French forests are currently at a crossroads, just as agriculture was in the 1950s and 1960s. Since the Grenelle Environment Forum in 2007, there have been increasing calls to expand the use of wood. Forests are increasingly seen as the solution to gradually replacing our dependence on fossil fuels. In France, as in many European countries, industrial wood energy projects are thus proliferating. For example, coal-fired power stations are being converted to biomass power stations. Whole trees are being processed into pellets, when they could be used for sustainable construction and contribute to carbon storage.

The lack of consideration in developing these projects is symptomatic of the lack of critical debate in France about forest management. The urgency to take action on climate change is becoming a pretext for promoting intensified forest management. Thus, France’s National Low Carbon Strategy allows for a significant increase in harvesting and a decrease in the natural capacity of forests to store carbon. This strategy runs counter to the recommendations made by the Intergovernmental Panel on Climate Change (IPCC), which warns of the risk of crossing thresholds for runaway climate change over the coming years.

This paper constitutes a summary of a report systematically exploring a different approach: leaving 25% of the forest area to evolve naturally, lengthening rotation times in managed forests and practising continuous cover forestry, in order to approach optimum carbon storage in ecosystems. This has the dual benefit of maximising absorption of carbon dioxide over the coming decades and significantly increasing the naturalness and biodiversity of forests.
Trees absorb CO₂ for growth. This carbon accumulates in the stem and branches (above-ground biomass) but also in the roots (below-ground biomass) and soil. When trees die, some of this carbon is gradually released into the atmosphere and some remains in the soil. The most recent scientific studies show that forests that are centuries or even millennia old continue to absorb carbon. They therefore act as carbon sinks. The explanation relates to carbon storage in forest soils, through mechanisms that are not yet well understood. This is a key point because in temperate forests, the soils store more carbon than the above-ground biomass.

UNDERSTANDING INTERACTIONS BETWEEN FOREST AND CLIMATE

CARBON STORAGE IN THE FOREST ECOSYSTEM

While the use of wood extracted via “soft” harvesting practices has a much lower carbon footprint than other materials, this is not true if the wood has been harvested using heavy machinery, and especially if the processing chain involves long-distance transportation. For example, if oak logs are harvested in France but sent to China to be processed into parquet flooring and then sold in Europe.
When a tree is harvested, it can be processed into different types of products: logs or pellets, paper or cardboard, or sawable timber for construction or furniture. These products store the carbon accumulated during the tree’s growth and release it at their end of life. There is therefore hardly any storage in the case of wood energy or paper, but much more for wood used to build a house.

There are two types of substitution effects: material and energy. The first results from the increased use of wood as a substitute for other materials for which sourcing and processing emits more CO₂. The second results from the use of wood energy to displace fossil fuels. Currently, the government is justifying increased forest harvesting because of higher use of these substitution effects. However, these effects are very difficult to measure, as they involve conducting and comparing life cycle assessments that cover very different realities and depend on many unknowns.
Nowadays, wood energy is presented as a carbon “neutral” energy, even though its combustion releases large amounts of carbon into the atmosphere – even more so than coal or oil because, per tonne burned, wood produces less energy than fossil fuels. This combustion is claimed to be “neutral” on the grounds that the carbon emitted has been absorbed during the trees’ growth and will be absorbed again by other trees. This concept is disputed by a growing number of scientists because it takes several decades, or even centuries, for a tree or stand to recover the carbon stock it had before it was cut down, depending on the management practice. However, the climate emergency requires us to massively reduce our emissions over the coming years and to restore the storage capacity of natural carbon sinks such as forests. The use of wood energy should therefore be strictly limited to end-of-life wood products and the byproducts of wood harvesting and processing, for which no other more sustainable use is possible (e.g. manufacture of wood panels).

WOOD ENERGY: THE MYTH OF CARBON «NEUTRALITY»

MAX. CO₂ STORAGE CAPACITY OF THE ECOSYSTEM

CARBON DEBT: THE TIME IT TAKES TO RECOVER THE SAME CARBON STOCK IN AN ECOSYSTEM AFTER FELLING.

35 YEARS MINIMUM PAYBACK TIME FOR THE CARBON DEBT GENERATED BY AN INCREASE IN HARVESTING TO PROVIDE WOOD ENERGY.

The climate effects of current large-scale substitution of coal by forest biomass may be increasing the risk of overshooting the Paris Agreement targets.

The European Academies Science Advisory Council of the Member States of the European Union (EASAC, 2019)
As carbon sinks, forests have an essential role to play in tackling global warming. Article 5.1 of the Paris Agreement thus calls for the conservation and enhancement of natural carbon sinks such as forests. But forests are also being hit hard by the effects of climate change, as evidenced by the increase in fires and drought-related dieback. Therefore, the main challenge for a new forestry strategy is to support the adaptation of forests to climate change while seeking to maximise their capacity to absorb and store carbon over the coming years, which will be decisive for the climate.

Working in partnership, Canopée, Fern and Friends of the Earth France have produced a report exploring different forest management scenarios. In particular, we wanted to model the impacts on the forest carbon sink of an increase in wood harvesting as set out in the National Low Carbon Strategy. This report demonstrates that maintaining current harvesting levels, while shifting forest management practices towards continuous cover forestry, is the best compromise between the necessary adaptation of forests to climate change and their essential contribution to mitigating the scale of change.

REPORT ASSUMPTIONS
To simulate the impact of different forest management scenarios between now and 2050, we developed a model based on the following assumptions:
• The surface area and biological productivity of forests remain constant.
• There is moderate or high progression (depending on the scenario) in the mortality rate for trees in forests, due to climate change.
• The area of forests under active management increases from 65% in 2020 to 75% in 2050.

25% OF FOREST AREA IS UNHARVESTED BY 2050. (OF WHICH 10% IS STRICTLY PROTECTED)

Forest area left natural
The area of forest that cannot be exploited due to technical reasons (accessibility, inclines, wetlands) or long-term land tenure barriers, or because of the need to protect water and soil, and conserve and restore biodiversity. In 2050, 10% of these areas will be legally and sustainably classified as protected. These protected and naturally evolving areas are distributed throughout the country and can be seen on different scales, from senescence islands within harvested forests to expanses of several thousand hectares.

75% OF FOREST AREA IS HARVESTED BY 2050, DIVIDED BETWEEN THE FOLLOWING CATEGORIES.

Exploited forest area under continuous cover forestry
This selective forestry approach, which is closer to natural cycles and has been trialled in France for decades, consists of letting the forest evolve towards an equilibrium volume so as to only carry out “selective cutting”. This gradually improves the quality, aiming for maximum timber production. This would be a good choice of forestry in view of the climate challenge: it maintains the initial carbon stock in the ecosystem and increases it in the wood and in the soil, while still allowing rational harvesting of wood. It also provides a clear benefit to biodiversity by restoring the proper functioning of forest ecosystems. In addition, it meets a growing social expectation.

Exploited forest area in “health deadlock”
These are plots in a critical state of health, in which natural regeneration is absent or unable to guarantee the return of a sustainable stand in view of the soil and climate. In 2020, we estimate that this situation affects 3% of French forests. However, due to climate change, by 2050 this area could represent up to 7% of French forests, assuming a high mortality rate.
The results below show average values per hectare, in natural forests and in exploited forests (assuming a moderate mortality rate).

**UNEXPLOITED FOREST**

**NATURAL FOREST**

No wood harvesting in the forest

**EXTENSIVE SCENARIO**

Harvesting is reduced to allow the forest to reach its equilibrium volume by 2050, keeping as much dead wood in the forest as possible.

**HARVEST =**

- **0**
- **40 MM³**

**INCREASE IN HARVESTING OF WOOD MEANS LOWER CARBON STORAGE**
The current harvesting level is maintained until 2050.

**HARVEST = 60 MM³**

Harvesting is increased to the maximum amount technically feasible.

**HARVEST = 95 MM³**

**DIFFERENCE IN STORAGE PER CUMULATIVE HECTARE IN THE FOREST ECOSYSTEM AND WOOD PRODUCTS BETWEEN 2020 AND 2050, UNDER THE DIFFERENT MANAGEMENT PRACTICES.**
RISKS ASSOCIATED WITH HARVEST INTENSIFICATION

LETTING TREES AGE: AN EFFECTIVE CLIMATE STRATEGY

79% OF TREES ARE UNDER 100 YEARS OLD

(Source: IFN, 2018)

Observation #1

MAXIMUM CARBON STORAGE CAPACITY IN FORESTS IS FAR FROM BEING REACHED

Our simulation clearly shows that natural forests provide the best potential for mitigation through storage between 2020 and 2050. Contrary to what is suggested by the National Low Carbon Strategy, we are therefore very far from achieving the maximum storage capacity in above-ground biomass and forest soils.

This can be explained by the relative youth of French forests, as they have resulted from agricultural decline or post-war reforestation programmes. Nearly 80% of French forests are under 100 years old. They are therefore still a long way from reaching their ecological optimum, which generally takes over 500 years.

The average volume of stemwood per hectare estimated for equilibrium in continuous cover forestry (205 m³/ha) is achieved in the extensive scenario but not in the other two scenarios, despite an increase between 2020 and 2050. The volume/ha in natural forest areas far exceeds the equilibrium in continuous cover forestry, because the dead wood stock is much higher in the natural forest cycle than in managed forests. In our study, a simulation beyond 2050 suggests that the total carbon stock in the ecosystem would increase significantly until at least 2100, gradually stabilising after 2200 at around 330 m³/ha of stemwood, 640 m³/ha of living biomass and 360 m³/ha of dead biomass (below-ground included). This represents double the current stock of living biomass and almost three times the total wood stock.

Observation #2

STEMWOOD

THIS IS THE MAIN STEM OF THE TREE UP TO 7 CM IN DIAMETER
The findings presented were based on an assumption of moderate increase in annual mortality (+1%/year). In practice, it is very difficult to assess how tree mortality will evolve over the coming years. Advocates of intensified harvesting point to the risk of widespread dieback as a justification for increased harvesting and for replacing existing stands with new plantations of supposedly better adapted trees.

To check the merits of this approach, we investigated the effect of a much faster increase in mortality (+3%/year). The gap remains between the different scenarios, with the harvest intensification scenario remaining the least favourable. The diebacks observed in 2018 and 2019 should therefore not lead us to rush to conclusions: they are indicative of a changing climate, but also of the weakness of fragile stands that were not adapted to the site.

Intensified harvesting, outside of areas that are in true health deadlock, is therefore not a climate solution in the event of worsened mortality.

### Observation #2

**Increased tree mortality does not justify increased harvesting**

Even in the event of increased tree mortality, the storage gap between the scenarios remains, with the intensive scenario being highly unfavourable.
In a healthy forest, where trees are allowed to age enough to produce sufficient amounts of seed and where there are not too many herbivores, there is no need to plant trees. When they have reached maturity, the large trees are felled and the light gap created allows the young trees in the undergrowth to take over: this is known as natural regeneration. Plantations can be useful to diversify existing stands, especially where forest has been reinstated on agricultural land using uniform planting. Currently, however, plantations are mostly employed after clear-cutting.

Another argument that is often put forward to justify clear-cutting is that the older a forest, the greater its risk of dieback. This argument is not currently supported by the science. On the contrary, scientific studies show that the older a forest, the more diversified it is; and the more diversified a forest, the more it is able to overcome shocks by relying on its genetic diversity and interactions among species.

On the pretext of better adapting the forest to climate change, natural stands are being razed to make way for single-species plantations. For many citizens, planting a tree represents an essential act in good forest management: a misconception that is maintained by the actors in the forest-wood sector with the most questionable practices.

Limiting the use of plantations

In a healthy forest, where trees are allowed to age enough to produce sufficient amounts of seed and where there are not too many herbivores, there is no need to plant trees. When they have reached maturity, the large trees are felled and the light gap created allows the young trees in the undergrowth to take over: this is known as natural regeneration. Plantations can be useful to diversify existing stands, especially where forest has been reinstated on agricultural land using uniform planting. Currently, however, plantations are mostly employed after clear-cutting.

Strict control of clear-cutting

Clear-cutting exposes bare soil and immediately releases carbon into the atmosphere. If soils are deeply tilled before a new plantation is established, the release of soil carbon may continue over several decades. To justify this clear-cutting, many stands deemed not sufficiently productive are classified as being in deadlock, when they could be improved through less intensive selective cutting operations. It is therefore critical to define the concept of deadlock through two criteria:

- critical health status (at least 50% of the trees showing at least 50% fine branch mortality or defoliation);
- absence of natural regeneration allowing the return of a stand adapted to the site

Clear-cutting should therefore be limited to those stands meeting these two criteria, and should be followed by planting of diversified species, after minimal tillage.

Resilience of ecosystems: a priority

Another argument that is often put forward to justify clear-cutting is that the older a forest, the greater its risk of dieback. This argument is not currently supported by the science. On the contrary, scientific studies show that the older a forest, the more diversified it is; and the more diversified a forest, the more it is able to overcome shocks by relying on its genetic diversity and interactions among species.

The more mixed a stand, the less exposed it is to the proliferation of insect pests such as bark beetles. Finally, the forest creates a microclimate that is destroyed when the soil is exposed. Replacing an existing stand with a new plantation means taking a significant risk of exposing these young trees to major water stress and thus to dieback.
Unlike storage effects, which are subject to physical laws, substitution effects are much more difficult to assess and take into account because they depend on many parameters and societal choices that may change. For example, there is no sense in calculating an energy displacement factor without specifying a timescale. Since wood combustion emits more CO₂ than fossil fuels, this displacement factor is initially negative; it then increases with the growth of new trees and only becomes positive after a period corresponding to the repayment time for the initial ‘carbon debt’. Similarly, evaluation of this displacement factor raises many questions, for example in relation to alternative scenarios: does the wood burned come from a tree specifically cut for this purpose (which could therefore have continued to grow) or is it part of a tree cut to be transformed into timber? Could this wood have been used to make panels instead of being burned? Could another form of renewable energy with lower CO₂ emissions have been used? Are the sectors used for comparison not going to change? Does this energy or do these materials reflect a truly essential need? Will all the wood harvested really reduce the consumption of other materials and energy?

In practice, it is impossible to answer all these questions with certainty. While the displacement factor of using wood in place of another material such as steel, concrete or aluminium is positive overall, in practice this displacement factor depends on the total emissions over the life cycle of the wood, and how this compares with that of materials that would be used instead. Again, this comparison may change over time.

Taking substitution effects into account reduces the gap between scenarios and is currently being used to justify arguments in favour of harvest intensification. As an indication, we have calculated these substitution effects using the average displacement factors used in France. This helps to rebalance the different scenarios, but there are still many unknowns as to the margin of error.

**Mitigation Potential Between 2020 and 2050 Over the Entire French Forest Area, Assuming a High Mortality Rate**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Material Substitution Effect</th>
<th>Energy Substitution Effect</th>
<th>Storage in Wood Products</th>
<th>Ecosystem Storage for Exploited Forests</th>
<th>Ecosystem Storage for Unexploited Forests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Without Taking into Account Substitution Effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extensive Scenario</td>
<td>3500</td>
<td>2000</td>
<td>2000</td>
<td>3500</td>
<td>2500</td>
</tr>
<tr>
<td>Scenario with Constant Harvesting</td>
<td>3500</td>
<td>2000</td>
<td>2000</td>
<td>3500</td>
<td>2500</td>
</tr>
<tr>
<td>Intensive Scenario</td>
<td>3500</td>
<td>2000</td>
<td>2000</td>
<td>3500</td>
<td>2500</td>
</tr>
<tr>
<td><strong>Including Substitution Effects</strong></td>
<td>3500</td>
<td>2000</td>
<td>2000</td>
<td>3500</td>
<td>2500</td>
</tr>
</tbody>
</table>

* Taking the average coefficients used in France.

**Observation #3**

Substitution effects are too uncertain to justify harvest intensification.
Over the last ten years or so, the idea that French forests are under-exploited has gradually taken centre stage in forest, climate and energy policies. This assumption is based on the fact that less timber is currently harvested than is biologically produced by forests. In reality, this is due more to the forests being young and partially unharvestable, than to under-exploitation.

Yet, the government is using this assumption of under-exploitation to justify a strategy of increased timber harvesting between now and 2050. The National Wood and Forest Programme thus proposes to increase harvesting by +12 Mm³ between 2016 and 2026 (i.e. 72 Mm³/year) and the National Low Carbon Strategy expects this increase to continue until 2050, which takes us beyond the intensive scenario of our modelling (119 Mm³/year, estimated figure).

As our simulation shows, the intensive scenario has the worst potential for mitigation through storage. This increase in harvesting would significantly reduce the forest carbon sink. In the draft National Integrated Energy and Climate Plan, the forest carbon sink is estimated to be -32 MtCO₂ eq/year by 2050, i.e. the current sink will be at least halved. To justify this decision, the French government highlights the substitution effects, although these are very uncertain.

This uncertainty is exacerbated by the fact that the increase in wood harvesting is mostly linked to an increase in use for energy. Whereas about 50% of the wood harvest is currently directed towards energy generation, this share could be 66% by 2050 according to France’s National Forestry Accounting Plan. This assumption is confirmed in the new draft National Low Carbon Strategy, which states that «meeting national objectives for developing renewable energies will in any case require a massive increase in forest-wood harvesting». Yet, specifically harvesting trees for energy generation is the worst option for the climate, as more than 700 scientists have pointed out in an open letter to the European Commission:
As our simulation shows, an increase in the harvest to 95 Mm³/year would lead to a sharply reduced average stock of dead wood by 2050. In practice, this is due to heavy harvesting of standing dead wood and branches, including fine branches, which are very rich in mineral content. A scenario of intensified harvesting, at the level envisaged by the government by 2050, would therefore have serious consequences for soil fertility. In practical terms, this would make it essential to apply more fertiliser in many forests.

Moreover, increased harvesting would result in the disappearance of large-diameter and very large-diameter trees and would thus reduce natural regeneration capacity. It would thus become essential to use plantations to rebuild stands.

Finally, the depletion of dead wood in managed forests would result in very significant erosion of biodiversity. Not only would this erosion run counter to France’s international commitments, more importantly it would threaten the very ecosystem balance and weaken capacity to resist attack (insects, fungi, etc.).

Increasing the harvest to 95 Mm³/year would require major efforts in terms of infrastructure (forest roads, tracks, storage spaces, tonnage levies on small roads) and in mobilisation and grouping of owners. It would thus involve heavy expenditure of public money, when there is already a lack of resources for the services responsible for improving management quality and monitoring of public and private forests. Social tensions would also be very high because some forest owners would be forced to intensify harvesting of their forests more than they would like. Because of changes to the landscape, harvest intensification would also elicit strong protests from other forest users.
The current carbon sink (excluding soil and products) is estimated to be between -65 and -87 MtCO₂eq/yr, depending on the source. We estimate it to be about -84 MtCO₂eq/yr in 2020, using the simulation parameters. Our simulation allows us to compare the evolution of the forest carbon sink under the different scenarios:

<table>
<thead>
<tr>
<th>SINK 2020 (65% MANAGED FOREST)</th>
<th>-84 MtCO₂eq/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATURAL FOREST THROUGHOUT FRANCE IN 2050</td>
<td>-110 MtCO₂eq/yr</td>
</tr>
<tr>
<td>EXTENSIVE SCENARIO IN 2050 (75% managed)</td>
<td>-98 MtCO₂eq/yr</td>
</tr>
<tr>
<td>CONSTANT HARVESTING SCENARIO IN 2050 (75% managed)</td>
<td>-79 MtCO₂eq/yr</td>
</tr>
<tr>
<td>INTENSIVE SCENARIO IN 2050 (75% managed)</td>
<td>-53 MtCO₂eq/yr</td>
</tr>
</tbody>
</table>

Results based on assumption of low mortality.
An assumption of high mortality would further increase the gap between the scenarios.

From a climate perspective, no longer harvesting any wood (totally natural forest) would be by far the best way to maximise the carbon sink in ecosystems. With harvesting of wood, the extensive scenario is the most effective by 2050. It only results in a significant decrease in carbon stock in deadlocked areas (where the sink is low), hence the overall increase in the sink by 2050. This scenario also maximises the positive impacts on biodiversity and soil fertility.

However, in assessing the value of this scenario, we must also take into account potential and desirable changes in demand for wood. While massive reductions in energy and material consumption are essential to stabilise the climate, we will still need wood to build (or repair) homes. While a large portion of our timber consumption is currently imported, a significant redirection in these flows is incompatible with a drastic reduction in harvesting of French forests. Processing French wood in France would also make it possible to maintain and develop employment in the timber industry without increasing harvesting.

The rebalancing scenario, with constant harvesting, is a compromise that allows the current level of harvesting to be maintained, while better distributing it among all the exploited forests in order to reduce local harvesting pressure. This scenario thus enables trees to be allowed to age and to approach equilibrium volumes by 2050. It allows the current sink to be maintained, while respecting soil fertility and biodiversity.

### CONCLUSION

Climate change is not a momentary crisis but a phenomenon that will put lasting pressure on forest ecosystems. Forests will play a key role in mitigating the scale of climate change. Our study shows that the majority of French forests are still very young and can therefore still store large quantities of carbon until 2050 and well beyond. Even in the event of increased tree mortality rates, this storage potential is not significantly threatened. On the other hand, increasing wood harvesting and relying on substitution effects means undertaking to diminish the natural carbon sink, at the very time scientists are warning us of the need to restore it and to drastically reduce our emissions. The difference between these two strategies is the level of risk they expose us to. It is also a particular vision of the forest and its relationship to society. Letting trees age is not only an effective strategy to mitigate climate change, but also the best option for preserving soil fertility, restoring biodiversity and giving new meaning to forestry and wood professions by focusing on quality.
RECOMMENDATIONS

Maintain wood harvesting at the 2016 level overall, with better distribution of harvesting activities by forest type, ownership status and region.

At the national level, leave 25% of the French forest area to evolve naturally, with a long-term guarantee and a minimum of 10% natural forest in each region.

Let stands age to maximise carbon storage capacity in the ecosystem, while increasing harvesting limits and seeking to move towards a standing capital that is constant over time and as high as possible at the plot level.

 Adopt a much more precise definition of health deadlock, to avoid stand conversion through clear-cutting when other forestry options are available. We propose two cumulative criteria:

- critical health status (at least 50% of the trees showing at least 50% fine branch mortality or defoliation);
- absence of natural regeneration allowing the return of a stand adapted to the site.

Steer forestry towards the production of quality timber.

Favour “soft” harvesting practices and local processing of wood.

Limit use of wood for energy to byproducts from forestry (thinning, branches) and from timber processing.

Prohibit the conversion of coal-fired power stations to biomass, particularly in Gardanne and Cordemais.