BETA Bureau d'économie théorique et appliquée

AgroParisTech Talents d'une planète soutenable

Master M2 EEET - EDDEE - *Module Economie de la Forêt et du bois*

Modélisation de la filière forestière française (FFSM)

Modelling

-- Forest Sector Modelling

-- French Forest sector Modelling

SCAN ME

https://bit.ly/ffsm2023

Antonello Lobianco

"Weather forecast for tonight: dark."
-- George Carlin, American comedian

Today's objectives

Understand how the complex interactions of the (French) Forest sector, linking forest dynamics, people pursuit's of own goals, markets "behaviours" and society objectives for a better environment, can be accounted, represented and modelled.

Modelling

Forest sector modelling

The French Forest Sector Model

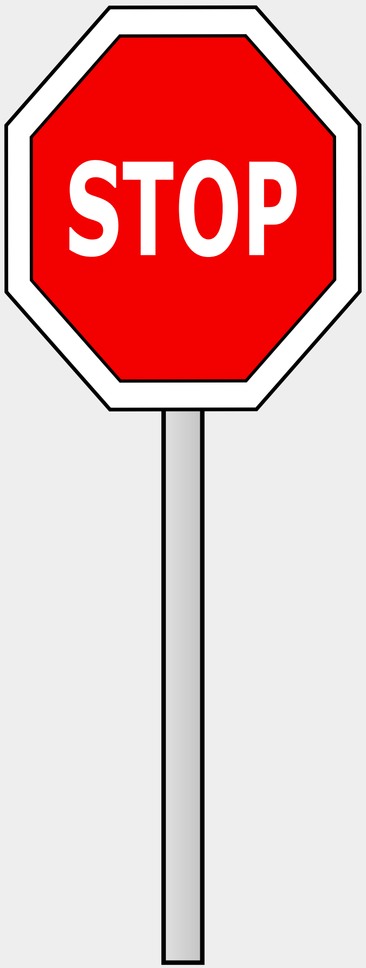
- **Forest resources dynamics**
  - recognition of forest diversity
  - path dependency
  - environmental changes
- **HWP markets**
  - supply, demand, trade
  - price transmission channels
- **Forest investments decisions**
  - how we model individual forest owners
- **Climate change**
  - cc effects on the forest (already seen)
  - do forests really mitigate climate change ?
  - implementation of a carbon module

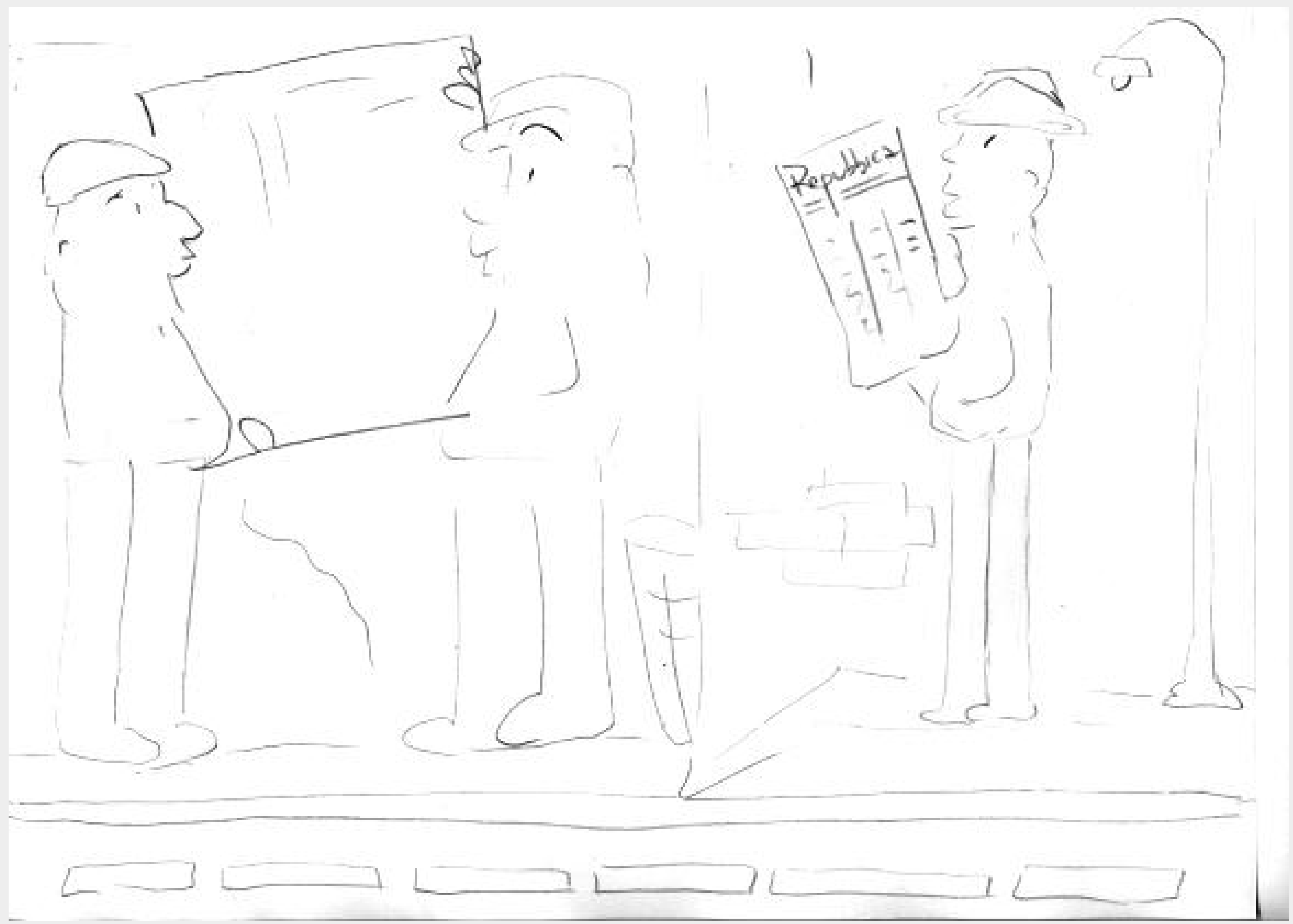
scheduled notes: forest doesn't need humans; 3M owners, <4ha

MODELLING

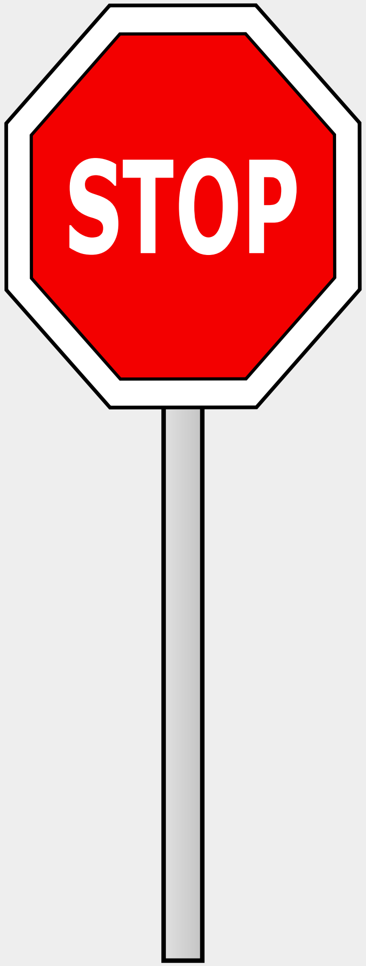
First step.. what is a *model* ??

Reality $\rightarrow$ model $\rightarrow$ math. form.

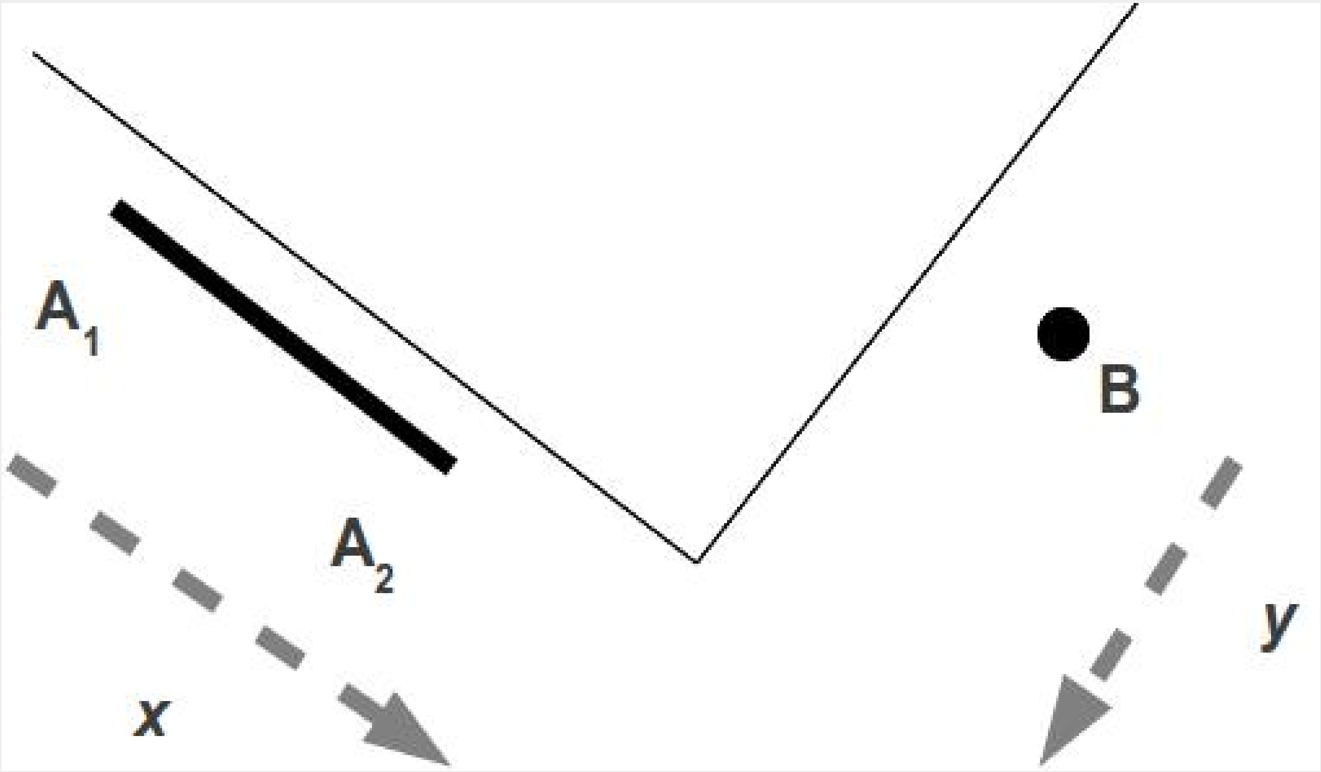




First step.. what is a *model* ??



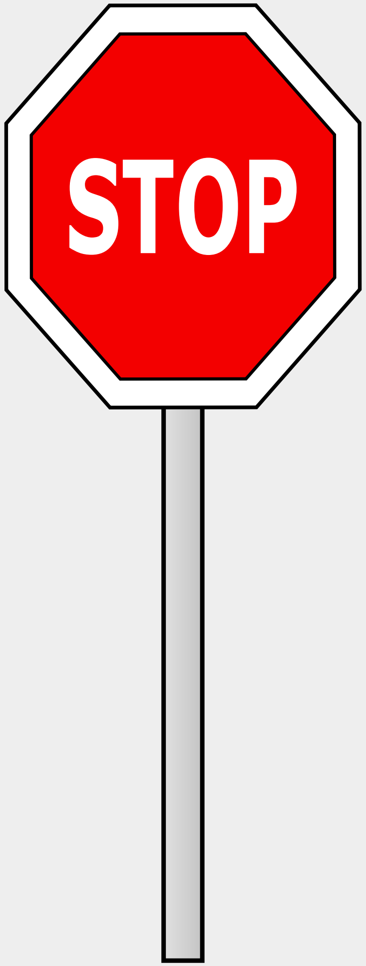
Reality → model → math. form.



A model is useful if it helps us to answer a research question, in this case if a crash will happen.

First step.. what is a *model* ??

Reality → <u>model</u> → math. form.



We need to define which elements to retrain from our observation of the reality (inductive reasoning), which assumptions to make and which data we need, and which reasoning to apply (deductive part) <u>in order to answer the research question</u>.

Info needed:
x_{A1}, x_{A2}, y_B, v_A, v_B

Assumptions:
v_A, v_B constant

Model:
physical space/time/speed relation

First step.. what is a *model* ??

Reality → model → <u>math. form.</u>

$t_{A1} = \frac{x_{A1}}{v_A}$ $t_{A2} = \frac{x_{A2}}{v_A}$ $t_B = \frac{y_B}{v_B}$ crash *iff* $t_{A2} \leqslant t_B \leqslant t_{A1}$

Implementation in Julia

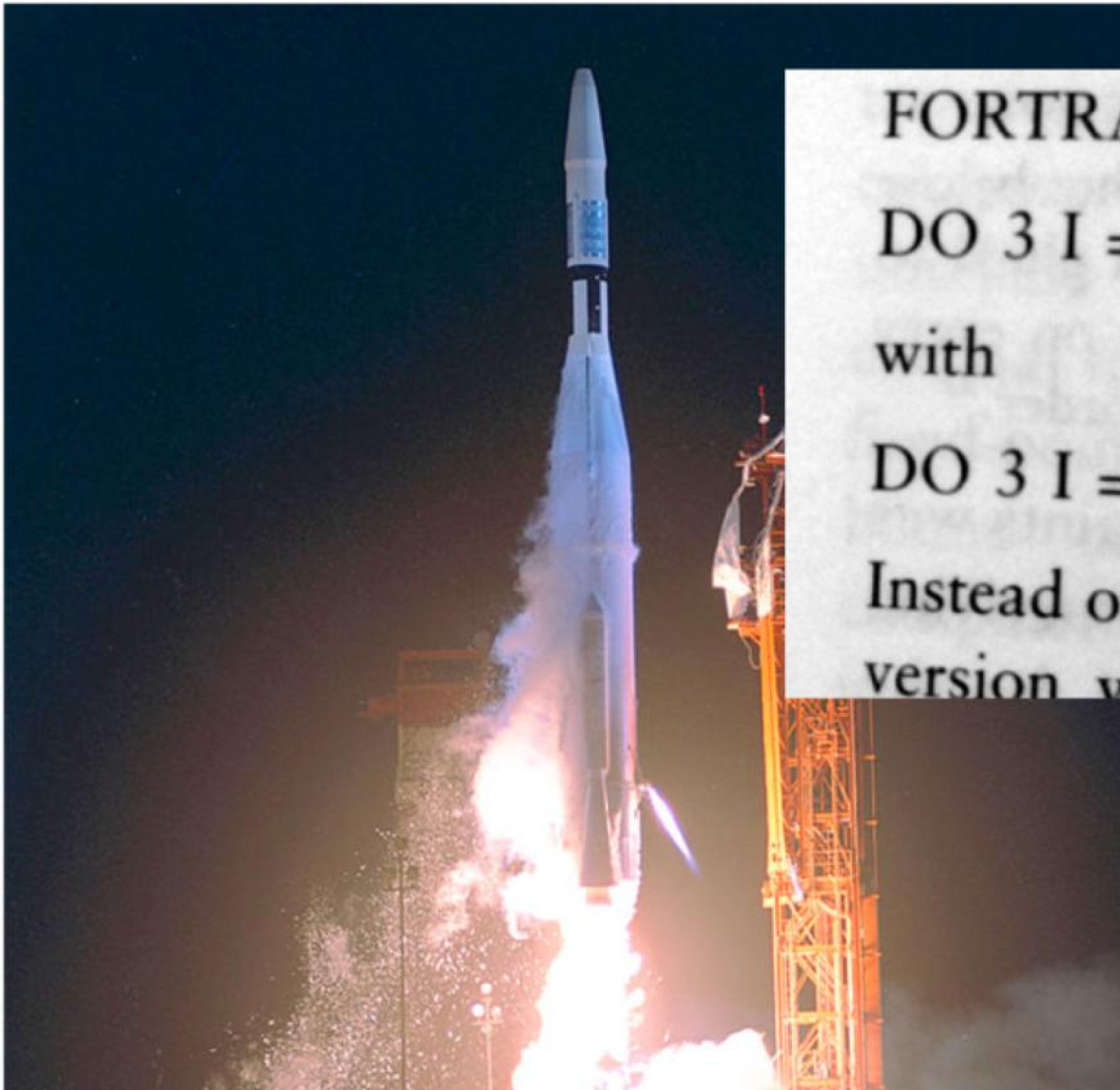
- Download and doc: https://julialang.org
- Run online: https://juliabox.com
- Tutorial: https://www.gitbook.com/book/sylvaticus/julia-language-a-concise-tutorial/details

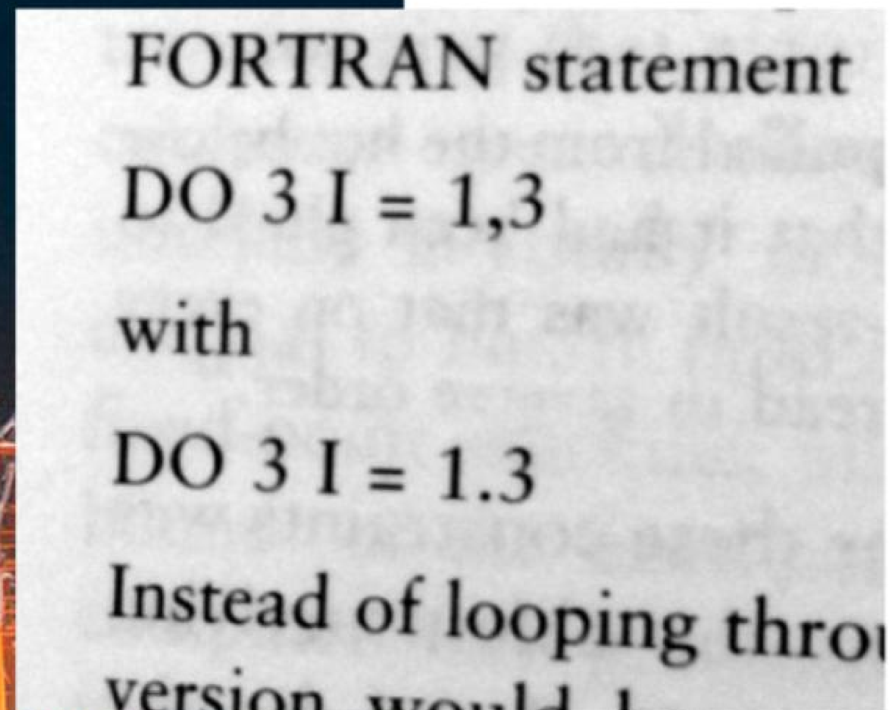
```
function determineClash(xa1, xa2, yb, va, vb)
  ta1 = xa1/va
  ta2 = xa2/va
  tb = yb/vb
  if (ta2 <= tb <= ta1)
     return true
  else
     return false
  end
end
```

```
determineClash(8,5,12,3,6) # true
determineClash(8,5,12,3,4) # false
```

Models can be "wrong" in both the translation of elements that matter in the modelling idea (assumptions) or in their formalisations (e.g. Mariner 1, 1962 satellite, Mars Climate Orbiter 1998)

Programming is error-prone





FORTRAN statement

DO 3 I = 1,3

with

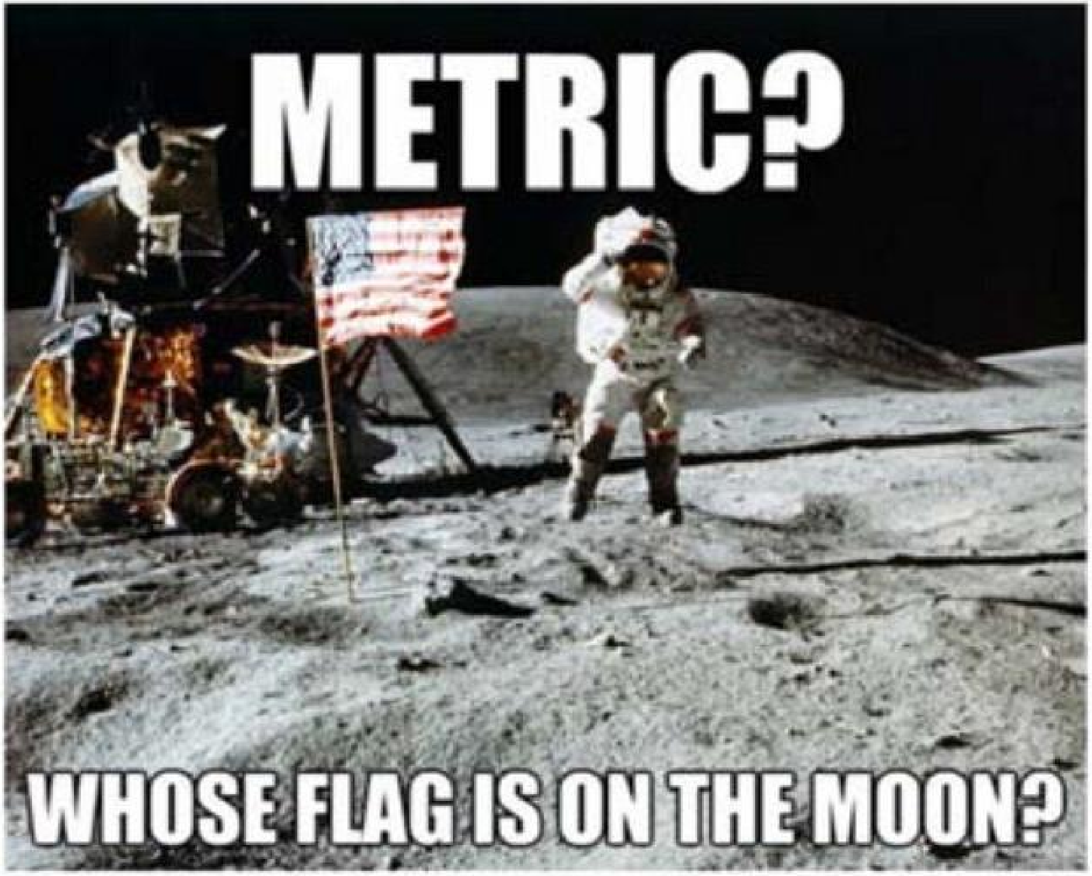
DO 3 I = 1.3

Instead of looping thro

Mariner 1
1962

F…A…I…L…U…R…E… (Famous bugs)

- Mars Climate Orbiter (1998)
  - $655M space probe crashes due to wrong units system.



FOREST SECTOR MODELLING

Which are the distinctive elements of the forest sector

- Why "forest economics" ?

- Strong link resource markets
    - wood (still) much less global than cotton, steel
        - Depends on the product: hardwood >> softwood >> industrial wood (e.g. Clairefontaine)
    - strong link with the spatial dimension
- Bounded ownerships rights, externalities, call for public policies:
  - optimal production of public goods
  - (optimal consumption of common resources)
- Very long investment (→ hazard)
- At the same time strongly influenced by climate change and a possible source of its mitigation (the "loop effect")
- Still an "important" sector in France (especially locally):
  - 3.3 M + 270 m people
  - 12 b€, 0.6% GDP

Who are the agents involved in the forest sector ?

- Forest Owners (→ Managers, owner unions)
- Wood sector agents (→ Unions, commerce bodies)
- Citizens (→ Gov and not gov. organisations)

Which are the research questions ?

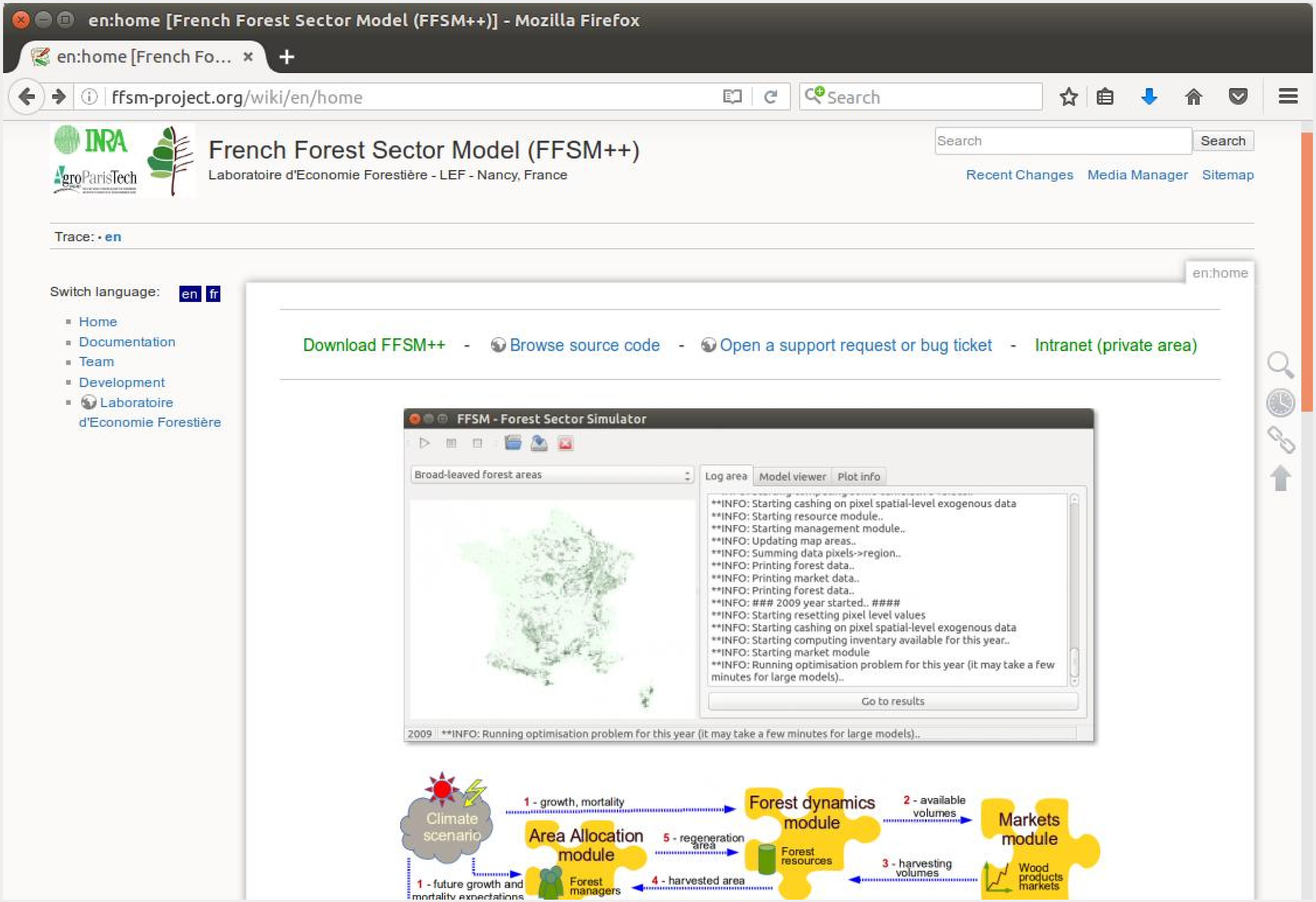
- Forest Owners
  - Timber production optimisations (optimal rotation, optimal choice of species);
  - Climate change adaptation;
  - Risk management (assurance, forest management changes, risk diversification - portfolio, ...)
  - Understand non-market benefits (and behaviour)
- Wood sector agents
  - Timber markets effect: producer's surplus, added value, trade balance, jobs
- Citizens
  - Consumer's surplus
  - Demand of ecosystem-services, production possibility frontier
    - Carbon mitigation

While we may have different research questions, some of the underlying assumptions/logic may be in common

→ *May have sense to have a modelling framework where to "plug" a specific model tailored to the research question*

THE FRENCH FOREST SECTOR MODEL

French Forest Sector Model (FFSM)



Which kind of research questions we aim to answer?

- Forest Owners
  - Optimal investment choice in a spatially explicit, evolving context
  - Their preferences are input for us
  - Not at the individual level
- Wood sector agents
  - Timber markets effect: added value, trade balance, jobs
  - Perennity of the resource
  - Optimal location / resource impact of wood transformation industries
- Citizens
  - Consumer's surplus
  - Carbon mitigation outcomes

Implementation

- FFSM development

- Multidisciplinary team at the Bureau d'Economie Théorique et Appliquée BETA
- Under continuous development since 2010
- Several PhD cycles (but few students touch the code)

Current Team

- Ahmed Barkaoui
- Felix Bastit
- Sylvain Caurla
- Philippe Delacote
- Antonello Lobianco
- Claire Montagné-Huck
- Alexandra Niedzwiedz
- Miguel Rivière
- David Shanafelt

Past members

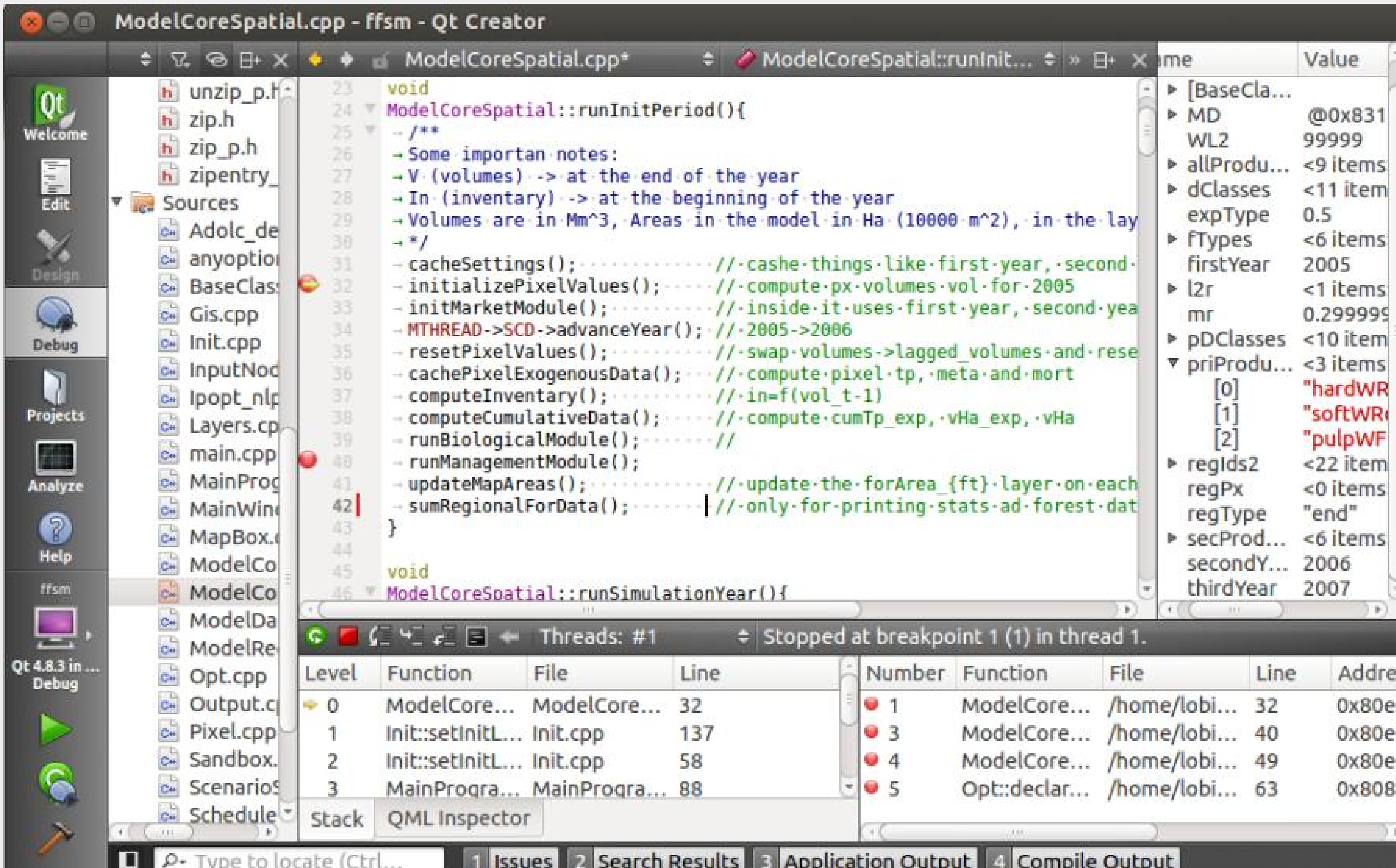
- Julien Barthès
- Thomas Beaussier
- Iason Diafas
- Frank Lecocq
- Etienne Lorang
- Claudio Petucco
- Alexandre Sauquet

External contributors

- Jean-Daniel Bontemps (SILVA)
- Hélène Chevalier (IGN)
- Antoine Colin (IGN)
- Pierre Mérian (IGN)
- Holger Wernsdörfer (SILVA)

Implementation

- development



Implementation

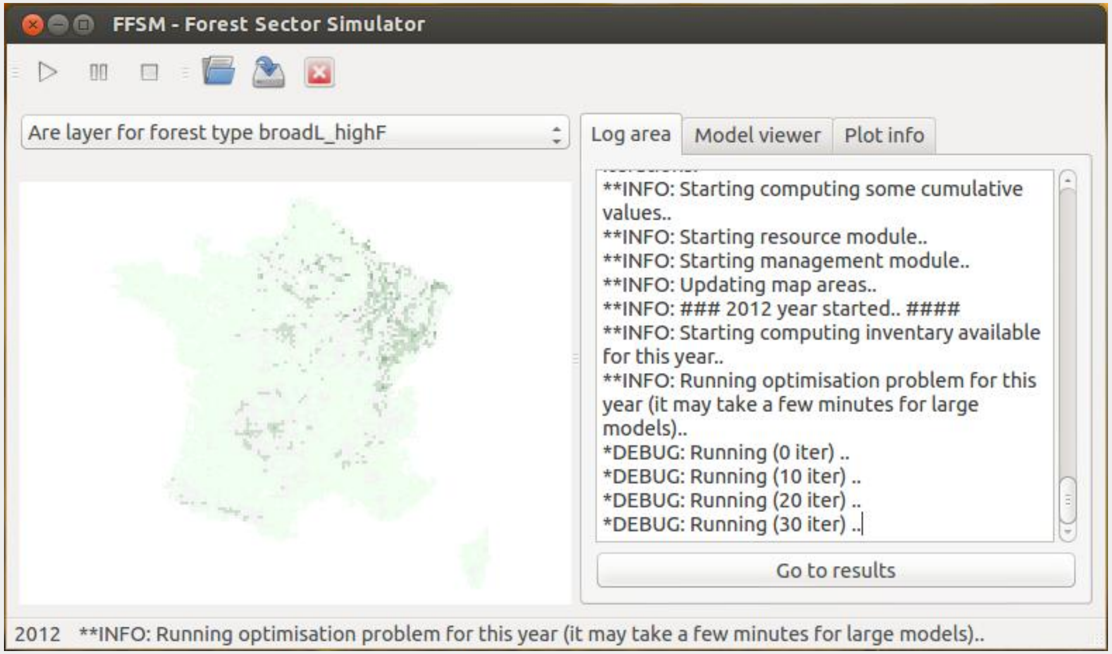
- development

- **GAMS version**
  - code: https://github.com/LEFNancy/ffsm
  - included modules: forest dynamics, mkt, (basic) area allocation
  - requires: gams, excel
- **C++ version (Desktop GUI/ command line)**
  - code:https://github.com/LEFNancy/ffsm_pp
  - included modules: forest dynamics (spatial), mkt, area allocation, carbon module, pathogen module
  - requires:
    - Linux: Qt5, Ipopt+ADOL-C+Colpack stack (all open source libraries)
    - Windows: MinGW, Qt5, optional Ipopt+ADOL-C+Colpack stack (all open source libraries)
- **Julia version**
  - code: https://github.com/LEFNancy/ffsm
  - included modules: forest dynamics, mkt
  - requires: Julia, libreoffice

Detailed development instructions on:
https://ffsm-project.org/wiki/en/dev/development

Implementation

- running scenarios



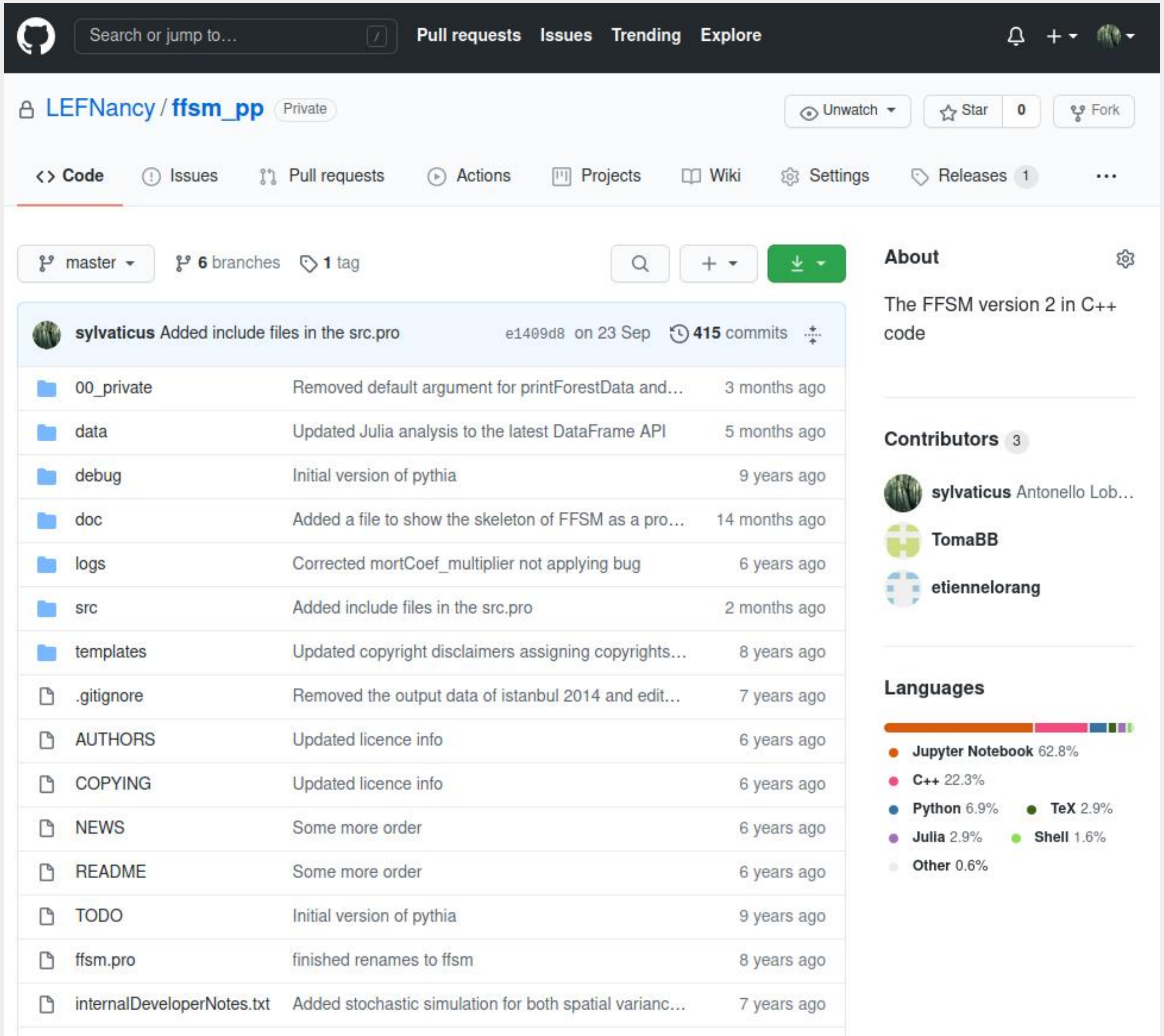
- Scenario-specific input data as LibreOffice Calc spreadsheet + simple text-based raster files
- Outputs as CSV, images and text-based rasters → analysed with ad hoc Python or Julia scripts
- Scenario run trough a GUI or command line
  - 1 run, 1 century, France → ~ 1 hour, 2GB RAM
  - "debug" mode available for quicker checks
  - multiple scenarios in parallel using the `parallel` command on a simple script

Installation and usage detailed instructions:
https://ffsm-project.org/wiki/en/doc/installation

AVAILABILITY

Availability

- source code + confidential data: private github repository:



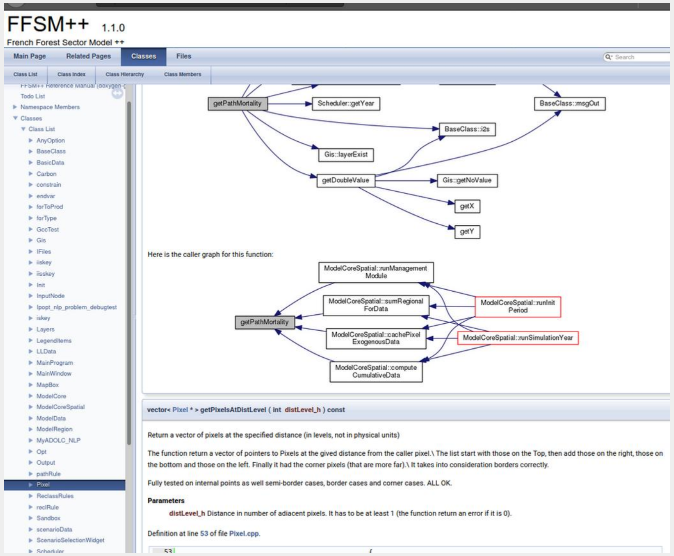
- strimmed down version (without our specific confidential projects): made available with a slightly modified GNU GPLv3 licence on a daily base

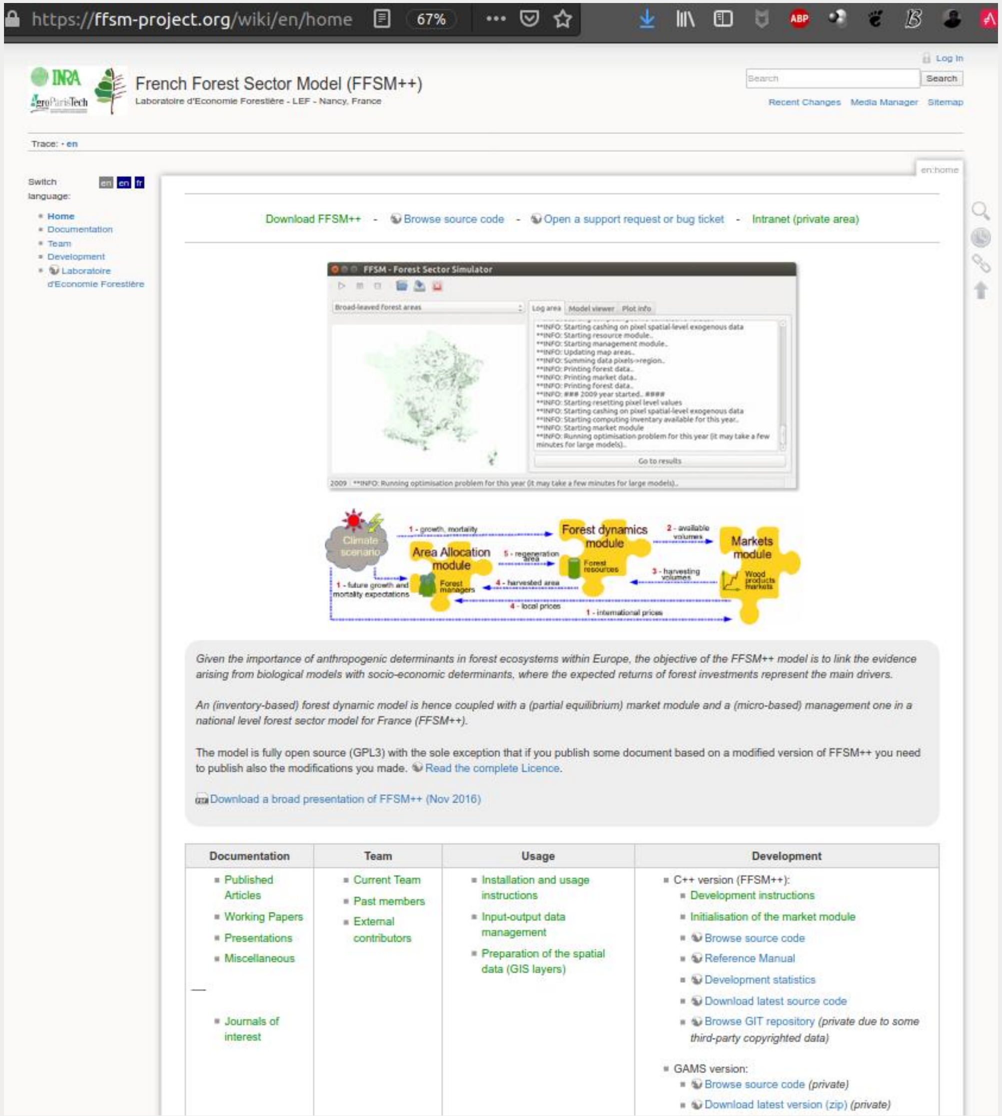
Availability

https://ffsm-project.org/wiki/en/

Exhaustive web site allowing the model to be discovered at different levels:

- Main mechanism, mathematical equations and theoretical foundations → academic papers
- Usage/development manuals → documentation (wiki pages)
- Detailed API → Reference Manual (automatically-generated from source code)
- Exact implementation: Source code



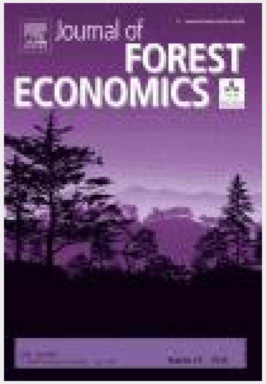


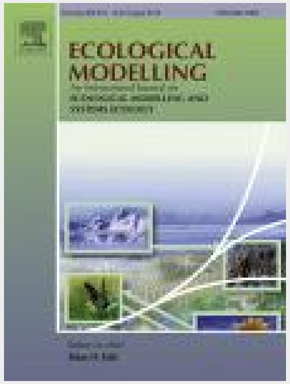
USE

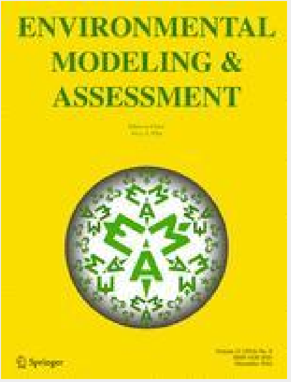
Use

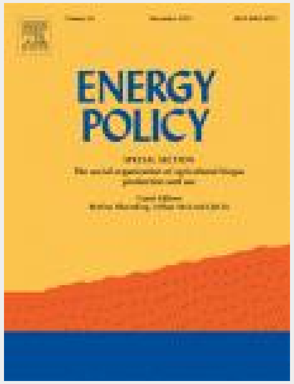
FFSM has been used for a wide range of analysis, of both positive and normative nature:

- Should policies subsides targeted to sequestrated carbon or fuelwood ?
- Economic and resource impact of fuelwood subsidies
- Carbon tax and mitigation policies: impact on the French forest sector
- Is it better to store or export the excess of timber following large windfalls ?
- How much the future of French forests depends from human management and forest managers risk-aversion
- What is the climate change mitigation potential of the French forest sector ?
- Which is the ecological and economic effect of the introduction of the ash pathogen ?





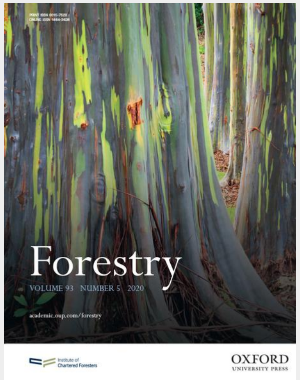


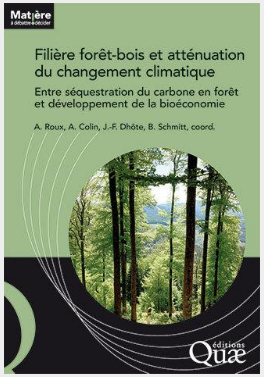


Use (2)

FFSM has been used for a wide range of analysis, of both positive and normative nature:

- Implications of managing forests for carbon sequestration
- Impact of increased timber usage on carbon mitigation (EN summary – FR Full Book)



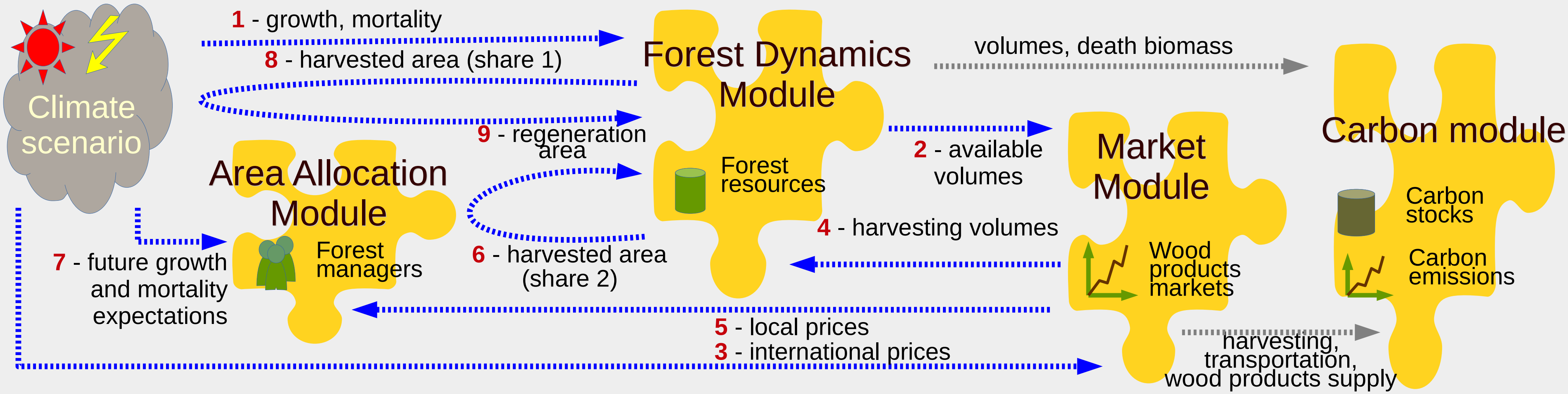


Work in progress:

- applications: implications of climate-induced changes in wildfire regimes for the forest sector and its ability to mitigate climate change; LCA assessment on a regional scale
- methodology: accounting for different behaviours small/large forest owners, private/public,...

FFSM MODULES

A modular approach

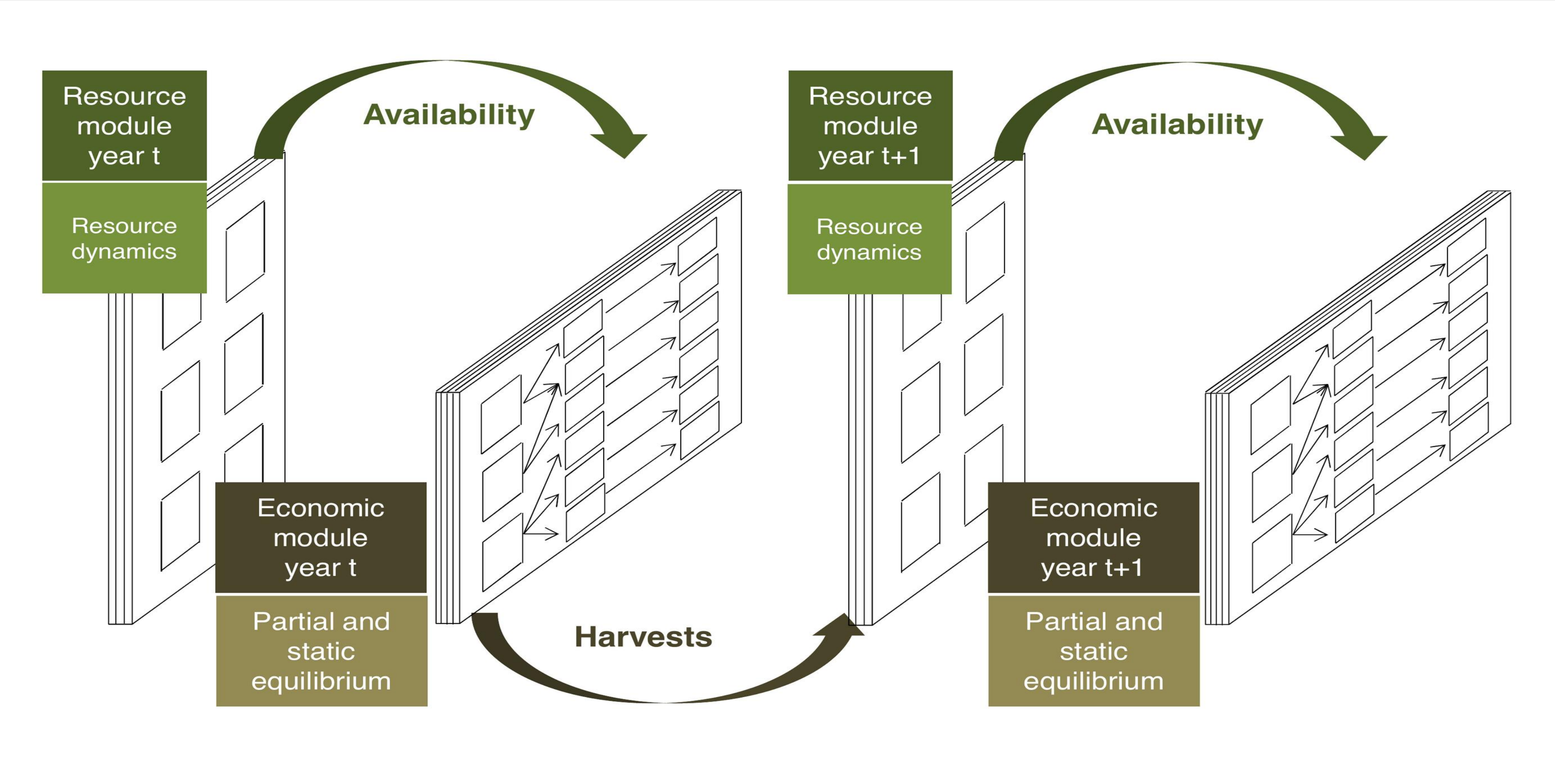


Recursive bio-economic model with coupled biological forest growth model and partial equilibrium market of forest products.

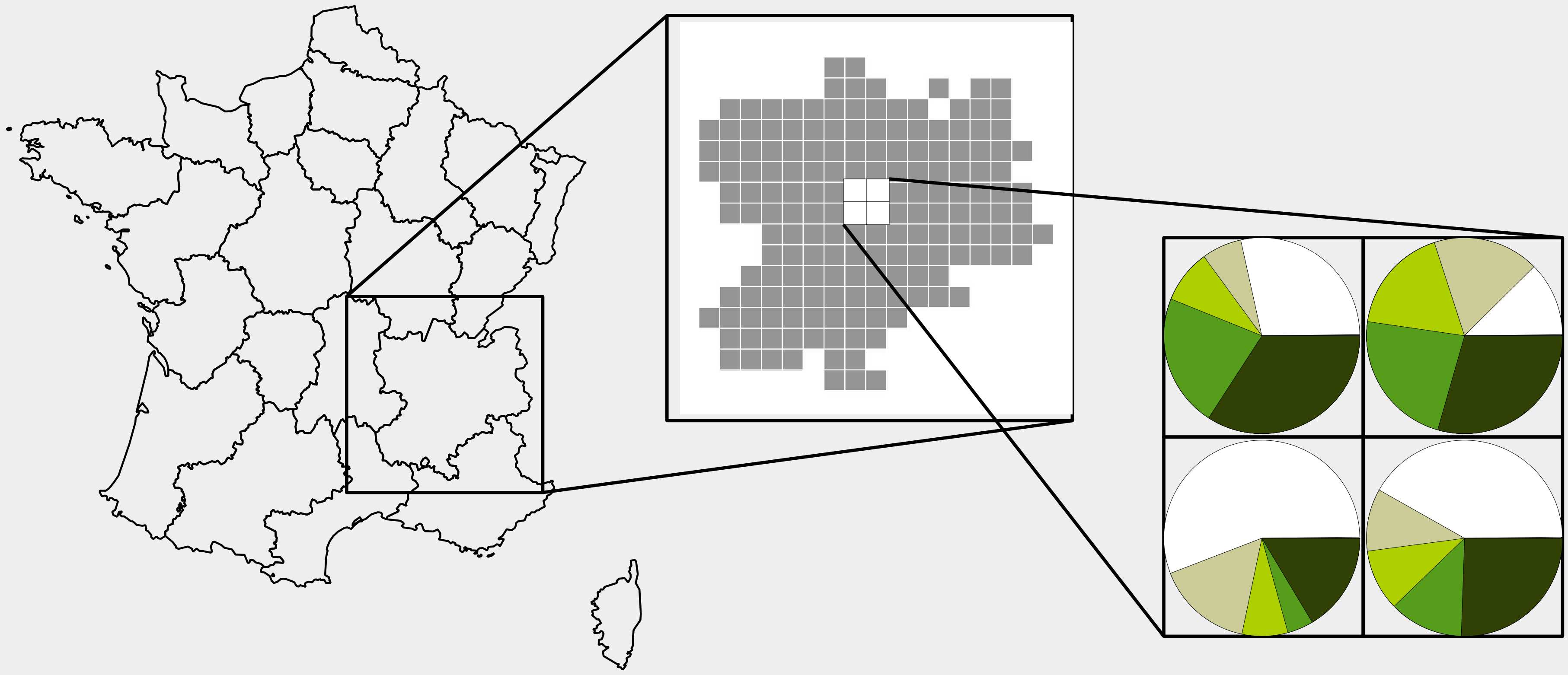
Major strength in the capacity to catch the interaction between drivers. Four interconnected modules:

Forest dynamics module: model forest resources
Pathogen module: simulation of a spatially explicit pathogen
Market module: HWP markets (supply, demand, trade..)
Area allocation module: forest investment choises
Carbon module: mitigation potentials of the forest sector

A recursive approach



Spatial representation



Decoupling the spatial scale of the market module (country and regional) from those of the resource and management modules (pixel level)

- regional scale reasonably adequate for the market module
- pixel level (area fraction) for resource and management model

Some notation..

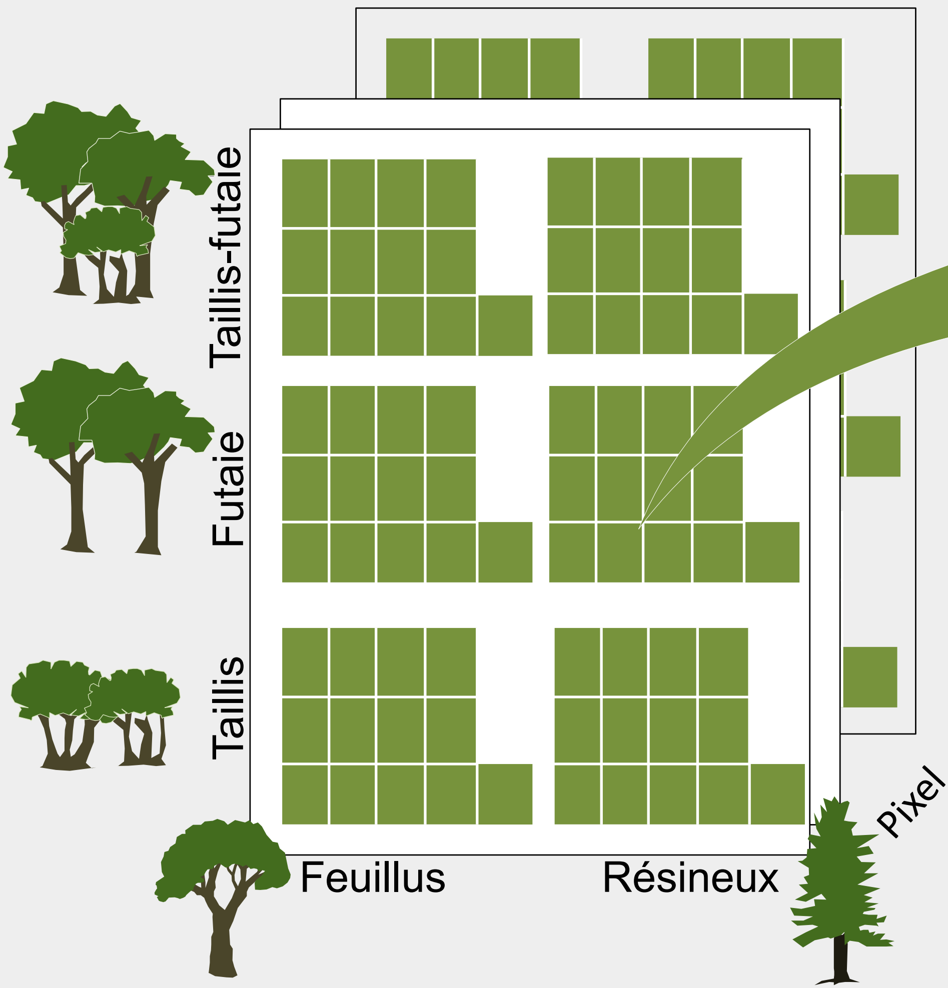
- index notation

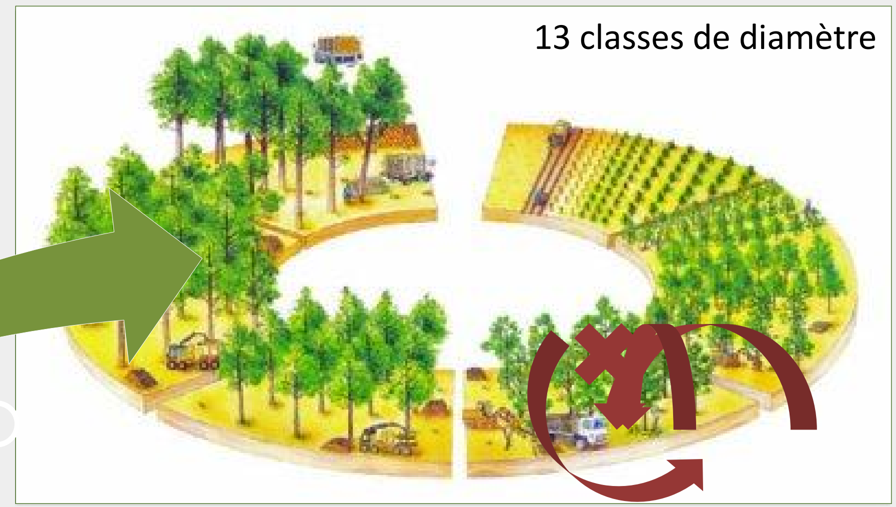
Notation	Definition	Values
t	Time	[2005 – 2100]
c	Country	{France}
r	Region	[22 administrative regions in France]
px	Pixel	8x8 km
sp	Forest species group	{Broadleaves, Coniferous}
mt	Forest management type	{High forests, Mixed forests, Coppices}
ft	Forest type (incl. mgm)	[sp x mt]
dc	Diameter class	[0,15,25...,95,150]
pp	Primary products	{Hardwood Roundwood, Softwood Roundwood, Pulpwood and Fuelwood}
tp	Transformed products	{Fuelwood, Hardwood Sawnwood, Softwood Sawnwood, Plywood, Pulpwood, Pannels}
prd	Products	[pp x tp]

FOREST RESOURCES DYNAMICS MODULE

Forest resources

- FFSM implementation (forest dynamics module)





Représentation d'un domaine d'étude (d'après dessin de Bernard Patricot CPFA)

- 147 rows
- 197 cols
- 10 dc
- 4 forest types
- 1,158,360 "cells"

- State variables: volume, area
- Dynamic variables: time of passage, mortality, volume ratio, harvesting

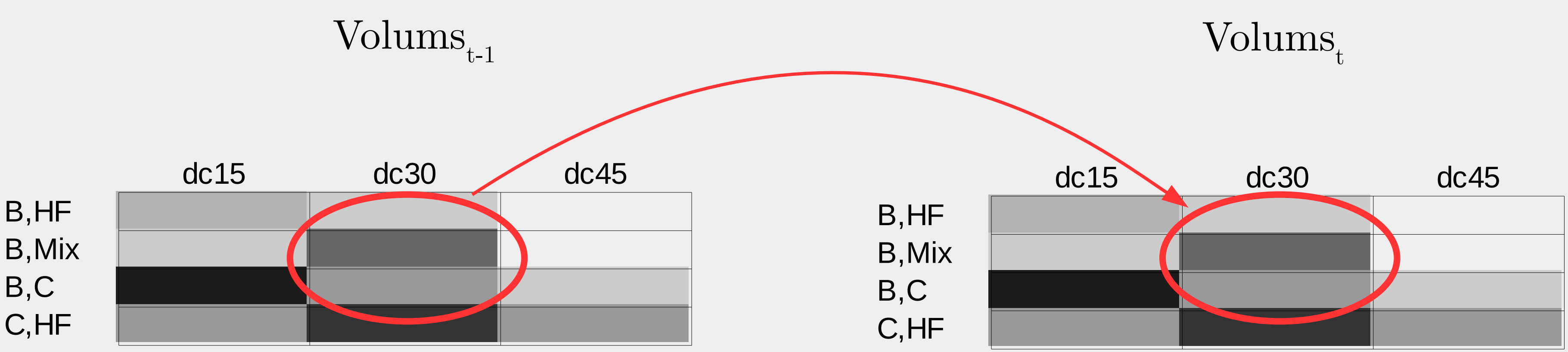
Forest resources

- FFSM implementation (forest dynamics module)

- **Resource module**: inventory based, Markov transition matrix model, 10 diameter classes, 2 species groups (coniferous, broadleavead). From: Usher, "A Matrix Model for Forest Management", 1969.

- For each pixel (8x8 km) and forest type:

$$Vol_{dc,t} = (1 - 1/timeOfPassage_{dc,t} - mortality_{dc,t} - harvestedRate_{dc,t}) * Vol_{dc,t-1} + (1/timeOfPassage_{dc-1,t-1}) * beta_{dc} * Vol_{dc-1,t-1}$$



Forest resources

- modelling CC effect on forest resources

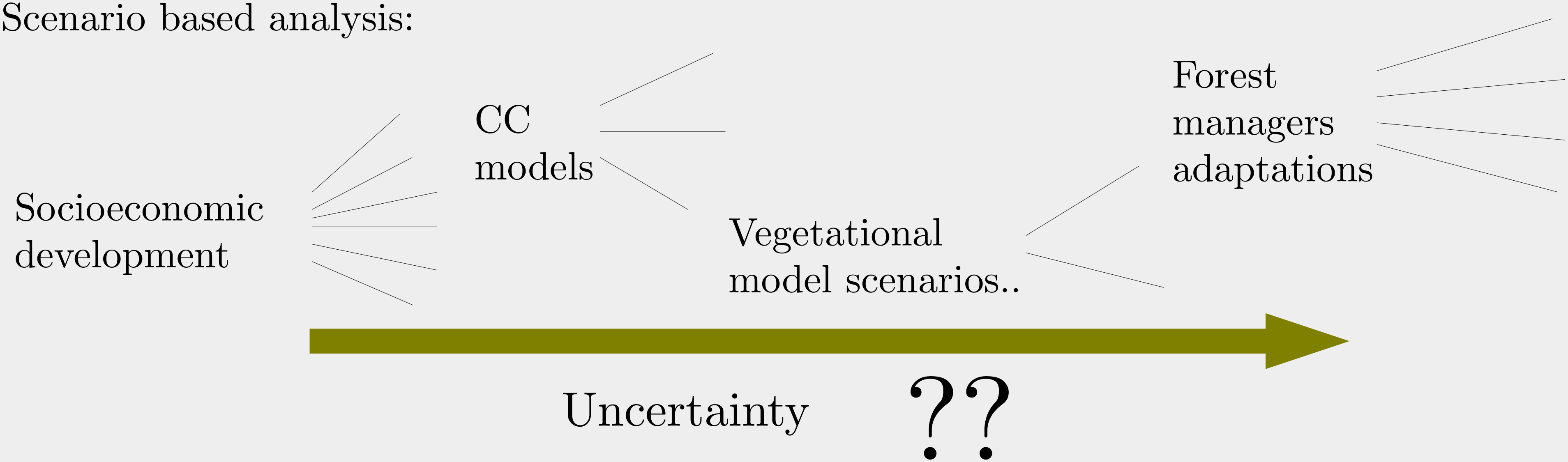
CC effects on the forest dynamics are exogenous to FFSM. Conversely, consequences on the management of the forest are explicitly accounted for.

Using $multipliers_{sc,px,ft,t}$ key input biological variables can change from the regional average along the spatial and temporal dimensions according to the CC scenario under study:

- time of passage: $tP_{sc,px,ft,dc,t} = tP_{r,ft,dc,t=0} * tpMultiplier_{sc,px,ft,t}$
- mortality rate: $mort_{sc,px,ft,dc,t} = mort_{r,ft,dc,t=0} * mort_{sc,px,ft,t}$

An exogenous parameter allows the model to consider (again, exogenously) land use changes with reference to the forest ($forestChangeAreaIncrementsRel_{sc,r,t}$ or $forestChangeAreaIncrementsHa_{sc,r,t}$)

Scenario based analysis:



HWP MARKETS MODULE

HWP markets

- partial vs general equilibrium

Partial equilibrium models → take into consideration only a part of the market (a single product, or a sector), *ceteris paribus*, to attain equilibrium.
They assume that, on one hand, the price of every other good or the wealth one has does not change (and hence is given), and on the other hand that what happens on the market one wants to analyse has no effect on other markets.

General equilibrium models → the analysis includes an entire economy. Every market has an effect on every other market and therefore one has to model every market simultaneously.

Advantages of PEM:

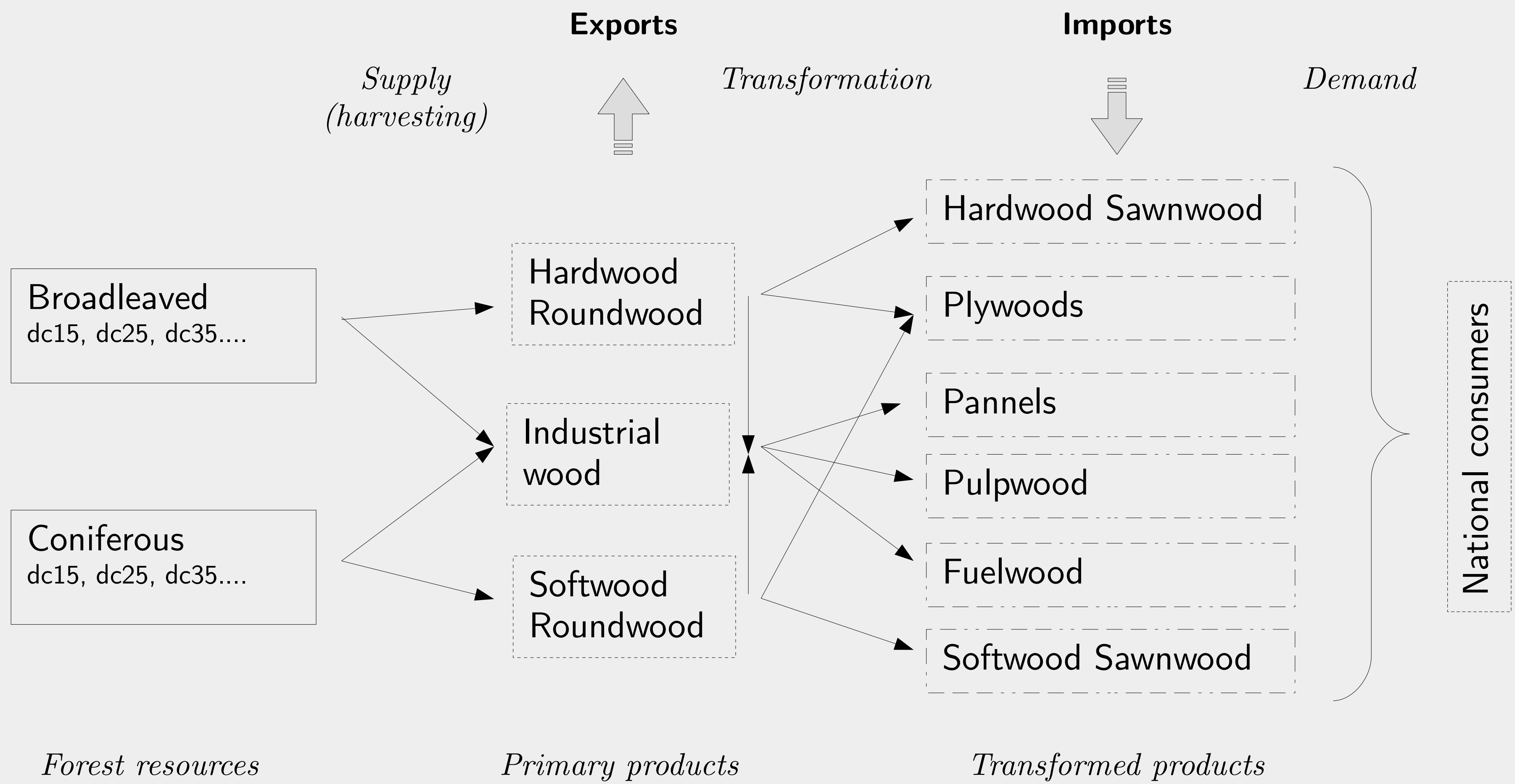
- simpler and easier to implement;
- can describe a sector in detail still guaranteeing resolution, stability and unicity of equilibrium;

Advantages of GEM:

- more realistic;
- necessary to model goods (e.g. labor, energy) that are so important, that they may have serious effects on other markets.

HWP markets

- **Market module**: partial equilibrium, 3 primary products and 6 transformed products (Leontief transformation), imperfect substitutability national vs international products, regional trade



HWP markets

- elasticity

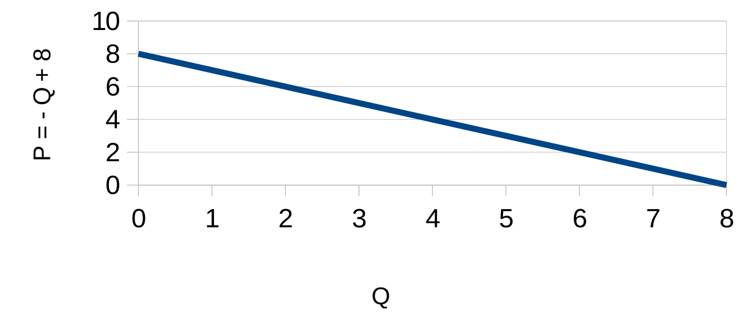
In general "elasticity of a with respect of b" means the relative change in a over a relative change in b:

$$\sigma \equiv \frac{\text{relative change in a}}{\text{relative change in b}}$$

It tells you how much something change percent when you change the other variable of one percent unit.

A simple version is for example the elasticity of demand with respect to price: with a value of, let's say, -5, it means that when you increase price of 1 percent, the demand reduces of 5 percent.

Like for simple derivatives, elasticity usually change across functions. It's only under special "constant elasticities" functions that it remains constant among the domain of the independent variable.



HWP markets

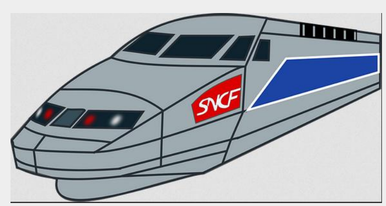
- elasticity of substitution

In particular, the "elasticity of substitution" measures the proportionate change in the ratio of two variables in response to a change in their relative prices.

$$\sigma \equiv \frac{\text{relative change in}\left(X_1/X_2\right)}{\text{relative change in}\left(P_1/P_2\right)} = \frac{\dfrac{d\left(X_1/X_2\right)}{X_1/X_2}}{\dfrac{d\left(P_1/P_2\right)}{P_1/P_2}}$$

$\sigma = 0$: Perfect complement goods

$0 < \sigma < \infty$: Intermediate goods



$\sigma = \infty$: Perfect substitute

HWP markets

- supply of primary products

Composite supply:

- It depends from own price and availability of the resource:

$$\frac{sc_{pp,t}}{sc_{pp,t-1}}=\left(\frac{pc_{pp,t}}{pc_{pp,t-1}}\right)^{eSP_{pp}}\left(\frac{inv_{pp,t}}{inv_{pp,t-1}}\right)^{eSI_{pp}}$$

$$S=f(p,res,\boldsymbol{k})$$

- While products in different regions are assumed perfectly homogeneous (and hence regional price depends diverge only by transport costs), national vs international products are assumed partially heterogeneous. A parameter (the Armington elasticity) defines how local prices are more or less dependant by local market condition vs external international prices:

$$sc_{pp,t}=\left[(1-tS_{pp,t})\,sl_{pp,t}^{\frac{eST_{pp}-1}{eST_{pp}}}+tS_{pp,t}\,sa_{pp,t}^{\frac{eST_{pp}-1}{eST_{pp}}}\right]^{\frac{eST_{pp}}{eST_{pp}-1}}$$

Supply to abroad (exports):

$$sa_{pp,t}=tS_{pp,t}\,sc_{pp,t}*\left(\frac{pc_{pp,t}}{pa_{pp,t}}\right)^{eST_{pp}}$$

Supply to local:

$$sl_{pp,t}=(1-tS_{pp,t})\,sc_{pp,t}*\left(\frac{pc_{pp,t}}{pl_{pp,t}}\right)^{eST_{pp}}$$

Supply value equation:

$$pc_{pp,t}\,sc_{pp,t}=pl_{pp,t}\,sl_{pp,t}+pa_{pp,t}\,sa_{pp,t}$$

HWP markets

- demand of transformed products

Composite demand:

- depends uniquely from the own price (but recently a cross-price elasticity has been introduced too):

$$\frac{dc_{tp,t}}{dc_{tp,t-1}} = \left(\frac{pc_{tp,t}}{pc_{tp,t-1}}\right)^{eDP_{tp}}$$

- also in the demand local (national) products are assumed partially heterogeneous vs international products:

$$dc_{tp,t} = \left[(1-tD_{tp,t})\, dl_{tp,t}^{\frac{eDT_{tp}-1}{eDT_{tp}}} + tD_{tp,t}\, da_{tp,t}^{\frac{eDT_{tp}-1}{eDT_{tp}}}\right]^{\frac{eDT_{tp}}{eDT_{tp}-1}}$$

Demand from abroad (imports):

$$da_{tp,t} = tD_{tp,t}\, dc_{tp,t} * \left(\frac{pc_{tp,t}}{pa_{tp,t}}\right)^{eDT_{tp}}$$

Demand from local:

$$dl_{tp,t} = (1-tD_{tp,t})\, dc_{tp,t} * \left(\frac{pc_{tp,t}}{pl_{tp,t}}\right)^{eDT_{tp}}$$

Demand value equation:

$$pc_{tp,t}\, dc_{tp,t} = pl_{tp,t}\, dl_{tp,t} + da_{tp,t}\, sa_{tp,t}$$

HWP markets

- transformation and mkt balance

Transformation: $dl_{pp,t} = \sum_{tp} a_{pp,tp,t} sl_{tp,t}$

Primary products market balance:

$$\underbrace{\underbrace{sl_{pp,r} + sa_{pp,r}}_{production} + \underbrace{\sum_{r2} rt_{pp,r2,r}}_{reg.\ trade\ in}}_{supply} = \underbrace{\underbrace{dl_{pp,r}}_{cons.} + \underbrace{sa_{pp,r}}_{exp.} + \underbrace{\sum_{r2} rt_{pp,r,r2}}_{reg.\ trade\ out}}_{demand}$$

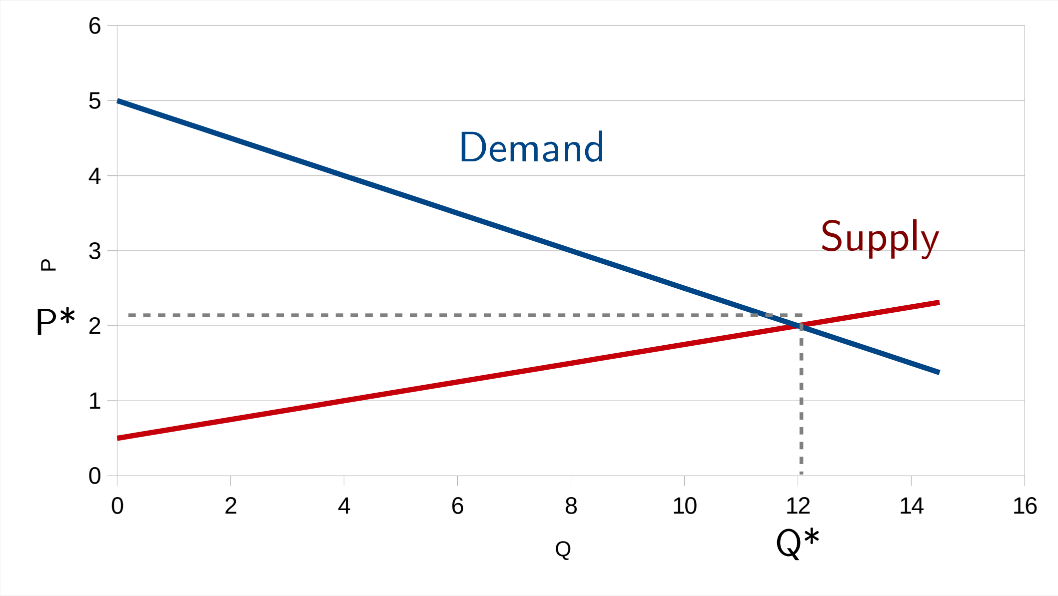
Transformed products market balance:

$$\underbrace{\underbrace{sl_{tp,r}}_{prod.} + \underbrace{da_{tp,r}}_{imp.} + \underbrace{\sum_{r2} rt_{tp,r2,r}}_{reg.\ trade\ in}}_{supply} = \underbrace{\underbrace{dl_{tp,r} + da_{tp,r}}_{consumption} + \underbrace{\sum_{r2} rt_{tp,r,r2}}_{reg.\ trade\ out}}_{demand}$$

Finding the equilibrium

- a possible implementation

- free markets
- linear forms of supply and demand functions



Q_D equal Q_S :

$$Q_D = 20 - 4p$$
$$Q_S = -4 + 8p$$

(direct demand and supply functions)

$$20 - 4p = -4 + 8p$$

$$p^* = 2 ; Q^*_D = Q^*_S = 12$$

P_D equal P_S :

$$P_D = \frac{-1}{4} Q + 5$$
$$P_S = \frac{1}{8} Q + \frac{1}{2}$$

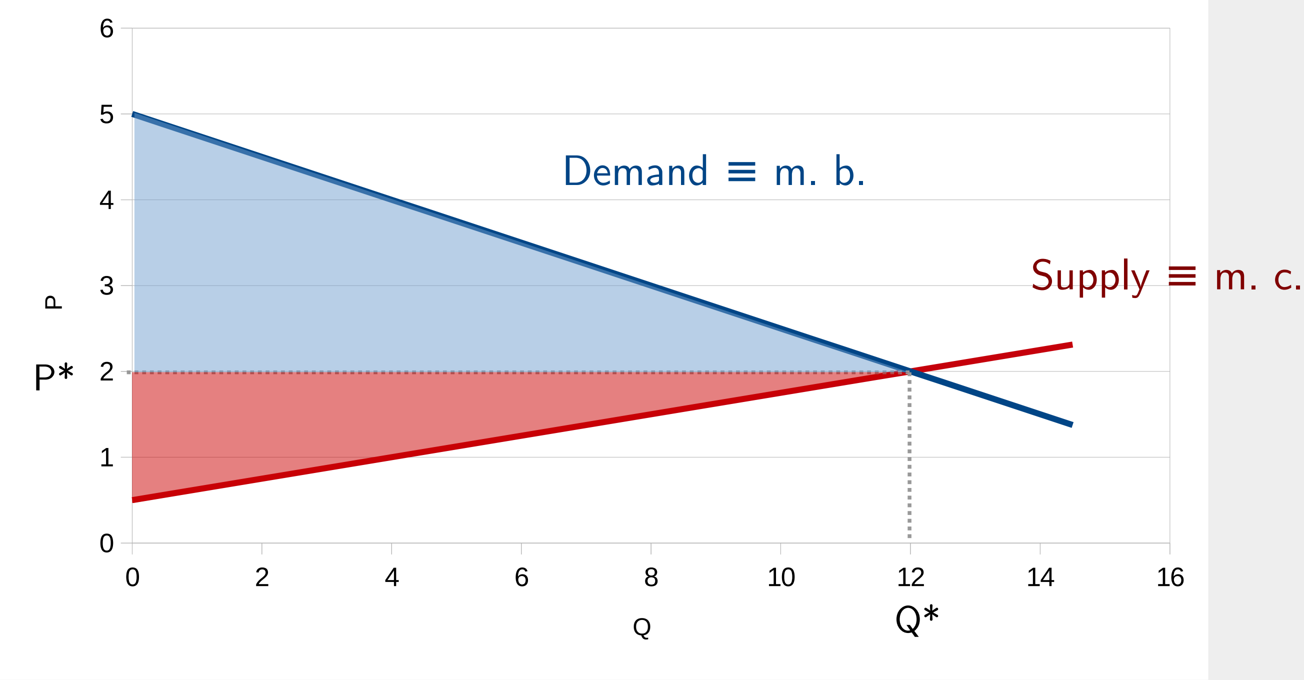
(inverse demand and supply functions)

$$-\frac{1}{4} Q + 5 = \frac{1}{8} Q + \frac{1}{2}$$

$$Q^* = 12 ; P^*_D = P^*_S = 2$$

Market equilibrium

- the max surplus approach



$$Consumer\ surplus = \int_0^{Q*} \frac{-1}{4} Q + 5\, dQ - p*Q* \qquad Producer\ surplus = p*Q* - \int_0^{Q*} \frac{1}{8} Q + \frac{1}{2}\, dQ$$

$$Total\ surplus = \left[\frac{-1}{4}\frac{1}{2}Q^2 + 5Q\right]_0^{Q*} - P_D*Q* + P_S*Q* - \left[\frac{1}{8}\frac{1}{2}Q^2 + \frac{1}{2}Q\right]_0^{Q*} = -\frac{1}{8}Q^{*2} + 5Q^* - \left(\frac{1}{16}Q^{*2} + \frac{1}{2}Q^*\right)$$

$$Max\ surplus = \frac{dSurplus}{dQ^*} = 0 \rightarrow -\frac{1}{4}Q^* + 5 \quad -\left(\frac{1}{8}Q^* + \frac{1}{2}\right) \rightarrow Q* = 12 ; P*_D = P*_S = 2$$

Market equilibrium

- max surplus

Welcome Guide | market2.jl | market.jl | testset_3.jl | market_supersin | transp.jl | market.gms

```julia
using JuMP

# Qd = -da p + db
da = 4
db = 20
# Qs = sa p - sb
sa = 8
sb = 4

m = Model()

@variable(m,  q >= 0)

@objective(m, Max, -(1/da)*(1/2)*q^2  + (db/da)*q - ((1/sa)*(1/2)*q^2+(sb/sa)*q))

print(m)

status = solve(m)

println("Objective value: ", getobjectivevalue(m))
println("q = ", getvalue(q))

```

Market module

- max surplus

Objective function: maximum total surplus

$$\sum_{tp,r}\left[\int_0^{dc_{tp,r}} pc_{tp,r}\{dc_{tp,r}\}\,d\,dc_{tp,r} - pc_{tp,r}*dc_{tp,r}\right]$$ *transformed products consumers surplus*

$$+\sum_{pp,r}\left[pc_{pp,r}*sc_{pp,r} - \int_0^{sc_{pp,r}} pc_{pp,r}\{sc_{pp,r}\}\,d\,sc_{pp,r}\right]$$ *primary products producers surplus*

$$+\sum_{tp,r} sl_{tp,r}*pl_{tp,r} - \sum_{tp,r} ac_{tp,r}*sl_{tp,r} - \sum_{pp,r} dl_{pp,r}*pl_{pp,r}$$ *domestic transformers (revenues - tr. costs - costs)*

$$+\sum_{prd,r,r2}\left(pl_{prd,r2} - pl_{prd,r} - tc_{prd,r,r2}\right)rt_{prd,r,r2}$$ *regional trader's surplus*

Market module

- constraints

$$sl_{pp,r}+sa_{pp,r}+\sum_{r2} rt_{pp,r2,r}-\left(dl_{pp,r}+sa_{pp,r}+\sum_{r2} rt_{pp,r,r2}\right) = 0$$
primary products material balance

$$sl_{tp,r}+da_{tp,r}+\sum_{r2} rt_{tp,r2,r}-\left(dl_{tp,r}+da_{tp,r}+\sum_{r2} rt_{tp,r,r2}\right) = 0$$
transformed products material balance

$$\frac{sc_{pp,t}}{sc_{pp,t-1}}-\left(\frac{pc_{pp,t}}{pc_{pp,t-1}}\right)^{eSP_{pp}}\left(\frac{inv_{pp,t}}{inv_{pp,t-1}}\right)^{eSI_{pp}} = 0$$
composite supply f(composite price)

$$\frac{dc_{tp,t}}{dc_{tp,t-1}}-\left(\frac{pc_{tp,t}}{pc_{tp,t-1}}\right)^{eDP_{tp}} = 0$$
composite demand f(composite price)

$$sc_{pp,t}-\left[(1-tS_{pp,t})sl_{pp,t}^{\frac{eST_{pp}-1}{eST_{pp}}}+tS_{pp,t}\,sa_{pp,t}^{\frac{eST_{pp}-1}{eST_{pp}}}\right]^{\frac{eST_{pp}}{eST_{pp}-1}} = 0$$
composite supply def. from local and abroad supplies

$$dc_{tp,t}-\left[(1-tD_{tp,t})dl_{tp,t}^{\frac{eDT_{tp}-1}{eDT_{tp}}}+tD_{tp,t}\,da_{tp,t}^{\frac{eDT_{tp}-1}{eDT_{tp}}}\right]^{\frac{eDT_{tp}}{eDT_{tp}-1}} = 0$$
composite demand def. from local and abroad deamndes

$$sa_{pp,t}-tS_{pp,t}\,sc_{pp,t}*\left(\frac{pc_{pp,t}}{pa_{pp,t}}\right)^{eSt_{pp}} = 0$$
exports

$$da_{tp,t}-tD_{tp,t}\,dc_{tp,t}*\left(\frac{pc_{tp,t}}{pa_{tp,t}}\right)^{eDt_{tp}} = 0$$
imports

$$pc_{pp,t}\,sc_{pp,t}-\left(pl_{pp,t}\,sl_{pp,t}+pa_{pp,t}\,sa_{pp,t}\right) = 0$$
value balance of composite price prim. products

$$pc_{tp,t}\,dc_{tp,t}-\left(pl_{tp,t}\,dl_{tp,t}+da_{tp,t}\,sa_{tp,t}\right) = 0$$
value balance of composite price transf. products

Market module

- summary

As result of surplus maximisation we have:

- quantities of primary products (pp) and transformed products (tp) supplied, demanded, imported, exported and regionally-traded in each region;
- prices of pp and tp in each region.

Prices for pp → used in the allocation module
Supply of pp → used in the forest resource dynamic module

Some other aspects we didn't saw:
- supply also from death timber (timber from mortality event in the forest dynamic module);
- supply of specific transformed products (fuelwood) also as by-product of transformation of other transformed products;
- as national products are homogeneous, prices in the various regions differ only by transport costs
→ we can study spillover effects

AREA ALLOCATION MODULE

Forest investment decisions

- FFSM implementation (area allocation module)

- **Area allocation module**: agent based micro-economic model; area allocation endogenised; regeneration = f (π(prices, growth, mortality)); forest managers heterogeneous for (a) managed forest resources, (b) degree of risk-aversion (prices and growth vs. mortality), (c) level of expectations (observed vs. future prices, growth, mortality);
- Forest investments are chosen based (comparing) on the SEV (WTP for amenities) .
- Two corrections are made before the comparison:
  - Transaction costs are subtracted from the SEV. These transaction costs are defined for each couple of *current forest type*, *compared forest type*.
  - As (a) forest investments involve a certain risk, (b) this risk is different for the different investments, and (c) the aversion for the risk is different for the various managers, the comparison is carried on over a certain equivalent SEV of the investment, computed as:

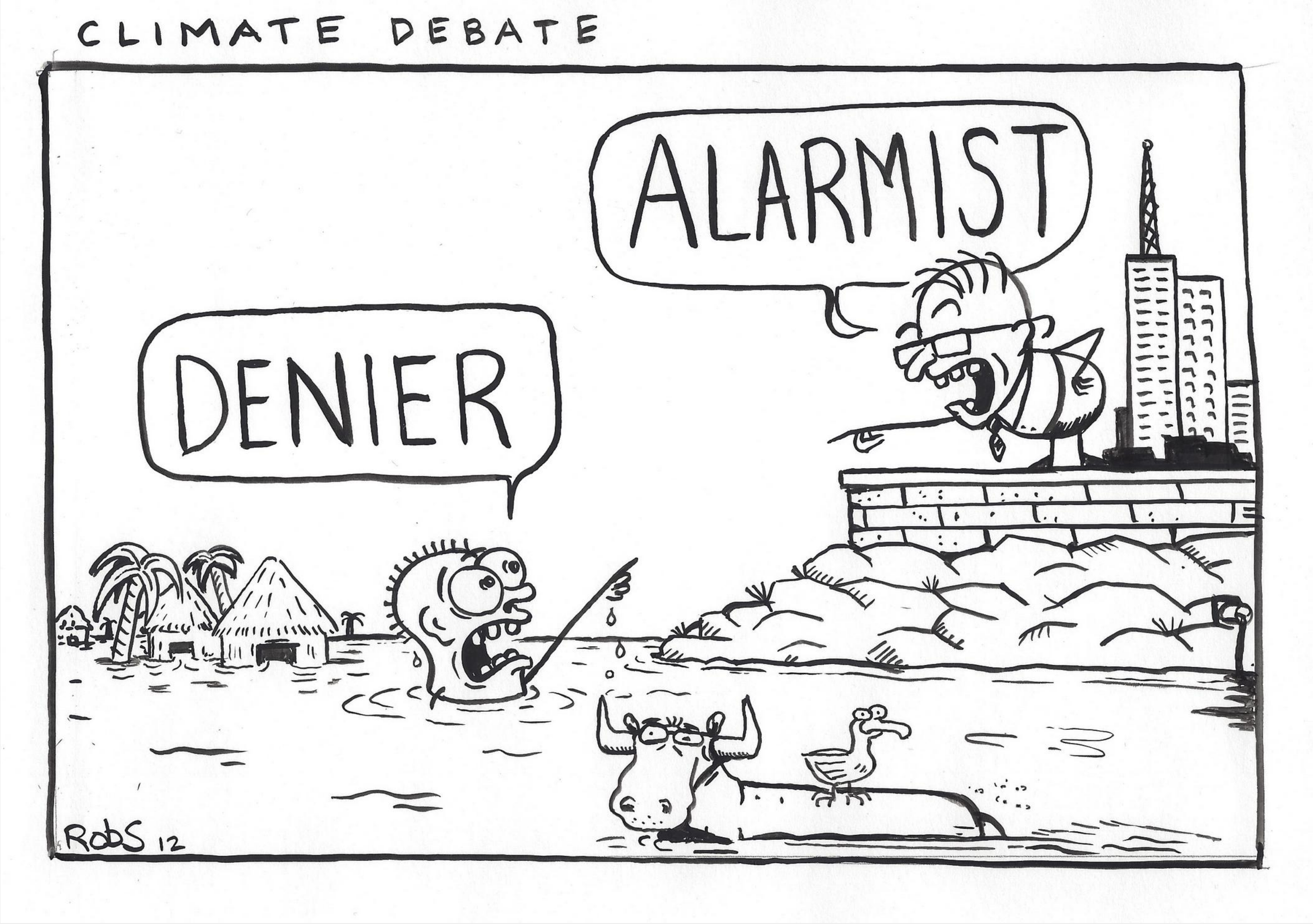
    $$CESEV_{i,j}=SEV_i*(1-ra_j*cumMort_i)$$

    where $CESEV_{i,j}$ is the certain equivalent SEV of forest investment i for the forest manager j, SEV_i is the original SEV, ra_j is the risk aversion coefficient for forest manager j and $cumMort_i$ is the average cumulative mortality expected for forest investment i before maturation.

- Future mortality and growth rates needed to compute the SEV can be those forecasted by the specific scenario or can be those prevailing at time to make the investment, depending from forest manager expectations

Forest investment decisions
- FFSM implementation (area allocation module)

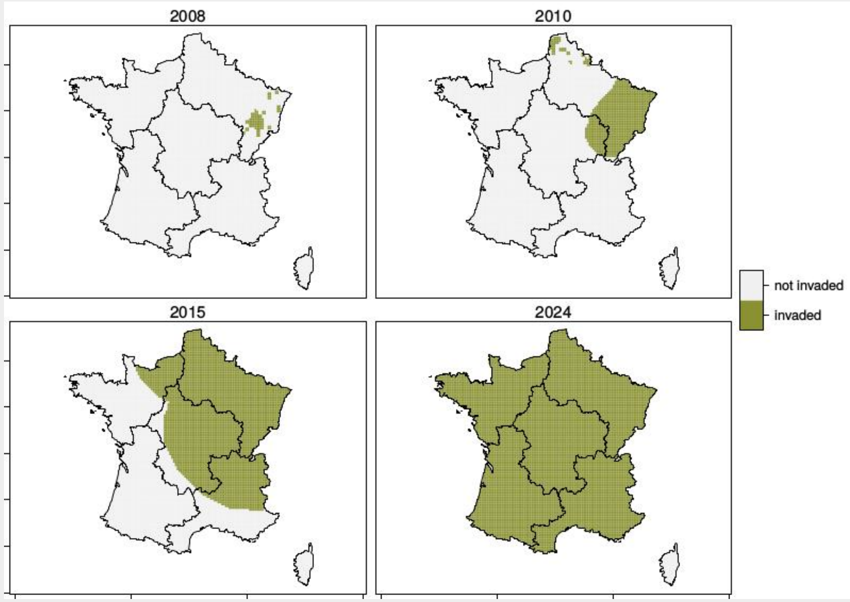
Heterogeneous expectations are important as.. **we don't all have the same opinion about climate change** !



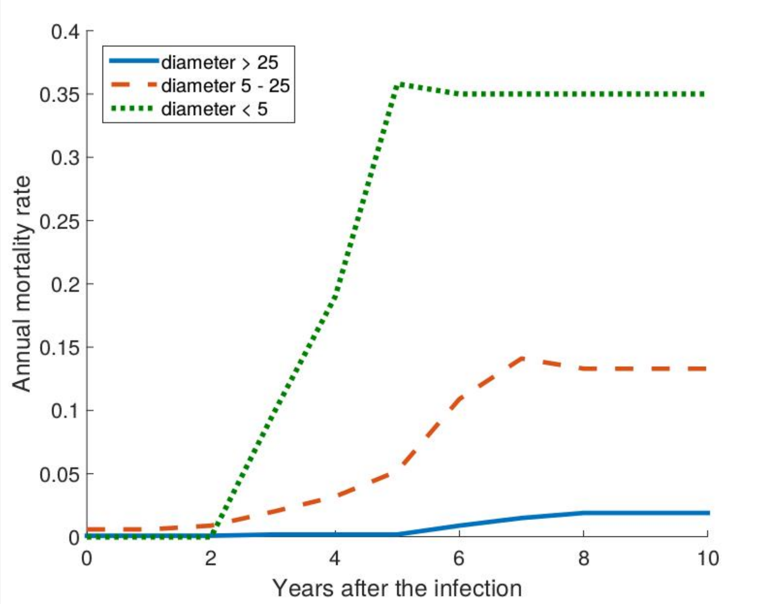
PATHOGEN MODULE

Forest resources

- pathogen module



Exogenous spread model of a pathogen (ash dieback here)



Increased mortality for specific px, ft, dc as a function of time of presence of the pathogen

Results:

- strong resource and market impact (up 80% less ash with the pathogen than without it);
- spillover effects: (temporary) benefits for the regions not yet involved, and benefits for the markets of other species;
- effect for ash owners depends strongly on the degree of substitutability between ash and other broadleaved;
- forest owner "economic adaptation" may further reduce ash presence.

CARBON BALANCE MODULE

Climate change

- impact on the forest sector

Physical impact

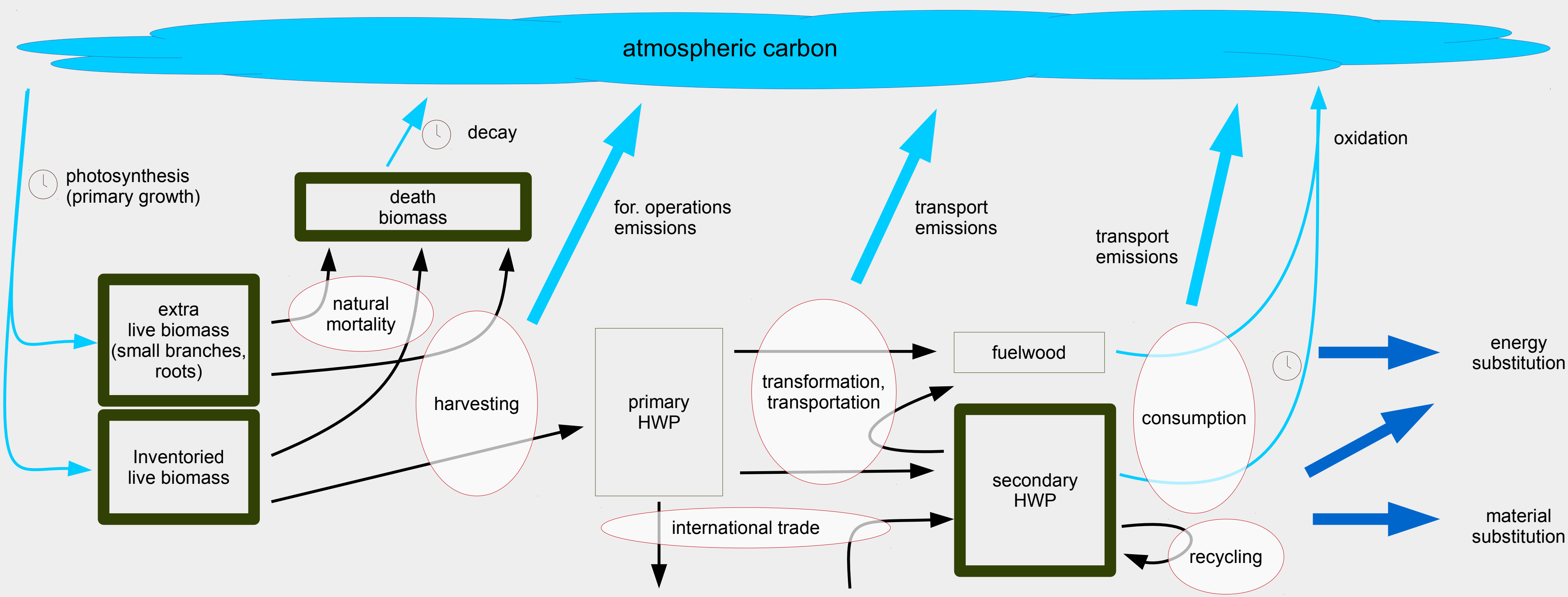
- Δ growth by so-called CO2 "fertilisation" (maybe)
- Δ growth and Δ mortality by
  - direct effect (drought, fires, storms..)
  - indirect effect (fungi, insects, pests in general)
    - "Cascade of effects": INRA (2017), Quel rôle pour les forêts et la filière forêt-bois françaises dans l'atténuation du changement climatique ?
    - Rapport d'étude pour le Ministre de l'Agriculture et de l'Alimentation

Market impact

- international wood prices impacted by cc induced variation in the wood supply and demand and in the competition of wood with other materials

Carbon module flowchart

- **Carbon module**: "registers and accounts" forest and forest sector carbon emitted/sequestrered/substituted;



Squares: carbon pools; ellipses: processes. The clock icon denotes multi-period flows. Elements accounted for in the module are drawn using wider contours.

Events handled by the carbon module

Event	Affected pool and direction
harvesting	cumEmittedForOper(+), forestPool(-)
wood production	woodProductsPool(+), cumSubstitutedEmissions(+)
wood transportation	cumEmittedForOper}(+)
forest growth	forestPool(+)
disturbance events	forestPool(alive: -; death: +)
(time passing)	forestPool(death: -), woodProductPool(-)

DATA

Data

- Spatial, temporal and forest type/dc automatic override – go as specific as you can!
- When we don't have data... we use scenarios/sensitivity analysis/MonteCarlo sampling
- Forest resource module:
  - forest static inventory data for initial year (volumes by ft, dc and region)
  - forest land cover GIS layer
  - forest dynamic inventory data for initial year (E[growth, mortality] and var(growth,mortality) by ft, dc, region)
  - CC: scenario-specific modifiers of {growth,mortality} by ft, dc, region|pixel
- Marked module:
  - initial demand/supply/trade/prices of HWP per product, region
  - supply, demand and trade (Armington) elasticity per product
  - initial and subsequent years international prices of HWP
- Area-allocation module:
  - E[risk aversion coefficient, expectation coefficient], var(risk aversion coefficient, expectation coefficient)
  - management rate by region
- Carbon module
  - inventory vs whole tree/roots/soil expansion factors
  - carbon sequestration coefficients
  - carbon substitution coefficients

RESULTS SUMMARY

Results

- background

Some results from a recent paper that "sum up" our latest work with the model for analysis of climate change impacts to give an overview of which could be the long-term impacts for the forest sector (up to a century).

For this study FFSM++ itself has been coupled with a statistical model of forest response to climate change and a statistical land-use model to deal with competition of forest activities with agricultural ones.

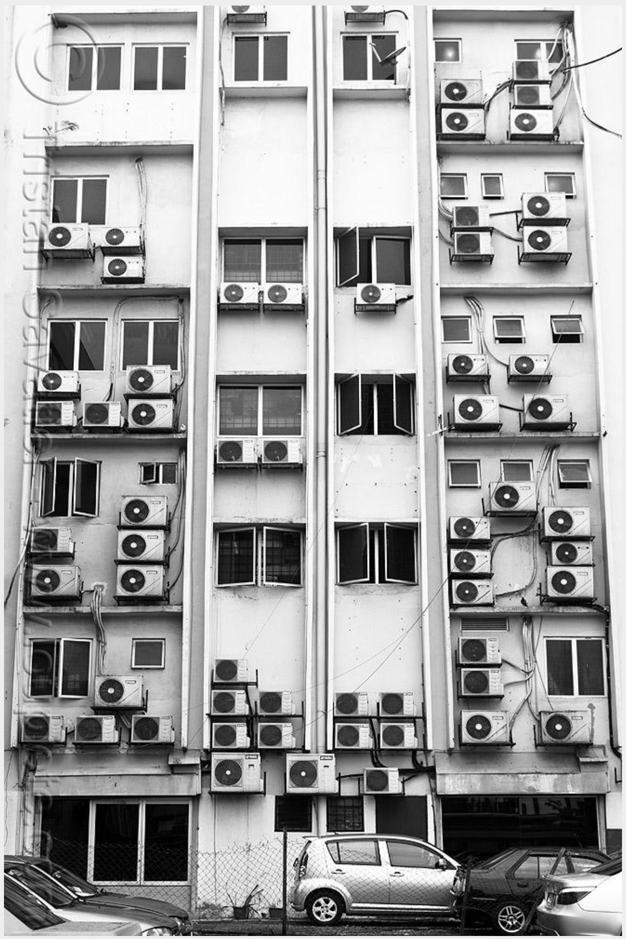
Entry points of the climate change cascade of impacts modelled are climatic anomalies and variations in international prices for timber products.

Delacote P., Lobianco A., Caurla S., Bontemps J.D., Lungarska A., Mérian P., Rivière M., Barkaoui A. (2021), "The loop effect: how climate change impacts the mitigation potential of the French forest sector", Journal of Forest Economics, 36(3)

Climate change

- the "loop" effect

Can we model mitigation and adaptation independently ?



Do our adaptation strategies have any influence on the mitigation? Or, in other words, does adaptation pose some limits on the possibilities we have to mitigate?

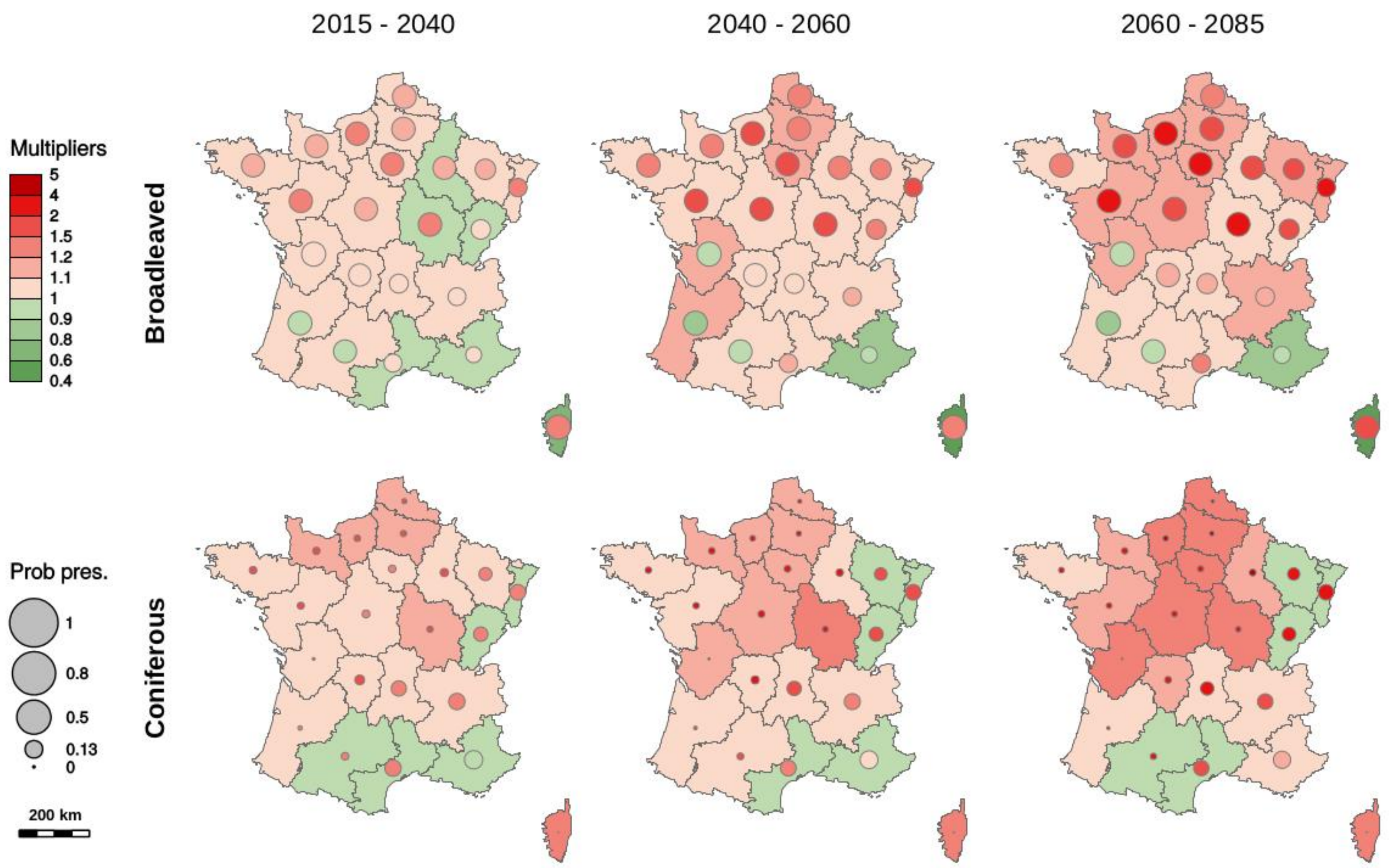
2022, Increased energy use for adaptation significantly impacts mitigation pathways

Nature Communications

Results

Climate change impacts on tree's mortality are more important that those on tree's growth variations;

Figure 2: Direct effects of climate change: time of passage (between diameter classes) multipliers, mortality multipliers and probabilities of presence.

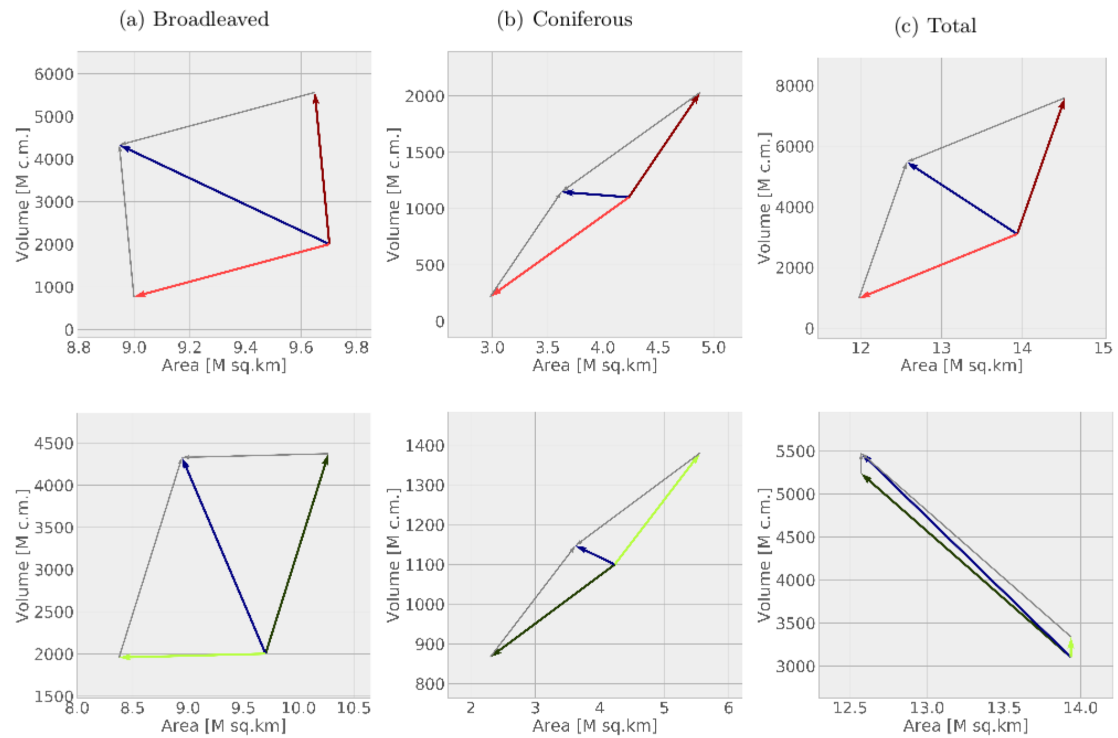


Background colour: time of passage multiplier; Circle colour: mortality multiplier

Results (2)

Climate change impact is more strong on coniferous species compared to broadleaved ones, and its effect may be strong enough to override substantial profit-driven preferences for coniferous forests by forest managers;

Figure 4: Breakdown of climate change and management effects.



The figure reveals the breakdown of the climate change effect (conditional to appropriate management) on the first row, and of the management effect (conditional to climate change) on the second row. 2015-2100 variations of volume (vertical axis) and area (horizontal axis)

Blue arrows: arpege_a1b scenario (including climate change and management);

Dark red arrows: constant scenario (without climate change); Light red arrow: overall climate change effect (conditional to managed forest);

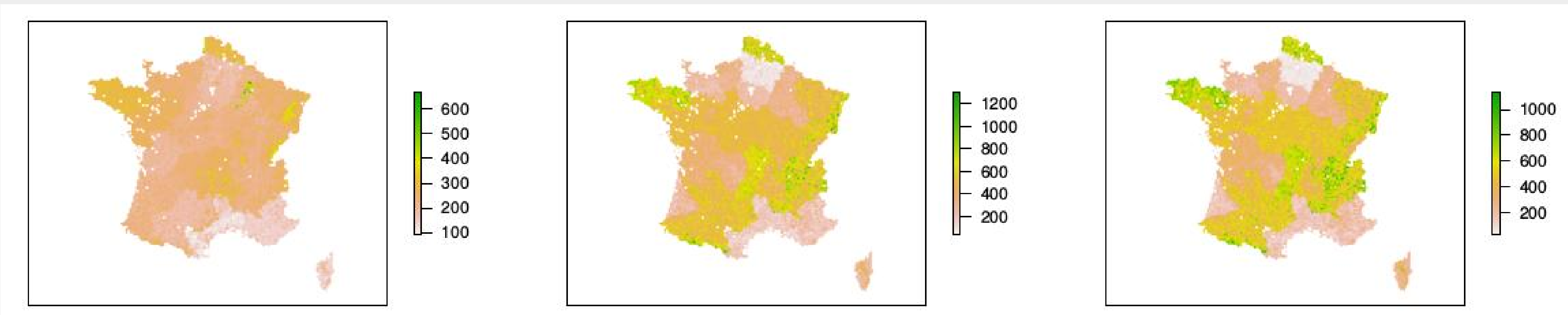
Dark green arrows: arpege_a1b_nomgm scenario; Light green arrows: overall management effect (conditional to climate change)

Results (3)

Despite an increase in harvesting intensity, primarily driven by increased international prices for harvested wood products, and increasing climate change impacts, the forest resource continue to expand in terms of volumes, but in terms of area they reduces;

Forest volume density (m^3/ha)

2015 | a1b, 2100 | a1b_nomgm, 2015



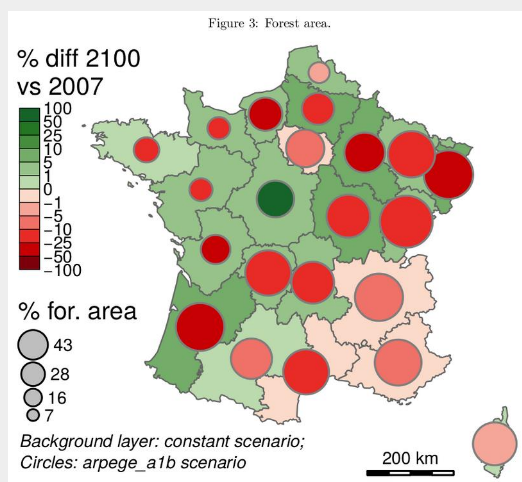


Figure 3: Forest area.

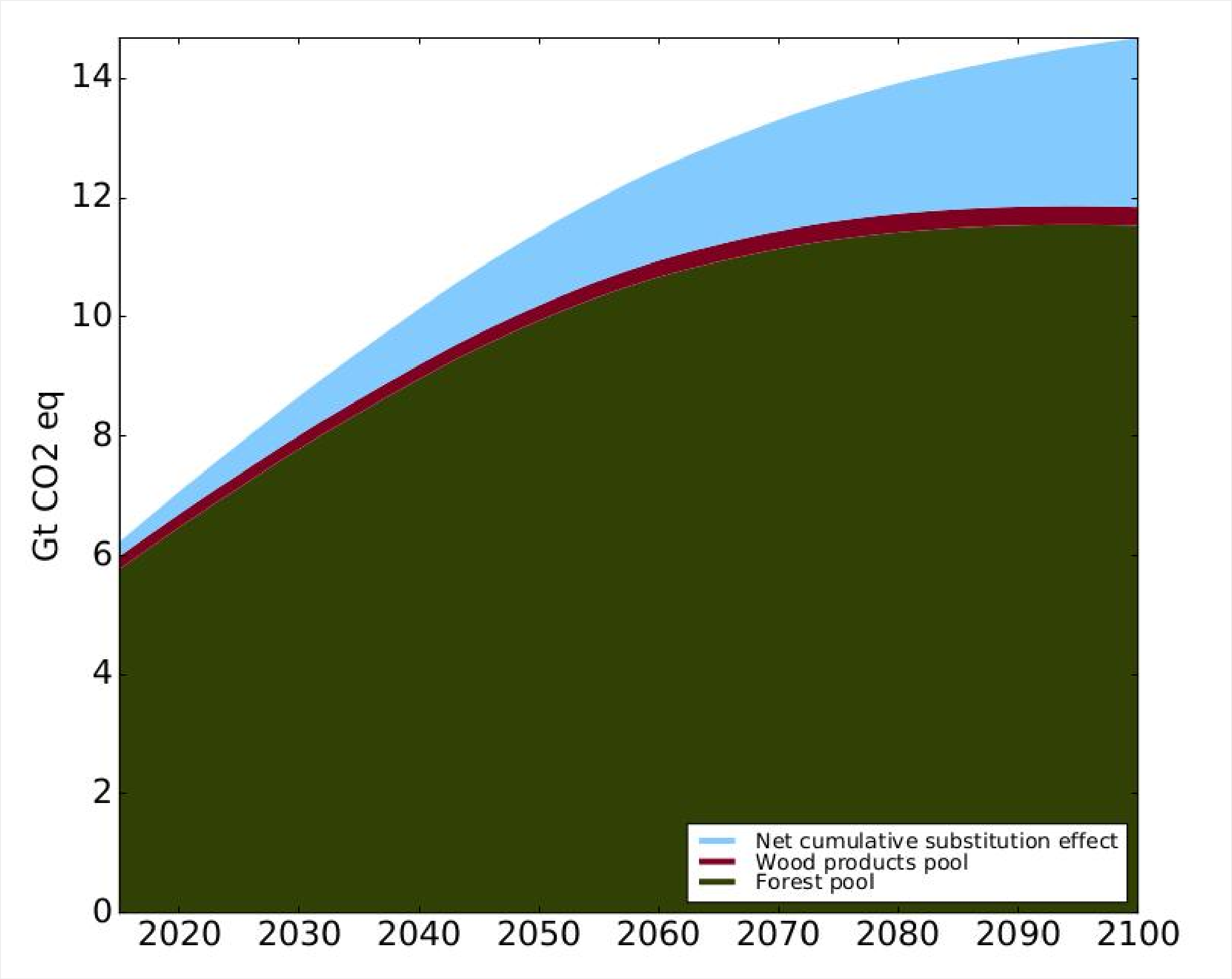
Results (4)

(a) Despite an increase in harvesting intensity and increasing climate change impacts, forest resources continue to expand;
(b) Due to the long term horizon of forest investments, future climate change impacts already have strong consequences on today's forest investment profitability;
(c) The expansion of harvesting wood products markets advantage both producers (+89.9% in producer's surplus) and consumers (+12.0%);
(d) Forest sector mitigation potential is estimated at 123 Mt CO2eq/y (94.7 Mt CO2eq/y from sequestration and 28.4 94.7 Mt CO2eq/y from substitution);

Results (5)

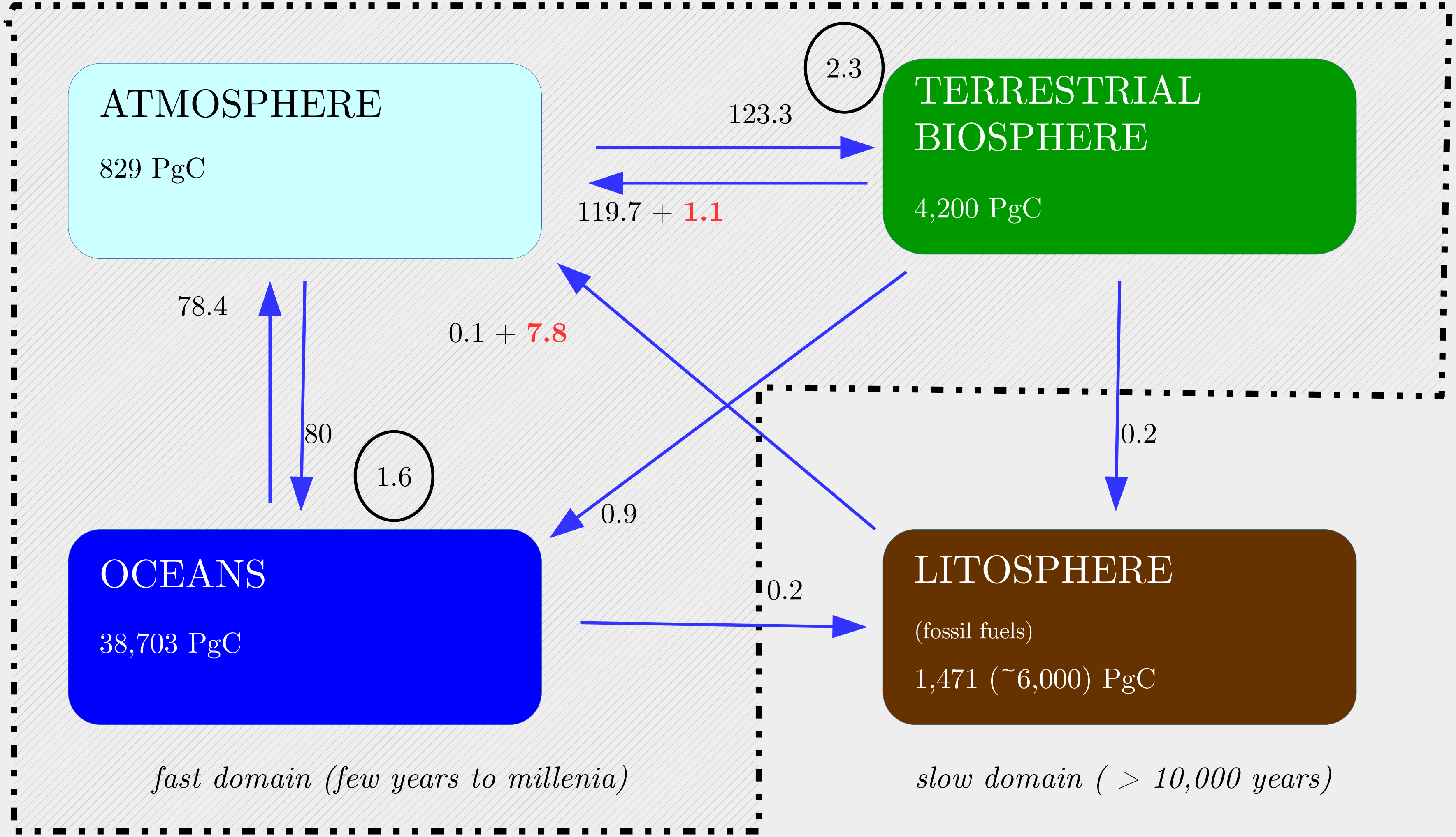
The forest capacity to provide sequestration opportunities for atmospheric carbon is strongly declining with time and it ceases around 2070-2080;

Dynamics of the carbon balance



In line with the increasing scientific evidence that the pool is becoming saturated – hence it will be less able in the future to absorb additional CO_2 from the atmosphere.

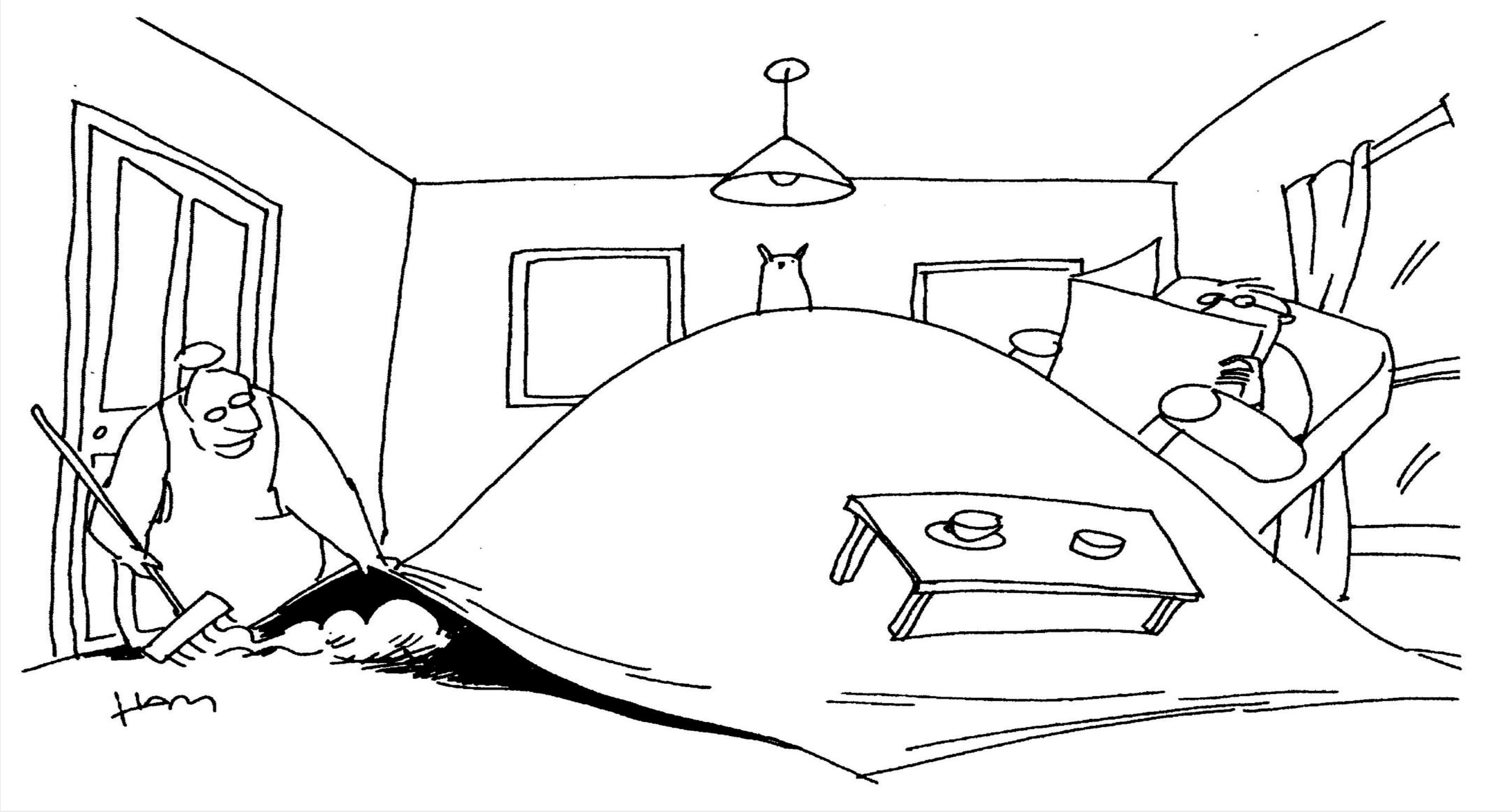
Climate change
- forest mitigation potential



Source: Lobianco et al. (2016), adapted from Ciais and Sabine (2013)

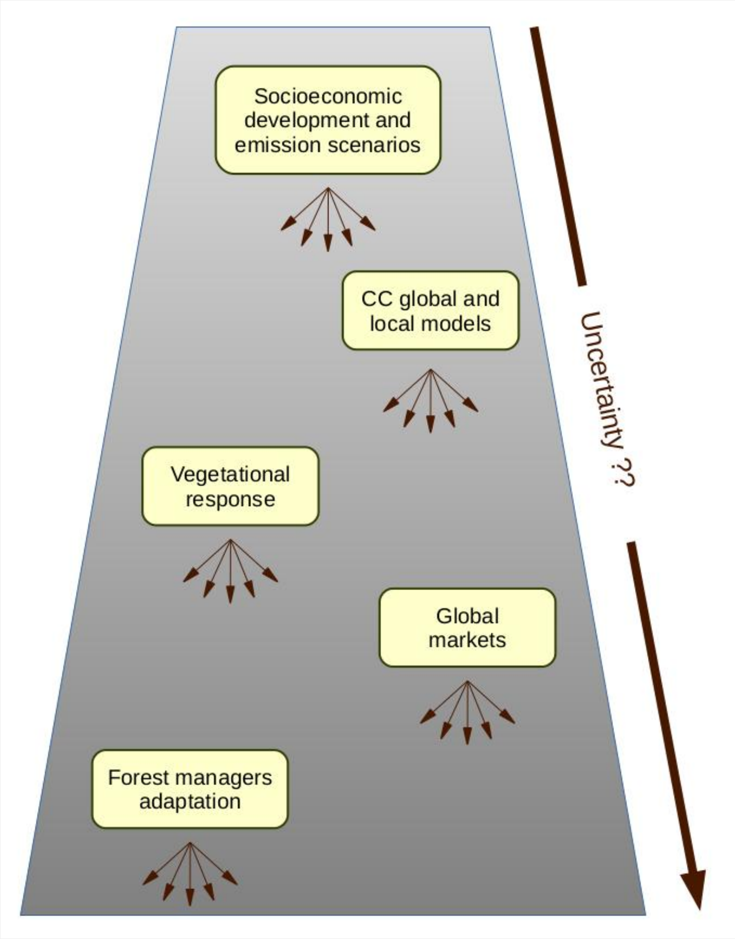
Climate change
- forest mitigation potential

Storing carbon in the terrestrial biosphere, within the fast domain sinks is a bit like ***sweeping the dirt under the carpet***



Results (6)

Uncertainty derived from employing different climatic models over the same IPCC storyline has the same order of magnitude than the uncertainty derived from employing the same climatic model under different storylines.



Climate change

- forest mitigation potential

removal

- appropriate, **removal**s, and how… 5
- and **removal**s in accordance wit… 5
- or **removal**s in their nationally d… 5
- or **removal**s are excluded; 32. D… 5
- and **removal**s by sinks covered b… 6
- and **removal**s by sinks of greenh… 22
- and **removal**s corresponding to … 23
- and **removal**s, Parties should ta… 23
- and **removal**s by sinks of greenh… 29

United Nations FCCC/CP/2015/L.9/Rev.1

Framework Convention on Climate Change

Distr.: Limited
12 December 2015

Original: English

Conference of the Parties
Twenty-first session
Paris, 30 November to 11 December 2015

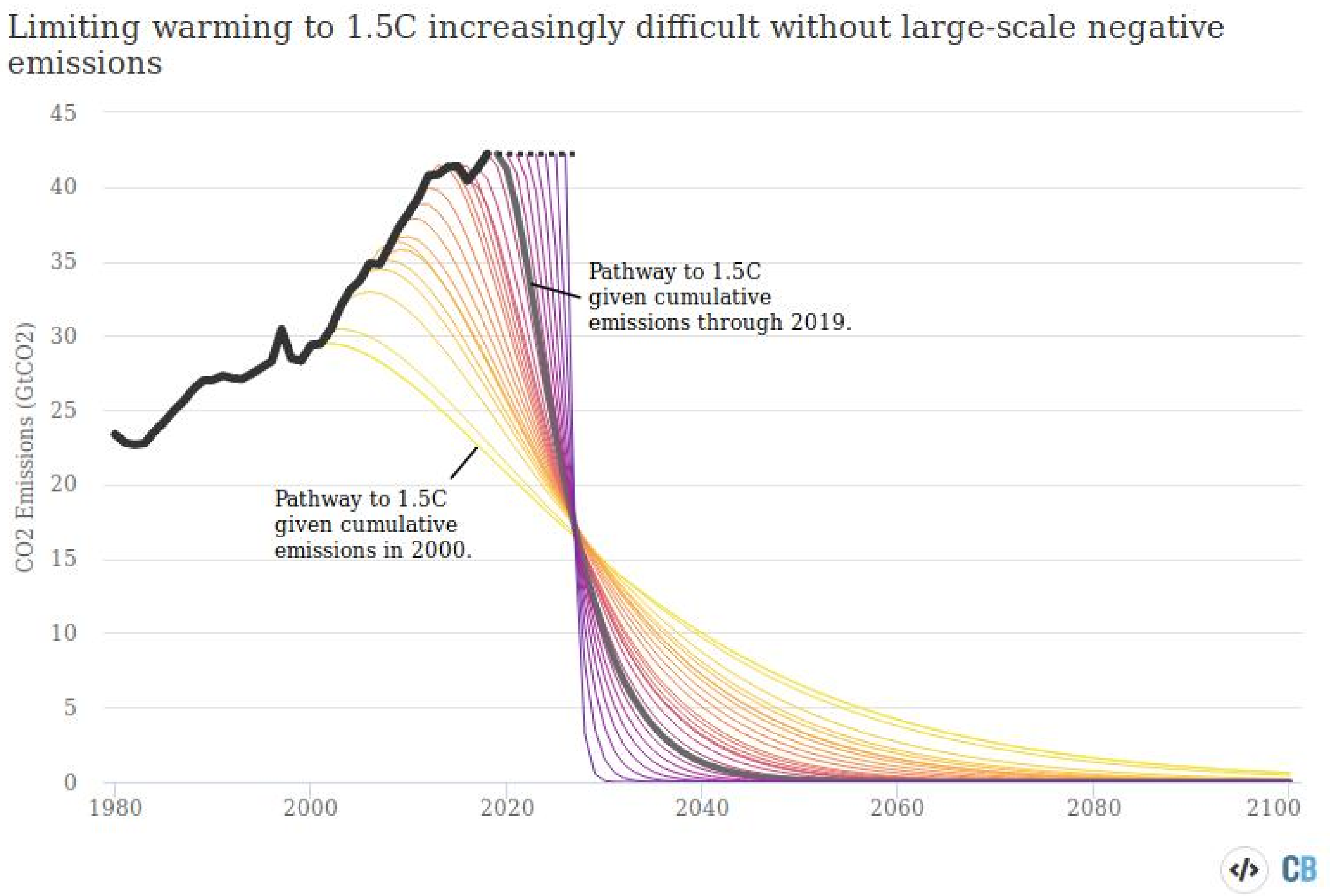
Agenda item 4(b)
Durban Platform for Enhanced Action (decision 1/CP.17)
Adoption of a protocol, another legal instrument, or an agreed outcome with legal force under the Convention applicable to all Parties

ADOPTION OF THE PARIS AGREEMENT

Proposal by the President

Draft decision -/CP.21

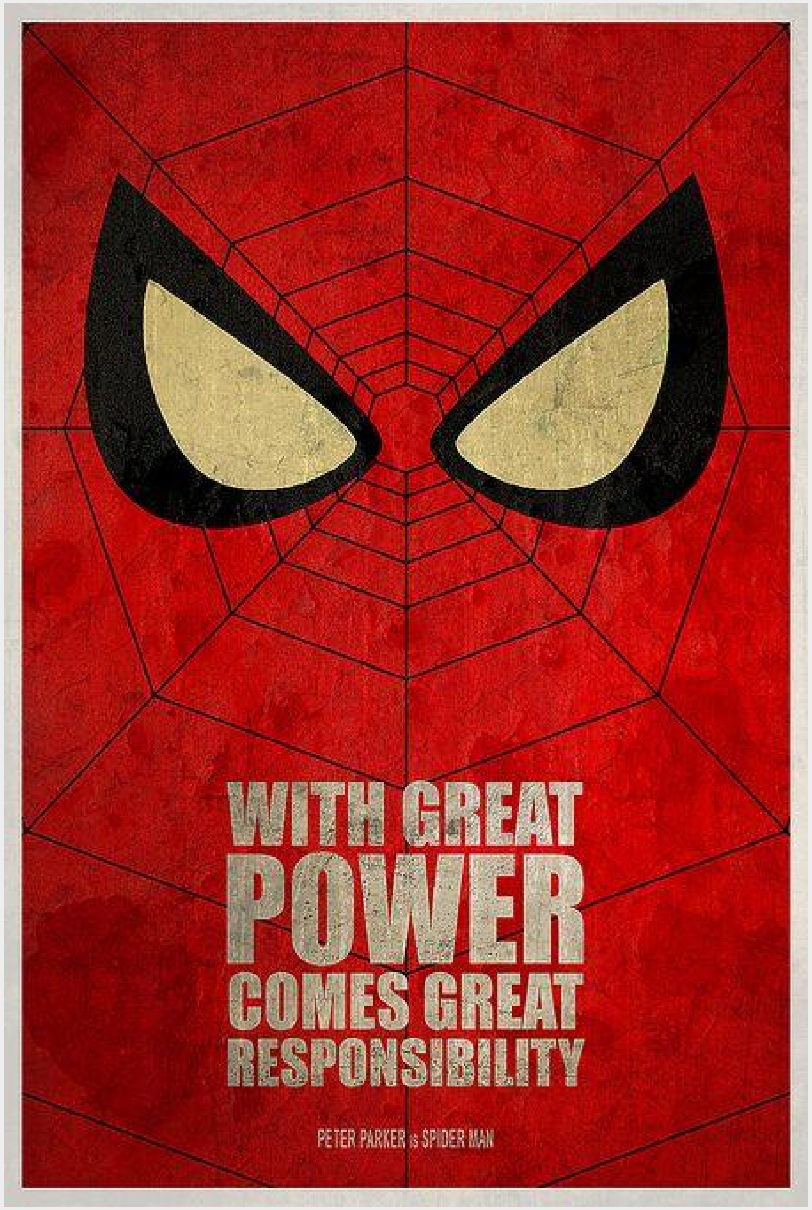
scheduled notes: art 6., COP25 Madrid



Emission reduction trajectories associated with limiting warming below 1.5C by starting year. Solid black line shows historical emissions, while dashed black line shows emissions constant at 2018 levels. Source: Historical CO2 emissions from the Global Carbon Project. 1.5C carbon budgets based on the IPCC SR15 report. Original figure from Robbie Andrews. Chart by Carbon Brief using Highcharts.

https://www.carbonbrief.org/unep-1-5c-climate-target-slipping-out-of-reach

The forest sector will save the world !



Selected references

https://ffsm-project.org/wiki/en/doc/home

Delacote P., Lobianco A., Caurla S., Bontemps J.D., Lungarska A., Mérian P., Rivière M., Barkaoui A. (2021), "The loop effect: how climate change impacts the mitigation potential of the French forest sector", Journal of Forest Economics, accepted paper

M. Riviere, C. Sylvain (2020) "Landscape implications of managing forests for carbon sequestration.", Forestry: An International Journal of Forest Research

C. Petucco, A. Lobianco, S. Caurla (2019), "Economic evaluation of an invasive forest pathogen at a large scale: the case of ash dieback in France", Environmental Modelling and Assessment

A. Lobianco, S. Caurla, P. Delacote, A. Barkaoui (2016), "Carbon mitigation potential of the French forest sector under threat of combined physical and market impacts due to climate change.", Journal of Forest Economics, Volume 23

A. Lobianco, P. Delacote, S. Caurla, A. Barkaoui (2016), "Accounting for active management and risk attitude in forest sector models. An impact study on French forests", Environmental Modeling and Assessment 21(3)

S. Caurla, S. Garcia, A. Niedzwiedz (2015), "Store or export? An economic evaluation of financial compensation to forest sector after windstorm. The case of Hurricane Klaus ", Forest Policy and Economics, Volume 61, December 2015, Pages 30-38, ISSN 1389-9341

S. Caurla and P. Delacote (2013), "FFSM: un modèle de la filière forêts-bois française qui prend en compte les enjeux forestiers dans la lutte contre le changement climatique", INRA Sciences Sociales 4/2012.

S. Caurla, P. Delacote, F. Lecocq, and A. Barkaoui (2013), "Combining an inter-sectoral carbon tax with sectoral mitigation policies: Impacts on the french forest sector", Journal of Forest Economics 19(4), 450–461

S. Caurla, F. Lecocq, P. Delacote, and A. Barkaoui (2013), "Stimulating fuelwood consumption through public policies: An assessment of economic and resource impacts based on the french forest sector model", Energy Policy 63, 338–347

F. Lecocq, S. Caurla, P. Delacote, A. Barkaoui and A. Sauquet (2011), "Paying for forest carbon or stimulating fuelwood demand? Insights from the French Forest Sector Model", Journal of Forest Economics, 17(2), 157–168

Roux A. (coord.), Colin A. (coord.), Dhôte J.-F. (coord.), Schmitt B. (coord.), Bailly A., Bastien J.-C., Bastick C., Berthelot A. Bréda N., Caurla S., Carnus J.-M., Gardiner B., Jactel H., Leban J.-M., Lobianco A., Loustau D., Marçais B., Meredieu C., Pâques L., Rigolot E., Saint-André L., Guehl J.-M., (2020). "Filière forêt-bois et atténuation du changement climatique : entre séquestration du carbone en forêt et développement de la bioéconomie.", Versailles, éditions Quæ, 170 p.

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