentives. Finally, it should be noted that the reforestation plan launched in 2020 will result in a slight improvement in the carbon sink by 2050 in these scenarios, but its positive effects will only become truly visible beyond that date.

> Finding 2. If the current crisis facing forests worsens and timber harvesting continues to increase, forests could become carbon emitters by 2050. However, shifting timber harvesting towards long-life products rather than wood energy would offset the impact of increased harvesting rates on the carbon balance.

Figure 2. Distribution of the average annual carbon balance between 2020 and 2050 of the timber industry



Reading: In the pessimistic climate scenario with increased harvesting rates, wood products store approximately 18 Mt of CO2 per year, while biomass emits approximately 10 Mt of CO2 per year. The total amount of carbon stored above ground, taking into account substitution effects, is 11 Mt of CO2 per year.

Source: Study report, IGN-FCBA, 2024.

These scenarios clearly illustrate the interdependence between the climate crisis, the state of the forest sink, harvesting levels and wood use. However, simply comparing physical indicators (expressed in tonnes of carbon) does not provide a precise answer to the central question: how can a sustainable balance be found between forest sequestration and increased wood use? It also does not allow for the identification of the economic costs associated with the various strategies.

To inform these trade-offs, it is essential to use consistent carbon accounting that applies the same valuation principles to all carbon sources and sinks, while taking into account the non-permanent nature of this storage.

Such an approach contributes as well to establishing a shared macroeconomic diagnosis by making the real contribution of forest ecosystem services, particularly carbon sequestration, visible in public accounts. It is part of a broader approach to valuing ecological functions, in line with the recommendations of the Dasgupta report[27] and the ongoing discussions in France on reforming wealth indicators.

[25] IGN-FCBA (2024) : « Projections des disponibilités en bois et des stocks et flux de carbone du secteur forestier français », Rapport d'étude.

[26] Grimault J., Tronquet C., Bellassen V., Bonvillain T., Foucherot C. (2022) : « Puits de carbone : l'ambition de la France est-elle réaliste ? Analyse de la Stratégie Nationale Bas-Carbone 2 », I4CE.

[27] P. Dasgupta (2021) : The Economics of Biodiversity : The Dasgupta Review, HM Treasury.

Integrating forest ecosystem services into national accounts

National accounts currently consider the timber industry solely from a market-based perspective. Given the complexity of the trade-offs involved and the tensions between economic and ecological objectives, it is necessary to update the sector's statistical indicators. Environmental satellite accounts applied to forests stand as a valuable tool in this regard: they are currently the only initiative linking environmental accounting and economic accounting. However, their scope remains limited[28]. Certain major positive externalities, such as biodiversity, water regulation and air quality, are not taken into account. Carbon sequestration is measured in physical quantities, but is not valued economically. In these accounts, as in the INSEE's asset accounts, the value of forests is thus reduced to their market value, linked to forestry and logging.

Data collection to be further developed

An integrated approach to the forest-wood sector, encompassing both forest resources and wood uses, requires better measurement of all carbon stocks and flows at each stage, from the forest to the finished product. However, existing data do not provide such a comprehensive and accurate overview. For example, wood stocks outside production forests (particularly in highly protected or inaccessible mountain forests) are only estimated on the basis of data on average surface areas and volumes per hectare. It is not known precisely, even though these trees also store carbon and provide other ecosystem services. Similarly, there is little data available on biomass from wooded areas (which do not meet the definition of forest) or other land with trees, such as agricultural land or clear-cut areas. Finally, although forests account for a significant share of the land area in overseas territories, data is sporadic and difficult to collect. This is particularly damaging given that new uses of forest biomass are likely to give rise to significant tensions. Some projections estimate that 30% of available biomass will be used for sustainable aviation fuels by 2050.[29]

Data on the timber industry exist but remain incomplete, particularly with regard to carbon sequestration capacity according to the different uses of harvested timber. The Interprofessional Technical Centre for Studies on Air Pollution (Citepa), which is responsible for the national emissions inventory, applies the methodologies of the Intergovernmental Panel on Climate Change (IPCC) to estimate the carbon sink associated with wood products, but these methods remain approximate. They are based on average storage times by category of use (construction, paper, furniture, etc.), without taking into account the subtle differences between species, processing methods or actual usage. Furthermore, the diversity of methods and units of measurement, as well as the lack of detailed monitoring of wood flows — particularly for imported products and those exported after processing — limit the accuracy of the assessments.

The use of wood energy is also inaccurately measured despite its economic and environmental importance. Estimates are based mainly on survey data that is not specific to wood energy (housing survey declarations) and numerous assumptions. More generally, the provision of supplies for heating systems (collective, industrial and tertiary) are not easily identifiable.

It is therefore necessary to improve the collection and linkage of data on forests and wood use in order to accurately determine wood and carbon stocks and flows throughout the sector. A commission similar to those that exist in the industrial and agricultural sectors (National Industry Council and Agricultural Accounts Commission) could improve the traceability and consistency of this information.

Recommendation 2. Improve the collection and linkage of data on forests and timber use in order to obtain a comprehensive and accurate overview of timber and carbon stocks throughout the sector. Set up an Economic and Forestry Accounts Commission, a forum for dialogue between producers and users.

How to value forest carbon sinks?

The next step is to establish accounts that assess the sector's actual production, including its impact on carbon emissions. This involves valuing the carbon sink, which is currently only measured in physical volumes in Citepa inventories. Two methodological difficulties arise. The first, which is a classic issue, concerns the choice of price to be used to value a tonne of CO_2 avoided. The second, which is specific to this case, relates to taking into account the non-permanent nature of CO_2 storage in forests.

How to value a tonne of carbon that remains in the atmosphere?

By considering only market value, national accounts do not accurately measure the production of polluting goods, since their direct value to users, reflected in their price, does not correspond to their value to society, which takes into account the cost of the damage resulting from associated pollution. Similarly, the benefits of ecosystem services, such as carbon sequestration, are not added to the sector's market output.

[28] Delacote P., Desrieux C., Huang L., Modena M., Niedzwiedz A. (2025) : « Face à l'incertitude climatique, quels outils pour suivre et anticiper l'évolution des forêts ? », *Focus du CAE* n° 119.

[29] Becken S., Mackey B., Lee, D. S. (2023) : « Implications of preferential access to land and clean energy for Sustainable Aviation Fuels », *Science of The Total Environement*, vol. 886.

Box 2 outlines the different approaches to measuring these climate costs and benefits.

In this Note, we rely on the social cost of carbon (SCC), i.e. €185 per tonne of CO_2 avoided.[30] This value represents a deliberately conservative estimate of the social cost of carbon.[31] This choice helps to inform public debate without assuming that climate policy, i.e. the reduction target and the instruments implemented, is optimal. It also allows trade-offs between carbon sequestration and the commercial use of wood to be established on a consistent basis, by comparing two marginal willingness-to-pay values: one for a tonne of CO_2 avoided, the other for the wood resource. In addition, we use an annual growth rate of 2% for the social cost of carbon, which results from the global temperature increase of +1.5°C to approximately +3°C in baseline scenarios by 2100, and very long-term global GDP growth, which could trend towards 1%.[32]

Box 2: Different carbon prices

There are three main approaches to carbon pricing:

1. The cost-based approach assesses the price of carbon as the present value of the damage avoided by society (present and future) through a reduction in emissions. This damage includes agricultural losses, climate hazards (heat waves, floods), damage to ecosystems and health impacts. This price, known as the social cost of carbon (SCC), corresponds to the marginal willingness to pay to reduce emissions.

2. The cost-effectiveness approach is based on a climate target that must not be exceeded in the long term – such as an annual carbon budget or a maximum GHG concentration – and seeks the most effective mitigation pathway to achieve it, i.e. the least costly. The carbon price then corresponds to the marginal abatement cost required to remain within this limit. This is referred to as the Value for Climate Action (VAC): only measures whose abatement cost is lower than this value should be selected.

3. The effective carbon price approach is based on actual observed prices, whether these are carbon taxes, emission allowances traded on carbon markets or other economic instruments put in place to compensate for the absence of a natural market price for CO_2 emissions.

In theory, the three approaches coincide if climate policy is optimal. In this case, the effective carbon price (3rd approach) is equal to the cost of the damage caused by the emission of one tonne of CO_2 (1st approach) and the cost of avoiding this emission (2nd approach). In practice, the implementation of French climate policies is based on the second approach.

How should we assess the value of carbon sequestration provided by forests?

The SCC measures the damage associated with one tonne of CO_2 considered to be permanently present in the atmosphere. However, forest sequestration does not offer this permanence. On the one hand, if forest harvesting increases as predicted in several scenarios (see **Figure 2**), part of the forest carbon stock will sooner or later be exploited and destroyed. On the other hand, extreme weather events, such as storms, play an unpredictable role in harvesting, calling into question the stability of carbon storage. Thus, in 2022, 38% of young trees planted did not survive.[33] Added to this is the risk of non- additionality in the long term: the artificial replacement of decaying biomass may result in temporary climate gains, but this does not necessarily lead to a better long-term carbon balance compared to natural regeneration. Therefore, temporary and uncertain storage cannot be valued at the same level as SCC, which justifies the application of a reduction factor.

Based on the work of Groom and Venmans,[34] which focuses on the valuation of carbon offset projects in forests, we define a «social value of forest sequestration» (SVFS) applicable to the valuation of carbon sinks in national inventories. The SVFS makes it possible to integrate the temporal dynamics of carbon storage in forests. Thanks to tree regrowth, one tonne of carbon extracted does not permanently reduce the carbon sink, even if it takes time to be replenished. Symmetrically, an additional tonne stored today is not stored forever: this storage is exposed to risks of non-permanence, and this tonne is not necessarily additional in the long term, due to the natural dynamics of forest stock evolution.

Based on a simplified model calibrated on projections of wood availability and carbon stocks and flows in the French forestry sector,[35] the SVFS is approximately 0.4 × SCC for an intermediary climate scenario with a trend rate of logging. This coefficient of 0.4 reflects the non-permanence of forest storage. Its value varies with the degree of impermanence: if carbon remained sequestered forever, the SVFS would be equal to the SCC and the coefficient would be equal to 1; conversely, if extreme climate events or harvesting increased to such an extent that any new tonne sequestered was immediately released, then the coefficient would be equal to 0.

[30] Rennert K. et al. (2022) : « Comprehensive evidence implies a higher social cost of CO2 », *Nature*, vol. 610.

[31] The 2023 report by the US Environmental Protection Agency suggests a cost range of $140 to $420 per tonne of CO2. More recently, Bilal and Känzig suggest a much higher figure of $1,400 per tonne of CO2. Bilal A. et Känzig D.R. (2024) : « The macroeconomic impact of climate change : Global vs. local temperature », *NBER Working paper series*, n° w32450.

[32] Bureau D., Henriet F., Huang L. (2025) : « Comment intégrer la valeur véritable de la forêt dans la comptabilité nationale ? », *Focus du CAE* n° 120.

[33] Département de la santé des forêts (2023) : « Bilan de la réussite des plantations forestières de l'année 2022 », ministère de l'Agriculture et de la Souveraineté alimentaire.

[34] Groom B., Venmans F. (2023) : « The social value of offsets », *Nature*, vol. 619.

[35] IGN-FCBA (2024) : « Projections des disponibilités en bois et des stocks et flux de carbone du secteur forestier français », Rapport d'étude.

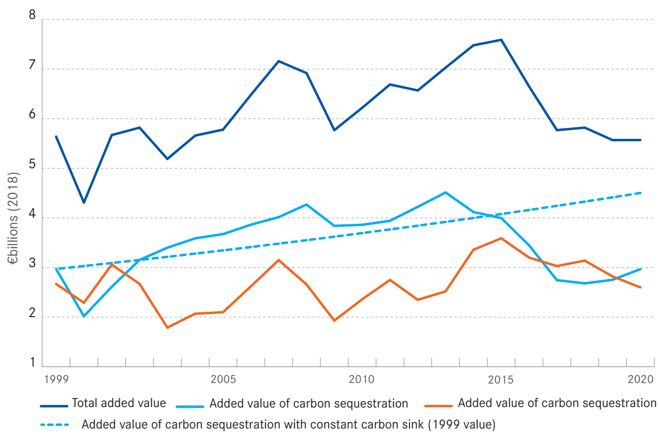
Recommendation 3. Value each tonne of CO_2 captured in forests at the social cost of carbon, to which a coefficient of 0.4 is applied to take into account the specific characteristics of forest carbon sinks. Continue work to refine the parameters of this estimate.

An adjusted added value for forests of €5.6 billion in 2020

This SVFS therefore makes it possible to estimate the adjusted added value of the forest-wood sector, incorporating the value of the sequestration service (**Figure 3**). The value of carbon sequestration corresponds to emissions absorbed by the LULUCF sector (land use, land-use change and forestry) as measured by Citepa in national inventories, to which the SVFS price is applied.

To complete this exercise, the added value of carbon stored in wood products would need to be added, but this contribution is generally minor.

Figure 3: Evolution of added value in the forestry and wood sector



Reading: In 2020, the added value of the forestry and wood sector is €2.6 billion, while the added value linked to the carbon sequestration service of forests is €3 billion. The value of the latter service would have been €4.5 billion if the carbon sink of forests had been similar to its 1999 state.

Sources: For market value: CGDD (2025); for carbon sink: Chiffres clés du climat and authors' calculations.

The value of carbon sequestration services is on average higher than forests' market-based added value, a finding that is all the more striking given that it is based on a relatively low price. This value also shows a very different temporal dynamic: while market-based added value stagnated until the mid-2010s, the value of carbon sequestration services grew strongly, driving up the total value of this sector. Its subsequent evolution reflects the slowdown in the carbon sink. However, even though the carbon sink has halved in ten years, the corresponding added value has not fallen by the same proportion. This can be explained by the increase in the social value of the sink, reflected in the evolution of the SCC price.[36] As the implicit price of carbon rises, the value lost in the case of non- permanence automatically increases, making the sustainability of forest carbon sinks a key issue for the effectiveness of climate policies. This means that policies aiming at strengthening the permanence of carbon storage through more resilient forest management practices, protection against climate hazards, or long-term monitoring mechanisms, are becoming strategic.

Finding 3. The socio-economic added value of carbon sinks is comparable in magnitude to the added value of forestry, as measured in national accounts (€3 billion in 2018).

Ignoring the value associated with the carbon sink service provided by forests, which is at least as important as the market-based added value of forestry, inevitably leads to a biased assessment, detrimental to the carbon sink, to favouring market-based or less sustainable alternative management and accounting methods, and to delaying the implementation of the economic incentives needed to restore the carbon sink.

Integration of other ecosystem services: a plurality of methods and values

Forests are multifunctional by nature: beyond timber production and carbon sequestration, they provide a wide range of ecosystem services, such as biodiversity conservation, flood control, air quality regulation and recreational services. This multitude of services can complicate analyses because the objectives of biodiversity conservation, for example, do not always coincide with those of reducing CO2 emissions. Taking into account the positive externalities of forests requires the use of complementary indicators, both physical (based in particular on indicators of sustainable management of French forests)[37] and monetary.

However, France is lagging when it comes to ecosystem accounting. The United Kingdom, for example, has adopted an annual accounting system for its natural resources that complies with the guidelines of the UN's economic and environmental accounting system. In 2021, the total annual value of services provided by forest ecosystems amounted to £10.4 billion (2022 prices).[38] This value includes the provision

[36] Strictly speaking, the SCC should exclude transitional damage from climate change affecting market activity, as these losses are already accounted for in the added value of the various economic sectors. However, we have chosen to ignore this double counting issue, as excluding these losses would have a negligible effect on the SCC assessment: on the one hand, transitional damage on French soil represents only a small proportion of overall climate damage and, on the other hand, there is a time lag between the emission of a tonne of carbon and its materialisation in physical and monetary damage.

[37] Indicateurs de gestion durable des forêts françaises.

[38] Office for National Statistics (2024) : « Woodland natural capital accounts, UK : 2024 », *Statistical Bulletin*.

of wood, carbon sequestration, recreational services, and the regulation of air quality, urban heat and noise.

However, the production of such values is subject to numerous criticisms and methodological difficulties. As Tromeur and Pommeret point out with regard to biodiversity accounts,[39] the first difficulty lies in the diversity of the services provided by ecosystems and, therefore, in the plurality of values they embody. The question of which valuation method to choose and what "price" to assign to the service being valued is another major challenge in any accounting exercise, as illustrated by the example of recreational services in forests (see **Box 3**). It appears that different environmental valuation methods can lead to very divergent figures, which is an obstacle to the development of public policies based on these data.

Recommendation 4. Pursue work to isolate the value of the recreational service specific to forests and avoid double counting with other types of services.

A valuation that informs public forestry policy

Key results: from production accounts to asset accounts

One of the main contributions of this Note is to establish the broader added value of the forestry and timber sector. Taking into account its market value, the value linked to carbon sequestration services as calculated above, and the values of other ecosystem services as calculated by the Joint Research Centre,[40] we find a value of €11.2 billion in 2018 (**Figure 4**).

The market production of forestry (supply service) thus represents only about one-third of the total added value when other services are taken into account. This breakdown highlights the importance of the regulatory and support services provided by forests, which account for 40% of the total value of the sector.

Box 3. Accounting for recreational services in forests

The monetary valuation of recreational services, excluding tourism, is based mainly on values of usage, i.e. observed prices and costs. Among these methods, those relying on travel cost are based on an analysis of the distances travelled to access a recreational site. It allows for an estimation of a transport cost, calculated on the basis of the journey time to travel to the place of visit and the number of visits. This cost can be used in two ways: either to estimate the price that the consumer is willing to pay for an additional visit, or to construct a demand function and estimate the average individual benefit provided by a visit. The first approach is more in line with the general principles of national accounting.

One of the advantages of the travel cost method is that it is based on observations of actual behaviour rather than on assumptions or statements made in surveys. However, it has one limitation: it can lead to an overestimation of the ecosystem's contribution to recreational services, insofar as forest visits are often included in multi-purpose trips (family visits, tourism, etc.).

The European Commission's Joint Research Centre applies this method by limiting the analysis to journeys of less than 4 km. The aim is to limit the overestimation of the economic value of recreational services by excluding multifunctional trips, which are difficult to attribute exclusively to recreational visits. The underlying assumption is that the probability of a visit to the forest being part of a multifunctional trip decreases with the distance travelled. This approach thus makes it possible to estimate a marginal value for the recreational service, corresponding to individuals' willingness to pay for an additional visit to the forest. However, strict application of this threshold may introduce bias: some longer journeys are specifically motivated by a visit to the forest and should be taken into account, while shorter journeys may also be motivated by other factors. Using this approach, the value of recreational services in French forests was estimated at €3.5 billion in 2012, similar to the market value of forestry and logging.

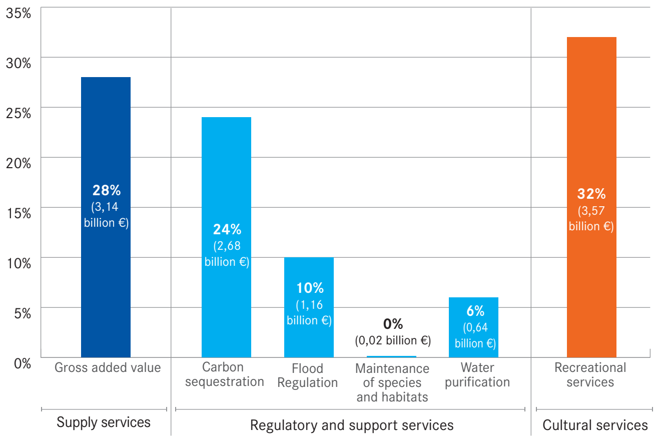
The Efese report also adopts the travel cost method, but seeks to assess the average individual surplus provided by a visit, without imposing a distance threshold. These methodological choices lead to significantly higher figures, ranging from €13 billion to €45 billion in 2018, depending on the assumptions made regarding the opportunity cost of time spent on these trips.

When it comes to enriching national accounts, it is essential to ensure that multifunctional trips are not accounted for twice, for instance, with services that would already be counted under tourism. Furthermore, it is important that the price used reflects the marginal willingness to pay for increased use of the service. Under these conditions, the Joint Research Centre's estimate appears to be a more prudent reference for assessing the annual output of the forestry and wood sector.

[39] Tromeur É., Pommeret A. (2024) : « Mettre en valeur(s) la biodiversité : état des lieux et perspectives », France Stratégie, *Note d'Analyse* n° 147.

[40] The JRC's method of accounting for recreational services avoids double counting (see Box 3). However, it has its limitations in the assessment of other types of services, for which the values for France are extrapolated from data from other European Union countries.

Figure 4: Breakdown of the added value of French forests in 2018



Note: For recreation and water purification services, data from 2012 was used. Subsequent data available is extrapolated from 2012 data. The value of habitat and species maintenance services is underestimated due to the low proportion of good-quality habitats in France.

Interpretation: In 2018, wood supply services accounted for 28% of the added value of French forests, regulatory and support services for 40%, and recreational services for 32%.

Sources: CGDD (2025), authors' calculations, Joint Research Centre (2022).

What about the heritage value of forests? Based on observed land transactions, the heritage value of French forests is estimated at €139 billion in 2023.[41] However, this estimate does not fully reflect their real value. On the one hand, market prices may suffer from selection bias: the plots put up for sale are not necessarily representative of all forest land. On the other hand, this value remains incomplete because it does not take into account all the ecosystem services provided by forests, starting with carbon storage, but also biodiversity, water regulation and cultural and recreational benefits.

Our analysis shows that, by including a stock of 5,138 million tonnes of CO_2 in biomass (i.e. excluding soils),[42] as well as the SVFS defined above (0.4 x 185), the social value of the carbon sink amounts to approximately €380 billion. Added to this is an estimated €270 billion for the net present value of future benefits related to other ecosystem services: hydrological regulation, biodiversity preservation, water purification, recreational services, etc. This estimate is based on an income elasticity of 0.6,[43] a discount rate of 3.2% and an annual growth rate of 2% (see Focus No. 120).

> Finding 4. Regulatory and support services and recreational services account for two-thirds of the total added value of the forestry and wood sector, which amounted to €11.2 billion in 2018.

The social value of carbon stored in biomass is approximately €380 billion, and the net present value of future benefits linked to other ecosystem services is estimated at €270 billion, that is to say 2.7 and 2 times the asset value of forests in 2023, respectively.

Forests should therefore be considered not only as a commercial asset, but also as a strategic natural heritage whose social value far exceeds what is reflected by market prices alone.

Informed decisions based on cost-benefit analyses

The broader value of forests should play a central role in determining what levers to prioritise in the design of forestry policies. Let us consider a real-world example: replacing a gas boiler with a wood-fired one. Here, we assume that the wood burned was cut exclusively for this purpose and does not come from residues.

If, as in the ADEME footprint database,[44] wood is considered carbon neutral, such a replacement reduces GHG emissions from 200 gCO2per kWh[45] (for gas boilers) to zero (for wood boilers) through the substitution effect. However, this assumption of neutrality does not take into account the fact that the carbon emitted during wood combustion is not entirely and immediately reabsorbed. In extreme cases, if we consider that it will never be reabsorbed due to a change in forest land use after felling, the reduction in GHG emissions calculated above would be offset by emissions from wood combustion. Using an emission factor of 340 gCO_2 per kWh[46] for wood, the balance of such a replacement would be negative, at -140 gCO2 per kWh. Conversely, if we follow the approach proposed in this Note and take into account the non-permanence of carbon storage, then the emissions associated with burning wood in a wood-fired boiler would amount to 136 gCO2 per kWh (0.4× 340). Compared to the 200 gCO2 per kWh emitted by a gas boiler, the difference in emissions is 64 gCO2 per kWh. Assumptions about the capacity of forests to sequester carbon therefore have a significant impact on the calculation of the climate benefits (in terms of CO_2 saved) associated with replacing a gas boiler with a wood-fired boiler.

What about the social profitability of such a replacement compared to purchasing a new gas boiler? Let us assume that the wood boiler costs €12,000, compared to €5,000 for a condensing gas boiler.[47] The additional investment cost is therefore €7,000. As a reminder, if wood is considered carbon neutral, the climate benefit of the replacement is 200 gCO_2per

[41] CGDD (2025) : *op. cit.*

[42] IGN (2023) : « Inventaire forestier national. Mémento Édition 2023 ».

[43] Drupp M. et al (2024) : « Global evidence on the income elasticity of willingness to pay, relative price changes and public natural capital values », *CESifo Working Papers*, n° 11500.

[44] Base empreinte de l'Ademe, qui se conforme aux standards internationaux (protocole GHG, ISO 14064).

[45] UK Department for Energy Security and Net Zero (2025), Greenhouse Gas Reporting: Conversion Factors 2025:

[46] *ibid*:

kWh. With an annual consumption of 20,000 kWh,[48] and assuming an initial social cost of carbon of €185 per tonne, increasing by 2% per year and discounted at a rate of 3.2%, the present value of the climate benefits over 20 years would rise to around €12,000, making the project profitable (12,000 > 7000). On the contrary, if we consider a scenario where the climate gain from the replacement is 64 gCO2 per kWh, which is based on assumptions that are far from unfavourable to wood energy, the present value of the climate benefits over 20 years would be around £4,000. The climate benefit appears to be lower than the additional investment cost. Following the same logic, replacement with a heat pump should be subject to the same type of assessment, and a comparison of the total benefits would help to inform the trade-offs between the different options.

This example shows how much the carbon neutrality assumption influences the economic evaluation of projects and public policy choices. The balance sheet for wood energy is at best slightly positive and remains highly uncertain, despite substitution effects. However, wood energy accounts for 33% of total wood production (see Focus 119) and receives most of the direct public support, through purchase subsidies for households, or indirect support. The latter is due in particular to the fact that, in large installations, no compensation is required for CO_2 emissions from wood combustion, unlike fossil fuels. This lack of pricing implicitly assumes that the carbon emitted by wood is immediately reabsorbed, which is far from guaranteed in reality. At the same time, the fossil fuels that wood is supposed to replace (gas, fuel oil or coal) are subject to carbon pricing via the European Emissions Trading System (ETS) or the Climate Energy Contribution. In other words, the carbon avoided by substitution is already partially valued by the market. By not taking wood emissions into account in the calculation of carbon credits, public policies are therefore skewing choices in favour of wood energy by overestimating its actual climate performance. It therefore seems necessary to revisit the integration of the timber industry into CO_2 quota markets. Doing so would allow the sector to access appropriate support while simultaneously promoting the most effective solutions.

Recommendation 5. Integrate the wood sector into CO_2 quota markets, with a price that reflects the non-permanence of storage.

It would be desirable to rebalance climate-related public subsidies in the timber sector so as not to favour one use (such as wood energy) at the expense of other options that are beneficial for the climate, such as the protection, restoration or sustainable management of forests. More generally, the principle that should guide the design of forestry policies is a logic of "internalizing" all the non-market benefits of forest management in order to align private incentives with the collective interest. Such an approach requires, above all, remuneration for carbon sequestration and pricing of withdrawals based on values representative of their climate impact.

In this context, the forestry methodologies of the low-carbon label[49] can serve as proof of concept for this integration. Rigorous ex-post impact analyses of low-carbon labelled projects should enable their evaluation. A number of academic studies have used quasi-experimental methods to evaluate forest regeneration and improved forest management projects in Australia[50] and California[51]. A systematic application of this type of assessments to certified low-carbon projects would be a way of establishing the credibility of these mechanisms and the possibility of their eventual integration into compliance markets. In this regard, the development of new satellite measurement devices combined with artificial intelligence should be examined.[52] However, a high level of transparency and the availability of data from the projects evaluated will be necessary.[53] In addition, low-carbon label-type subsidies could be supplemented in order to promote the use of long-term wood storage, for example by introducing payments for environmental services, conditional on compliance with good biodiversity practices. In all cases, the methods that provide the most guarantees in relation to the service provided should be given priority, for example, real environmental obligations.[54]

Recommendation 6. When evaluating public policies, take into account the non-permanence of carbon sequestration and other forest ecosystem services. Specify baseline scenarios.

Recommendation 7. To preserve biodiversity, develop strategies based on species diversification, a form of restraint in forestry operations and a flexible approach to management choices, relying in particular on payments for ecosystem services.

[47] Ademe (2024) : Adopter le chauffage au bois.; Fournisseurs-electricite.com (2025) : Prix d'une chaudière gaz : achat et installation en 2025.

[48] Les 20 000 kWh correspondent à la consommation de chauffage d'une maison de 120 m² construite après 1975, selon la base carbone de l'Ademe. Il s'agit donc plutôt d'une grosse consommation : une maison plus petite serait moins favorable au bois dans la comparaison. L'analyse coût-bénéfice dépendant évidemment de la surface à chauffer et d'autres paramètres, l'évaluation devrait donc être faite au cas par cas.

[49] Delacote, P. et al. (2025) : « Restoring credibility in carbon offsets through systematic ex post evaluation », *Nature Sustainability*.

[50] Macintosh A., Butler D., Larraondo P. et al. (2024) : « Australian human-induced native forest regeneration carbon offset projects have limited impact on changes in woody vegetation cover and carbon removals » *Commun Earth Environ* 5, 149.

[51] Stapp J., Nolte C., Potts M. et al.(2023) : « Little evidence of management change in California's forest offset program » *Commun Earth Environ* 4, 331.

[52] Brandt M., Chave J., Li S. et al. (2025) : « High-resolution sensors and deep learning models for tree resource monitoring », *Nature Revues Electrical Engineering*, vol. 2.

[53] Delacote, P., L'Horty, T., Kontoleon, A. et al. (2020) : « Strong transparency required for carbon credit mechanisms », *Nature Sustainability*.

[54] Bureau D., Bureau J.-C. et Schubert K. (2020) : « Biodiversité en danger : quelle réponse économique ? », *Les Notes du CAE* n° 59.

The integration of the environmental benefits of the forestry sector into national accounts appears necessary in order to assess the true value created by this activity, as well as that of our forest heritage. This is equally true when it comes to comparing prospective forest management scenarios and developing effective public policies, the evaluation of which is hampered by the impossibility of balancing multiple and conflicting effects between the economy and resilience, or between substitution effects and in situ sequestration in the context of carbon accounting. It is therefore necessary to strengthen the work of monetary valuation of ecosystem services in order to establish comprehensive assessments that can inform decision-making.

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