Green OAT Evaluation Report

National Forestry Commission of France

Impacts on Biodiversity and Climate Change Mitigation and Adaptation

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Acknowledgements

This report has benefited from valuable input and comments from the scientific referees: Marion Gosselin (INRAE) and Jean-Luc Peyron (ECOFOR).

The evaluation teams also thanks Albert Maillet (ONF) and Patrick Falcone (ONF) for providing helpful documentation and data on the ONF.

Table of Contents

Executive Summary

This report assesses the environmental impact of the subsidies received by France's National Forestry Commission, the *Office National des Forêts* (ONF). The assessment centres on three environmental objectives defined in the Green OAT framework: climate change mitigation, climate change adaptation and biodiversity protection.

The underlying assumption of this report's counterfactual analysis is that the subsidies have allowed the ONF to ensure public management of France's forests with specific environmental objectives and results. Had an annual subsidy not be granted to the ONF over several decades, the country's forests would have been managed much differently. We attempt to analyse the impact that public management has had against the three Green OAT objectives.

Our methodology is as follows: for each objective, we provide evidence of the stakes for public forests, how ambitious public management policies are from an environmental perspective, how effectively these policies are being implemented and the resulting impacts. At each step, where relevant and depending on data availability, we look at private forestry practices, compare results and discuss how differences in these results may be attributed to public management practices.

Results

Using the above-mentioned methodology, we concluded that public forestry management has had a positive effect on:

- Climate change mitigation, as **sustainable public management practices are associated with significantly larger harvests**, amounting to an estimated **2.7 million cubic metres of wood per year**. Based on the current distribution of wood use and wood substitution, the additional harvest associated with sustainable management practices may potentially deliver a **modest reduction in atmospheric CO_2 levels**, mainly from the use of timber as a substitute to high-emitting materials such as cement and steel.

- Climate change adaptation, as public management allows for **clear methodology** to be developed and **consistently implemented**, from which **localised solutions** can be developed for forest adaptation, fire risk mitigation and protection against natural hazards. It also allows for data to be collected, contributing to scientific knowledge.

- Biodiversity protection, as public management involves creating a connected, effectively managed and representative ecological network, allowing for targeted action to be taken to protect vulnerable species. **Public forests have 34% of their surface area protected**,[1] compared with 23% for private forests, and **2.9 times more common birds are observed** annually per hectare in public forests.

[1] According to the IUCN protected area category system.

Ultimately, the added value of the ONF is that it is able to provide multifunctional management, invest in innovation, and produce data and scientific knowledge. This is particularly valuable in a context where the environmental stakes are multifactorial, interconnected and plagued with uncertainty in the face of climate change.

Introduction

On 24 January 2017, *Agence France Trésor*[2] introduced France's first green sovereign bond, the Green OAT.[3] It funds expenditure from the central government budget and the Invest for the Future programme to fight climate change, adapt to climate change, protect biodiversity and fight pollution. It is in line with the government's commitments under the Paris Agreement to redirect investment toward positive action for the environment.

To determine the impact of France's eligible green expenditure, an environmental assessment is required. Accordingly, alongside the launch of the Green OAT on 24 January 2017, France committed to provide a thorough *ex post* environmental impact evaluation of eligible green expenditure, overseen by the Green OAT Evaluation Council. The evaluation provides a more detailed analysis of the ONF's impacts on the environment, following the results of the IGF[4] report on green budgeting (CGEDD, 2019), which qualified state spending associated with the ONF subsidy as beneficial to the environment.

For centuries, areas of France's forests have been managed by the state. The ONF was created in 1966 as an industrial and commercial public undertaking (EPIC[5]) to oversee their management. Today, the ONF manages 10.9 million hectares (around 40%) of France's forests, of which 4.6 million hectares is located in mainland France and 6.3 million in its overseas territories. The ONF is the manager of public forests (both state- and locally owned) and plays a central role in enforcing France's forestry regulations, which aim to protect public forests, govern their operation and ensure the integrity of the land, according to principles of sustainable and multifunctional management and taking into account social, economic and environmental issues.

As an EPIC, the ONF is partially self-funded through commercial activities (mainly timber sales and local community services) and only parts of its operations are publicly funded. The subsidy it receives, the subject of this report, is made up of three components: funding for general interest activities (which funds ONF management activities in both locally owned and state-owned forests); a compensatory payment (which funds ONF management activities in locally owned forests); and a balancing subsidy (which partially funds ONF management activities in state-owned forests). This amounts to approximately €175m out of an annual €860m budget.

The final report on the EU Taxonomy by the Technical Expert Group (TEG) on Sustainable Finance describes how to assess the impact of forest management practices in two areas: (i) climate change mitigation and (ii) potential negative spillover effects on any of the other five environmental objectives

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[2] https://www.aft.gouv.fr/fr/oat-verte, accessed on 29/07/2019.
[3] Yield: 1.75%; maturity date: 25 June 2039; issuance amount: €7bn.
[4] *Inspection Générale des Finances* (Inspectorate General of Finance).
[5] *Etablissement Public à caractère Industriel et Commercial*.

set out in the EU Taxonomy Regulation, including adaptation to climate change. For the first, the methodology proposed in the EU Taxonomy uses three criteria: compliance with sustainable forest management (SFM) requirements; the establishment of a GHG balance baseline for above-ground carbon pools, based on growth yield curves; and the demonstration of permanence and steady progress with respect to the other two criteria (EU, 2019). For the second, the methodology proposed in the EU Taxonomy uses the criterion of Do No Significant Harm (DNSH). Based on these four criteria, we consider the methodology used in this OAT report to be aligned with the principles of the EU Taxonomy. We studied: (i) the impact of the ONF's management practices, compared to the private sector, on GHG emissions; (ii) the ONF's performance with respect to SFM requirements and the DNSH criterion, by identifying the area of forests with PEFC[6] and FSC[7] certification and detailing the ONF's performance, not only regarding climate change mitigation, but also taking into account the impact of its activities on biodiversity protection and climate change adaptation; and (iii) the ONF's ability to monitor its environmental impact over time, through the analysis of its open data output and its collaboration with the research community. Based on this assessment, we believe the ONF's management activities are likely to qualify under the EU Taxonomy. A full-fledged in-depth analysis, using the detailed criteria provided in the TEG reports, is beyond the scope of this assessment but could be undertaken in the future.[8]

The goal of this report is to provide a detailed analysis of the impact of public management on France's forests. The report starts with a description of the methodology and a contextualisation of the ONF in the French forestry landscape. Following this introduction, the three green OAT objectives are each described in their own chapter: climate change mitigation, climate change adaptation and biodiversity protection.[9]

[6] Programme for the Endorsement of Forest Certification.
[7] Forest Stewardship Council.
[8] More details about the information needed for such an analysis are provided in Appendix 4.
[9] As all three objectives relate to the ONF's activities in mainland France; part IV looks specifically at the ONF's overseas activities.

Policy Background

France’s forests

France has over 25 million hectares (ha) of forests, of which 17 million ha are located in mainland France and 9 million ha are in overseas territories,[10] primarily French Guiana. Public forests account for 13 million ha,[11] 6.3 million ha of which is overseas. There are two types of public forest: those where the land is owned by the state (1.7 million ha in mainland France and all 6.3 million ha of overseas public forests) and those where the land is owned by local authorities (2.9 million ha in mainland France, none overseas).

The other 12 million ha of France’s forests are privately owned, a large portion of which is highly fragmented into small properties with little or no management. In terms of surface area, 17% of private forests consist of patches of 10 to 25 ha, 36% of patches under 10 ha, and 6.5% of patches under 1 ha, which are not legally required to be operated under a management plan. In contrast, only 0.80% of public forest surface area consists of patches under 10 ha and 0.0008% of patches under 1 ha. Furthermore, patches larger than 100 ha account for 93% of public forests but only 27% of private forests.[12]

This is partly due to successive inheritances, which often result in subdivisions of land ownership. As a result, there is less logging activity in private forests, on average, than in public ones; the average extraction rate is 72% in state-owned forests, 54% in locally owned forests and 51% in private forests. However, some private forests are made up of larger properties, which are often intensively managed and logged. For instance, in the Aquitaine region, 92% of forest land is privately owned and intensively logged; the extraction rate in this area is 88%. In the remaining 8% of forest area that is publicly owned, the extraction rate is 83%.

On average, old-growth forests (more than 200 years of continuous forest cover) are more frequently public, while private forests tend to host younger stands, due to new expansions. Stands more than 120 years old account for 41% of public forest surface area vs. 27% of private forests (ONF, 2015c).

Though deforestation is a global issue, France’s forest surface area has been increasing 0.7% annually for the last 30 years. This is partially explained by a low national extraction rate: approximately 41% for hardwood and 64% for softwood.[13] These figures hide some regional disparities: the lowest extraction rates are 4% for hardwood in Corsica and 22% for softwood in Midi-Pyrénées, while the highest extraction rates are 62% for hardwood in Lorraine and 119% for softwood in Aquitaine.[14] Overall, for hardwood, 13 regions have an extraction rate above the national average, and 9 below. For softwood, 8 regions have an extraction rate above the national average, and 14 below. Moreover, French forests, both public and private, are largely naturally regenerated: only a very small share is regenerated

[10] Taking into account New Caledonia and Polynesia.
[11] Of which the ONF manages 10.9 million ha.
[12] Data source: IGN.
[13] Date source: IGN.
[14] The extraction rate is the share of wood that is harvested out of the total available wood supply in production forests. Here, we have used a two-year average.

artificially (through tree planting). On the whole, French forests, including those in mainland France, are a carbon sink.

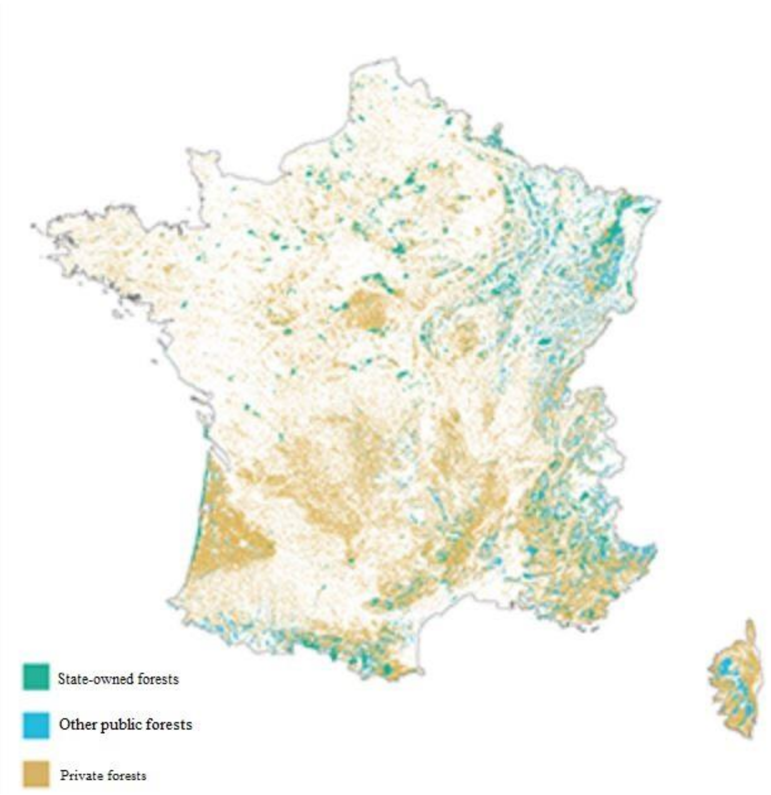

Figure 1: Breakdown of forest ownership in mainland France

Source: IGN.[15]

The ONF and public forest management

Continuing the tradition of public forest management it inherited from the *Administration des Eaux et Forêts*, which dates back to the 13th century, the ONF is responsible for enforcing France's forestry regulations, which govern how its public forests are managed. The mandate of the ONF is to grow and harvest timber to meet the needs of the industry, to preserve the environment and to provide services for the public. That mandate translates into the following activities, among others: forest management, including knowledge building and sustainable timber production; land management, including the

[15] https://inventaire-forestier.ign.fr/spip.php?rubrique70, accessed on 11/09/2019.

drafting of administrative documentation, the execution and improvement of cutting programs and the monitoring of related policies; forest maintenance and other general interest activities; and consulting. In summary, the ONF oversees a multifunctional forest management programme involving production, biodiversity protection and visitor services.

Under France's Forestry Code, any owner of a forest larger than 25 ha is required to submit a *plan simple de gestion* (simple management plan) to the CRPF.[16] This means that even some private forest owners[17] have to comply with national rules by drafting a management plan, which is specific to each forest. Currently, this requirement applies to just 11% of private forests (by surface area); however, the private sector has been known to follow the lead of public forestry management practices, whose success stories may inspire private owners to some extent.

Methodology

Overall description

The objective of this evaluation is to assess the environmental impact of the ONF subsidy against three OAT objectives: climate change mitigation, climate change adaptation and biodiversity protection. (There is a fourth objective, fighting pollution, but it was discarded because no significant stakes were identified in relation to forest management.) For each objective, the evaluation will, where possible, work out an estimate of the environmental impact of the ONF subsidy.

The steps are as follows:

- We will first provide evidence of the **stakes** of the objective for public forests.
- If the stakes are high, we will assess how **ambitious** the ONF's policies are from an environmental perspective with regard to the objective.
- We will then assess how effectively the ONF implements its policies.
- Finally, we will attempt to provide **evidence of the impacts** of these policies. This is an ambitious aim and will require adapting our methodology in some areas depending on data availability. There are two levels to our methodology:
    - The first level consists in assessing whether **best practices** are being effectively implemented. For example, we may investigate whether the ONF engages in a practice that is known to help restore the population of an endangered species. This level provides indirect and qualitative evidence of impact.
    - The second level aims to **quantify the impact**. To do so, we look at biophysical indicators, for example the number of common birds or the volume of deadwood, which is known to be a vital habitat for biodiversity. This level provides direct evidence of impact.

[16] *Centre Régional de la Propriété Forestière* (Regional Centre for Forestry Ownership).
[17] Of forests larger than 25 ha.

	Climate change mitigation	Climate change adaptation	Biodiversity	Pollution
Stake	✓	✓	✓	
Ambitiousness	✓	✓	✓	
Implementation	✓	✓	✓	
Impact	✓		✓	
Indirect evidence				
(best practices)	✓		✓	
(observations)			✓	
Direct evidence				
(modelling)	✓			
(observations)			✓	

Table 1: Evaluation of the four environmental objectives of the Green OAT programme

Comment: The four levels of evaluation (stake, ambitiousness, implementation, impact) are explained in the text. For the evaluation of impact, indirect evidence includes observing practices that have been scientifically proven to have an impact (best practices) or observing impacts in other areas that suggest an impact on the objective in question. Direct evidence includes cases where a quantitative estimate of an impact can be provided, even if partial. Such estimates may be derived from modelling or direct measurement.

Where relevant, detailed computation and modelling methods are presented in the appendices.

Counterfactuals

The chosen counterfactual scenario, for mainland France, is based on the following assumption: since the ONF's subsidies fund not only specific environmental activities but also its general operations, without the subsidy, the ONF would tend toward a private, profit-oriented structure. It would have to rely exclusively on market-based revenues, which would affect its actions toward the environment.

To define the scenario, we looked at private forests in France. By comparing public and private forests, we can expect to see the added value of the ONF's subsidies, and by extension the public management of France's forests.

At each of the steps mentioned above, specifically for estimating impacts, ONF-managed forests are compared with private forests. We discuss differences in results and causality to decide whether they can be attributed to the ONF and to public forestry management.

Arguments in favour of a long-term counterfactual

To effectively evaluate the impact of the subsidies, and by extension the impact of public management on the environment, we required a counterfactual scenario that would work for different timescales:

- In the short term, many properties of France's forests are not expected to change (e.g. tree species or stand structure), and only very specific protection measures or management practices

would have discernible impacts. These impacts could be measured directly or via a comparison of public and private forests that have similarities in terms of tree species and stand structure.
- However, over the longer term, public forest management is expected to have an impact on properties such as continuity of tree cover, tree species and stand structure.

A long-term perspective is crucial for this assessment. The ONF's operations are part of a long tradition of public forest management, and forest management cycles can span centuries, with decisions made today having long-lasting impacts. As we will see later on, many of the environmental benefits seen today can be attributed to the impacts of management practices implemented long ago, which speaks to the accumulated impact of the ONF's subsidies over time.

Such long-term impacts cannot be measured via a present-day comparison of similar forests. However, it is reason to compare forests that may seem incomparable by today's standards, but whose differences are the result of diverging forest management practices over the long term. For instance, public forests in France are on average older than private forests: tree stands are older, and the soil has been forested for a longer period. As the continuity of forest cover over large timescales can be a major determinant of biological diversity, this factor is likely to explain profound differences in terms of biodiversity. A comparison of similar public and private forests would not capture these impacts, even if there are compelling reasons to attribute the observed differences to public forest management.

In this evaluation, we will attempt to account for the long-term effects of public management by comparing of seemingly dissimilar public and private forests.

Accounting for the impacts of long-term public forest management is a key aspect of our methodology for two reasons:

- First, it creates two ways of analysing the impact of public management, over the short term and over the long term, both of which must therefore be taken into account when discussing the causality of our results.
- Second, it precludes an analysis of differences between observed indicators before and after forests became public. While such a strategy would have controlled for potential selection bias (since the impact could have been evaluated through longitudinal analysis of the same forest units over time), the obvious lack of data from before the creation of public forests makes this impossible.

Other counterfactuals

Other counterfactual scenarios were considered before being excluded for methodological reasons and due to limited access to data.

Originally, we considered using the breakdown of the subsidy and looking at precisely what it funds. As mentioned in the introduction, the subsidy breaks down as follows:

- Funding for general interest tasks, which funds ONF management activities in both locally owned and state-owned forests
- A compensatory payment, which funds ONF management activities in locally owned forests

- A balancing subsidy, which partially funds ONF management activities in state-owned forests

However, a more detailed breakdown of how the ONF allocates each component of the subsidy is not available, which prevented us from using this information for a quantitative counterfactual analysis. Nevertheless, it is possible to take a qualitative approach to deduce what would happen if each component of the subsidy were to disappear (see Part V).

As previously explained, our chosen counterfactual allows us to capture both long- and short-term effects, though it is more challenging to distinguish them. A way to isolate and capture short-term effects would have been to limit comparisons to private and public forests with similar structural features (at least size and age). However, such an approach was not possible due to a lack of appropriate data.

Overseas forests as a special case

As seen in the introduction, of France's 13 million ha of public forests, 6.3 million ha is located overseas, primarily in French Guiana (5.8 million ha). All of France's overseas public forests are state-owned. There is no logging of overseas forests, particularly those in French Guiana, with very minimal exceptions.

The ONF's activities in French Guiana are exclusively funded through general interest funding, which is part of the subsidy evaluated in this study. Without this funding, the ONF would have no activities in French Guiana.

This makes overseas forests a special case, requiring slightly different methodology. Applying the same counterfactual mentioned above, no subsidy would imply no management at all of overseas forests, as they are almost exclusively managed by the ONF. In other words, in contrast to our approach for mainland forests, we cannot consider that without the subsidy, overseas forests would be managed similarly to private forests; we must consider that there would not be any management at all. For that reason, the whole of the ONF's overseas activities will be considered as additional benefit.

A special part of this report is dedicated to the ONF's overseas activities (particularly in French Guiana and Martinique) and what they mean for climate change mitigation and adaptation and biodiversity protection.

I. The ONF's Impact on Climate Change Mitigation

Key results

- **Public forest management is associated with large-scale sustainable harvesting of wood products.** In contrast, the situations of privately owned forests vary widely, ranging from unmanaged small properties to intensively managed forests.
- **Sustainable public management practices are associated with significantly higher harvests**, amounting to an estimated 2.7 million cubic metres of wood per year, predominantly from state-owned forests.
- Based on the current distribution of wood use and wood substitution, the additional harvest associated with sustainable management practices is estimated to deliver **a modest reduction in atmospheric CO_2 levels**, mainly due to the use of timber as a substitute to high-emitting materials.
- In a set of monitoring plots located in public forests, soil carbon levels have shown a significant increase, equivalent to a rate of 4/1000.
- The ONF's activities reduce the exposure of carbon stocks to climate change risks (through research and monitoring, tree species selection and fire risk mitigation).

Introduction

Carbon sequestration is the process of capturing CO_2 and storing it on a long-term basis to mitigate or delay climate change. CO_2 is naturally captured through biological, chemical and physical processes such as tree growth. Tree growth results in the incorporation of atmospheric CO_2 into biomass, creating a carbon sink. The carbon sequestration capacity of trees depends on various factors such as species, location and age. In theory, the older the tree, the less CO_2 it captures, ultimately reaching a saturation point and becoming a carbon reservoir.

In France, forests are the largest carbon sink, absorbing 20% of the country's GHG emissions (Ecofor, 2018). This is mainly due to a significant increase in tree biomass and young tree growth, and because of recent increases in atmospheric CO_2 concentrations, making old trees recapture CO_2. This sink, of which public forests account for a quarter, was estimated to be 57 $MtCO_2eq$ per year on average between 2008 and 2016.

Once cut and used as raw material, trees release part of the CO_2 they have captured. The quantity and timing of the carbon emission depends on factors such as cutting method, how the timber is used, etc. For instance, wood used as firewood will release more CO_2 and release it faster than wood used as a construction material.

In addition to the importance of forests as carbon sinks (*in situ* sequestration), France's National Low-Carbon Strategy[18] underscores the need to balance the growth in forest carbon stocks with wood production. When made from sustainably harvested wood, wood products (buildings, furniture, etc.) continue to store carbon (*ex situ* sequestration), making them a lower-carbon alternative to high-emitting materials such as cement or fossil fuel energy.

That is the general perspective from which we evaluate the impact of public forest management in this chapter. We start with a quantitative estimate of the overall impact of public forest management on GHG emissions. We then present other aspects of forest management that could not be included in the quantitative evaluation.

A. Quantifying the effects of public forest management on climate change mitigation

Public forest management is associated with large-scale sustainable harvesting of wood products. In contrast, the situations of privately owned forests vary widely, ranging from unmanaged small properties to intensively managed forests.

(in m^3/ha/year)	**Timber**	**Industry**	**Firewood**	**Total**
State-owned	2.07	1.11	1.11	4.30
Other public	1.33	0.73	0.73	2.80
Private	1.11	0.80	0.80	2.70
Total	4.51	2.64	2.64	9.80

Table 2: Estimated harvest intensity broken down by use and ownership

Source: Derived from the national forest inventory, IGN FCBA (2015) and FCBA (2013).

Taking into account the differences in average harvesting rates in public and private forests and applying them to the total surface area of public forests, we estimate that sustainable public harvesting is associated with an additional harvest of 2.7 million cubic metres of wood per year, predominantly from state-owned forests (see Table 3).

[18] *Stratégie Nationale Bas-Carbone*.

(in millions of m^3/year)	**Timber**	**Industry**	**Firewood**
State-owned forests	1.46	0.49	0.49
Other public forests	0.61	-0.17	-0.17
Total	2.07	0.32	0.32
	2.7		

Table 3: Estimated additional harvest associated with large-scale sustainable management of public forests

Comment: Volumes are for round wood with bark. The extraction rate differences between public and private forests have been applied to the total surface area of public forests. The method, assumptions and data sources are detailed in Appendix 1.

This additional harvest is significant: it represents about 5% of the estimated current wood harvest in France. The climate change mitigation impact of this increased harvest from sustainable management practices depends on the relative intensity of three effects:

- A decrease in *in situ* carbon sequestration, partially offset by forest regeneration
- An increase in *ex situ* sequestration in wood products

Reduced use of fossil fuels and high-emitting materials (e.g. cement and steel) due to increased availability of wood substitutesTable 4 presents the estimated impacts of this additional timber harvest on GHG sequestration for each of these three components of the carbon balance sheet. It suggests that the increased harvest associated with sustainable management practices can be linked to a modest reduction of GHG in the atmosphere, equivalent to several hundred thousand tonnes of CO_2eq per year. However, this is not a highly accurate measure: the confidence interval ranges from significant emissions source to significant emissions sink, as high as 1% of current annual national GHG.

(in million tons of CO_2eq per year)	Impact on *in situ* sequestration	Impact on *ex situ* sequestration	Substitution effects	Total
Central value	-2.83	0.30	2.93	0.41
Min	-3.97	0.10	1.21	-2.66
Max	-1.68	0.50	6.09	4.92

Table 4: Estimated impacts on GHG sequestration associated with increased harvest in public forests

Comment: Impacts on in situ *sequestration include both the reduction of emissions associated with tree harvesting and subsequent forest regrowth and the long-term differences in carbon sequestration compared to old-growth forests. Impacts on* ex situ *sequestration include the change in* ex situ *carbon stocks associated with increased wood supply. Substitution effects include the impacts on GHG emissions associated with the substitution of wood products for fossil fuel sources and high-emitting materials. All of these effects have been calculated using the methodology, assumptions and data sources described in Appendix 1.*

This evaluation reaches a similar conclusion to that of recent simulations[19] which compared the relative merits of national wood harvesting scenarios on carbon sequestration in 2050. While different strategies did not reveal significant differences in carbon sequestration, the authors highlighted the utility of wood harvesting for reducing the exposure of carbon stocks to non-permanence risks and offering opportunities for adaptation.

The uncertainty of this result is not surprising given that the effect of increased harvests and the saturation age of uncut trees remain highly debated and have been shown to depend considerably on the details of each situation.[20] For this evaluation, we have assumed a steady distribution of wood use and wood substitution from current levels. The results suggest that **the increase of *ex situ* sequestration in wood products does not have a significant impact, but the substitution effects are significant enough to offset the decrease in *in situ* sequestration.** These relative effects are valid in relation to current circumstances, in which fossil fuels and high-emitting materials remain widely used and wood products have short lifespans. In several decades, we may expect the substitution effects to be much lower and *ex situ* sequestration to be more significant, due to longer wood product lifespans. That is the vision of France's National Low-Carbon Strategy, which has forests playing a larger role in climate change mitigation, mostly driven by increased wood harvests and longer wood product lifespans;[21] this could be facilitated by increased timber production from the ONF.

Based on this evaluation, the increased harvest associated with the ONF's sustainable forest management practices has a theoretically positive impact on climate change mitigation. This impact could reasonably be estimated at several hundred thousand tonnes of CO_2eq per year based on the current distribution of wood use and wood substitution. This conclusion of a positive impact is supported by other findings that could not be included in this quantitative assessment.

Box 1. The substitution effect in carbon evaluations

The study estimates the additional amount of wood extracted from public forests compared with private forests to be 2.7 million cubic metres per year. The impact of this additional amount on the contribution of forests to climate change mitigation has been evaluated (over the long run, assuming forestry cycles remain steady) taking into account three effects, one of which is the substitution effect generated by the increased availability of wood products as substitutes for high-emitting materials.

The substitution effect is key to this study: it is why we have qualified the overall contribution of France's forests to climate change mitigation as positive. However, it is sometimes called into question.

Admittedly, it is a difficult phenomenon to measure, as the data needed to accurately quantify it are not comprehensive. However, we believe it should be taken into account for the following reasons:

[19] Roux et al., 2018.
[20] See e.g. Valade et al., 2017.
[21] French government, 2018, p. 80.

- Even though the effect can only be approximated, its existence is not denied (even in the EU Taxonomy, which recognises it as playing a part in the carbon sequestration capacity of forests). It is only the intensity of the effect that is debated.
- The overall approach of taking the substitution effect into account is original. Faced with the previously mentioned difficulty of accurately quantifying the effect, the report has used scientific literature and transparent parameters to incorporate it into its analysis. The sensitivity of the results with respect to this parameter, and the resulting uncertainty, is not denied.
- The substitution of wood products for high-emitting materials is key to the National Low-Carbon Strategy. Ruling out this effect would introduce an inconsistency with French public policy.
- It highlights the important role that the ONF plays across France in terms of balancing the different objectives of sustainable forest management: climate change adaptation, climate change mitigation and biodiversity protection.

B. Other contributions to climate mitigation

Aside from harvesting intensity, other aspects of forest management can significantly enhance or compromise its contribution to climate change mitigation. This section evaluates these other aspects.

The first deals with harvesting practices. They can have strong effects on long-term sequestration potential, by reducing organic matter inputs to the soil (logging slash, tree stumps, etc.) and compromising soil fertility (impoverishment, compaction, erosion, etc.). Another crucial element is the management of tree remnants (leaves, small branches, roots, etc.), as these can help increase soil carbon and maintain soil fertility, with an impact on future carbon sequestration[22] (ADEME, 2019 and 2014).

Box 2. PEFC certification

PEFC certification guarantees that forests and forest lands are used and managed in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity and vitality and their capacity to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national and global levels, without causing damage to other ecosystems. In France, PEFC certification is awarded to forests whose owners and managers comply with sustainable forest management standards.

According to sustainable management indicators (Maaf, 2015), 84% of public forests have been granted PEFC certification, compared to only 17% of private forests.

Sustainable forest management standards and PEFC requirements are compatible with the three OAT objectives being evaluated in this study in the following respects:

[22] Cacot et al., 2006.

Climate change mitigation

PEFC certification promotes and guarantees cutting practices that are not harmful to the sustainable development of forests in a climate change context. Clear cutting, for instance, is strictly regulated (criterion 2.6). After cuts, how residuals and stumps are dealt with must be specified in the operator contract and must not harm soil quality (criterion 3.9). More broadly, soil quality must be preserved during maintenance and cutting operations (criterion 5.4).

Climate change adaptation

PEFC requirements acknowledge that France's forests are threatened by climate change and its impacts and need to undergo an ecological transition. They state that sustainable forest management should promote and guarantee diversified, forward-thinking strategies to cope with the consequences of climate change, as well as broader risk management strategies. This includes ensuring the continuous renewal of stands (whether naturally or semi-artificially), trying new species combinations that are more likely to adapt to climate change, and diversifying tree species and management approaches (different woodland types, rotated with natural forests, etc.) (criteria 2.4, 2.5 and 2.6).

As regards risk management, PEFC certification requires forest managers to identify fire hazardous areas, implement relevant management practices, protect ecosystems that regulate fire risk, monitor stand health and curb the spread of diseases. The use of GMOs is banned (criterion 4.3).

Biodiversity protection

There is a set of criteria for the protection of biodiversity, soils and water, which includes a requirement to consider, respect and support any noteworthy components of biodiversity that have been identified or are known to exist, specifically ponds and wetlands, in particular during maintenance operations (criterion 3.1). Forest managers are also expected to introduce and/or maintain biodiversity and maintain over-mature forest patches and dead trees (criteria 3.4 and 3.5).

For forest maintenance, the use of fertilisers and phytopharmaceuticals must be very strictly regulated (criteria 3.6, 3.7 and 3.8). After cuts, how residuals and stumps are dealt with must be specified in the operator contract and must not harm soil quality (criterion 3.9). The use of GMOs is banned (criterion 4.3). More broadly, soil quality, wetlands and watercourses must be preserved (criteria 5.4 and 5.5).

Forest management practices can also significantly enhance carbon sequestration. For instance, *balivage* is a recognised management practice which involves converting low tree stands (coppices or similar)[23]

[23] In French: *taillis et assimilés*.

into higher ones (high forest or similar),[24] which sequester more carbon. Of the available wood supply in state-owned forests,[25] 92% is composed of high tree stands and 3% of low tree stands; 80% of the available wood supply in locally owned forests[26] is composed of 90% high tree stands and 10% low tree stands. Moreover, according to IGN figures, there are higher tree stands in public forests than in private ones. However, it was not possible to quantify *in situ* carbon sequestration associated with these management practices.[27]

Soil carbon sequestration is also a major challenge. Some ONF management practices are known to enhance soil carbon sequestration. In a set of monitoring plots located in public forests, soil carbon levels have shown a significant increase, equivalent to a rate of 4/1000 (Jonard et al., 2017). As this kind of monitoring network has only been set up in public forests, it is not possible to compare rates with private forests.

Finally, the adaptation of forest stands to climate change is a major mitigation issue because it is key to reducing the risk of non-permanence of *in situ* carbon sequestration. This issue will be addressed in the next chapter.

Box 3. Relationship between climate change adaptation and mitigation

France's National Low-Carbon Strategy states that "[a] particularity of [the forestry sector] is its engagement in an especially long time frame. Production cycles can go beyond a century in length, meaning that current forestry choices, particularly species choices, must take end-of-century climate projections into consideration. Therefore, it is necessary to combine actions for mitigation, climate change adaptation and risk management (droughts, fires, phytosanitary attacks, storms etc.)".

As we will expand on in the second part of this report, climate change will have consequences on numerous resources that impact human systems, including forests. The relationship between climate change mitigation and adaptation is the following: higher atmospheric CO_2 concentrations mean higher average temperatures, which means more vulnerable trees, creating uncertainty as to which species may adapt and which may not. And beyond the rarefaction of forest resources, which is an issue in and of itself, the death of trees will also release more carbon into the atmosphere and reduce carbon stock capacity, further elevating atmospheric CO_2 levels.

[24] In French: *futaie et assimilés*.
[25] Silviculture is practised in 75% of state-owned forests.
[26] Silviculture is practised in 80% of locally owned forests.
[27] The impacts of these management practices may vary. An evaluation methodology was developed in 2019 to capture the effects for a single project. The result was an estimated decrease in emissions of 183tCO_2eq. More details are available here.

II. The ONF's Impact on Climate Change Adaptation

Key results

- **The ONF is responsible of large areas of land facing adaptation issues**: 25% of France's mainland forests, which represent 50% of its fire hazardous areas, 34% of its mountain forest areas and 76% of its dunes.
- Facing deep uncertainty regarding the impact of climate change on forests, the ONF is taking active measures to adapt public forests to climate change, in line with recent academic and government recommendations. This includes diversifying its strategies: fostering natural genetic adaptation in some areas and substituting species with known resistance to climate change in others.
- **Just under half of France's *départements* exposed to fire risk are managed by the ONF.** In these areas, the office also carries out special fire risk mitigation activities in private forests.
- **The ONF also manages 34% of the country's mountain forest areas and 76% of its mainland dune forests.** It invests resources in identifying and preserving the role these forests play in protecting against climate change.
- On all these issues, the ONF plays an active role in monitoring ecosystems, creating knowledge and testing science-based innovations.

Introduction

In its 2018 summary for policymakers, the Intergovernmental Panel on Climate Change (IPCC) stated that "global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate". Such a rise will have an impact on human and natural systems, including forest ecosystems.

Among other things, climate change is likely to affect the geographical distribution of species and the reproduction and growth of trees. Fire risk will increase due to rising temperatures and decreased precipitation, and erosion risk will increase for mountains and coastlines. An even bigger threat is the outbreak of these risks in new, less resilient areas. At present, the severity of these risks and the effectiveness of potential solutions remain unclear. For the ONF, the challenge of climate change adaptation lies in understanding these risks in order to implement the most effective solutions and to adapt public forests and society to the likely consequences of climate change.

Due to a lack of available data, it is not possible to assess the impact of the ONF's activities and management practices in this area. However, for specific activities and management practices, we can evaluate how ambitious they are and how effectively they are being implemented to adapt public forests and society to the above-mentioned risks.

The first section of this chapter deals with the ONF's initiatives to address the expected increased vulnerability of tree stands. Fire risk and mountain and coastal risk are evaluated in the second and third sections.

A. The ONF's involvement in mortality mitigation

Rising temperatures and atmospheric CO_2 levels, increased nitrogen pollution and more frequent extreme weather events will all have consequences on tree stands: increased productivity for specific species (oak and beech) and increased mortality due to changes in climate conditions and the spread of pests.

The ONF actively collects data on the vulnerability of its stands. It has found that approximately 27% of public forests are a source of concern, of which 6.5% are a source of serious concern. Accordingly, it follows a number of practices to make forest ecosystems more resilient. This includes:

- **Adapting silviculture cycles** to make them more dynamic, which includes diminishing wind exposure by managing the mean height and age structure of stands for resilience, and monitoring leaf surfaces for water stress in 18% of the public forests identified by the ONF as being a source of concern or serious concern.
- **Controlling for current risks** by protecting soils from compacting, safeguarding their mineral fertility and preventing the introduction of new pests.
- **Substituting tree species within stands, favouring better-adapted and water-saving species**. The ONF has identified a species/location mismatch in 50% of public forests and considers 36% to be in a precarious situation. The objective is to introduce substitutes for the most vulnerable species in the most sensitive areas and encourage tree species diversity. More specifically, on small plots called *ilôts d'avenir* (islands for the future), the ONF is experimenting with indigenous and exotic tree species whose properties may make them resilient to climate change. According to the ONF, this solution is being applied in 64% of public forests that are a source of concern or serious concern.
- **Mixing tree species**, as it reduces damage by forest insects (Jactel, 2007).

The above-mentioned practices are detailed in *instructions* (regulatory instruments). Furthermore, all management plans have to explain the species chosen for planting with respect to climate change adaptation.

Moreover, thanks to the ONF's management practices, 83% of the surface area in state-owned forests has a natural tree regeneration rate; this figure is 82% in locally owned forests and only 72% in private forests (Maaf, 2015). Conversely, tree planting, which uses a single species not necessarily selected for climate change adaptability, is by definition weakly biodiverse. These kinds of stands represent less than 10% of public forest surface area, down from 20% in 1990. Natural regeneration interacts with climate change adaptation challenges in different ways: it promotes genetic health and adaptability and ensures the gene pool is compatible with a given area, which makes a stand more likely to adapt to climate change. However, the pace of climate change is much faster than the pace of natural adaptation.

Although there is no question that forests will be impacted by climate change, the nature and consequences of these impacts are not fully known. For that reason, each adaptation strategy is based on the speculation of a *possible* future. To address this uncertainty, **the ONF is diversifying its**

strategies: fostering natural genetic adaptation in some areas and substituting species with known resistance to climate change in others. This approach is in line with PEFC[28] requirements, which cover 100% of state-owned forests and 56% of locally owned ones.

In summary, the ONF is taking active measures to adapt public forests to climate change that are consistent with appropriate strategies for effective adaptation. A report by ONERC[29] (2014) states that even though not much is known about how forests will adapt to climate change (magnitude, speed, breaking point), it is certain that it will depend on genetic diversity and evolutionary forces. Faced with the multifactorial and uncertain nature of the situation, the report advocated for diversified strategies, such as those used by the ONF. Implementing both natural genetic adaptation and species selection is also recommended by the PNACC[30] (2011) to combat climate change in forest areas.

B. The ONF's actions on fire risk mitigation

Global warming means changes in the moisture status of vegetation due to changes in temperature, air moisture, wind speed and rainfall. According to *Météo France* and Chatry et al. (2010), the proportion of mainland France prone to forest fires has been trending upward since the 60s. Paradoxically, damage caused by forest fires has been trending downward, thanks to efforts to prevent risks and combat fires.[31] However, the situation is precarious, and climatically extreme years can still have substantial consequences for forests (Maaf, 2015, p. 127). In addition to climate change, abandonment of farmland and demographic pressure contribute to fire risk. Over the next 30 years, the consequences will likely be increased fire frequency in already fire-sensitive areas and the emergence of new sensitive areas, in winter and summer.[32]

In 2015, on average[33] more than 25% of mainland France was classified as being prone to forest fires on a daily basis for more than one month.[34] To this day, 32 French *départements* are identified as being particularly exposed to forest fire risk. In 2017, close to 24,000 ha of forest was affected by fire.

Of the 32 French *départements* identified as being exposed to fire risk, 14 fall within the ONF's fire risk management mandate, all located in south-eastern France (Provence-Alpes-Côte-d'Azur, Languedoc-Roussillon, Ardèche and Corse). In other *départements*, forest fire risks are managed by private operators.

In south-eastern France, the ONF manages both public and private forests. The ONF carries out forest work, conducts appraisals, detects fires, manages post-fire risks and restores severely burned areas: **190 specialised fire workers are employed by the ONF to do fieldwork and conduct patrols.** During summer, state-certified patrol agents raise awareness and issue tickets, even in private forests, as individual forest owners are required to comply with mandatory brushing regulations, which ONF

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[28] Criteria 2.4 and 2.5 of the sustainable forest management standard (PEFC France, 2017).
[29] *Observatoire National des Effets du Réchauffement Climatique* (National Observatory on the Effects of Global Warming).
[30] *Plan National d'Adaptation au Changement Climatique* (National Plan for Climate Change Adaptation).
[31] "Forest fires can similarly be considered as a risk to society, even if outbreaks of fire are mainly due to malicious acts or human carelessness (source Prométhée). Hence the major, effective efforts by the State to prevent the risks and combat fires (IGD, 2015 p.18 6.4; Fig. 40)".
[32] ONF interview.
[33] Moving five-year average, 1980–2015.
[34] *Météo France*.

patrols enforce. These agents are also mobilised in case of crisis. In 2017, for example, 600 foresters were assigned to a variety of forest fire risk mitigation activities, with 100 to 150 patrol vehicles mobilised daily, depending on the severity of the fire risk.

As stated in the introduction, even though fire risk has been increasing, the number of fires has been decreasing in the south of France, in terms of both surface area and number of fires, as can be seen in Figure 2. This trend suggests that fire risk is being effectively managed in these areas.

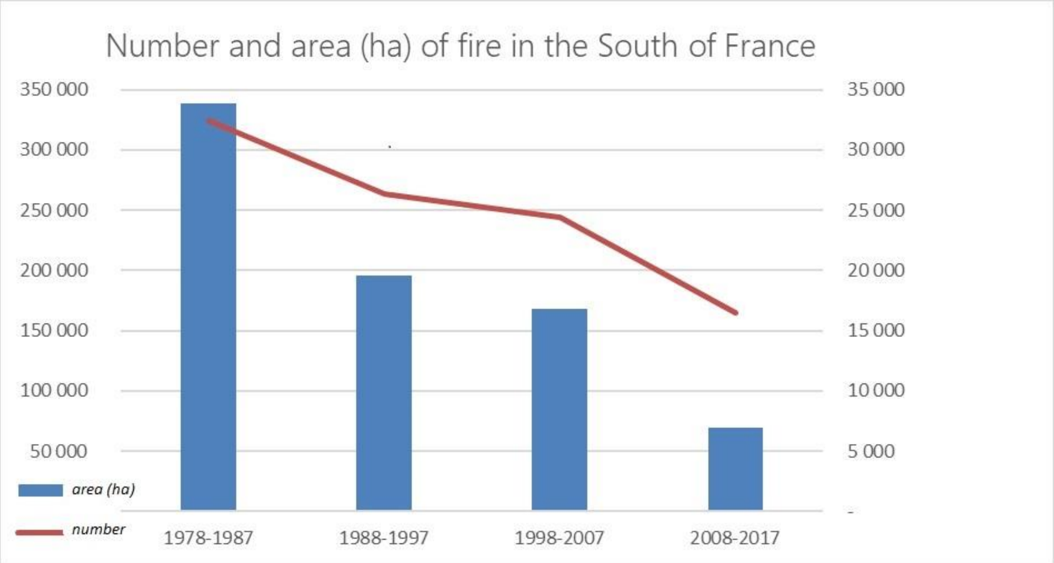

Figure 2: Number of fires (right) and hectares of area burned (left) in the south of France

Source: ONF.

Working with *Météo France*, the ONF also **plays a role in research and development**. It uses the latest IPCC assumptions to monitor fire-sensitive areas. An interministerial taskforce (Chatry et al., 2010) published the most recent national map in 2009. The ONF also **identifies tree species that are the most adaptable to future climate conditions** and resistant to fire. It also **raises awareness** about fire risk in fire-sensitive areas and those already stricken, by maintaining a strong response force, conducting appraisals after each fire and alerting local authorities to risks.

C. The ONF's involvement in protection against natural hazards

As stated in PNACC (2011) and Maaf (2015), climate change will severely impact mountain and coastal areas. In mountain areas, a rise in the number of avalanches and torrential downfalls and increased erosion are expected. In coastal areas, sea levels and intense winter storms are expected to exacerbate coastal erosion and flooding. In both mountain and coastal areas, well-managed forests can play a protective role: mountain forests can act as barriers against avalanches and falling rocks, and coastal forests can limit flooding (e.g. mangroves in overseas France). Because of climate change, this protective role is both at risk and more necessary.

i. The ONF's involvement in mountain forest management

The ONF carries out mountain forest restoration operations on behalf of the ministry in charge of forestry. The ONF manages state-owned forests within mountain land restoration perimeters as part of the RTM[35] programme. To date, nearly 390,000 ha of land has been acquired by the state under the RTM programme. However, RTM areas are based on older administrative divisions[36] which do not fully cover the ONF's current field of activity, as other parts of state-owned forests have a need for mountain area risk mitigation. Overall, the **ONF manages 34% of French mainland mountain forest areas.[37]** The parts of these forests that are sensitive to natural hazards and/or serve a protective role are summarised in Tables 5 and 6.

	High mountain *départements*[38]		**Other mountain *départements*[39]**
Type of forest	RTM SOF	Non-RTM SOF	RTM SOF
% sensitive to natural hazards	87%	52%	54%

Table 5: Percentage of state-owned forests (SOF) sensitive to natural hazards such as soil erosion, falling rocks, avalanches and mudflows[40]

Source: ONF.

	High mountain *départements*		**Other mountain *départements***
Type of forest	RTM SOF	Non-RTM SOF	RTM SOF
% with a protective role	74%	40%	36%

Table 6: Percentage of state-owned forests (SOF) serving a protective role against natural hazards

Source: ONF.

Comment: This assessment cross-references natural risks, as detailed in Table 5, and the presence of populations or socio-economic concerns downstream from forests.

Forests serve a protective role against natural hazards as they can provide natural barriers against falling rocks, floods and mudflows.

The ONF assesses the protective potential of tree stands by computing a risk control index for them. The ONF uses this information to strengthen the forest's protective role where needed. This includes active protection work (such as torrent correction, drainage of waterlogged and therefore unstable soils), biological engineering work and passive protection work to supplement active protection (such as limiting or diverting material flows) (Maaf, 2016).

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[35] *Restauration des Terrains de Montagne* (restoration of mountain land).
[36] The RTM programme was initially created to reforest mountain areas and dunes to protect soil from erosion and urban areas from sand.
[37] Not all mountain forest areas are sensitive to natural hazards or serve a protective role.
[38] Alpine (74, 73, 38, 05, 04, 06) and Pyrenean (66, 09, 31, 65) French *départements*.
[39] *Départements* 01, 07, 11, 12, 13, 26, 30, 34, 43, 48, 63, 81, 83, 84.
[40] Calculations covering 2007–2011.

As part of this commitment, since 2016, nine RTM teams have been located in three "mountain agencies" (Alpes du Nord, Alpes du Sud and Pyrénées). **These teams carry out work in 25 *départements*** where close to 400,000 ha of land is exposed to soil erosion risk and natural disasters. Their activities include diagnosing risk and enhancing protective capacity with regard to floods, lava flows, falling rocks, landslides and avalanches.

Expenditure incurred for mountain land restoration has been €15m to €20m a year over the last decade. This expenditure increased in 2012 due to extreme weather events (heavy winter snowfall) and in 2013 because of the major spring flooding this caused in the southwest.

ii. The ONF's involvement in coastal erosion mitigation and dune management

The ONF is mandated by the ministry in charge of the environment to manage state-owned dunes over 379 km of coastline, which represents **76% of France's dune forests**.[41]

The ONF maintains and stabilises dunes on the edge of state-owned forests using plants (arenaceous plants), windbreaks, safety fences and footpaths. These activities are mostly carried out on the Atlantic coast. Using ecological engineering, they flexibly stabilise and re-profile dunes, protect them from erosion, protect or improve their biodiversity levels, provide public access without disturbing natural balances, and renew forest stands (ONF, 2015a).

Once used to protect land infrastructure against dune mobility, dune and coastal forest engineering can provide protection against emerging risks related to climate change.[42] Using newly available technologies and knowledge on the protective role of dunes, the ONF is undertaking an update of its planning documentation. It is trying to figure out the interaction between dunes and infrastructure protection by identifying areas facing challenges and monitoring them for impacts such as erosion.

France's Ministry of Agriculture subsidises the ONF for these activities, through general interest funding of up to €1.6m annually.[43] Expenditure on dune stabilisation has increased considerably since 2011, due to the cost of reconstituting dunes following Cyclone Xynthia in 2010 and successive strong winter storms in 2014, which prevented dune renewal. After the cyclone, the French government added €1m to the ONF's budget for dune restoration.

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[41] France has the largest dune area in Europe, 500 km (Fevennec, 1998).
[42] See e.g. CGDD, 2018b.
[43] This amount is for annual maintenance without any special expenditure.

Box 4. Other potential effects of public forest management on climate change adaptation

Contribution to local climate regulation in urban areas

Several hypotheses can be proposed to explain the predominance of public forests close to urban areas. However, it is reasonable to presume that in regions experiencing population growth and urban sprawl, state-owned forests have been the ones able to stave off deforestation. In contrast, the presence of forests in less population-dense areas is mainly due to the decline of farmland, making them more likely to be private.

In 2015, the surface area of suburban protective forests totalled nearly 81,000 ha (public and private). Protective forest areas changed little between 2010 and 2015, with only suburban forest areas increasing by about 500 ha.[44] Protecting suburban forests against urban sprawl ensures the survival of other ecosystem functions and thus the welfare of populations (Maaf, 2015 p. 232). Moreover, through their nature and biophysical functioning, forests positively impact the local climate in several ways (effects on the water cycle, evapotranspiration, albedo, filtering leaves, wind shields, etc.) (CGDD, 2018a).

Contribution to renewable energy deployment

In line with the French government’s position on renewable energy deployment in forests, the ONF has started an impact analysis to identify potential state-owned forest areas where renewable energy infrastructure could be installed. This analysis could also be useful for locally owned forests.

[44] After inclusion of the *massif du Kreutzwald* in 2012.

III. The ONF's Impact on Biodiversity Protection

Key results

- Overall, the ONF spends €26m per year on biodiversity protection, with €19m in direct investment and €7m in forgone revenue.
- The ONF has expanded a connected, representative and effectively managed network of deadwood areas and large veteran trees in public forests and is helping other such networks thrive. Public forests are more protected than private ones: 36% of public forests are protected, compared with 24% of private forests, with a larger share under strong protection status.
- Indirect and direct indicators suggest that public forest management has **a significant and positive impact** on biodiversity carrying capacity:
  - There are more large trees in public forests than in private forests, indicating a better state of biodiversity.
  - Deadwood quantities are comparable in both public and private forests, despite more logging in public forests as part of sustainable management practices.
  - On average, 2.9 times more common birds are observed in public forests than in private ones.
- The ONF also plays an important role in biodiversity protection in France's overseas forests, with specific actions targeted at protecting their ecosystems.

Introduction

Biodiversity is the variety and variability of life on Earth. It is useful to the functioning of human societies and economies in many direct and indirect ways. Biodiversity is unevenly distributed on Earth, and it can be nurtured or altered by human interaction with the environment.

Forests can host rich biodiversity depending on their natural features and, if logged, how they are managed. As part of a worldwide environment, they also serve as an indicator of the status of global biodiversity.

Even though they are less impacted than areas such as farmland, France's forests are, like other environments, experiencing biodiversity erosion.

Loss of biodiversity manifests itself in a larger proportion of endangered species, a higher frequency of extinctions and decreasing populations of common species. As an example, Table 7 shows that the proportion of endangered breeding bird and reptile species increased in French forests between 2008 and 2016.

	Breeding birds	
	2008	**2016**
Forest species	18%	25%
All species	27%	33%
	Mammals	
	2009	**2017**
Forest species	9%	8%
All species	26%	16%
	Amphibians	
	2008	**2015**
Forest species	8%	8%
All species	21%	23%
	Reptiles	
	2008	**2015**
Forest species	9%	18%
All species	19%	24%

Table 7: Proportion of endangered species[45] by type of environment.

Source: Marion Gosselin and Guillaume Gigot, from the red list and forest species list established by France's National Museum of Natural History in 1995.

Regarding forest biodiversity, the EFESE[46] report on forest ecosystems (EFESE, 2018) states that after a period of erosion in the late 1980s, common bird population abundance in forests[47] (an indicator of the general state of biodiversity) stabilised itself, as shown in Figure 3.

[45] Statuses are: "in critical danger", "in danger", "vulnerable", "quasi-endangered", "of minor concern" and "unavailable data". The figures in the table correspond to the total of the first three statuses.
[46] *Évaluation française des écosystèmes et des services écosystémiques* (France-wide evaluation of ecosystems and ecosystem services).
[47] Forest ecosystems being less impacted than others, for instance farmland (EFESE, 2018).

Figure 3: Abundance of common forest bird populations (index 100 in 1989)
<u>Source</u>: ONB,[48] *STOC database.*
<u>Comment</u>: Overall, between 1989 and 2017, common bird population abundance decreased by 3%.

In the first chapter of this report, we saw that, due to the implementation of large-scale sustainable management activities, public forests are, on average, more intensively harvested than private forests. This could occur at the expense of biodiversity. However, the ONF's sustainable management practices seek to balance wood production with other goals, including biodiversity protection. This chapter evaluates the impact of such practices on biodiversity.

The first section of this chapter presents the main biodiversity-oriented management practices and evaluates how effectively they have been implemented. The second section provides direct and indirect evidence of their impact on biodiversity.

[48] *Observatoire national de la biodiversité* (national biodiversity observatory).

A. The ONF's involvement in forest ecosystem protection

Overall, the ONF spends €26m per year on biodiversity protection, with €19m in direct investment and €7m in forgone revenue.

i. The ONF's protected area network

Under French law, there are two possible statuses for ecological reserves: national and regional. Acquiring either status requires going through a cumbersome administrative procedure, since it affects the property rights of forest owners.[49] To facilitate its protection activities, the ONF created a special protection status applicable to public land: biological reserves.

There are two types of biological reserves: *intégrale* (wilderness reserve) and *dirigée* (managed reserve). Wilderness reserves are not managed and are generally closed to the public, creating isolated areas experiencing natural evolution that are used for scientific purposes. The ONF secures these sites and informs the public about potential hazards (falling trees, etc.). Managed reserves are areas where specific ecological engineering measures are carried out to encourage the propagation of rare or endangered species or habitats. There are **two *instructions*** governing the policymaking for these biological reserves (ONF, 1995; ONF, 1998).

At present, there are **257 biological reserves**, covering 155,000 ha (of which 238 are in mainland France, covering 50,000 ha); **71 are managed reserves and 186 are wilderness reserves.** The ONF has set up a steering committee that monitors the status of biological reserves and develops the strategy for expanding its connected and managed network. Creating new biological reserves used to be dependent on financial capacity, making it a secondary objective. **In its 2016–2020 strategic plan, the ONF set a target of creating five new biological reserves per year,** including one overseas.

Biological reserves are crucial components of a network of protected areas. In addition to these protected areas, the ONF is undertaking actions to build and maintain a representative, connected and effectively managed network of large veteran trees and deadwood areas in public forests. The network also includes two kinds of "islands of ecological interest": *îlots de sénescence* and *îlots de vieillissement*. The former are similar to small biological reserves, where trees die without being removed or cut. The latter are areas where trees are not harvested until they have reached an extended rotation age.[50] In addition to these islands, all public forests include trees marked as "*arbres bios*",[51] which are not harvested. All these elements work together to create a connected network of protected areas.

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[49] Usually only state-owned forests are concerned, but with mayoral consent, biological reserves can be located in locally owned forests.
[50] Approximately 50% older than usual.
[51] Policymaking for these trees is governed by an *instruction* (ONF, 2008).

In 2016, the ONF set targets to have 1% of public forests be *îlots de sénescence* by 2030 and 2% be *îlots de vieillissement* by 2069, and to have 3 *bio* trees per hectare by the end of the forestry cycle. At present, 2.36% of public forests are already being managed as *îlots de sénescence* (above target) and 0.98% as *îlots de vieillissement*, and there is an average of 0.45 *bio* trees per hectare.

All these measures guarantee the existence of **a wide network of protected areas in public forests,** and this network is **representative, connected and effectively managed,** three properties known to be key to ensure thriving biodiversity.[52] Today this network is recognised as **95% representative** of the types of forest habitats of community interest considered at the rank of alliance within phytosociological nomenclature.

ii. The ONF's involvement in other protected areas

The ONF has also long played a role in the development of protected areas outside public forests. For instance, the ONF manages or co-manages 6.4% of nature reserves (45% of which are in forest areas[53]).

The ONF notably played a central role in the development of the Natura 2000 network of protected areas. Its contribution was twofold. First, 30% of public forests and 38% of state-owned forests are Natura 2000 areas, making the ONF a natural contributor. Second, thanks to its expertise drafting simple management plans, the ONF has often been asked to write objective-setting documents ("*docobs*") to frame the management and implementation of Natura 2000 areas and involve opposing stakeholders, particularly in locally contentious situations. At the national level, 20% of France's Natura 2000 areas had their *docobs* written by the ONF; in 14% of areas, the ONF is involved in the management of the site. Of the 38% of state-owned forests that are Natura 2000 sites, 36% are also under charter, which means they follow a bundle of commitments presented in an appendix of the objectives document.

iii. The ONF's involvement in species protection

Beyond its network of protected areas, the ONF promotes biodiversity through a set of activities and management practices designed to protect species.

For instance, the ONF integrates the protection of vulnerable species into its management practices by, among other things, factoring in breeding periods for logging and other activities and maintaining silence perimeters.

The ONF is also involved in the direct management and funding of six national action plans. These plans define measures to foster the development of protected, rare or valuable species or groups of species, with the cooperation of stakeholders. The ONF is involved in national action plans when the species are found in forest areas. Six naturalist forestry networks, created by the ONF 15 years ago,

[52] IPBES, 2019, message D4 and table SPM1.

[53] There are 330 nature reserves in France, representing 300,000 ha in mainland France; 18 are overseas, 150 concern forest areas, and 21 are managed by the ONF.

work on valuable species. These networks have a combined 235 members who contribute to 190 to 200 initiatives per year, amounting to 6,500 working days.

Whereas this section has mainly presented evidence of the ambitiousness of biodiversity-promoting measures and how well they have been implemented, the following section presents evidence (both direct and indirect) of the impacts of these measures on biodiversity.

Box 5. Other ONF activities and management practices that promote biodiversity

Management of aquatic environments

The ONF implements internal management *instructions* concerning aquatic environments and wetlands under a partnership agreement with six water agencies, which fund the management of these areas in state-owned forests.

Involvement in national parks

The ONF has also been asked to oversee the creation the new *Parc national de forêts de Champagne et Bourgogne*, as it will encompass predominantly state-owned forest land. The ONF has four years to create the 3,000 ha wilderness reserve, which it will co-manage with national park staff.

Involvement in research

Through RENECOFOR, a research programme monitoring soil quality, air pollution, biodiversity and tree growth in public forests, the ONF is contributing to public data. It is composed of a network of 102 plots, set up in 1992 for a 30-year monitoring period, with an annual budget of €1.2m. The programme monitors soil eutrophication and acidification. It includes a major investment in data collection and research.

Precautions for soil quality

Soil fertility and packing are also monitored through the RENECOFOR programme. Strict limitations on phyto-sanitarian products and a ban on glyphosate also contribute to biodiversity protection. And in order to preserve soil quality, the ONF partitions areas for logging, restricting areas where equipment is allowed to operate, and adapts harvesting methods to soil quality.[54]

[54] More details are available in the *Praticsol* and *Prosol* sustainable management guides published by the ONF.

B. Evidence of impact of public management on biodiversity

This section focuses on the direct and indirect evidence of the impact of public management practices on biodiversity.

i. Indirect evidence: More protected areas in public forests

Regional variations notwithstanding, public forests are, proportionally, more protected than private ones, with more stringent protections. Across all IUCN[55] protected area categories, 36% of public forest area is protected, compared to 24% of private forest area. A larger proportion of public forests is also under stringent protection (categories I to IV). Tables 8 and 9 detail the proportion of surface area classified as a protected area by type for all regions and Figure 4 details the results by region.

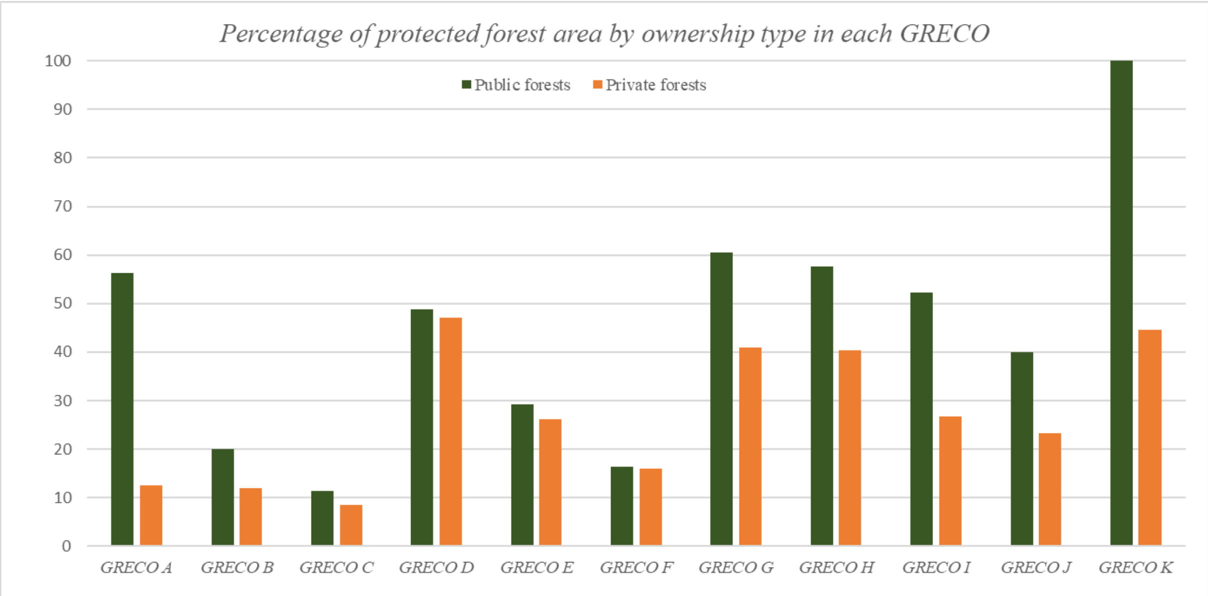
	ZNIEFF[56] area (type 1)	ZNIEFF area (type 2)	ZICO[57] area	SCAP[58] status
State-owned forests	37%	68%	25%	7%
Private forests	11%	36%	7%	2%

Table 8: State-owned vs. private forests in specific areas
Source: ONF.

[55] International Union for Conservation of Nature.
[56] Launched in 1982, the ZNIEFF inventory (*Zones Naturelles d'Intérêt Ecologique Faunistique et Floristique* – natural areas of ecological interest in terms of flora or fauna) aims to identify and describe areas of strong biological interest. There are two types of ZNIEFF: type 1 is areas of strong ecological or biological interest; type 2 is large, rich natural (or lightly altered) areas with strong potential.
[57] *Zone Importante pour la Conservation des Oiseaux* (important area for bird conservation).
[58] *Stratégie de Création des Aires Protégées* (strategy for creating protected areas), developed to enforce consistency, representativeness and efficiency of the protected area network in mainland France.

	Ia – Strict Nature Reserve	Ib – Wilderness Area	II – National Park	III – Natural Monument or Feature	IV – Habitat/Species Management Area	V – Protected Landscape/Seascape	VI – Protected area with sustainable use of natural resources	Total across all categories
Public forests	0.32%	0.00[59]%	1.56%	0.011%	3.49%	30.95%	N/A	36.33%
Private forests	0.001%	0.00[60]%	0.14%	0.010%	0.92%	22.84%	N/A	23.92%

Table 9: Percentage of protected forests by IUCN protection category and ownership type
Source: Authors' calculations.[61]
Comment: For instance, 0.3% of public forest areas are classified by the IUCN as strict nature reserves, while only 0.001% of private forests are.



[59] 4.86219200350753E-09.
[60] 1.16399805986993E-08.
[61] See Appendix 2 for methodology.

Figure 4: Percentage of protected forests by ownership type in each GRECO,[62] across all IUCN categories

Source: Authors' calculations.[63]

*Comment: In GRECO A (*Grand Ouest cristallin et océanique*), 58% of public forests are classified in one or several IUCN protection categories, compared to only 11% for private forests.*

We qualify this result as indirect evidence because protected areas are scientifically known to allow biodiversity to thrive, but are not a direct biophysical measure of its state. The fact that public forests are more protected than private ones could be explained by the following hypotheses:

i. The ONF facilitates the classification of its forests as protected areas, which reflects its ambition to take a biodiversity-oriented approach to its management activities.
ii. Due to their unique properties, public forests have more features of biological interest, making these areas more likely to meet protected area requirements.
iii. Protected forest status involves strict management requirements, which might deter some private forest owners. It is easier for the state to impose such requirements in public forests, particularly state-owned ones.

Hypothesis (i) was partly upheld by the previous sub-section, detailing the role of the ONF in expanding a network of protected areas in public forests (biological reserves, islands and *bio* trees). In particular, the ONF has been pursuing a proactive expansion policy for biological reserves since the 2000s. The ONF also plays an active role in supporting the implementation of existing protection statuses in public forests. However, it can hardly explain global figures, unlike hypotheses (ii) and (iii), as these actions relate to only small areas of forest.

Hypothesis (ii) can be at least partly attributed to long-term public management. Indeed, it has helped ensure continuous forest cover over time, leading to a greater surface area and a greater proportion of old-growth forests, which are beneficial to biodiversity (ONF, 2017). However, another explanation could be found in the process through which forests became public, which could have led to a selection bias irrespective of public management practices (e.g. location). However, this explanation is unlikely, as the locations of public forests are tied to historical factors.

It therefore appears appropriate to attribute the larger proportion of protected areas in public forests at least partly to the public management activities of the ONF.

[62] GRECO stands for *Grande Région Ecologique*, a large ecological region characterised by its unique geomorphology, geology, climate, soils, water resources, flora and fauna.
[63] See Appendix 2 for methodology.

Figure 5: GRECOs in France

ii. Direct evidence: More favourable habitats and more common birds in public forests

In this subsection we will detail direct evidence of impact, that is to say biophysical measurements demonstrating the healthy state of biodiversity. The effective level of biodiversity in public and private forests has been compared using three indicators: volume of deadwood, volume of large living trees and population size of common birds.

The literature emphasises the positive relationship between the volume of deadwood[64] and large living trees (elements of biodiversity in and of themselves) and the thriving of a rich ecosystem (ONF, 2017). The abundance of common birds is also considered an indicator of the general state of biodiversity; as stated in Pearman and Weber (2007), spatial patterns of species richness are determined mainly by common species.

Table 10 shows that, despite higher logging rates, the volume of large living trees per hectare is higher in public forests than in private ones. The volume of deadwood is also higher, although the difference is not significant.

	Deadwood volume/production forest surface area (m^3/ha)	Large living trees with a diameter above 47.5 cm (m^3/ha)	Large living trees with a diameter above 67.5 cm (m^3/ha)

[64] A relevant indicator is also the diversity of deadwood pieces, which unfortunately was not available for this study.

	Public forests	Private forests	Public forests	Private forests	Public forests	Private forests
France total	18	16	**46**	**29**	**20**	**8**
Mean by GRECO	18	17	**46**	**31**	**23**	**9**
Student test						
Unilateral Bilateral[65]	(0.34) (0.69)		(0.03) (0.05)		(0.009) (0.02)	

Table 10: Indirect measurement of biodiversity levels for private and public forests.

Source: Authors' calculations based on IGN data.

Furthermore**, 2.9 times more common birds per hectare have been observed in public forests than in private ones.**[66] The nationwide results are shown in Table 11. Across all GRECOs, the ratio ranges from 0.7 to 12. All these differences are statistically significant (the p-value is 0.07).

GRECO	Ratio public/private
A – *Grand Ouest cristallin et océanique*	12
B – *Centre Nord semi-océanique*	4.83
C – *Grand Est semi-continental*	1.12
D – *Vosges*	0.69
E – *Jura*	1.12
F – *Sud-ouest océanique*	12.58
G – *Massif central*	7.43
H – *Alpes*	1.45
I – *Pyrénées*	1.32

[65] Significant differences between public and private forests are indicated in bold.
[66] On average per year, between 2014 and 2017 (data only available for these years). As seen in Figure 3, there are some rather strong short-term variations in common bird abundance, making it irrelevant to calculate a rate of change between 2014 and 2017.

J – *Méditerranée*	3.17
National average	2.97

Table 11: Number of common birds observed per hectare, for each GRECO and nationwide

*Source: Authors' calculations; methodology presented in Appendix 3. GRECO K (*Corse*) is not included due to lack of data.*

As explained above, these three elements suggest a relatively better general state of biodiversity in public forests than in private ones. Common bird abundance is a possible indicator of a better state of biodiversity; however, there is a lack of detail in the chosen indicator, which was determined by data availability.[67]

The following points provide some indication as to how the ONF's public management activities can at least partly explain these results.

First of all, it is known that old, large forests are more biodiverse than small, young ones (CGDD, 2018a). As stated in the previous section, thanks to the long-term public management of the ONF and its policy to actively preserve forest areas from urban and agricultural sprawl, public forests are older and larger than private ones, explaining the larger volumes, per hectare, of large living trees, deadwood and common birds.

Moreover, in private (and often small) forests, owners might be more likely to favour relatively fast-growing tree species to ensure at least one harvest in their lifetime. However, public forests are increasingly promoting the practices of planting fast-growing species and decreasing rotation age and diameter as a climate change adaptation strategy.

Another explanation could be that the ONF's management practices promote high rates of wood production and deadwood preservation and help common bird populations thrive. For instance, frequent clearing encourages tree growth. The ONF is working on oak tree stands, which are cut only after reaching a large diameter, and mountain conifers, which can also grow to become very large,[68] owing partly to the difficulty of cutting them due to their mountain location. Furthermore, the ONF published a technical guide on deadwood management in 2017. It is also undertaking a large-scale avifauna management initiative.

Ultimately, even though climate change adaptation practices and biodiversity protection measures can sometimes be at odds, it appears appropriate to attribute, at least in part, the equal proportions of deadwood, higher volumes of large living trees (despite higher extraction rates) and larger populations of common birds to the public management activities of the ONF.

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[67] As there is no distinction made between species, a high number of common bird observations can be explained either by a large number of individuals per species, which indicates a good state of biodiversity, or by a larger number of species, the significance of which is unclear, as it can result from intensification practices.
[68] For instance, the majestic fir trees of the hinterlands of Nice.

IV. The ONF's Overseas Activities

Key points

- **Overseas forests** are an important part of the ONF's operations, representing **60% of the forests it manages** and 24% of France's forests.
- They are also key for biodiversity protection (hosting around **80% of France's biodiversity**) and climate change mitigation (representing a substantial carbon sink in geographical areas under pressure).
  - French Guiana's carbon stock represents 2.6 billion tonnes of carbon.
  - Martinique's carbon stock represents 12 million tonnes of carbon.
- **There is very little logging of overseas forests**. The ONF's efforts are mainly dedicated to protecting biodiversity, safeguarding public land and providing recreational services.
- The ONF's main overseas activities targeting biodiversity and climate change mitigation are: creating and managing nature reserves; protecting public land against illegal deforestation, gold mining and illegal occupation; monitoring the national action plan; and drafting and enforcing planning documents.
- Since 1990, French Guiana's forest cover has decreased by only **1%** (88,000 ha).
- Since the 1950s, forest cover has remained **stable** in Martinique.

Introduction

The ONF oversees the management of state-owned forests overseas (French Guiana, Martinique, Réunion, Mayotte, Antilles, Guadeloupe). Overseas forests are an important part of the ONF's operations, because of their size (they represent 60% of the forests managed by the ONF and 24% of France's forests), because of the types of habitat they are home to (both rare and globally endangered) and because of the pressures they face (poaching, illegal mining, illegal deforestation, etc.). As they are mostly unharvested,[69] the ONF dedicates most of its efforts to protecting biodiversity, safeguarding public land and providing recreational services.

As mentioned in the general introduction, without the ONF's public subsidy, there would be no management of France's overseas forests. The financial and human capital investments in these forests to develop biological reserves, combat invasive foreign species and stop illegal activities are therefore considered as purely additional benefit.

French Guiana and Martinique: Geographic and economic context

France's overseas territories each have their own unique characteristics. What they all have in common is that they are geographically, economically and socially different from mainland France. Their

[69] Except for approximately 0.01% of the forest surface area in French Guiana, yearly.

demography is much more dynamic, making for markedly different economic and social development issues. They are also located in tropical regions that provide them with extraordinary ecosystems hosting around 80% of France's biodiversity. The size of their forests, especially in French Guiana, means their conservation plays a key role in mitigating climate change at the national level. Overall, the stakes in terms of biodiversity protection and climate change mitigation and adaptation are very high in these regions.

The following two subsections will provide context for France's two most forested overseas territories: French Guiana and Martinique. French Guiana is located in a region with high tensions regarding deforestation, and Martinique is regularly confronted with the illegal occupation of state-owned forest land.

French Guiana

French Guiana covers 8.4 million ha, making it the second largest French region after Nouvelle-Aquitaine. It is primarily a forest region, with 97% of its surface covered by forest; it is France's largest forest region.

As private forests and plantations are extremely limited in French Guiana, its forests are almost exclusively under public management, which means they benefit from a relatively high level of protection. Moreover, they are almost entirely natural, not fragmented or divided.

Ownership of French Guiana's public forests is split among several types of owners:

- The permanent forest estate is state-owned. Located in the northern part of French Guiana, it represents 29% of the region's total forest surface area and is managed by the ONF. Harvesting and economic development are permitted at the expense of forest cover, but only within the limits set out in the ONF's planning documents (less than 0.01% of surface area per year).
- The Amazonian Park of French Guiana (APFG), created in 2007 and located in the southern part of the region, represents 25% of the region's total forest surface area. It is managed and owned by the park administrators. It is entirely protected, with a closed zone at the south of the Elaé-Camopi border (see Figure 6).
- The National Coastal Conservatory, the Guiana Space Centre and the *département* own less than 1% of the total forest surface area, which is managed by the ONF. These areas are left untouched.
- The remaining 45% of the total forest surface area is state-owned: it includes areas adjacent to the APFG that are included in the protected area.

Type of owner/ownership	Location/share of total forest surface area (2015)	Manager	Protection status and use
Permanent forest estate (state-owned)	Northern area – 29%	ONF	Can be harvested or deforested for economic development (less than 0.01% of surface area per year)
Amazonian Park of French Guiana (APFG)	Southern area – 25%	Park administration	Entirely protected, with a closed zone at the south of the Elaé-Camopi border
National Coastal Conservatory	Northern coastal area – 0.4%	ONF	Some protected areas; some deforested for development needs associated with demographic growth
French Guiana Space Centre	Northern coastal area – 0.6 %	ONF	Unused
Département	Northern coastal area – 0.1%	ONF	Unused
Rest of state-owned forests	Northern area – 45%	ONF	Protected (apart from some isolated parts in the north); includes APFG access areas

Table 12: Different public ownership types of French Guiana's forests

Source: Adapted from Maaf 2019.

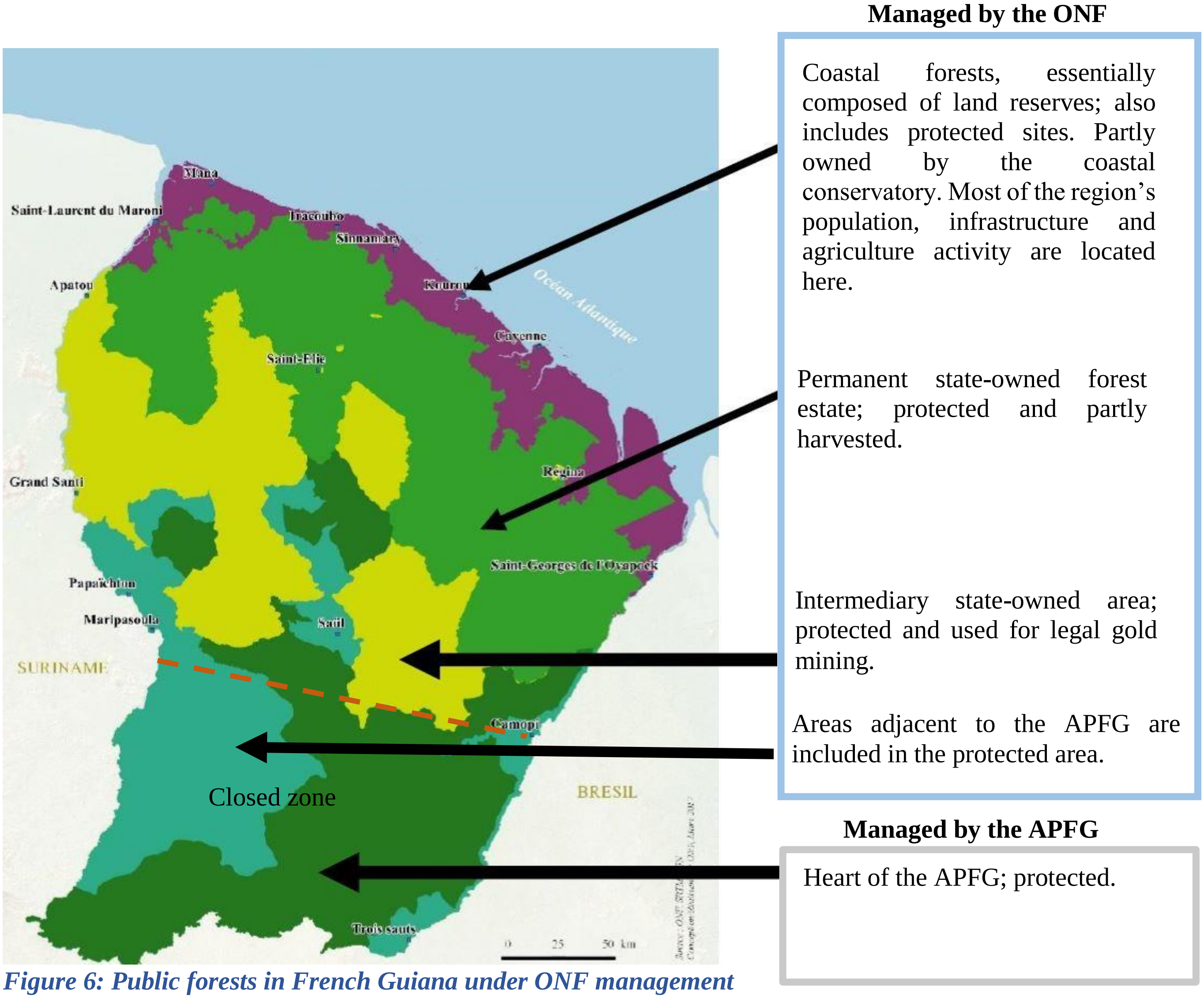

Figure 6: Public forests in French Guiana under ONF management

Source: Adapted from ONF.

Due to the prevalence of forested land, most of the population lives along the coast. The population is growing fast but still remains below 250,000 inhabitants, making French Guiana the second least populated region of France after Mayotte.

The tertiary sector dominates French Guiana’s economy, with less than a quarter of local GDP coming from the primary and secondary sectors. As economic activity is not particularly extraction-oriented, it has relatively little impact on forest surface area. Farming activity mostly accounts for deforestation, which is occurring at a rate of 1,500 to 2,000 ha per year. This is at the expense of forest cover, but in response to development needs expressed by local authorities.

There is less deforestation due to gold mining than there used to be. Between 1990 and 2012, it represented 800 ha per year, growing rapidly between 1990 and 1999 before stabilizing at around 1,500 ha per year between 1999 and 2008. Illegal gold mining was the main contributor to deforestation during that period but was later curbed by Operation Harpie. Overall, the cumulative impact of gold mining between 1990 and 2014 amounts to 25,000 ha, approximately 0.3% of total forest cover.

There is a timber industry in French Guiana, but it does not fully satisfy local demand as the region is still importing wood, which demonstrates its relatively small impact. Urban and transport infrastructure development are responsible for between 300 and 400 ha of deforestation per year.

A significant amount of the surface area deforested for infrastructure development or farming needs is reforested after several years (see green arrows in Figure 7). This is explained by the fact that traditional farming practices typically involve small plots under 1 ha.

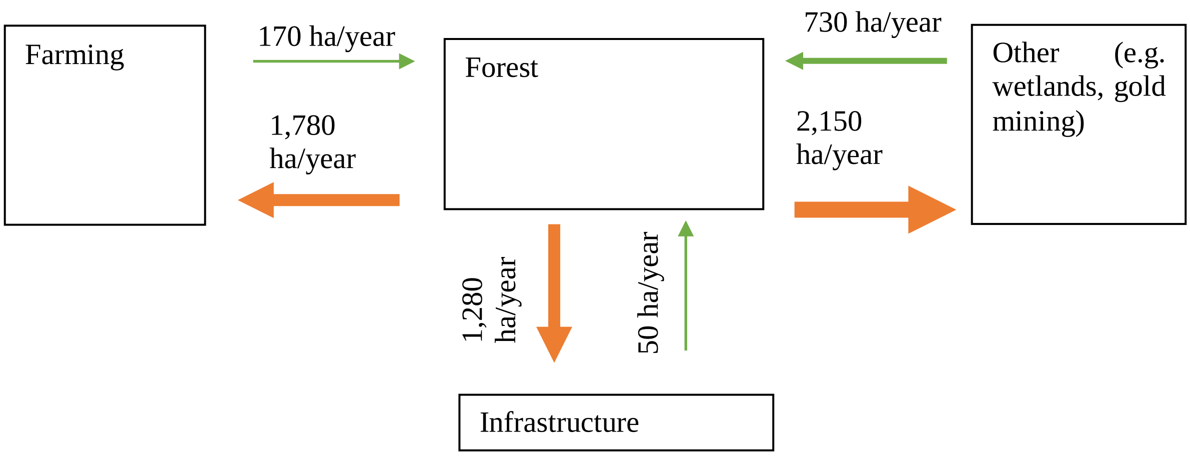

Figure 7: Land-use changes between 1990 and 2012 in French Guiana

Source: Adapted from Maaf, 2018.

Since 1990, the overall degree of afforestation has decreased by 1%, due to demographic expansion and the resulting economic development needs (food and energy self-reliance). More specifically, as detailed in Figure 7, since 1990 French Guiana's forests have lost 0.35% of their surface area to farming, 0.2% to infrastructure and the rest to other land use, including wetlands.[70] Apart from illegal gold mining, these deforestation activities are legal and are overseen by local authorities, in particular through the enforcement of ONF development plans.

This is a small decrease in forest cover, considering that only 3% of the region's remaining land is available for crops, livestock, infrastructure, urban development, and anything beyond that must be made at the expense of forest cover. Furthermore, while **French Guiana lost just 1% of its forest cover** over a 25-year span, **neighbouring countries have lost much more.** Brazil lost 20% of its forest cover over 28 years (1970–2018) and Argentina lost 22% over 24 years (1990–2014).

[70] Mangrove movement explains the loss of forest cover to wetlands.

An essential contributor to climate change mitigation is the carbon stocks of forests. This is particularly true of French Guiana, whose forests are virtually unharvested and have long forestry cycles, and where the level of carbon sequestered in harvested wood products is low. These factors prevent sustainable harvesting as practised in mainland France.

Due to their size, French Guiana's forests represent a significant carbon stock: between 2 and 2.6 billion tonnes of carbon, which represents 250 to 325 tC/ha[71] (Maaf, 2018). However, as the forests are simultaneously experiencing decreasing surface area (approximately 0.01% per year) and increasing biomass per hectare, it is not possible, based on current knowledge, to evaluate the average annual variation of their carbon stock.

Martinique

Martinique is an island covering 112,800 ha, approximately the size of a small French *département*; it measures 73 kilometres long and 39 kilometres across at its widest point. It is mainly volcanic.

Forest areas totalling 56,000 ha cover around 50% of the island. This includes partially treed mountain forests, mangroves, tropical rainforests, mahogany plantations, tropical dry forests, bamboo forests and beach forests.

Not enough is known about private forests in Martinique, which represent 69% of forested surface area. Private owners do not invest in forest management, and a structured plan for Martinique's forests has yet to be developed. The remaining 31% of forest area is public, covering strategic regions such as the island's highest points (Mount Pelée, Carbet Mountains) and its coastlines. Public ownership takes different forms:

- Forests owned by both the state and the *département* represent 61% of the island's public forest surface area (9,700 ha, of which 9,200 ha is forested).
- State-owned coastal forests represent 9% of public forest surface area (1,800 ha, of which 1,300 ha is forested). Created in 1981, these forests face pressure from tourism-related land development and used to be partially illegally occupied. The latter issue is now under control; however, the region has not fully recovered its forested nature yet.
- *Département*-owned forest land represents 10% of public forest surface area (1,500 ha, almost fully forested). Created in the 1980s through regular purchases, its size is steadily increasing.
- Forest land owned by the National Coastal Conservatory represents 8% of public forest surface area. Its size is steadily increasing thanks to regular land purchases.
- The *domaine public maritime* (public maritime domain) represents 12% of public forests (1,900 ha). It is mainly composed of mangroves.

In the 1700s, the island was almost entirely covered by forest. At the end of the 18th century and during the 19th, it was heavily deforested for agricultural and urban development. Mount Pelée also erupted in 1902, severely affecting the northern part of the island. In the 1990s, the alarm was raised about the state of the forests, which led to the creation of a forestry service; mahogany trees were also planted as a

[71] Above-ground biomass and soil organic matter taken into account.

restoration measure. Today 80% of Martinique's forests belong to a protected area (mainly within the Regional Natural Park of Martinique).

The two main threats to Martinique's forests are cyclones, occurring every three or four years, and biological invasions caused by invasive foreign species such as bamboo. There is a relatively strong degree of anthropisation, but the island remains mainly natural. Variation in terrain elevation prevents the logging industry from expanding; as a result, only 12% of forest surface area is harvested.

Overall, just under half of the island has been relatively steadily covered in forest area since the 1950s. This includes expansions (due to agricultural decline) and contractions (due infrastructure development). Public forests cover fragile ecosystems and tend to spread, whereas private forests tend to come from the recovery of old farmland and are more commonly confronted with urban sprawl.

An essential contributor to climate change mitigation is the carbon stocks of forests. This is particularly true of Martinique, whose forests are not heavily harvested and where the level of carbon sequestered in harvested wood products is low. These factors prevent sustainable harvesting as practised in mainland France.

The island's biomass stock varies from one location to another and depends on tree settlement, but it is rather high on average. Above ground, it amounts to 300 cubic metres (up to 500 in rainforest areas), and it is double that with the addition of roots, deadwood and soil. Rainforest areas host two-thirds of the island's biomass. Overall, Martinique's forests store 12 million tonnes of carbon, which represents 240 tC/ha on average (Maaf, 2018b). Based on current knowledge, biomass variation is only affected by regular changes in forested surface over the course of the year, and therefore remains greenhouse-neutral.

The ONF's overseas activities

In these territories, the ONF has a specific role. As seen, there is little harvesting of overseas forests. This means that unlike in mainland France, where regulating logging is a large part of its role, the ONF's overseas activities are mainly dedicated to protecting biodiversity, safeguarding public land and providing recreational services. These activities have impacts, whether direct or indirect, on climate change mitigation and biodiversity protection. The ONF's climate change adaptation activities, however, are more difficult to carry out overseas, where, for example, low harvesting levels are not conducive to tree species selection through sustainable harvesting.

Climate change mitigation

One of the main roles of the ONF overseas is to protect land against urban sprawl and illegal deforestation from logging and gold mining. As an example, in Martinique today, 150 ha of state-owned forests are illegally occupied; in French Guiana, 476 ha of state-owned forests were destroyed by illegal mining activities in 2018. Protecting forests against illegal deforestation is key in the fight against climate change as overseas forests represent a significant carbon stock. Consequently, the ONF is undertaking several actions.

In French Guiana, where illegal deforestation is more pervasive than in the other overseas territories, the ONF works in cooperation with local authorities, police and customs to locate, track and prevent illegal activity and rehabilitate the land. Since 1996, there has been an eight-person team monitoring the territory and tracking the environmental impact of gold mining activity. The ONF also works with legal mine operators, raising awareness about environmental concerns and offering training to help minimise their impact. As part of Operation Harpie, a program launched in 2008 to combat illegal mining, the ONF also reports illegal gold mining activity to law enforcement and records its environmental impact.

Consequently, the annual level of deforestation caused by illegal and legal mining fell by two-thirds in 2009 and 2010. Since 2011, gold mining (both legal and illegal) has been on the rise again. However, without downplaying this phenomenon, it should be kept in mind that between 1990 and 2014, French Guiana's forests lost "only" 0.3% of their surface area to gold mining (Maaf, 2018).

A small share of the ONF-managed permanent forest estate (0.01%) can be harvested and/or deforested for urban or agricultural development. The ONF chooses specific patches of forested land for such purpose by drafting a planning document. This process allows the region to undertake large-scale economic development planning while also keeping environmental protection as a key objective. It therefore works to discourage unorganised sprawl and the destruction of ecologically important areas such as ecological corridors. As stated in the previous section, French Guiana lost 1% of its forests to development associated with economic activity between 1990 and 2015.

In Martinique, the ONF deploys efforts to combat illegal occupation of state-owned land, which can damage habitats or lead to illegal logging. There has been a decrease in this phenomenon in recent years (Maaf, 2018).

Finally, the preservation of overseas forests, through the creation of biological reserves, enhances carbon sequestration capacity, which contributes to climate change mitigation.

Biodiversity protection

France's overseas territories are home to rare habitats such as mangroves, primary forests, volcanic structures, etc. and several endangered species. That makes biodiversity protection a particularly important issue overseas, in the context of the global extinction crisis. Taking into account all types of habitat (not only forests), half of the endangered species in France are located overseas.[72] More specifically, the IUCN has recorded 65 threatened forest species in Martinique, most of them in danger of extinction.

In the previous section, we detailed the ONF's efforts to combat illegal deforestation as a way of mitigating climate change; of course, that work also involves preventing the destruction of habitats, which also contributes to biodiversity protection. Beyond the inherent benefits of halting deforestation, curbing illegal gold mining also benefits biodiversity as it is known to pollute water resources through mercury spills.

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[72] Excluding French Guiana (data not yet available).

The ONF also uses more direct measures to protect biodiversity.

First, components of national action plans are implemented in France's overseas territories. For instance, there have been national action plans to protect endangered sea turtles since 2006 for Guadeloupe and Martinique, 2014 for French Guiana and 2015 for Mayotte, Reunion, and the Scattered Islands. The ONF is involved in their implementation.

Sea turtles are threatened in more than one respect: they are poached or accidentally caught by anglers, and their egg-laying areas are altered or destroyed. The national action plan for Martinique, for instance, seeks to identify and protect egg-laying areas and contain poaching on these sites; reduce mortality linked to accidental capture; reduce offshore poaching; reduce terrestrial threats; and monitor populations to assess the impact of these actions. In 2011, a substantive increase of the sea turtle population was seen in Martinique (DIREN, 2012).

Second, the ONF is involved in managing three national parks located overseas. In 1989, France's first overseas national park was created in Guadeloupe. In 2007, two more were created, in Guadeloupe and in French Guiana. Overall, France has 11 national parks.

The ONF is also expanding its natural reserve network overseas. Currently, France's overseas territories are home to its largest reserves, with just 19 sites accounting for 68% of the total surface area of all 257 biological reserves in France.

Finally, the ONF's overseas work involves fighting invasive foreign species, one of the biggest threats to overseas forests. For instance, in Martinique, €115,000 is allocated every year to preventing the spread of *Miconia,* iguanas, mongooses and rats. Campaigns to control *Spathodea* and *Triphasia Trifolia* were also launched in 2014. Furthermore, in Reunion, the ONF, the national park, the local coastal conservatory and the National Botanical Conservatory work together to combat invasive foreign species, having collaborated with the CIRAD[73] to map out the island's conservation challenges and prioritise actions in a context of budget constraints. In 2019, the cost of the ONF's invasive foreign species program was €1,600,000.

[73] *Centre de coopération International en Recherche Agronomique pour le Développement* (Centre for International Cooperation in Agronomical Research for Development).

V. Referee Observations

Scientific referees: Jean-Luc Peyron and Marion Vinot-Gosselin

Jean-Luc Peyron is a doctor of economics. His background includes work on sustainable and multi-functional forest management and indicators, biodiversity and ecosystem services, climate change and public policy. He is currently the head of ECOFOR, a public interest group which aims to support, lead and promote research and expertise programs on temperate and tropical forests. He has chaired, at the European level, an intergovernmental action programme on climate change and forests, named ECHOES (Expected climate change and options for European silviculture), and at the international level, a research group on economics and forestry accounting. He is a member of the French Academy of Agriculture and a board member of the International Union of Forest Research Organizations (IUFRO).

Marion Vinot-Gosselin is a specialised engineer in forest ecology at INRAE (National Research Institute for Agriculture, Food and Environment) in the Biodiversity and Forest Management team of the Forest Ecosystems research unit. She is in charge of knowledge production and transfer on the relationships between forest management and biodiversity, particularly forest biodiversity monitoring.

I. General comments

The referees both highlighted the serious and earnest approach taken to the report, especially given the lack of data.

They mentioned the lack of evaluation design for assessing the impact of public forest practices on carbon emissions in the atmosphere or forest biodiversity. Indeed, there is no basis for comparison apart from the subsidies granted to the ONF. The differences with other forests are related to their location, history and other contextual factors, as well as the species composition, structure and ecological functioning specific to them, all of which is independent of the forest management applied to them.

II. Comments on methodology and counterfactual

Jean-Luc Peyron

Contrasting the characteristics of public and private forests has the merit of relativizing those of the former with respect to the latter but cannot constitute a comparison of the situation with and without subsidies, all other things being equal.

From this, it is also possible to question how public forests would be managed in the absence of such subsidies and how the three criteria would be affected. Since they have specific and focused objectives, general interest activities can be handled separately:

- It is clear that forest fire prevention also prevents the depletion of carbon stocks and the resulting carbon emissions, thus contributing to climate change mitigation; the same can be said for the prevention of erosion of mountain and coastal forest soils.

- After a forest fire or soil erosion, restoration poses specific problems in addition to those of climate change adaptation; it can be deduced that prevention facilitates climate change adaptation and can even be combined with it.
- Fires and soil erosion are primarily the cause of a change or destruction of natural habitats. Destruction of habitats is also a major cause of biodiversity erosion; that is why prevention of fires and erosion helps conserve biodiversity. Admittedly, in some particular cases, fires or erosion can allow for the regeneration of special species adapted to this type of situation, but prevention does not mean suppression; it is just a matter of significantly reducing the phenomena that we are trying to avoid. This means that these special species continue to find opportunities to survive or even expand.
- In overseas territories, public subsidies for general interest activities probably have no or little connection with climate change; on the contrary, they facilitate biodiversity conservation when used toward public visitor programmes in forests, for example.

It seems that general interest activities contribute to the conservation of biodiversity and climate change adaptation and mitigation.

Let us turn now to subsidies related to the management of state-owned and locally owned forests (funded through a balancing subsidy and compensatory payment). The lack of such funding would contribute to two potential scenarios:

- Intensification of silviculture in order to increase revenues and compensate for the loss of the subsidies; this shift would then likely prioritise profitability to achieve this compensation, which would be to the detriment of environmental services rendered to biodiversity and climate change mitigation because of the intensity and speed of changes needed to ensure profitability. Perhaps forest adaptation would be ensured through this strategy; however, the likelihood of this strategy being implemented is low, according to the German example of Baden-Württemberg, where forestry activity has declined since responsibility for timber sales was taken away from the forest administration.[74]
- Reduced management in general, since a large part of management costs would no longer be covered. It would probably mean less monitoring, less investment (maintenance work) and improvement cutting or harvesting. The sustainability of forest management would be threatened in that the provision of ecosystem services would not necessarily be assured, and it would be the same for risk prevention. Forest adaptation would be more difficult to achieve; the stands would store carbon temporarily until threatened by droughts, biotic invasions, fires or storms, and a reduction of the sink could not be offset by a substitution effect from mostly accidental products.

The subsidies we are talking about here are mostly used to cover the costs of sustainable forest management, which is complex and requires know-how and skills. This is especially true when it comes to dealing with issues related to biodiversity or the consideration of climate change and associated uncertainties. When subsidised, forest management can be more precise, adapted and sustainable,

[74] Personal communication from Christian Barthod, member of the General Council for the Environment and Sustainable Development (CGEDD).

somewhere in between the two strategies briefly described earlier. Ultimately, these subsidies serve as payments for environmental services that allow the state to:

- Balance the response between ecological, economic and social issues.
- Facilitate adaptation to climate change by stimulating stand management and improvement.
- Enable climate change mitigation by promoting a good compromise between *in situ* carbon sequestration on the one hand, and *ex situ* carbon sequestration and material and energy substitution on the other hand, while maintaining effective biodiversity.

These comments support the same conclusion as the evaluation report. They are ultimately complementary to the results of the evaluation report, shedding light on them from a slightly different viewpoint.

Marion Vinot-Gosselin

The referee found that a clearer and more meaningful distinction was made between the ambitiousness of environmental practices and their implementation and impacts in the chapter on biodiversity, compared with the climate change mitigation and adaptation chapters.

The referee questions the fact that the pollution criterion was discarded from the evaluation. Pollution risks do exist, for example soil or water pollution due to wood harvesting equipment. These risks are taken into account in public forest management.

Due to the lack of data and a dedicated evaluation design, the report chose to compare public forests with private ones. This is an understandable choice, considering the lack of data.

However, this comparison not only demonstrates the short-term effects of public forest management practices, it also reveals historical differences between public and private forests (for example, age of forest cover, with public forests being mostly old royal forests and private forests being more recent, created through afforestation on abandoned farmland) and geographical differences. An alternative way to isolate the short-term effects of public management would have been to compare public forests with large private forests that have management plans, or better yet, with large private old-growth forests. However, the data needed to perform such an analysis were not made available by the administrative services in charge of private forests.

Another alternative would have been to evaluate only general interest activities. However, that would have excluded the ONF’s everyday management activities in favour of biodiversity (e.g. deadwood and large veteran tree retention).

Although caution is advised in interpreting the results due to the comparison method used, the report shows that public forest management does achieve a good balance between climate change mitigation, climate change adaptation and biodiversity protection.

III. Comments on results

Marion Gosselin

With regard to climate change adaptation, the reported results are more revealing about the ambitiousness of the objectives than how well they have been achieved. This is not surprising; evidence of the resilience of the forests to future climate conditions is lacking. However, the report could cite several scientific results that consistently show links between mixed stands and resistance to insect pests, for example.[75]

As for climate change mitigation, the reported higher harvesting activity in public forests leads to a reduction of GHG emissions, taking into account not only the effects of the harvest itself, but also the effects of the regrowth of young stands and the substitution effects (use of wood rather than fuel or cement).

It is important to note that public forest management, which is enabled by the state subsidies, leads to a good balance between:

- Long-term *in situ* sequestration (in trees, in soil and old biodiversity-friendly stands), combined with special care to avoid forest fires or windstorms that would increase carbon emissions.
- Long-term *ex situ* sequestration and substitution, thanks to regular harvesting, combined with special care to conserve old stands and trees that are favourable for biodiversity.

In terms of biodiversity results, it is useful how the report clearly and distinctly presents, on the one hand, the activities being implemented to enhance biodiversity habitats, and on the other hand, the effects on habitats and species diversity.

The distinction between indirect indicators of biodiversity (habitats) and direct indicators is crucial, since the presence of a favourable habitat does not mean that the related species are present. It is a necessary but insufficient condition. It is known that deadwood and old large living trees are crucial habitats for forest biodiversity, and the report shows that public forests hold comparable or better quantities of these habitats than private ones. For direct indicators, there are very few available data at the national level.

In order to compare private and public forests, the only available data are flora and bird data. Flora data could not be used here due to sampling biases (many plots in floodplain forests are sampled in winter, thus underestimating the richness of the flora). For that reason, the only direct indicator is common birds (a very small subset of biodiversity), with significantly higher levels of common bird abundance in public forests. In addition, this direct indicator applies only to mainland France.

As previously stated, due to the chosen methodology, this does not necessarily indicate that public management is more effective than private management (better indicator values may be attributable to historical or geographical differences), but it does indicate, at least, that public management does not lead to the destruction of biological heritage.

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[75] See e.g. Guyot et al., 2015, Plos One, http://dx.doi.org/10.1371/journal.pone.0136469.g001, or Jactel, H. et al., 2017, Tree Diversity Drives Forest Stand Resistance to Natural Disturbances, Current Forestry Reports, 3 (3), pp. 223-243, or Jactel, H. and Brockerhoff, E.G., 2007, Tree diversity reduces herbivory by forest insects, Ecology Letters, 10 (9), pp. 835-848.

These comments speak to the lack of available data required to assess the status and dynamics of forest biodiversity, and in turn to assess the impact of public forestry practices and policy on forest biodiversity.

With regard to the results for overseas France, the arguments dealing with the carbon cycle may be seen as puzzling. They are not presented in the same way as for the mainland: in the overseas section, the fact that the forest is virtually unharvested is seen as positive because it enhances the *in situ* carbon sequestration; in the mainland section, the fact that most forests are harvested is also seen as positive because it enables both substitution and sequestration (in young stands). An explanation for these two seemingly opposite points of view would be welcome. It can in fact be explained by societal choices: both cases (harvesting vs. no harvesting) can be considered relative to the specifics of the wood sector and current uses of wood. But in the case of harvested forests, the impacts of biodiversity protection measures and the use of sustainable harvesting practices must be considered in terms of carbon sequestration, substitution effects and biodiversity conservation.

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Appendices

Appendix 1 – Climate change mitigation: Methodology

This method seeks to account for the effects of increased forest use on climate change mitigation by considering the effects of extended *ex situ* sequestration and the substitution effects associated with wood used as an energy source and as a material whose current substitutes are significant sources of greenhouse gas (GHG) emissions.

We propose first estimating the effect of the ONF's activities on wood harvesting. The next step is to estimate the current effects of active management on GHG emissions. To do this, we propose evaluating:

- The average *in situ* and *ex situ* carbon sequestration rates over a management period, based on the current distribution of wood uses[76]
- The energy and material substitution allowed by the increased production of wood given the current distribution of wood uses, based on data and literature

These evaluations make it possible to evaluate the overall effects of large-scale sustainable forest management.

Estimated changes in harvesting associated with public management

Data for the national forest inventory show greater harvesting intensity in public forests than in private forests (see Table 13). This can be explained by the fact that a large proportion of private forests are small properties with different owners and that harvesting is a more routine practice in public management as it is one of the objectives of multifunctional management.

Attributing the differences to public management, we infer an additional volume of harvested wood associated with public management. We estimate that sustainable public harvesting is associated with an increase of 2.7 million cubic metres of wood per year, predominantly timber from state-owned forests (see Table 14).

[76] For this evaluation criterion, we used an average level at the steady state of the model. The different wood uses we have accounted for are based on current levels and do not factor in potential changes over time. This evaluation criterion is consistent with the principle that it is necessary for France to increase the shadow price (*valeur tutélaire*) of carbon at the same pace as the discount rate (Quinet, 2019). Under this assumption, the discounting is exactly offset by the increase in carbon value, and it is the average effect at the steady state that is relevant for our analysis. Similar criteria have also been used in other evaluations (e.g. by West et al. (2019) in designing offset payments for extended forest rotation periods).

(in m^3/ha/year)	Timber	Industry	Firewood
State-owned	2.07	1.11	1.11
Other public	1.33	0.73	0.73
Private	1.11	0.80	0.80

Table 13: Average harvest intensity broken down by use and ownership

Source: Derived from the National forest inventory, IGN FCBA (2015) and FCBA (2013).

Comment: We have used data on average harvesting rates observed during the 2008–2016 period, excluding windfalls resulting from Cyclone Klaus and poplar wood. They are based on in situ *observation of tree removal from one inventory period to another. The uses of wood are based on an assessment of two tiers of tree quality. The higher-quality tier is associated with timber ("*bois d'oeuvre*"). In order to better approximate actual use, we then correct by the average proportion of higher-quality wood that is actually used as industrial input or energy product. This discrepancy between the estimated quantity of higher-quality wood and the quantity actually used as timber is significant and amounts to 26% of the former on average. It is assessed based on a comparison of the data with the data from a survey of wood users (IGN-FCBA, 2015, table 8), with weightings attributed to tree species according to their share in total volume (FCBA, 2013). The remaining quantities of higher-quality and lower-quality wood are attributed equally to industry ("*bois d'industrie*") and energy ("*bois-énergie*") uses.*

(in millions of m^3/year)	Timber	Industry	Firewood
State-owned	1.46	0.49	0.49
Other public	0.61	-0.17	-0.17
Total	2.07	0.32	0.32
	2.70		

Table 14: Additional wood harvest volumes associated with public management

Source: Derived from the national forest inventory, own computation.

Comment: These figures have been obtained by multiplying the difference in average harvesting intensity during the 2008–2016 period between private and public forests by the surface areas of state-owned (15,200 km²) and other public forests (27,300 km²). An estimate for 2005–2012 yields similar results.

Estimated impact of wood production on climate change mitigation

The removal of wood from a forest is associated with an immediate decrease in *in situ* carbon stocks. However, this does not reflect the overall effect on climate change mitigation, which requires an evaluation of three components:[77]

- The impact of wood harvesting on average *in situ* carbon stocks, taking into account forest regrowth
- The impact of wood production on average *ex situ* carbon stocks, taking into account what wood products are used for and their lifespans

[77] See e.g. Valade et al., 2017.

- The substitution effects associated with increased availability of substitutes to high-emitting materials and energy sources

We will explain the method before presenting the results of the estimate.

We interpret the average difference observed in harvesting rates as mainly resulting from sustainable management practices in public forests, which are wide-reaching and routinely employed, in contrast with the broad range of different situations in private forests, which leaves large areas unmanaged.

The first part of the method aims to assess an equivalent permanent level of carbon sequestration, taking into account forest regrowth and sequestration in wood products.

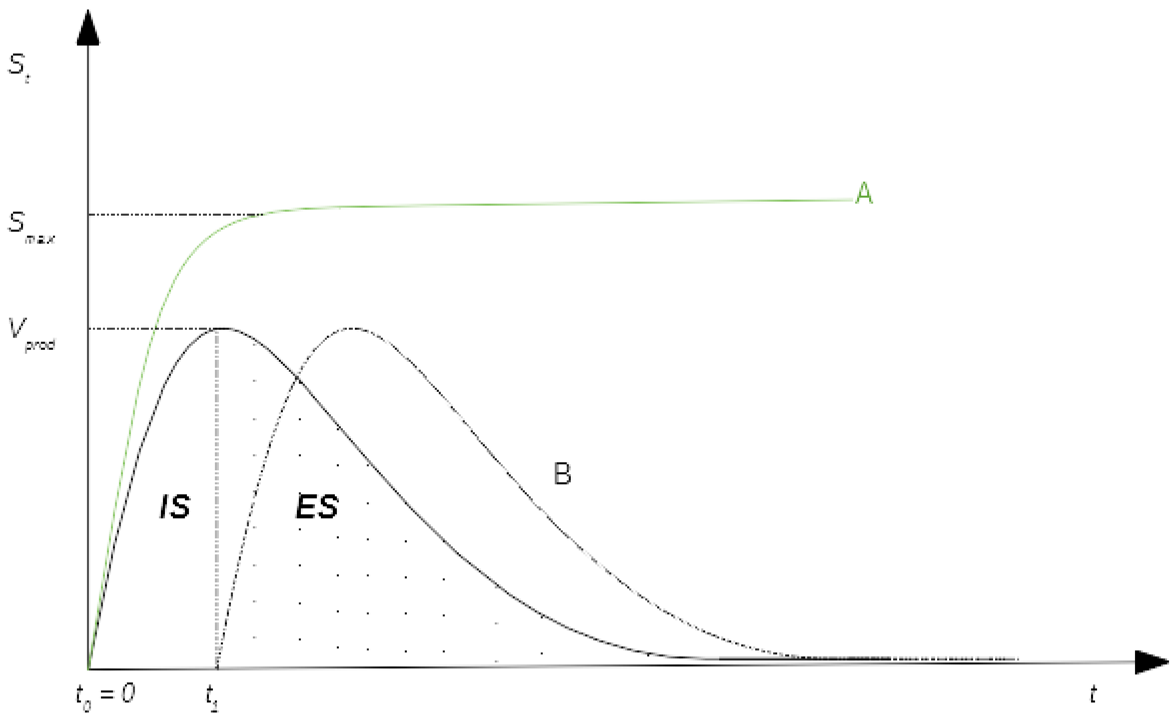

Figure 8: Comparison of the dynamics of* in situ *and* ex situ *(hatched) sequestration of a forest, harvested (B) and unharvested (A)

Comment: Figure assumes a local scale, for example a 1 ha stand as opposed to a mountain range. Products resulting from thinning cuts are not included in this figure but could easily be reintegrated into the analysis.

Figure 8 contrasts the dynamics of carbon stocks in harvested and unharvested forest stands. The average *in situ* and *ex situ* carbon sequestration rate of a harvested forest stand (B) corresponds to the average *in situ* carbon over a management cycle (IS area divided by t_1) plus the hatched area divided by the duration of a management cycle (ES area divided by t_1). **Erreur ! Source du renvoi introuvable.**15 summarises the comparison between harvested and unharvested forests.

(in tCO_2eq/ha)		Equivalent permanent level of *in situ* carbon sequestration	Equivalent permanent level of *ex situ* carbon sequestration
A	**Unharvested**	S_{max}	0
B	**Harvested**	$S_{IS} = IS / t_1$	$S_{ES} = ES / t_1$

Table 15: Comparison of sequestration levels between harvested and unharvested forests

Based on growth simulations, the rate of reconstitution of *in situ* sequestration is defined by $\tau_{IS} = S_{IS} / V_{prod}$. The rate of maintenance of *ex situ* sequestration is defined by $\tau_{ES} = S_{ES} / V_{prod}$. The sum τ is called the *sequestration maintenance rate*. It refers to the part of the harvested carbon that remains sequestered in a steady state. This rate can be estimated from simulations, and then used to estimate, from the quantities collected, the average proportion of carbon removed from the forest that remains sequestered in the forest and in wood products. Due to the diversity of situations, it is not feasible to calculate an average value for this evaluation. However, it can be estimated for a set of contrasting situations in terms of tree species, soil fertility and climate conditions. Such simulations make it possible to define a range of reasonable values.

Box 6. Parametrisation of wood product decomposition

For one cubic metre of wood, it is assumed that its decomposition follows a law of exponential decay by a factor $\exp(-\lambda t)$, where λ denotes a decay constant. The half-life, $t_{1/2}$, is the time by which half of the carbon stock is considered to have been re-emitted into the atmosphere. It is directly related to λ through the relationship $t_{1/2}=\ln(2)/\lambda$. The average sequestration time is $1/\lambda$ year, which in terms of half-life corresponds to $t_{1/2}/\ln(2)$. To obtain the average sequestration time of a cubic metre of wood, it is therefore sufficient to multiply its half-life by 1.44.

Following the values proposed in Roux et al., we have used the following values for the half-life of different products:

- 20 years for timber
- 5 years for industry wood
- 0 years for firewood

Simulations were performed on two contrasting situations representative of the diversity of public forest land being harvested. They are presented in **Erreur ! Source du renvoi introuvable.** 16. **The associated sequestration maintenance rates are 30% and 48%. We propose using a mid-point value of 39% for a national average and using 30% and 48% as extremes of the range of possible values.** These rates can be directly applied to the additional harvest.

	V_{prod} (in tCO_2eq/ha)	Turnover duration t_1 (in years)	Share of products (in % for timber, industry and firewood)	τ_{IS}	τ_{ES}	τ
Oak Champenoux F1 fertility	1,710	181 years	(20%, 35%, 45%)	25%	5%	30%
Douglas Duesme F3 fertility	1,120	92 years	(70%, 5%, 25%)	26%	22%	48%

Table 16: Simulated levels of* in situ *and* ex situ *sequestration in two harvested forests

Source: Growth simulations conducted in the Respire project.

Comment: Calculations of reconstitution rates for in situ *sequestration were performed from growth models under typical management conditions. Calculation of* ex situ *sequestration retention rates are based on classical exponential decay modelling (see Box 6). Half-life parameters are set to 20 years for timber (Roux et al., 2016), 5 years for industrial timber (Roux et al., 2016) and zero for fuel wood.*

A shown in Figure 8, an additional potential impact of wood harvesting is not only removing a fraction of current stock but also preventing trees from continuing to grow into the future. This is captured by the difference between S_{max} and V_{prod}. The evaluation of this difference is complex and the subject of much debate. It is acknowledged that the average carbon stock of a mature stand, S_{max}, may be significantly greater[78] than V_{prod} when the forest rotation length is driven by economic considerations, calling for a value as high as three times V_{prod}[79]. On the contrary, there are two considerations that call for a lower value of S_{max}. The first is that the ONF generally sets a larger forest rotation length than what is optimal from a purely economic perspective.[80] The second is that unmanaged stands are vulnerable to

[78] One might assume that this difference could be even greater when accounting for soil carbon. However, we found no compelling reason or observation to support such an assumption.
[79] For instance, Dupouey et al. (2000) report that “when a stand is cut at an age close to its maximum annual average increase, it is shown that the average carbon stock of that stand over the forest cycle represents only about one-third of the maximum stock that the same stand could have reached at maturity (Cooper, 1982)”.
[80] In the same article, Dupouey et al. also report that “In fertile beech forests, for example, the stock of standing timber is increased by more than 50% by extending the length of the revolution from 100 to 140 years”.

perturbations and may periodically turn into carbon sources.[81] This is particularly relevant in the current context of climate change, where forest management can stabilise vulnerable carbon pools by transferring them to the economy[82] and facilitate forest adaptation measures. **In consideration of the above, we propose setting (S_{max} –V_{prod}) to V_{prod}/2 and exploring a range of values from 0 to + V_{prod}.** The former value corresponds to a case where reduced risks through forest management perfectly offset the average difference in long-term carbon stocks. The latter value corresponds to a case where the carbon stocks of a mature forest are double those of a public forest at the time of harvest.

Substitution effects will not be derived from simulations. They will be directly calculated from the observed average volumes of wood produced by use category, applying the average substitution rate proposed in a recent literature review (Roux et al., 2016). This corresponds to the values presented in Table 17.

(in avoided tC emissions/tC of wood used)	**Central value**	**Min**	**Max**
Timber	1.54	0.57	3.35
Industry	1.54	0.57	3.35
Firewood	0.48	0.36	0.62

Table 17: Substitution factors used

Source: These values are taken from Roux et al. (2016). Values have been converted considering an infradensity of 0.482 tonnes of dry wood/m³ of round wood with bark, a carbon concentration of 0.475 tC/tonne of dry wood, and 1 tC = 44/12 tCO_2eq.

Erreur ! Source du renvoi introuvable.18 presents the estimated impacts of increased harvesting on GHG emissions. The results are interpreted in the body of the report.

[81] For instance, such a mechanism has already been shown to be responsible for the shift of Canada's 303 million ha of boreal forest from carbon sink to carbon source following the increase in disturbance intensity in the 1970s and 1980s (Price et al., 1998 in Dupouey et al., 2000). The authors, however, emphasise that observed differences in stocks between old-growth forests and managed forests suggest that current-level perturbation regimes might not reduce the sink to an extent where harvesting is no longer useful. This conclusion might be revised in the face of climate change and the associated evolution of perturbation regimes. The importance of these changes is acknowledged in most studies emphasizing the importance of old-growth forest (Luyssaert et al., 2008).

[82] This role of forest harvesting is central to recent results comparing the relative merits of greater harvesting rates in France (Roux et al., 2016).

(in $MtCO_2eq$)	***In situ***	***Ex situ***	**Substitution**	**Total**
Average estimate	-2.83	0.30	2.93	0.41
Low estimate	-3.97	0.10	1.21	-2.66
High estimate	-1.68	0.50	6.09	4.92

Table 18: Effects of increased harvesting on carbon sequestration

Comment: Impacts on in situ *sequestration include reductions associated with tree harvesting, forest regrowth and long-term differences in carbon sequestration with old-growth forests. Impacts on* ex situ *sequestration include the change in* ex situ *carbon stocks associated with increased wood supply. Substitution effects include the impacts on GHG emissions associated with increased wood supply. All these effects have been calculated using the methodology and values described above. Volumes have been converted to carbon stock considering an infradensity of 0.482 tonnes of dry wood/m^3 of round wood with bark, a carbon concentration of 0.475 tC/tonne of dry wood, and 1 tC = 44/12 tCO_2eq.*

Appendix 2 – Protected areas by ownership type: Methodology

Introduction

In trying to assess whether the ONF's management activities have a positive effect on biodiversity protection, showing that the forests it manages are more protected could imply two things: (i) over the long and/or short term, the ONF's activities result in higher-quality biodiversity than what is found in privately managed forests, making public forests more likely to meet protected area requirements; (ii) the ONF facilitates the classification of its forests as protected areas, which guarantees a certain level of biodiversity-oriented management for the future.

The methodology used to test these hypotheses was to look at all IUCN protected area categories and all GRECOs and compare whether the proportion of protected areas is higher in public forests than private forests.

IUCN categories

There are several types of protected areas worldwide. The IUCN has classified them into six categories:[83]

Ia – Strict Nature Reserve: Category Ia are strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphical features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.

Ib – Wilderness Area: Category Ib protected areas are usually large unmodified or slightly modified areas, retaining their natural character and influence without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.

II – National Park: Category II protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational, and visitor opportunities.

III – Natural Monument or Feature: Category III protected areas are set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.

IV – Habitat/Species Management Area: Category IV protected areas aim to protect particular species or habitats and management reflects this priority. Many Category IV protected areas will need regular,

[83] https://www.iucn.org/theme/protected-areas/about/protected-area-categories, accessed on 12/08/2019.

active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.

V – Protected Landscape/Seascape: A protected area where the interaction of people and nature over time has produced an area of distinct character with significant, ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.

VI – Protected area with sustainable use of natural resources: Category VI protected areas conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

In this report, only the first five categories were used, as data for the sixth was not available.

GRECOs

A GRECO (*grande région écologique* or large ecological region) is characterised by its unique geomorphology, geology, climate, soils, water resources, flora and fauna. There are 11 GRECOs in France, each one coded with a letter: A is *Grand Ouest cristallin et océanique*; B is *Centre Nord semi-océanique*; C is *Grand Est semi-continental*; D is *Vosges*; E is *Jura*; F is *Sud-ouest océanique*; G is *Massif central*; H is *Alpes*; I is *Pyrénées*; J is *Méditerranée*; and K is *Corse*.[84]

Comparing results within each GRECO is a way to control for these biophysical characteristics and to roughly isolate the effects of the ONF's more recent management activities. However, some biophysical characteristics, such as stand type, are the result of ONF management policies implemented long ago; the effect of this long-term management is then reflected when comparing results at the national scale.

To obtain the proportion of protected areas by IUCN category and by GRECO, three map layers were overlaid: forests by ownership type, GRECOs and IUCN categories.[85]

The ownership map was obtained by combining the BD FORET[86]/BD TOPO[87] datasets and the ONF's own public forest mapping. Where contour lines do not match, the ONF's have been used. Areas identified by the BD FORET/BD TOPO as forest areas but not identified as public forests by the ONF have been classified as private forests.[88] Areas that are referred to as forest areas in the BD FORET/BD TOPO but that do not match any GRECO contour lines have been omitted from the analyses.[89]

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[84] We have excluded *Corse* as it is often considered a special case.
[85] Available here: https://www.protectedplanet.net/, accessed on 12/08/2019.
[86] Available here: http://www.professionnels.ign.fr/bdforet#tab-1, accessed on 12/08/2019.
[87] Available here: http://www.professionnels.ign.fr/bdtopo, accessed on 12/08/2019.
[88] It could have been possible to use data from the CNPF (*Centre National de la Propriété Forestière*, National Centre of Forest Property), referencing the contour lines of both private forests with a simple management plan and those without. This distinction could have been used to go further in the analyses but were not made available to the authors by the CNPF.
[89] This accounts for approximately 3 ha of public forest.

In the IUCN categories map, "hard" zones can be assigned to an IUCN category when they: (a) are clearly mapped; (b) are recognised by legal or other effective means; and (c) have distinct and unambiguous management aims that can be assigned to a particular protected area category. On the contrary, "soft" zones are not assigned (and referred to as "not assignable") to an IUCN category when they: (a) are subject to regular review, such as through a management planning process; (b) are not recognised by legal or other effective means; and (c) do not correspond to a particular protected area category (IUCN, 2008).

Furthermore, some international protected areas are referred to as "not applicable". The national protected areas where an IUCN category has not been adopted are referred to as "not reported".

Results

Table 19 reports all results by GRECO and by IUCN protected area category. Bold has been used to indicate the higher value between public and private forests. For the first five IUCN categories (except category III), public forests are proportionally more protected. This is also true on average over all GRECOs and all IUCN categories. It is interesting to note that except for category V, there is a low variability of results across GRECOs.

GRECO	A – *Grand Ouest cristallin et océanique*	B – *Centre Nord semi-océanique*	C – *Grand Est semi-continental*	D – *Vosges*	E – *Jura*	F – *Sud-Ouest océanique*	G – *Massif central*	H – *Alpes*	I – *Pyrénées*	J – *Méditerranée*	K – *Corse*	National Average
	Ia – Strict Nature Reserve											
Public forest	0.12	0.09	0.09	0.16	N/A	1.43	0.06	**0.65**	0.08	0.92	**1.07**	**0.32**
Private forest	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.01	N/A	N/A	0.01	0.00
	Ib – Wilderness Area											
Public forest	N/A	N/A	0.00000002	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00
Private forest	N/A	N/A	**0.00000013**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00

	II – National Park											
Public forest	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**9.06**	**1.57**	**1.53**	N/A	**1.56**
Private forest	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.49	0.51	0.21	N/A	0.14
	III – Natural Monument or Feature											
Public forest	N/A	N/A	**0.02**	N/A	N/A	0.02	N/A	0.01	0.004	**0.07**	N/A	0.01
Private forest	N/A	N/A	0.01	N/A	N/A	**0.03**	0.0005	0.01	N/A	0.02	N/A	0.01
	IV – Habitat/Species Management Area											
Public forest	**7.40**	**1.31**	**1.45**	**4.65**	**7.98**	**4.01**	**1.76**	**4.52**	**3.76**	**9.42**	1.34	**3.49**
Private forest	0.76	0.90	1.02	1.15	3.96	0.27	0.19	1.55	0.58	1.76	**3.36**	0.91
	V – Protected Landscape/Seascape/Area											
Public forest	**48.81**	**18.69**	**9.85**	44.02	21.18	10.92	**58.71**	**43.37**	**46.94**	**28.04**	**100.00**	**30.95**
Private forest	11.81	11.10	7.53	**45.85**	**22.28**	**15.64**	40.71	37.23	25.62	21.30	41.14	22.85
	VI – Protected area with sustainable use of natural resources											
Public forest	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Private forest	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Total (Ia, Ib, II, III, IV, V)											
Public forest	**56.33**	**20.10**	**11.41**	**48.84**	**29.16**	**16.38**	**60.53**	**57.61**	**52.35**	**39.99**	**100.00**	**36.33**
Private forest	12.57	12.00	8.57	47.00	26.25	15.94	40.90	40.28	26.72	23.29	44.50	23.92

	Not applicable											
Public forest	**1.56**	0.02	N/A	N/A	N/A	0.02	N/A	N/A	**0.11**	N/A	0.45	
Private forest	0.54	**0.04**	N/A	N/A	N/A	0.02	N/A	N/A	0.07	0.01	**1.54**	

	Not assigned											
Public forest	**26.14**	**36.14**	**26.51**	**20.00**	22.68	**25.45**	**33.31**	**38.08**	**57.84**	**54.75**	0.00	
Private forest	6.80	21.91	14.87	13.24	**22.74**	5.80	16.61	16.46	16.25	20.93	**0.06**	
	Not reportable											
Public forest	**26.14**	**36.14**	**26.51**	**20.00**	22.68	**25.45**	**33.31**	**38.08**	**57.84**	**54.75**	**43.14**	
Private forest	6.80	21.91	14.87	13.24	**22.74**	5.80	16.61	16.46	16.25	20.93	11.31	

Table 19: Share of protected areas by GRECO, protected area category and ownership type (%)
Source: Authors' calculations.

These results reasonably suggest that the ONF's management activities have a positive effect on the implementation of protected areas. It is, however, not possible to determine whether it is hypothesis (i), (ii) or a combination of both that best explains this phenomenon.

Appendix 3 – Common bird abundance: Methodology

Introduction

Showing that a higher number of common birds are observed in ONF-managed forests than in private forests could indicate that public management is likely to encourage biodiversity to thrive for two reasons: (i) because a higher number of common birds is a result in itself; and (ii) because common bird proliferation is also an indirect indicator of the overall state of biodiversity. That said, it is only one indicator of a multifaceted concept; the state of biodiversity can hardly be captured by a single metric.

STOC database

To calculate the annual average common bird abundance in public and private forests, data from the STOC program[90] were used. This data collection program has existed since 2009 and has included geolocation since 2014. It can be used to capture variations in common bird abundance. The collection protocol, which has been standardised since the beginning of the program, is as follows: the observer stands in a randomly selected 2 km by 2 km square within a 10 km radius of their home, to avoid the selection bias of using a location the observer particularly likes. The observer then chooses 10 points within the square, which should be representative of the environment. The observer visits these 10 points twice a year (in spring: once before 8 May and once after) and spends 5 minutes at each point. Birds are both visually and audibly detected; counting is more accurate for single birds than for groups of birds.

Methodology

The indicator used is the higher number between the two data collections, using an average for the 2 km by 2 km square, tagged with GPS coordinates, for each year between 2014 and 2017. By cross-referencing this geolocated indicator with the GRECO map and the forest ownership map, it was possible to sum the indicator for each type of forest, by GRECO, per year. The average over the 2014–2017 period was then calculated and divided by the surface area of the type of forest concerned, by GRECO, to obtain the average number of common birds observed, per hectare, between 2014 and 2017. The ratio between public and private forests was also calculated.

Results

GRECO	**Public**	**Private**	**Public/private ratio**
A	1.150	0.097	11.82
B	0.107	0.022	4.83
C	0.054	0.048	1.12

[90] More information here: https://crbpo.mnhn.fr/spip.php?article41.

D	0.155	0.225	0.69
E	0.212	0.189	1.12
F	0.286	0.023	12.58
G	0.170	0.023	7.43
H	0.086	0.059	1.45
I	0.167	0.127	1.32
J	0.170	0.053	3.17
National average	1.36353E-05	4.589E-06	2.97

Table 20: Number of common birds observed per hectare for each GRECO

Source: Authors' calculations.

The standardised nature of the STOC database collection protocol makes it well-suited to calculating inter-annual variations. However, the length of the available period, 2014–2017, is too short to provide any significant trend, as there is high variability of common bird abundance over a 4-year period. The analysis should therefore rely on the average difference in stocks between private and public forests.

A Student test was performed to investigate the significance of the difference. As the number of common birds per hectare is consistently higher in public forests than in private ones, and as the variance is similar for both, a unilateral Student test under the hypothesis of homoscedasticity was chosen. As the p-value is 0.07, the null hypothesis can be rejected, and the difference between the two samples is significant. Put differently, between 2014 and 2017, there were, on average, significantly more common birds per hectare in public forests than in private forests.

It could have been interesting to investigate differences in variation of common bird abundance between public and private forests; however, as only a 4-year sample was available, it was not sufficient to extract significant information from the trend. As can be seen in Figure 3, there is a lot of noise in common bird observation trends.

Appendix 4 – Consistency with the European Framework to Facilitate Sustainable Investment (or "EU Taxonomy")

In March 2018, the European Commission launched an EU action plan on financing sustainable growth, aimed at (i) reorienting capital flows toward sustainable investments, (ii) managing sustainability-related financial risks, and (iii) enhancing transparency and long-term vision in economic and financial activities. In order to set up a legislative framework around this action plan, in May 2018 the Commission published three proposed regulations, one of which involves the creation of a framework to facilitate sustainable investment, referred to as the "EU Taxonomy".

The taxonomy proposal presented by the European Commission consists of determining whether an economic activity is "environmentally sustainable" with regard to six environmental objectives: climate mitigation; climate adaptation; sustainable use and protection of water and marine resources; transition to a circular economy, waste prevention and recycling; pollution prevention and control; protection of healthy ecosystems. An economic activity will be eligible for the taxonomy if it meets four criteria: (i) make a substantive contribution to at least one of the six environmental objectives; (ii) do no significant harm to the other objectives; (iii) meet minimum social safeguards; (iv) meet technical screening criteria. Within this framework, a technical expert group (TEG) has been mandated by the Commission to develop principles and metrics in relation to these criteria for each activity to be evaluated. Based on this work, the TEG makes recommendations to the Commission as to whether activities should be included in or excluded from the taxonomy.

In March 2020, just before the EU Taxonomy regulation entered into force,[91] the TEG published its final technical report on the taxonomy, dealing with the first two environmental objectives.[92] The report sets out a list of 72 economic activities eligible for the taxonomy.

The Green OAT objectives, which are the subject of the evaluation in the present study, are climate change mitigation, climate change adaptation and biodiversity protection. They are partly aligned with the EU Taxonomy's principles.

A chapter of the TEG report is dedicated to the evaluating the sustainability of forestry activities. For five forestry-related activities (afforestation, reforestation, restoration/rehabilitation, existing forest management, conservation forest), the report describes how to assess: (i) the contribution to climate change mitigation; and (ii) potential negative spillover effects on any of the other five environmental objectives set out in the EU Taxonomy Regulation, which include adaptation to climate change. Regarding the objective of climate change mitigation, part (i) of the assessment methodology relies on three items: compliance with sustainable forest management (SFM) requirements; the establishment of a GHG balance baseline for above-ground carbon pools based on growth yield curves; and the demonstration of permanence and steady progress with respect to the other two criteria (EU, 2019). Part (ii) of the assessment methodology relies on the criterion of Do No Significant Harm (DNSH), which itself encompasses four aspects: the ability of forests to adapt to a changing climate; the impact on water resources and on water quality; the pollution to water, air and soil and the risks associated from the use

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[91] The regulation entered into force on 12 July 2020.
[92] Climate change mitigation and climate change adaptation.

of pesticides and fertilisers; and the impacts on biodiversity and ecosystems caused by intensification practices, conversion of land of high ecological value to forest land, and illegal logging.

Our aim was to make our study compatible with the TEG final report, taking into account the fact that the criteria are not exactly the same. Regarding both parts of the TEG's assessment methodology, it appears relevant to quote from its report: "Forestry operations that are FSC[93] and PEFC[94] certified are likely to meet the SFM and Do No Significant Harm criterion of the forest Taxonomy".[95] As previously mentioned, 100% of state-owned and 56% of locally owned forests are PEFC-certified, which attests to the ONF's high level of compliance with the first item of the first part and the second part of the EU Taxonomy assessment methodology. Overall, 84% of public forest surface area is PEFC-certified, compared to 17% for private forests. The Office also manages 15,280 ha of forest under FSC certification, of which 50% is state-owned.

Going deeper into the first part of the assessment methodology, it is relevant to mention that this study establishes the impact of the ONF's management practices, compared to the private sector, on GHG emissions, which accounts for the indirect effects of wood supply on climate change mitigation, a crucial component of France's National Low-Carbon Strategy. The results show that the ONF's practices have a positive effect on carbon sequestration, owing in large part to the substitution effect. The methodology used was based on the counterfactual, as required, but did not aim to establish an overall GHG balance resulting from the ONF's activities. Moreover, the ONF plays a major role in data collection, thereby contributing to research and allowing the impacts of its management practices to be monitored, which is in line with the last item of the first part of the assessment methodology proposed in the TEG report.

Looking more closely at the second part of the assessment methodology, the four objectives of the Do No Significant Harm criterion can be reviewed against the information provided in this report:

- First, the ability of forests to adapt to a changing climate has been assessed through an analysis of the ONF's climate adaptation strategy, which relies, *inter alia*, on specific tree species selection in relevant regions.

- Second, there is a very low impact on water resources, water quality, and water, air and soil pollution; the risks associated with the use of pesticides and fertilisers are also low; and there is a very low impact on biodiversity and ecosystems from intensification practices, conversion of land of high ecological value to forest land, and illegal logging.

Not only is the ONF not involved in any deforestation practices, it actively fights against them and combats illegal logging, specifically overseas. As stated in the report, the surface area of France's forests has been increasing by 0.7% each year for the last 30 years, which means French forests are a carbon sink and help control air pollution. Moreover, the proportion of France's forests that are intensively harvested is very low, regeneration is mainly natural, and the ONF is not involved in intensification

[93] Forest Stewardship Council.

[94] Program for the Endorsement of Forest Certification.

[95] European Commission, 2019, p. 158.

practices. Finally, as detailed in this report, the ONF implements a biodiversity protection policy on its land, relying primarily on a network of protected areas.

Overall, thanks to this assessment, we believe the ONF's management practices are likely to be eligible for the EU Taxonomy. A full-fledged in-depth analysis, using the detailed criteria provided in the TEG reports, is beyond the scope of this assessment but could be undertaken in the future.

Beyond the principles discussed above, the EU Taxonomy provides the following three metrics and thresholds for assessing the eligibility of existing forest management practices for the taxonomy:

1. Continued compliance with SFM requirements is demonstrated and continuously disclosed at 10-year intervals through a forest management plan (or equivalent instrument) that shall be reviewed by an independent third-party certifier and/or competent authority.

2. Verified GHG balance baseline is calculated for above-ground carbon pools, based on growth yield curves for species per m^3/year/ha, carbon convertible. Calculating the GHG balance baseline requires knowledge of the area, the species and number of trees. Using the growth-yield curves, information will be given on the annual increment in m^3/year/ha, which can be used for the basis of the GHG balance. The methodology is consistent with the approach in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines), which recommends a recalculation of the amount of carbon sequestered (1 tonne of biomass representing approximately 0.5 tonnes of carbon and one tonne of carbon equalling 44/12 = 3.67 tonnes of carbon dioxide).

3. Above-ground carbon stocks shall be maintained or increased relative to the carbon baseline over the rotation period of the forest. Changes in carbon stocks should be disclosed based on growth yield curves in 10-year intervals through a forest management plan (or equivalent instrument) that shall be reviewed by an independent third-party certifier and/or competent authority.

For the first criterion, as mentioned previously, 84% of the surface area of France's public forests is PEFC-certified, which is regarded by the EU Taxonomy as proof of compliance with SFM requirements. Regarding disclosure, the ONF uses 15- to 20-year development plans, which are approved France's Ministry for Agriculture and Food (for state-owned forests) or the regional authority (for locally owned forests). These plans include sustainable management targets and strategies for reaching them. As the period covered by these plans is only slightly longer than the 10 years required by the EU Taxonomy, this criterion is very close to being fully met.

For the second criterion, there is the model used in this study to capture the carbon impact of the ONF's forest management practices. Its output is a yearly amount of additional sequestered CO_{2eq}. As explained above, the model was designed to represent the consequences of a withdrawal of the subsidy granted to the ONF. The corresponding counterfactual is that public forests would be managed by the private sector. The design of this model is different from one that would be used to assess, as required by the EU Taxonomy, a yearly GHG balance baseline of the ONF's management activities. We are confident that the ONF could generate the data for such an analysis, some of which was provided to us for this study, such as average species diversity and growth yield curves. Further research would, however, be needed to properly assess this criterion of the EU Taxonomy.

Finally, though the above-ground carbon stock of France's forests increased from 45 tC/ha in 1981 to 59 tC/ha in 2012,[96] we do not know how much of this increase can be attributed to public forests. The ONF does not include this kind of tracking or forecasting in its development plans and does not regularly disclose this kind of information. Modelling past variations and predicting future variations in above-ground carbon stocks over 10-year intervals, using the ONF's acquired knowledge and data, would be a project in and of itself, requiring more time and collaboration with the ONF's research teams.

[96] IGD 2015, p. 90.