Methodologies and challenges encountered when producing projections for the French LULUCF sector

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Citepa

Political context - LULUCF Projections for 2050

National – toward climate neutrality in 2050 :
- Objectives set in the French Energy-Climate Strategy, including the National Low-Carbon Strategy (SNBC)
→ LULUCF target for 2050, with carbon budgets along the trajectory

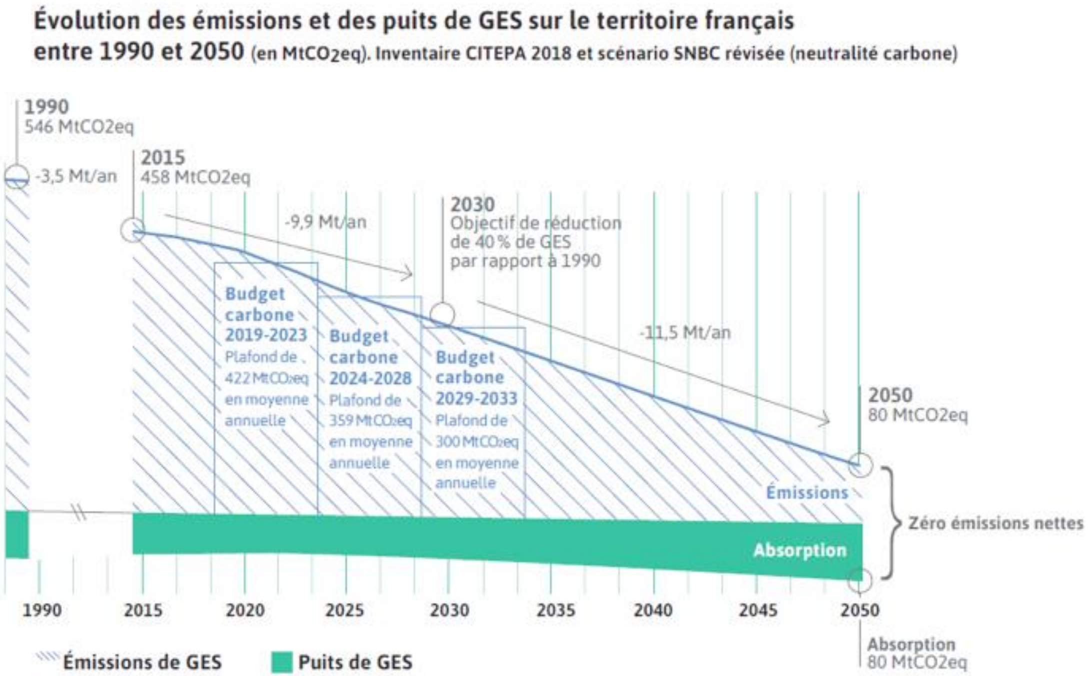
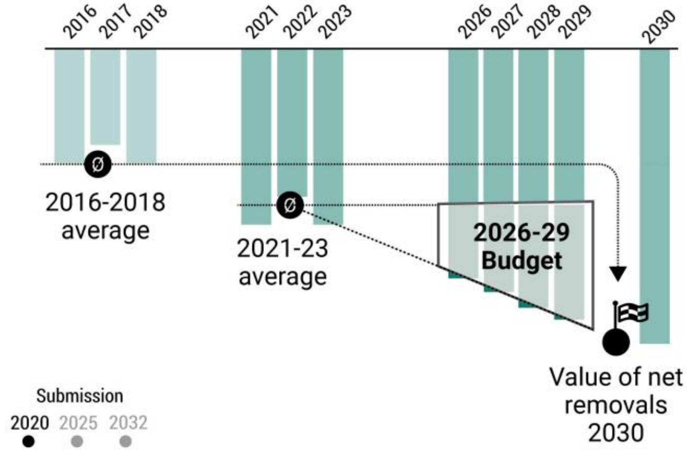


Figure 11: Example of a Member States' budget calculation 2026-2029



LULUCF handbook

EU : LULUCF regulation, governance

→ LULUCF target and budgets

Political context - LULUCF Projections for 2050

GHG **sinks**: 80 MtCO2e in 2050

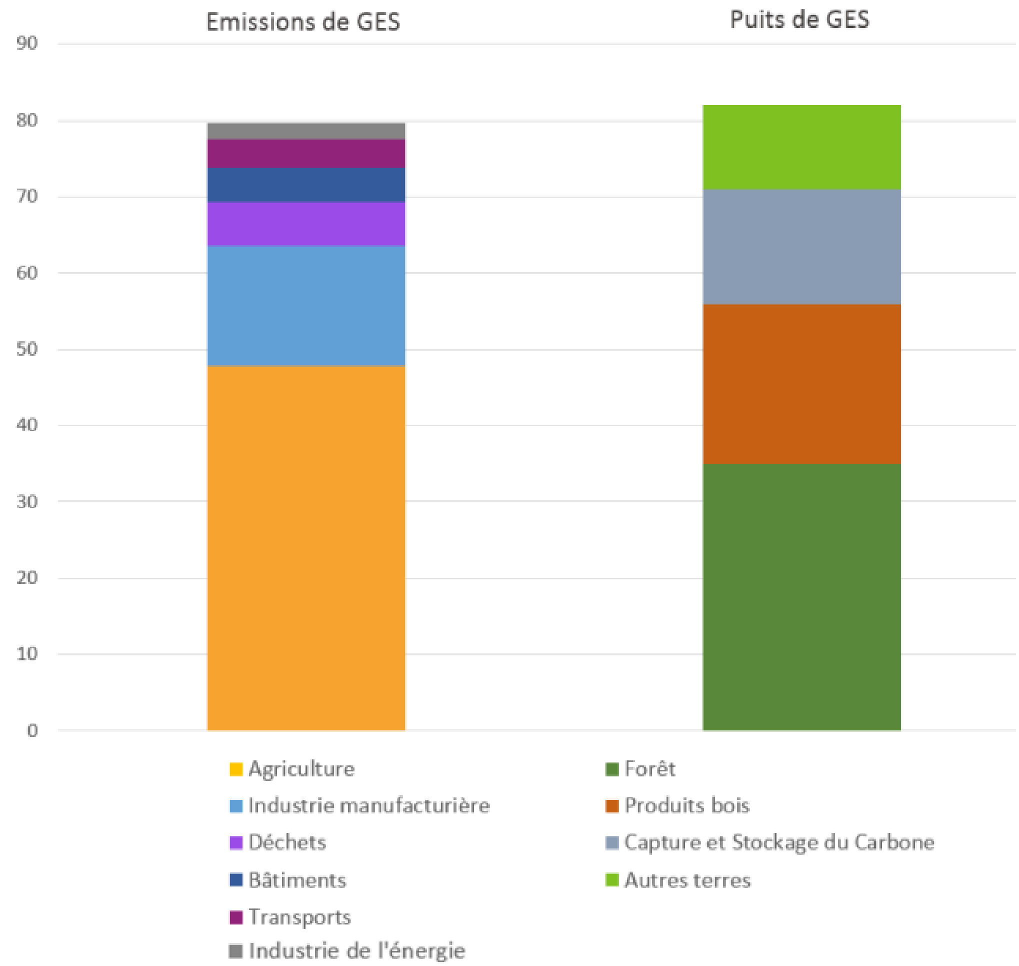
Significant ambition for the forest carbon sink: ~ 35 MtCO2e

Carbon sinks outside forest (mainly sequestration of agricultural soils)

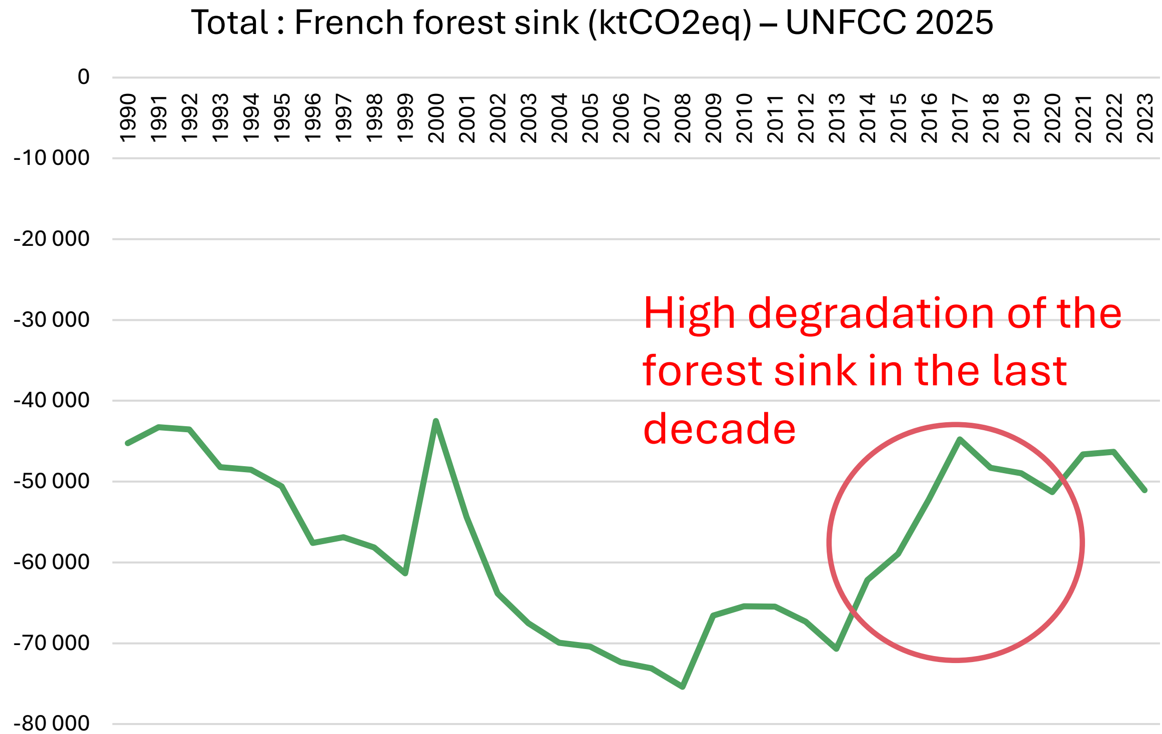
Additional Carbon Storage and Capture sink

Large share of wood products (~ 20 MtCO2e)

Emissions / absorptions targets in 2050 in the 2nd French Energy-Climate Strategy



Recent forest trends



[Crise scolytes sur épicéas - Bilan fin 2020 : 10 millions de m^3 et 30 000 ha de bois scolytés depuis 2018 | Ministère de l'Agriculture, de la Souveraineté alimentaire et de la Forêt]

Bark beetle crisis

- Sharp decline of the sink (with a temporary sequestration in dead wood)
- Explanatory factors:
  - an increase in tree **mortality** due to droughts and pests,
  - slowing increment,
  - increase in wood removals

What's next ?

LULUCF Projections, specificities

- Sector with large uncertainties, even for the past dynamics

- The sink estimates **calibrate the efforts** the other sectors must make to reduce their emissions to achieve neutrality.

- Necessary output from the projections :

- emissions and removals estimates
- wood availability that can be injected in the energy sector / used as material → calibrates the decarbonation of the other sectors

Outline

Ongoing update of the LULUCF projections for the new national strategy law (Citepa – French ministry)

- **Forest sink forecasting – focus on the choices made for modelling climate effects**
- **Land use changes modelling – link to the spatially explicit method**

1 Forest sink forecasting

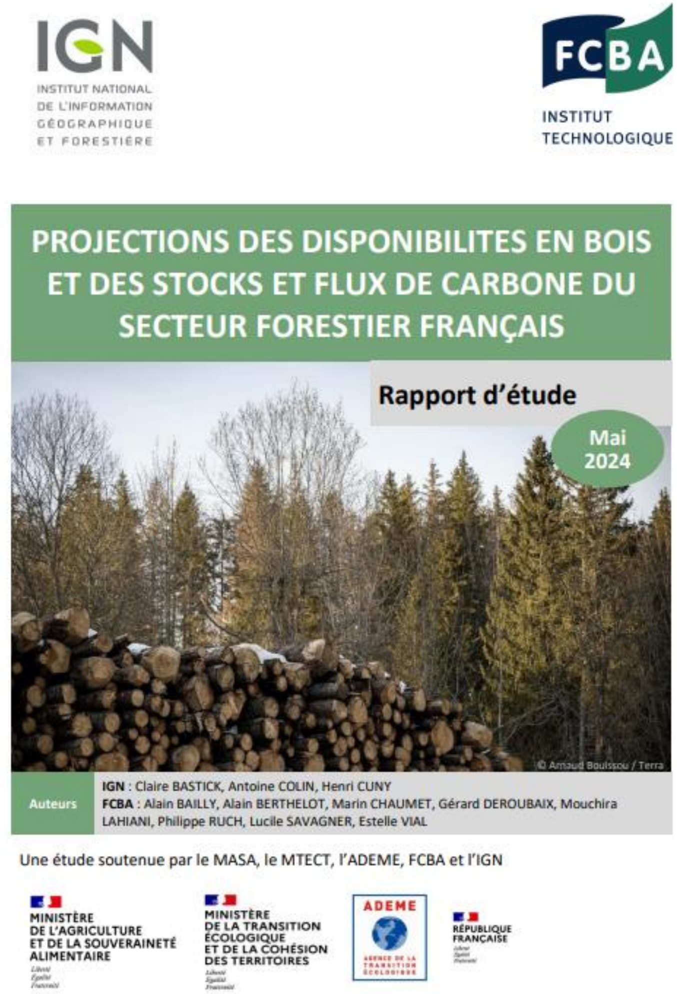
Forest sink estimates : based on NFI study

Projections of carbon stocks and flows in the French forestry & timber sector in the context of climate change – june 2024

Simulate a wide range of trajectories, with a gradient of :

- harvesting levels (**6 management scenarios**),
- effects of climate change (**3 climate impact scenarios**)
- reforestation strategies (2 scenarios),
- Distribution of harvest within the forestry sectors (**10 industry scenarios**)

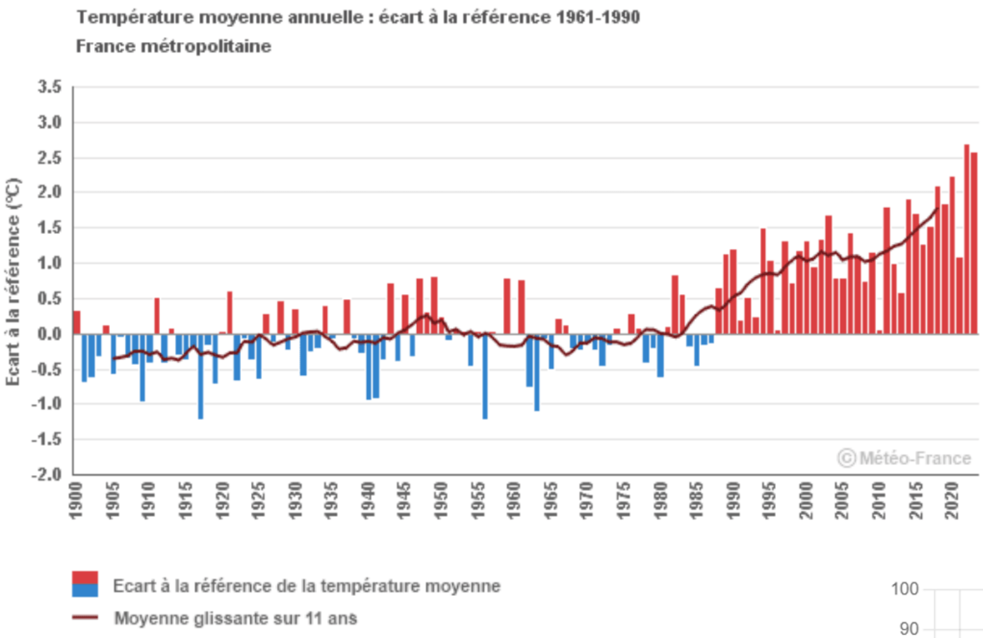
Time horizon: 2025 to 2050 in 5-year periods and then up to 2080 for some results



La forêt en 2050 : projection des disponibilités en bois et des stocks et flux de carbone du secteur forestier français - Institut - IGN

How to deal with climate effects on forests ?

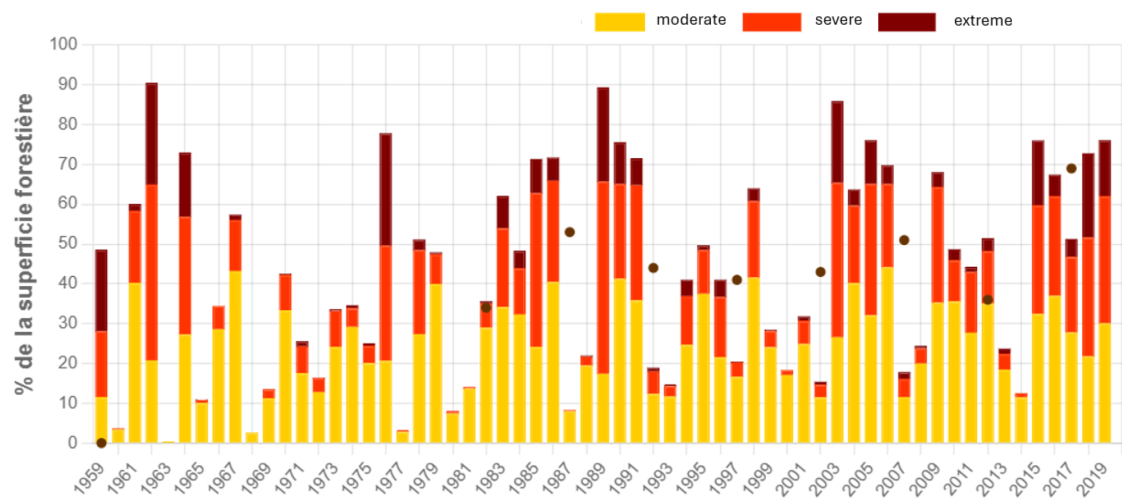
Strong evidence of climate impact on forests (e.g., increased mortality since 2015 due to drought and heat).



Raising temperatures (+1,7°C since 1900)

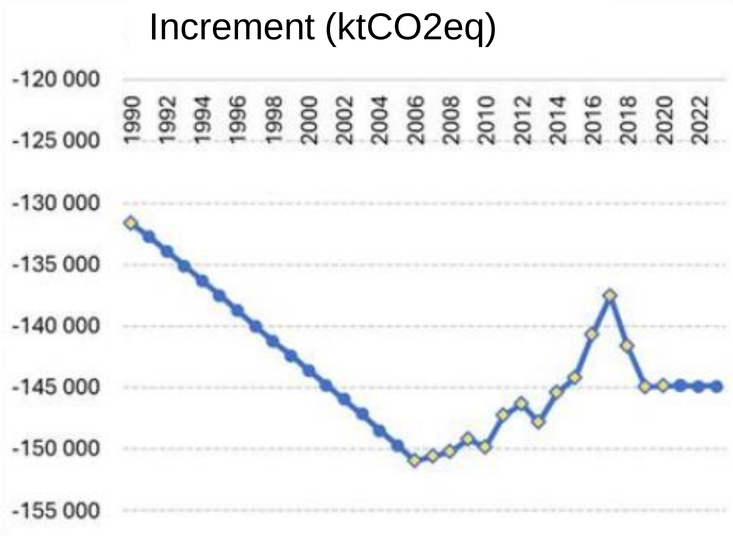
1. Météo-France. Météo-France sheds light on the climate in France until 2100. (2020).
2. MTECT. The Reference Warming Pathway for Adaptation to Climate Change (TRACC). 31 p. (2023).

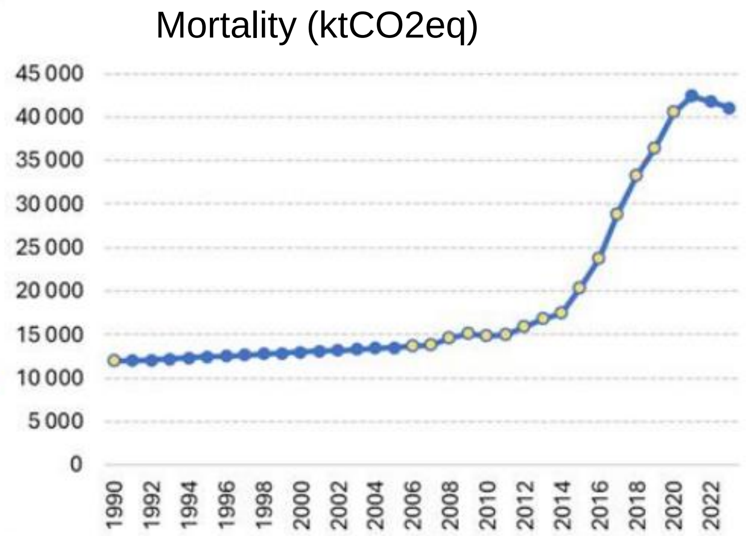
Severe droughts in recent years

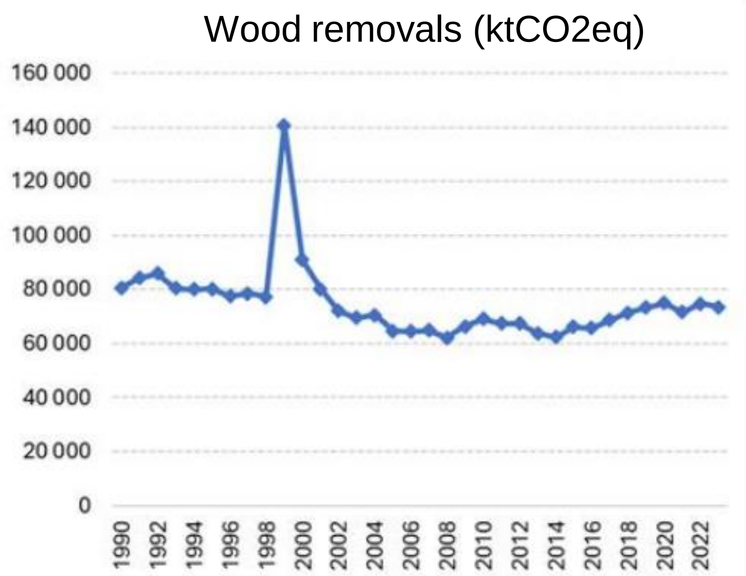


How to forecast these elements and estimate their impact on the carbon sink ?

Recent forest trends (NFI data)



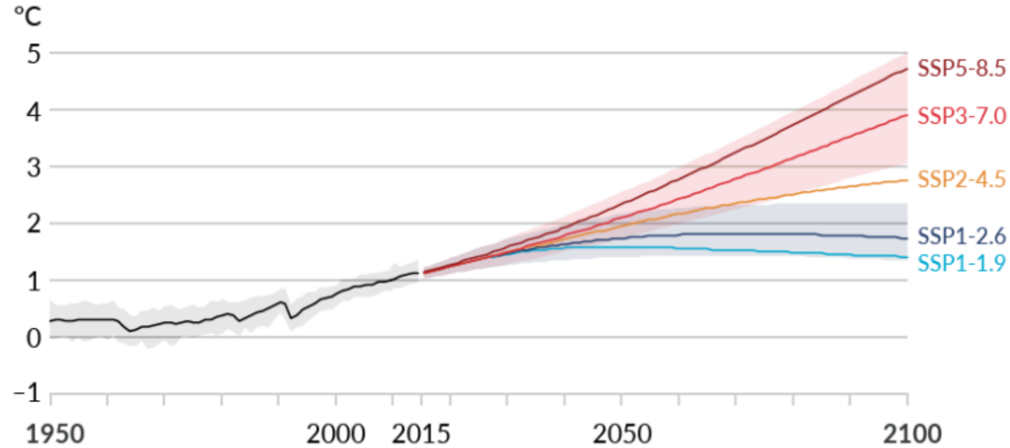




How to deal with climate effects on forests ?

Use of IPCC climate scenarios ?

Evolution of the global surface temperature compared to the period 1850-1900. IPCC 6th Assessment Report



First source of uncertainty

The regionalization and translation of these scenarios into climatic variables (temperature, precipitation, etc.) and at the sub-national scale.

How to deal with climate effects on forests ?

Second (and even more important) source of uncertainty

= modelling of the impact of these climate scenarios on forest mortality and growth

→ it remains very difficult to quantify and model the climate effects on forests on a large scale, even on recent observed data, due to :

- genetic variability on individual resilience, integration of trees' spontaneous adaptation and threshold effects
- the ability of trees to adapt differently depending on the forest regions,
- the effect of species mixing on water stress (...)

Different families of models seek to link climatic variables and their future evolution with vulnerability, distribution, mortality or stand growth.

- Eco-physiological models of biochemical processes (Castanea-SSM7, GO+...)
- Hydraulic modelling of plants (SurEau),
- Specific tools developed for species selection (ClimEssences, BioClimSol).

How to deal with climate effects on forests ?

Second (and even more important) source of uncertainty

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- Eco-physiological models of biochemical processes (Castanea-SSM7, GO+...)
- Hydraulic modelling of plants (SurEau),
- Specific tools developed for species selection (ClimEssences, BioClimSol).

- **Tests** were made by the NFI team, but various limitations were raised.

→ These models only study certain species and only pure stands, whereas the French forest is very diverse (< than 50% pure stands)

→ These models are often calibrated on data from local experimental sites.

Overall, the variability linked to scientific uncertainties (regional climate model, CO_2 fertilizing effect, etc.) was often greater than the variability of the climate scenarios themselves

How to deal with climate effects on forests ?

- Difficulty to quantitatively link growth decline and mortality to IPCC climate parameters (RCP scenarios). **Absence of mature predictive model**.

→ Decision made by the NFI team :

- Build **trajectories** for mortality and increment based on recent trends in growth decline and increased mortality observed in NFI data, adjusted along a spatial severity gradient **defined by expert judgment**.

- Discussions focused on distinguishing background mortality (mainly from competition among young trees) from crisis- and shock-induced mortality.

- Objective = integration of the most up-to-date knowledge on possible future mortality trends, to build scenarios representing a **range of possible forest responses to climate change.**

All scenarios

Management scenarios

A → scenarios defined by a removal rate*

- A1: removal rate remains at the current level of 70% (equivalent to maintained management intensity)
- A2: removal rate of 80% achieved in 2030 (equivalent to current removal rate in state-owned forest)
- A3: 100% removal rate achieved by 2035 (equivalent to a carbon-neutral forest)

B → scenarios defined by harvest volume

- B1: current harvest volume is maintained (at 53Mm3/year)
- B2: harvesting increases to 63 Mm3/year in 2050 (national forest and wood program (PNFB) reached in 2030, then harvesting level is stable)

*≈ AME in the Dec 23 version and AMS in the Nov 23 version***

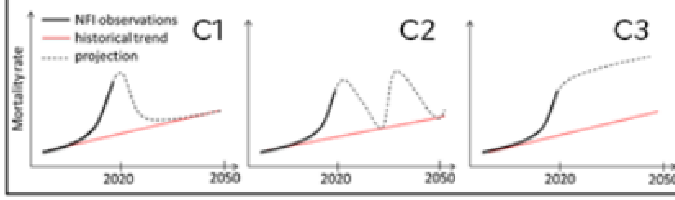
- B3: harvest with AMSs in 2023 to 75 Mm3/year in 2080 (PNFB reached in 2026 then harvest increases)

*≈ AMS June 23 version***

✖

Climate impact scenarios

- C1: optimistic scenario, considering the current crisis to be temporary
- C2: scenario of successive crises such as the current one, spaced a few years apart (analogy with successive periods of drought)
- C3: pessimistic scenario of an upward plateau in mortality and a downward plateau in production



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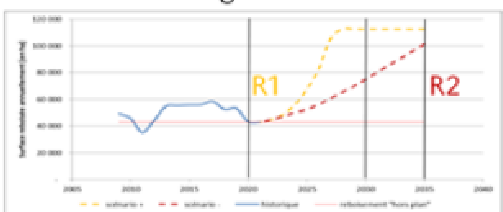
Renewal plan scenarios

- R1: scenario in which one billion trees are planted by 2030 (government's target)
- R2: scenario in which the target is reached more gradually



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Scenarios of downstream evolution (harvest allocation)

- F1: additional harvesting to meet demand (mainly for construction for BO and 70% for energy and 30% for construction for BI/BE)
- F2: additional BI and related products for energy purposes
- F3: additional BI for energy
- F4: additional BI in panels
- F5: additional BI and related products in panels
- F6: same as F5 + additional BO in construction
- F7: same as F6 + decrease in the rate of BO not used in sawing or veneering
- F8: same as F7 + increase in recycling in France
- F9: same as F8 + domestic recycling of wood waste / exported recycled material considered
- F10: same as F9 + use of a greater proportion of BI from the entire harvest in panels

* Theoretical scenarios, as management is not directly controlled by a national removal rate

** AME: with existing measures / AMS: with additional measures (SFEC scenarios)

BO/BI/BE: construction/ industrial/ energy wood

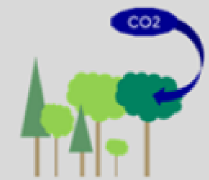
36 scenario combinations for "forestry upstream"

and

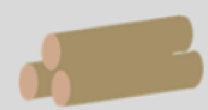
Selection of 20 scenario combinations integrating "upstream" and "downstream" of the forestry & wood sector

↓

Carbon balance



Wood availability



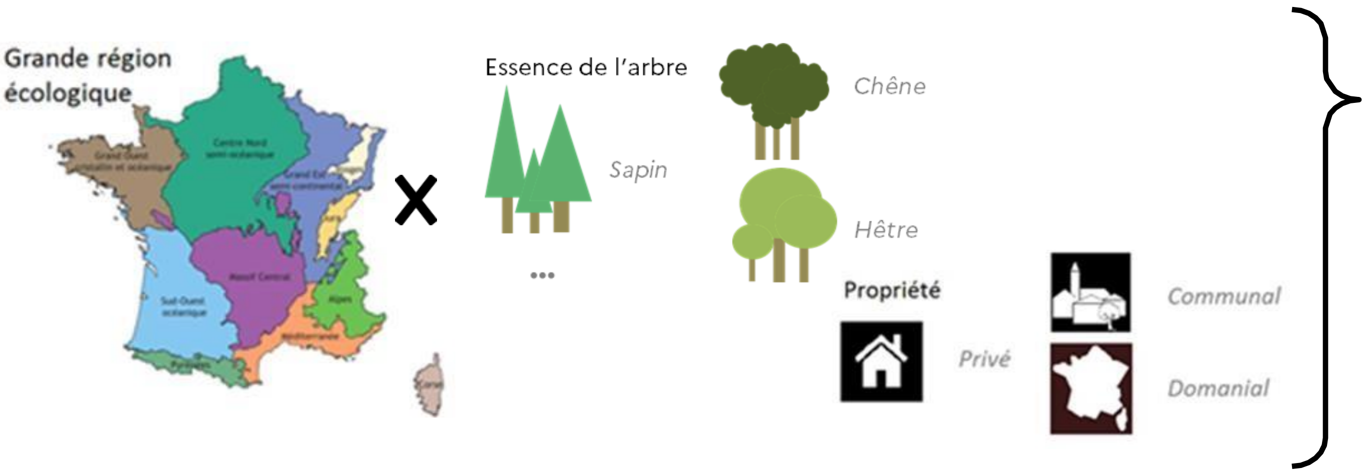
Forest sink estimates : based on NFI study

Initialisation data:

Initial standing resource of production forests : 2020 (2018-2022 NFI campaigns)

Initial parameters of the dynamics (growth, mortality, wood removals) : 2013-2022 period (excluding crises for mortality and wood removals)

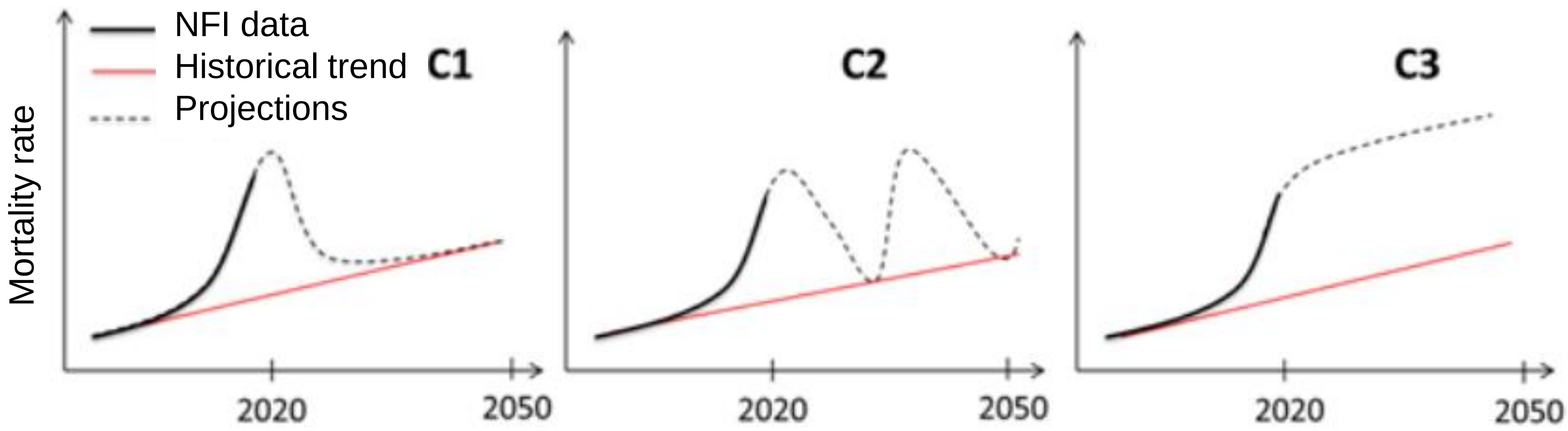
→ variables modulated according to the climate effect scenarios and management scenarios



≈ = 120 strata, subdivided by 3 density classes, described by diameter class

→ By region, type of property, species

3 Climate impact scenarios



C1 scenario: An optimistic trajectory, viewing the current crisis as temporary : after the mortality peak, trends return to a slight historical increase in mortality and a slight decrease in productivity.

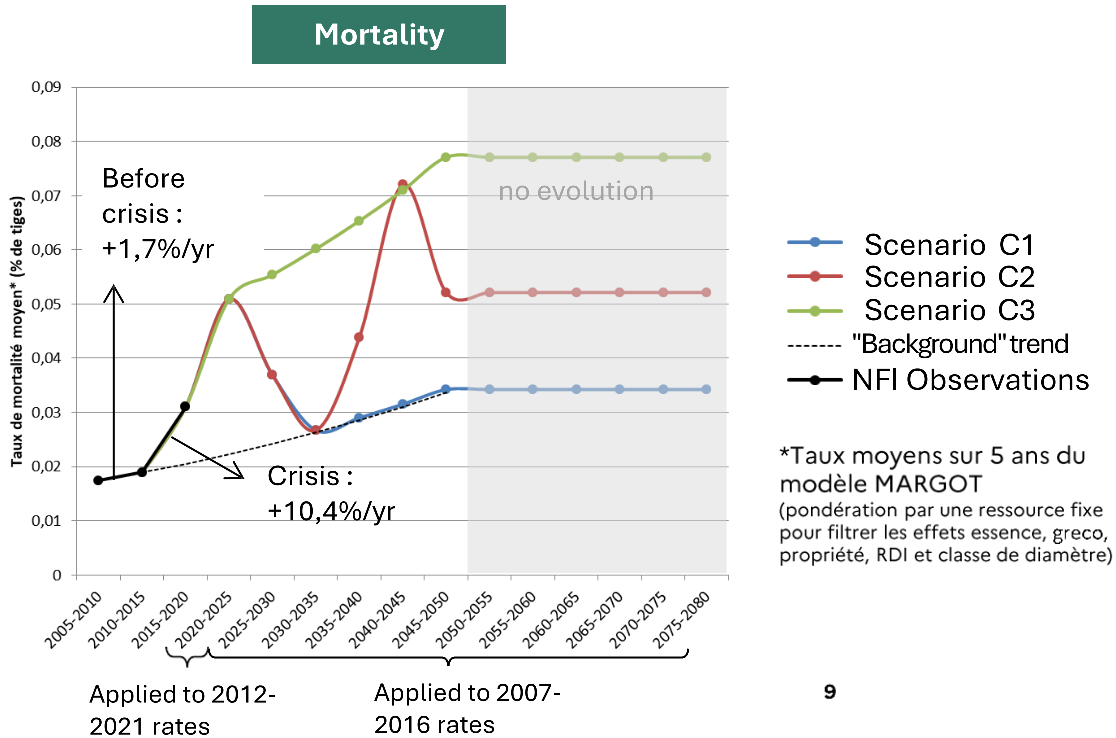
C2 scenario: A trajectory of episodic "waves" of crises, driven by alternating dry and wet years, following the dynamics observed during past drought-induced crises.

C3 scenario: A pessimistic trajectory, where the current crisis marks a transition to a permanently higher mortality rate and lower productivity, with a continuing worsening trend like observed before the crisis.

3 Climate impact scenarios : use of modulators

Modulators of the climate change effect scenarios:

Modulators applied on initial natural dynamics (mortality, growth, recruitment) based on the orders of magnitude of variation of the rates observed by the NFI before and during the current crisis



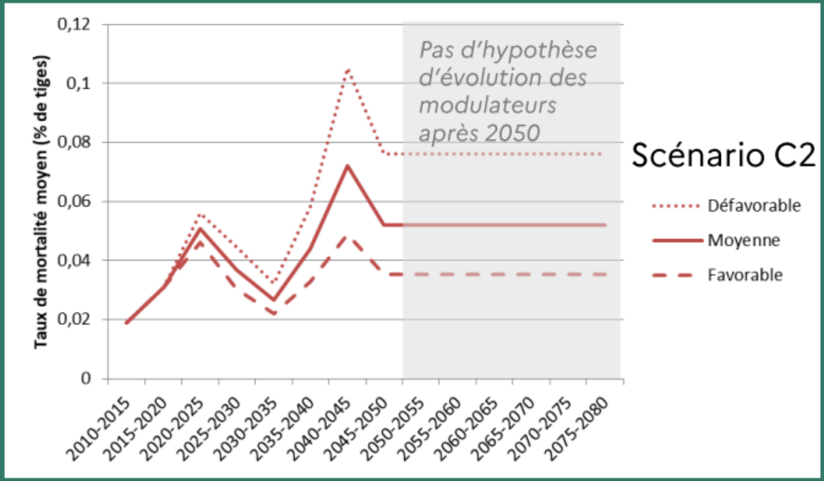
3 Climate impact scenarios : use of modulators

Local variation of the climate change effect scenarios:

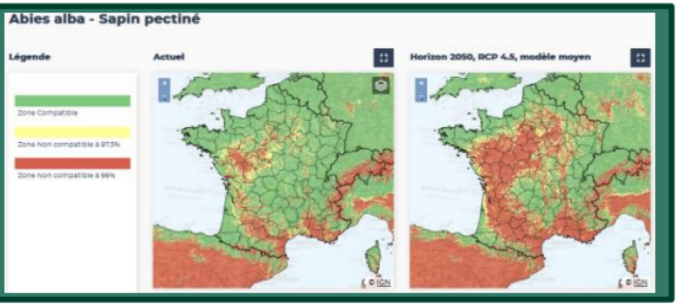
Distinction modulators according to the future compatibility determined by the ClimEssences tool

ClimEssences is a French decision-support tool that models the potential distribution of tree species under various climate change scenarios, helping forest managers anticipate ecological suitability and adaptation strategies.

1. Modulator calculation using NFI data: positive/negative modulation



2. Distribution by stratum of stands classified as not compatible by ClimEssence



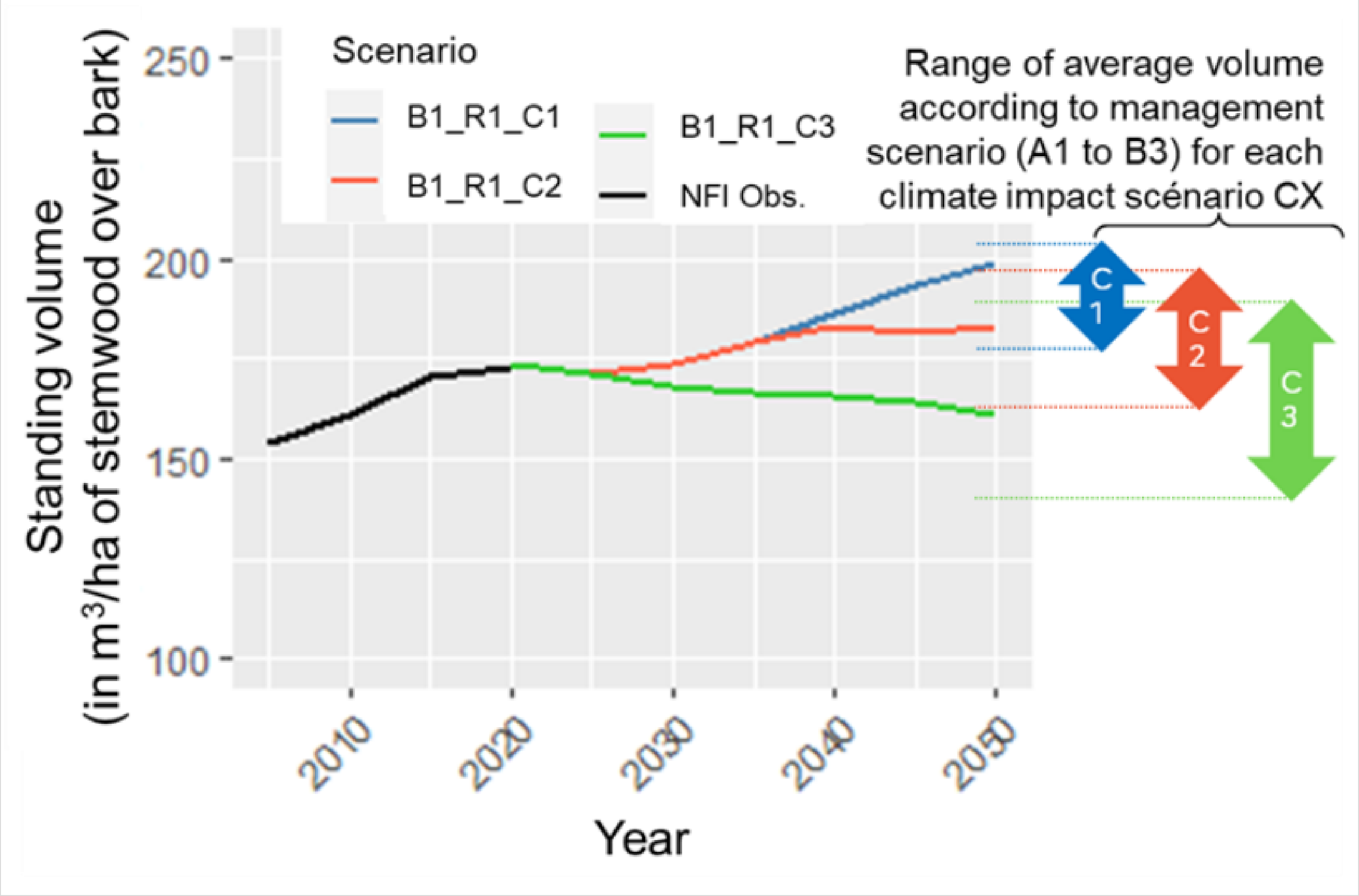
3. Calculation of the stratum modulator based on its average vulnerability

	strate	defav	fav
1:	G_Publique_Sapin pectiné	96%	4%
2:	B.continental_Publique_Chêne rouvre	96%	4%
3:	I_Publique_Sapin pectiné	94%	6%
4:	G_Privee_Epicéa commun	93%	7%
5:	B.continental_Privee_Chêne rouvre	93%	7%

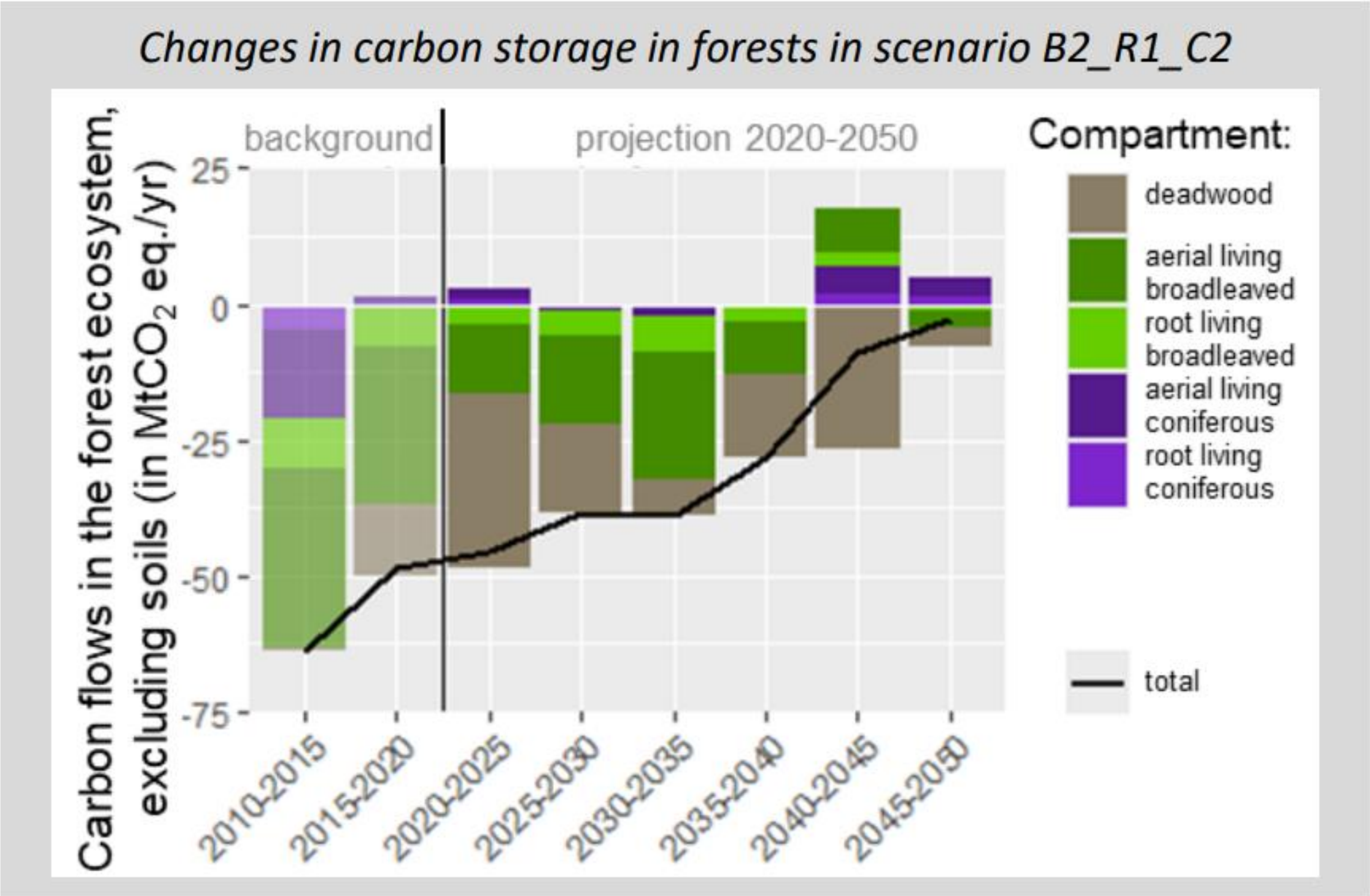
115:	F.gascogne_Privee_Pin maritime	3%	97%
116:	A_Privee_Pin maritime	2%	98%
117:	K_Privee_Chêne vert	0%	100%
118:	E_Privee_Divers résineux	0%	100%
119:	F.gascogne_Publique_Pin maritime	0%	100%

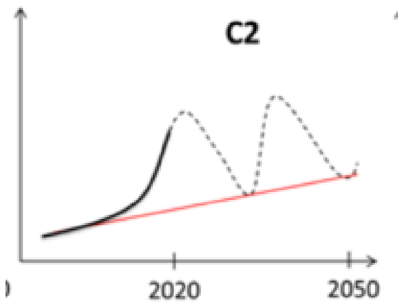
3 Climate impact scenarios : some results

Changes in standing volume according to climate effect scenarios

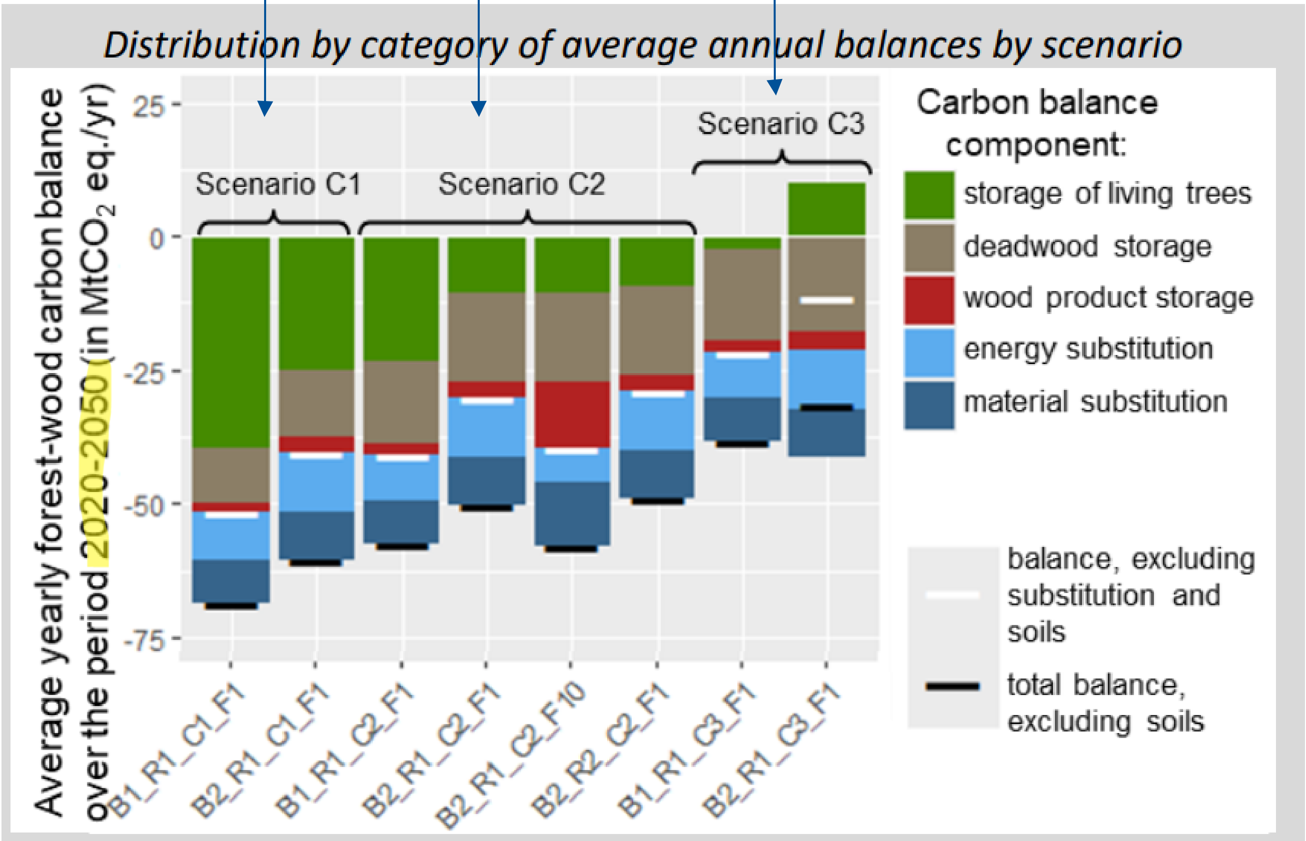


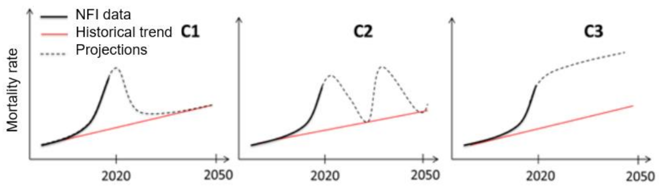
Overview of one scenario





Scenario intercomparison

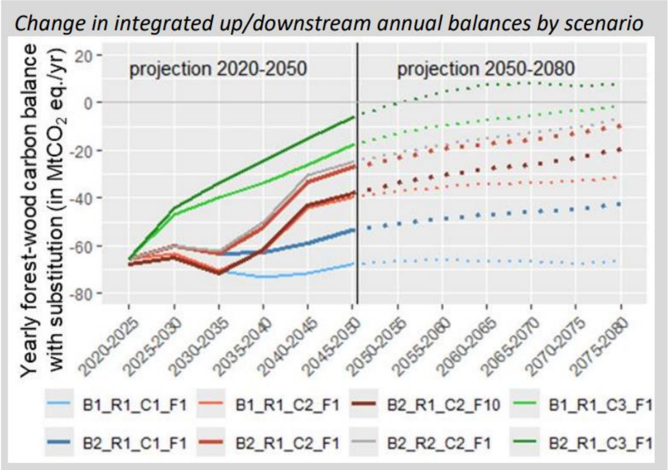




Climate scenarios = highest impact

Strong link with the industry sector and HWP

Temporary sinks in deadwood

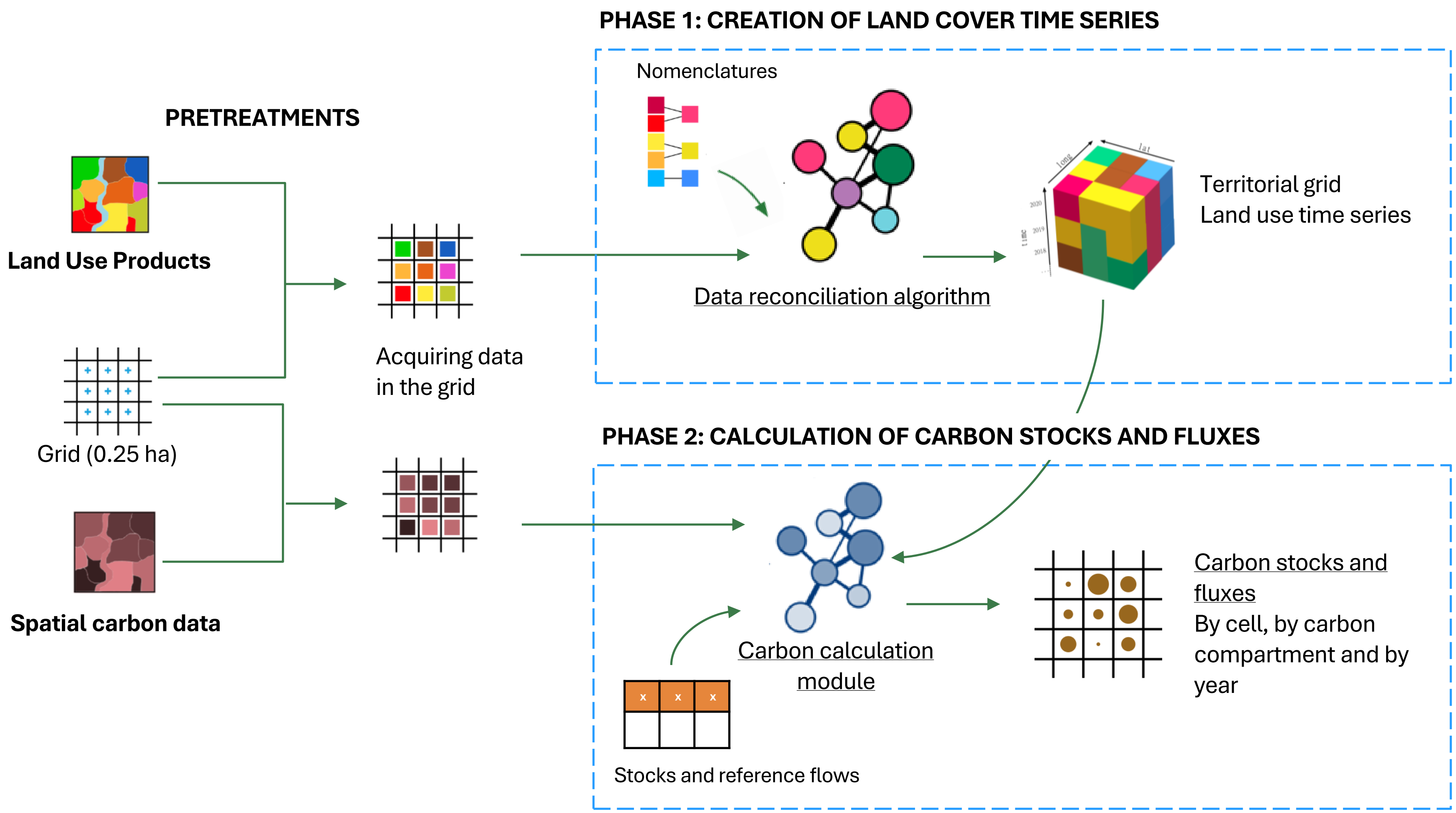


Conclusions - Limits

- Use of an empirical approach, with various **scenarios of <u>climate effects</u>, not climate scenarios**, to present possible futures with reaction of the wood industry and effects on the carbon sink
- Method disconnected from climate variables, or RCP, as models tested were not conclusive
- Lack of retro-effects in existing models, or thresholds effects (e.g. CO2 fertilization effect not switching to a negative effect when climate conditions deteriorate the potential growth)
- Obvious limits to the validity of the elected scenario for political binding projections.
- Need for further research, multidisciplinary expertise, and the acquisition of additional data on the climate effects

2 Land use modelling

General concept of the spatially explicit inventory

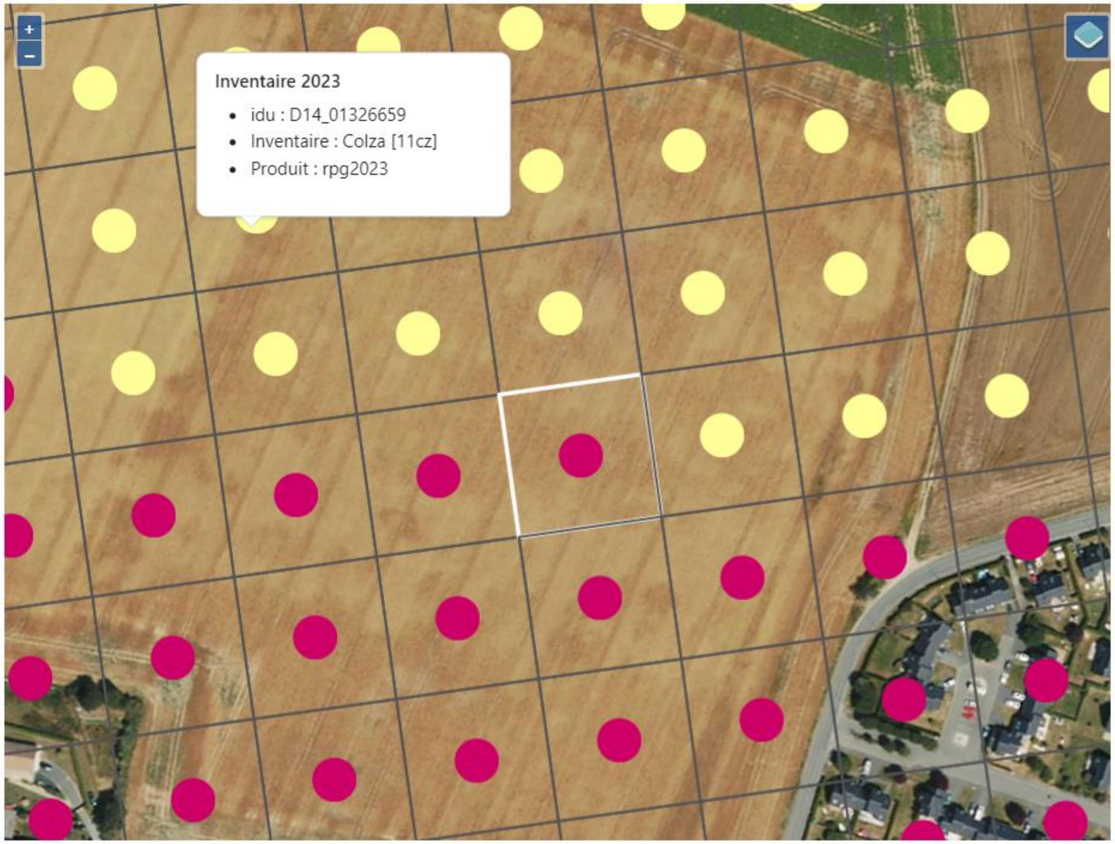


Skeleton of the projection model

- Same skeleton as the historical inventory
- Base unit: 0.25 ha grid (220 M° cells)

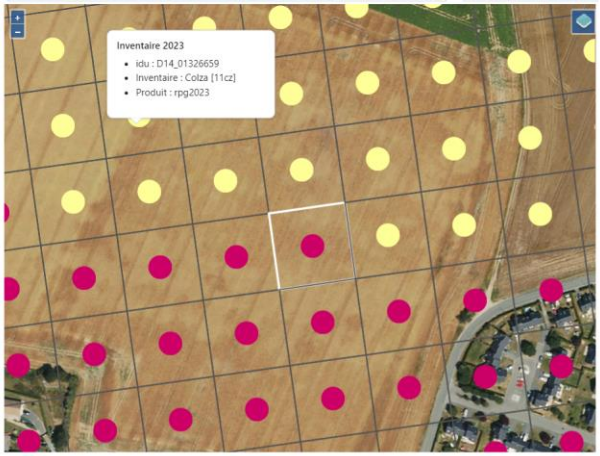
- The model identifies many land use changes, as well as rotations within agricultural crops. Interrupting this method to apply another one in projection creates major temporal discontinuities

- A method has been proposed to continue working with centroids and carbon calculations at the grid cell level.



Sampling

- Extraction of 1,000,000 centroids out of the 220 million, with their historical land use series 1990-2022



* 220 000 000

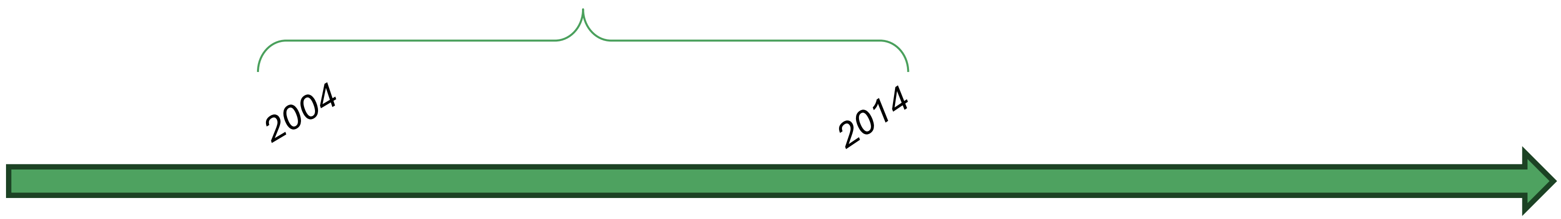
* 1 000 000

Centroid id	Landuse 1990	Landuse 1991	(...)	Landuse 2022
D87_xxx	F	F		C
D87_xx2	F	P		P
D87_xx3	W	W		W
(...)				

Probabilities of conversion (change regime)

- Analysis of historical changes: we focus on the period 2004 - 2014 which is 100% spatially explicit
- Calculation of conversion probabilities (based on 2004-2014) : matrices, with average annual conversion probabilities, for all land use subcategories
  - Probability distribution:

	Grains and oilseeds	Protein crops	Temporary grassland	Industrial culture	Permanent grassland	Vegetable crops, flowers	Permanent crops	...
Grains and oilseeds	85%	2%	5%	2%	3%	1%	0%	
Protein crops	84%	4%	4%	0%	5%	0%	0%	
Temporary grassland	3%	0%	96%	0%	0%	0%	0%	
Industrial culture	84%	0%	2%	9%	0%	3%	0%	
Permanent grassland	15%	0%	9%	0%	74%	0%	0%	
Vegetable crops, flowers	24%	0%	2%	4%	0%	66%	1%	
Permanent crops	0%	0%	1%	0%	0%	0%	98%	
...								



Option 1: Simple, unconstrained projection

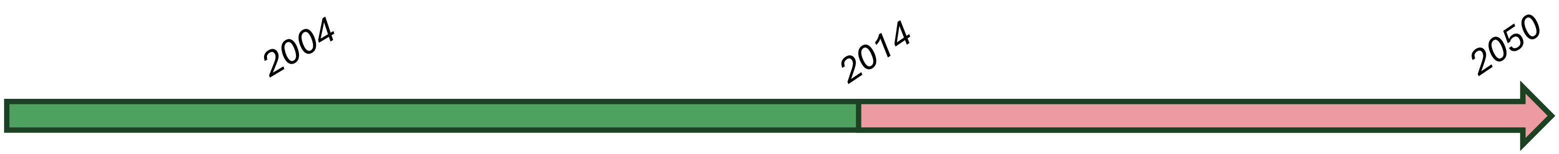
- Application of the conversion probabilities on the 1 M° sample of cells, until 2050.

Constant probability law

↱	Grains and oilseeds	Protein crops	Temporary grassland	Industrial culture	Permanent grassland	Vegetable crops, flowers	Permanent crops	…
Grains and oilseeds	85%	2%	5%	2%	3%	1%	0%	
Protein crops	84%	4%	4%	0%	5%	0%	0%	
Temporary grassland	3%	0%	96%	0%	0%	0%	0%	
Industrial culture	84%	0%	2%	9%	0%	3%	0%	
Permanent grassland	15%	0%	9%	0%	74%	0%	0%	
Vegetable crops, flowers	24%	0%	2%	4%	0%	66%	1%	
Permanent crops	0%	0%	1%	0%	0%	0%	98%	
…								

1 M° sample of centroids

Centroid id	Landuse 1990	Landuse 1991	(…)	Landuse 2014	Landuse 2015	Landuse 2016	Landuse 2017	(…)	Landuse 2030	(…)	Landuse 2050
D87_xxx	F	F		C	C	C	C		C		C
D87_xx2	F	P		P	P	P	C		C		C
D87_xx3	W	W		W	W	W	W		W		W
(…)											



The carbon stock change model is applied to each time series, from 1990 to 2050. The results are extrapolated to the entire territory.

Option 2: Surface Constrained Projection

- Modification of the probability matrix to adapt to the net land use area constraints in 2030 and 2050 given by the user.

Historical Probability Law (x_ij_hist)

	Grains and oilseeds	Protein crops	Temporary grassland	Industrial culture	Permanent grassland	Vegetable crops, flowers	Permanent crops	…
Grains and oilseeds	85%	2%	5%	2%	3%	1%	0%	
Protein crops	84%	4%	4%	0%	5%	0%	0%	
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Vegetable crops, flowers	24%	0%	2%	4%	0%	66%	1%	
Permanent crops	0%	0%	1%	0%	0%	0%	98%	
…								

Grouping into sub-categories within the matrix, to apply constraints (forests, grasslands, etc.)

- Initial surface area: 2014
- **Objectives set by the user**: in 2030 and 2050, by major categories of use.
- **Linear interpolation** between 2014 and 2030, 2030 and 2050.

Each year, **modification of the probability matrix**, responding to these constraints:
- The new probability distribution must make it possible to reach the surface values of the year n+1
- Each cell in the probability matrix should be as close to historical probability as possible **to create less distortion and less carbon impact**

Conclusions - Limits

- Land use projections raised huge discontinuity issues with the spatially explicit modelling
- Development of a new projection model based on historical conversions

- Possible developments to add other constraints to the conversion matrix.
- Applied for the last update of the LULUCF projections. Unpublished yet.
- Still presents difficulties to make the recent results of the historical period and the near projection to fit.
- Difficulty to constraint a specific dynamic without creating conversions/emissions elsewhere.

Thank you!

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Elle évalue l'impact des activités humaines sur le climat et la pollution atmosphérique. Elle produit des données de référence et développe des solutions pour favoriser la réduction des émissions, l'amélioration de la qualité de l'air et l'adaptation au changement climatique.

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