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## Modelisation of the French forest Sector

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# Cours Filière, Bois et Commercialisation (Ing2A-SCD1)

## Modelisation of the French forest Sector

*Antonello Lobianco*

*“I recognize the right and duty of this generation to develop and use our natural resources, but I do not recognize the right to waste them, or to rob by wasteful use, the generations that come after us.”*

-- Theodore Roosevelt (26th President of the United States from 1901 to 1909, naturalist and Nobel Peace Prize winner)



# 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.*

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



# French Forest Sector Model (FFSM)

The screenshot shows the website for the French Forest Sector Model (FFSM++) at [ffsm-project.org/wiki/en/home](http://ffsm-project.org/wiki/en/home). The page features the INRA and AgroParisTech logos, a search bar, and navigation links for 'Recent Changes', 'Media Manager', and 'Sitemap'. A sidebar on the left offers a 'Trace' in English and a language switch to French. The main content area includes links to 'Download FFSM++', 'Browse source code', 'Open a support request or bug ticket', and 'Intranet (private area)'. A central window titled 'FFSM - Forest Sector Simulator' displays a map of France and a log window with the following text:

```

**INFO: Starting cashing on pixel spatial-level exogenous data
**INFO: Starting resource module..
**INFO: Starting management module..
**INFO: Updating map areas..
**INFO: Summing data pixels->region..
**INFO: Printing forest data..
**INFO: Printing market data..
**INFO: Printing forest data..
**INFO: ### 2009 year started.. ###
**INFO: Starting resetting pixel level values
**INFO: Starting cashing on pixel spatial-level exogenous data
**INFO: Starting computing inventory available for this year..
**INFO: Starting market module
**INFO: Running optimisation problem for this year (it may take a few
minutes for large models)..
    
```

Below the screenshot is a flowchart diagram of the model's modules:

- Climate scenario** (represented by a sun and lightning bolt icon) provides input to the **Area Allocation module**.
- Area Allocation module** (represented by a puzzle piece) outputs **1 - growth, mortality** to the **Forest dynamics module**.
- Area Allocation module** also outputs **1 - future growth and mortality expectations** to **Forest managers**.
- Forest managers** (represented by a person icon) outputs **4 - harvested area** to the **Forest dynamics module**.
- Forest dynamics module** (represented by a puzzle piece) contains **Forest resources** and outputs **2 - available volumes** to the **Markets module**.
- Forest dynamics module** also outputs **3 - harvesting volumes** to the **Markets module**.
- Markets module** (represented by a puzzle piece) contains **Wood products markets** and outputs **5 - regeneration area** back to the **Area Allocation module**.



# FFSM development

Multidisciplinary team at the Laboratoire d'Economie Forestiere (UMR INRA/AgroPARISTech)

## Current Team

- Ahmed Barkaoui
- Sylvain Caurla
- Philippe Delacote
- Antonello Lobianco
- Claire Montagné-Huck
- Alexandra Niedzwiedz

## Past members

- Frank Lecocq
- Julien Barthès
- Alexandre Sauquet
- Iason Diafas

## External contributors

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



# FFSM++ development

The screenshot shows the Qt Creator IDE with the following components:

- Left Panel:** Project Explorer showing a 'Sources' folder with files like `unzip_p.h`, `zip.h`, `zip_p.h`, `zipentry.h`, `Adolc_de`, `anyoption`, `BaseClass`, `Gis.cpp`, `Init.cpp`, `InputNod`, `lpopt_nlp`, `Layers.cp`, `main.cpp`, `MainProg`, `MainWind`, `MapBox.c`, `ModelCo`, `ModelCo`, `ModelDa`, `ModelRe`, `Opt.cpp`, `Output.c`, `Pixel.cpp`, `Sandbox.`, `Scenarios`, and `Schedule`.
- Editor:** `ModelCoreSpatial.cpp` with the following code:
 

```

                23 void
                24 ModelCoreSpatial::runInitPeriod(){
                25     /**
                26     -> Some important notes:
                27     -> V (volumes) -> at the end of the year
                28     -> In (inventory) -> at the beginning of the year
                29     -> Volumes are in Mm^3, Areas in the model in Ha (10000 m^2), in the lay
                30     -> */
                31     - cacheSettings(); ..... // cashe things like first year, second
                32     - initializePixelValues(); ..... // compute px volumes vol for 2005
                33     - initMarketModule(); ..... // inside it uses first year, second yea
                34     - MTHREAD->SCD->advanceYear(); // 2005->2006
                35     - resetPixelValues(); ..... // swap volumes -> lagged volumes and rese
                36     - cachePixelExogenousData(); ..... // compute pixel tp, meta and mort
                37     - computeInventory(); ..... // in=f(vol_t-1)
                38     - computeCumulativeData(); ..... // compute cumTp_exp, vHa_exp, vHa
                39     - runBiologicalModule(); ..... //
                40     - runManagementModule();
                41     - updateMapAreas(); ..... // update the forArea {ft} layer on each
                42     - sumRegionalForData(); ..... // only for printing stats ad forest dat
                43     }
                44
                45 void
                46 ModelCoreSpatial::runSimulationYear(){
            
```
- Right Panel:** Variable Inspector showing a list of variables and their values:
  - [BaseCla...
  - MD @0x831
  - WL2 99999
  - allProdu... <9 items
  - dClasses <11 item
  - expType 0.5
  - fTypes <6 items
  - firstYear 2005
  - l2r <1 items
  - mr 0.299999
  - pDClasses <10 item
  - priProdu... <3 items
    - [0] "hardWR
    - [1] "softWR
    - [2] "pulpWF
  - reglds2 <22 item
  - regPx <0 items
  - regType "end"
  - secProd... <6 items
  - secondY... 2006
  - thirdYear 2007
- Debugger:** Shows 'Threads: #1' and 'Stopped at breakpoint 1 (1) in thread 1.' Below is a stack trace table:
 

Level	Function	File	Line	Number	Function	File	Line	Address
0	ModelCore...	ModelCore...	32	1	ModelCore...	/home/lobi...	32	0x80e5
1	Init::setNinL...	Init.cpp	137	3	ModelCore...	/home/lobi...	40	0x80e5
2	Init::setNinL...	Init.cpp	58	4	ModelCore...	/home/lobi...	49	0x80e5
3	MainProgra...	MainProgra...	88	5	Opt::declar...	/home/lobi...	63	0x808b

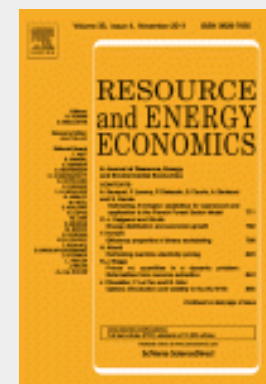
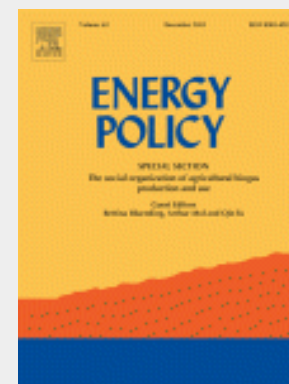
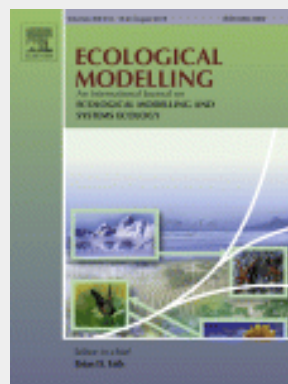




# Uses

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

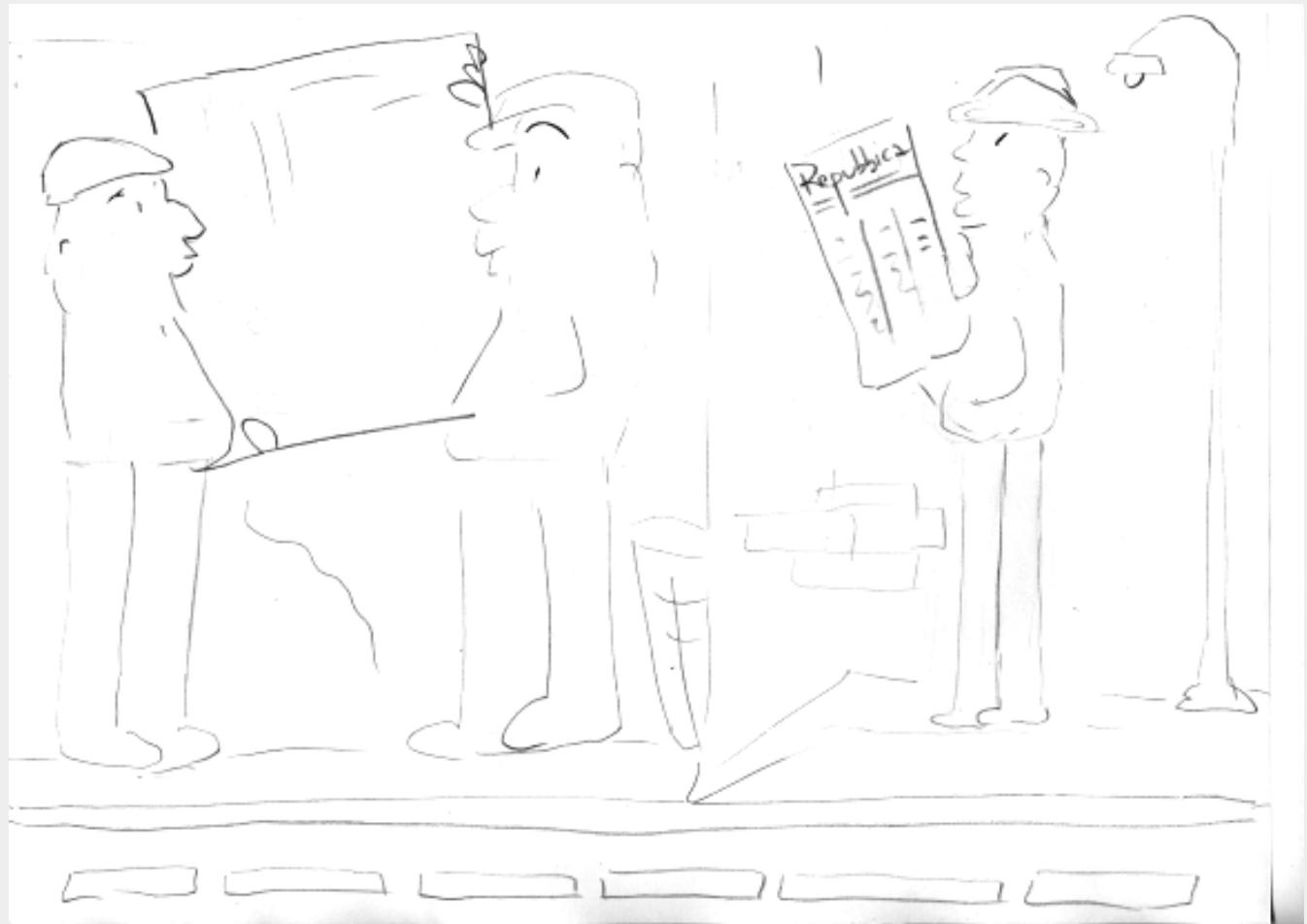
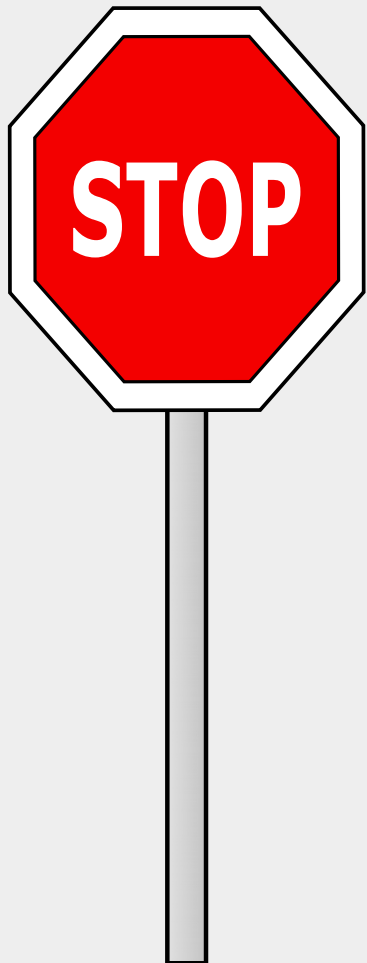
- Should policies subsidies targeted to sequestrated carbon or fuelwood ?
- Economic and resource impact of fuelwood subsidies
- Carbon tax and mitigation policies: impact on the French forest sector
- Is it better to store or export the excess of timber following large windfalls ?
- How much the future 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 ?





# Ok, we developed a model.. but what is a *model* ??

Reality → model → math. form.

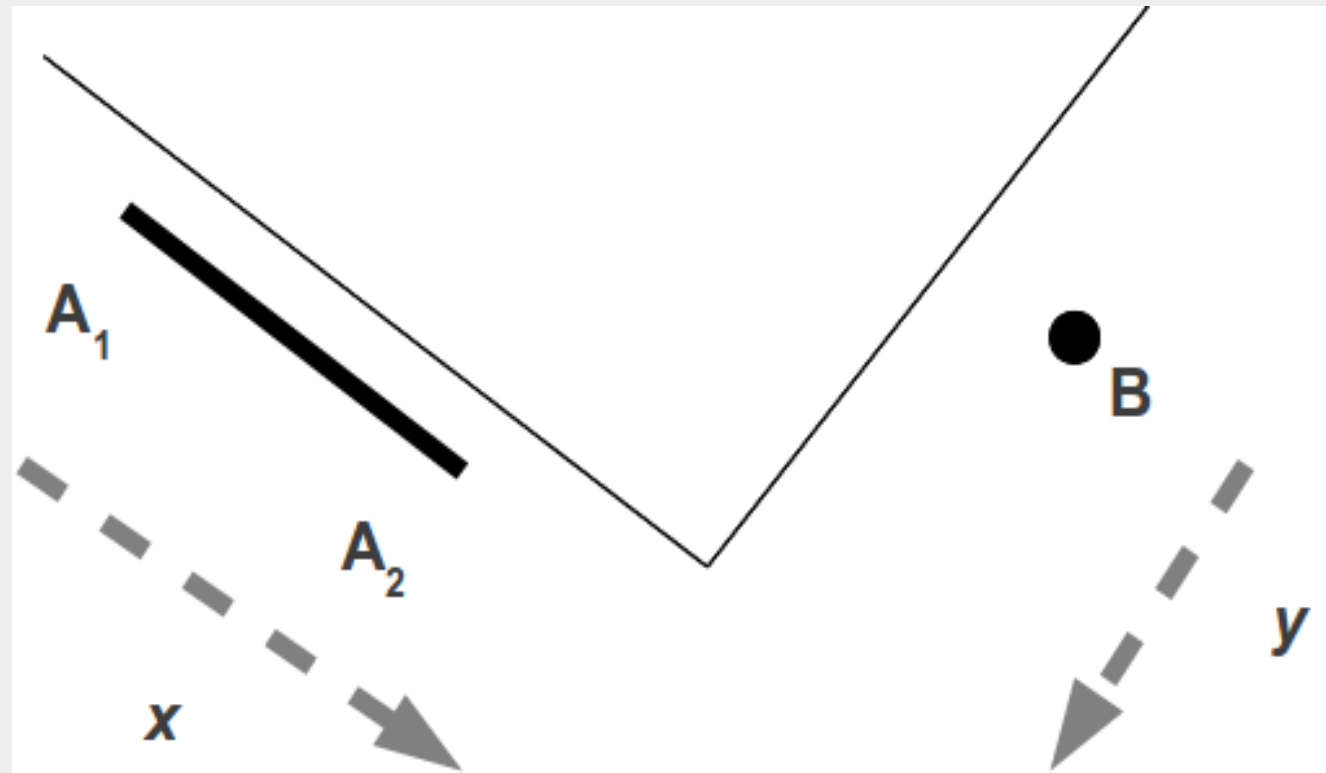
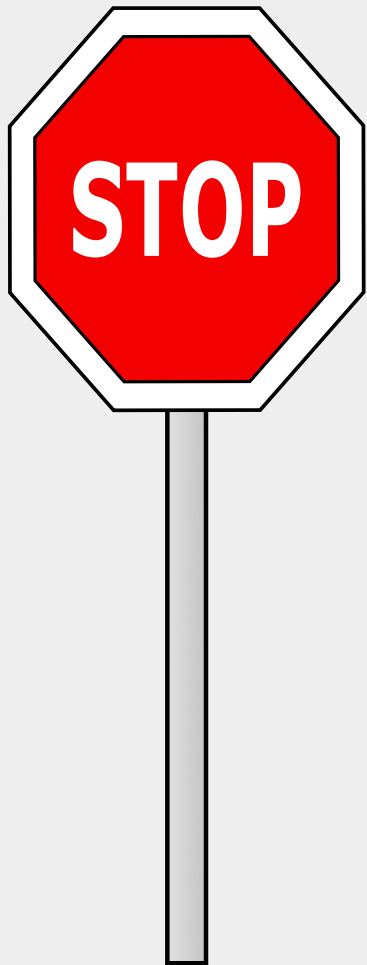






Ok, we developed a model.. but what is a *model* ??

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

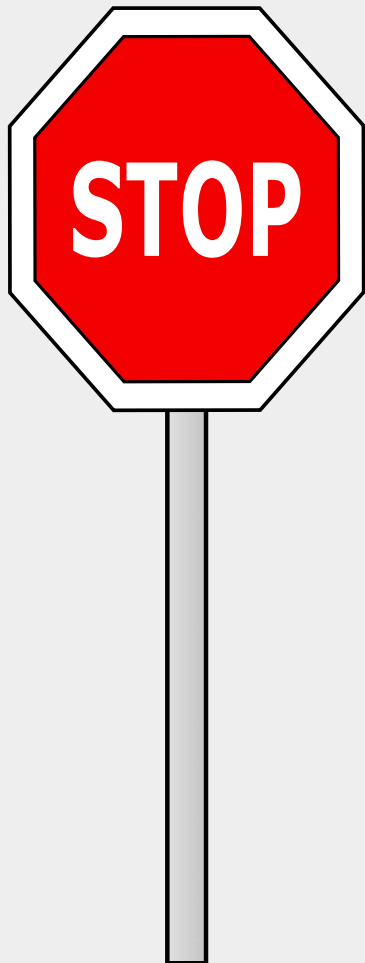


A model is useful if it helps us to predict something, in this case if a crash will happen.



# Ok, we developed a model.. but what is a *model* ??

Reality → model → math. form.



$$t_{A1} = \frac{x_{A1}}{v_A}$$

$$t_{A2} = \frac{x_{A2}}{v_A}$$

$$t_B = \frac{x_B}{v_B}$$

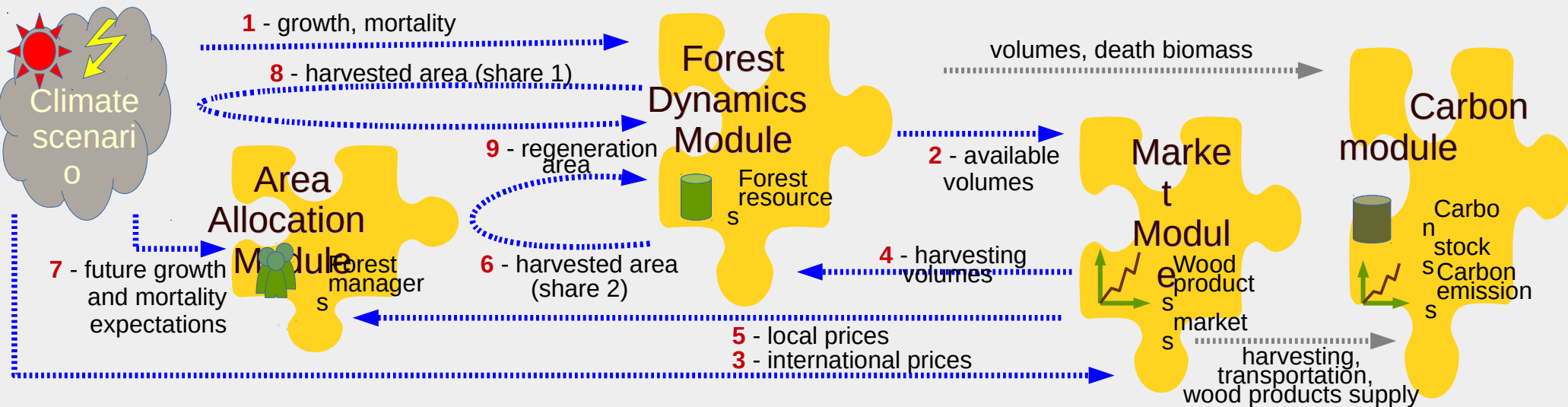
$$t_{A2} \leq t_B \leq t_{A1} \Rightarrow \text{crash}$$

```
int main () {
    float xa1, xa2, yb, va;
    float vb, ta1, ta2, tb;
    cin >> xa1;
    cin >> xa2;
    cin >> yb;
    cin >> va;
    cin >> vb;
    ta1 = xa1/va;
    ta2 = xa2/va;
    tb = yb/vb;
    if (tb >= ta2 && tb <= ta1) {
        cout << "Crash..." << endl;
    } else {
        cout << "No crash.." <<
endl;
    }
}
```

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)



# A modular approach



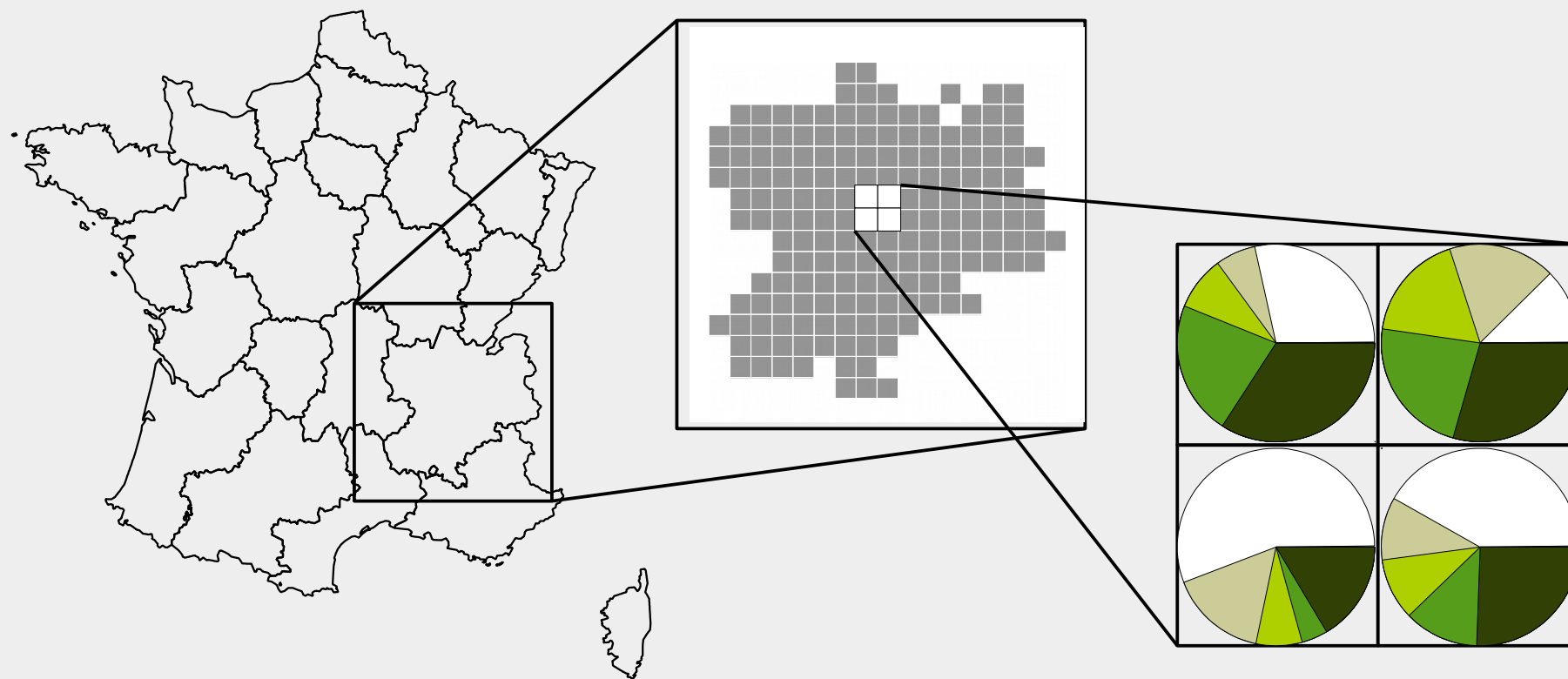
Recursive bio-economic model with coupled biological forest growth model and partial equilibrium market of forest products.

Four interconnected modules:

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



# 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



# Forest resources

## - definition

### Box 18.1 Forest, other woodland, and other land with tree cover: definitions of terms

<b>Forest</b>	Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.
<b>Other wooded land</b>	Land not classified as forest, spanning more than 0.5 hectares; with trees higher than 5 m and a canopy cover of 5–10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.
<b>Other land with tree cover</b>	All land that is <b>not</b> classified as forest or other wooded land is called ' <i>other land</i> '. Of this, ' <i>other land with tree cover</i> ' is defined as land spanning more than 0.5 hectares with a canopy cover of more than 10 percent of trees able to reach a height of 5 m at maturity.

- Min Size
- Min tree height
- Min cover
- Exclusion clauses

*"The group considers the FAO definition of a forest as the basic one, but acknowledge that many other useful definitions of "forest" exist in published form. The fact that "forest" has been defined in many ways is a reflection of the diversity of forests and forest ecosystems in the world and of the diversity of human approaches to forest"* (Convention on biological diversity)



# Forest resources

## - types

### **Primary forest**

A primary forest is a forest that has never been logged and has developed following natural disturbances and under natural processes, regardless of its age.

### **Secondary forest**

A secondary forest is a forest that has been logged and has recovered naturally or artificially. Not all secondary forests provide the same value to sustaining biological diversity, or goods and services, as did primary forest in the same location.

### **Plantation forest**

A plantation forest may be afforested land or a secondary forest established by planting or direct seeding. A gradient exists among plantation forests from even-aged, single species monocultures of exotic species with a fibre production objective to mixed species, native to the site with both fibre and biodiversity objectives.

P.S.: Classification may vary





# Forest resources

- how, which and where

	Forest 1000ha	Primary	Type %		Oth. wooded land 1000ha	Wooded land		
			Nat. reg.	Plantation		% land area	ha cap.	% world
<b>Africa</b>	<b>624,103</b>	<b>21.6</b>	<b>71.5</b>	<b>2.6</b>	<b>367,041</b>	<b>33.2</b>	<b>0.86</b>	<b>19.0</b>
- east & south	274,886	2.1	96.3	1.7	171,344	44.6	1.04	8.6
- north	36,217	3.7	53.3	23.3	60,091	10.1	0.40	1.9
- west & central	313,000	40.9	51.9	1.0	135,606	43.4	0.92	8.6
<b>Asia</b>	<b>593,362</b>	<b>19.8</b>	<b>58.1</b>	<b>21.7</b>	<b>234,729</b>	<b>26.6</b>	<b>0.19</b>	<b>15.9</b>
- east	257,047	12.9	51.3	35.7	108,762	31.6	0.23	7.0
- south & south-east	292,804	27.6	62.1	10.2	60,673	42.2	0.15	6.8
- west & central	43,511	7.1	70.5	15.6	65,294	9.7	0.25	2.1
<b>Europe</b>	<b>1,015,482</b>	<b>27.3</b>	<b>64.0</b>	<b>8.1</b>	<b>100,014</b>	<b>50.4</b>	<b>1.51</b>	<b>21.4</b>
- Italy	9,297	1.0	92.1	6.9	1,813	37.8	0.18	0.2
- France	16,989	0.0	88.4	11.6	590	32.1	0.27	0.3
- Germany	11,419	0.0	53.6	46.4	0	32.8	0.14	0.2
- Sweden	28,073	8.6	42.5	48.9	2,432	74.3	3.17	0.6
<b>North and central Am.</b>	<b>750,653</b>	<b>42.6</b>	<b>51.6</b>	<b>5.8</b>	<b>89,049</b>	<b>39.3</b>	<b>1.48</b>	<b>16.1</b>
- central	20,250	26.9	71.4	1.7	6,116	51.9	0.57	0.5
- caribbeans	7,195	3.2	85.4	10.2	1,066	36.7	0.19	0.2
- north	723,207	43.5	50.7	5.8	81,868	39.1	1.68	15.5
<b>Oceania</b>	<b>173,524</b>	<b>15.5</b>	<b>81.7</b>	<b>2.5</b>	<b>257,208</b>	<b>50.7</b>	<b>10.96</b>	<b>8.3</b>
<b>South America</b>	<b>842,011</b>	<b>47.6</b>	<b>43.7</b>	<b>1.8</b>	<b>156,429</b>	<b>57.2</b>	<b>2.42</b>	<b>19.2</b>
<b>World</b>	<b>3,999,134</b>	<b>31.9</b>	<b>58.5</b>	<b>7.2</b>	<b>1,204,471</b>	<b>39.9</b>	<b>0.72</b>	<b>100.0</b>

Source: FAO FRA 2015



# Forest resources

## - trends (1)

	Wooded land				Forest				Other wooded land			
	2000	2005	2010	2015	2000	2005	2010	2015	2000	2005	2010	2015
<b>Africa</b>	-4.9	-2.3	0.1	-3.4	-5.0	-2.3	-2.5	-2.2	-4.6	-2.3	4.6	-5.4
- east & south	-5.1	-2.4	-2.8	-3.3	-6.1	-2.9	-3.2	-2.7	-3.5	-1.7	-2.2	-4.4
- north	-3.1	-1.0	-1.2	-1.7	-4.3	-1.2	-0.4	-2.3	-2.4	-0.9	-1.7	-1.4
- west & central	-5.0	-2.5	3.3	-3.9	-4.1	-2.0	-2.2	-1.8	-7.2	-3.9	17.5	-8.3
<b>Asia</b>	-0.2	2.6	1.2	0.0	-0.4	2.6	1.5	0.7	0.2	2.5	0.7	-1.7
- east	3.9	6.4	3.2	1.6	8.4	6.6	3.6	2.6	-5.0	5.9	2.5	-0.8
- south & south-east	-4.5	-0.6	-0.7	-1.1	-6.6	-0.7	-0.2	-1.1	6.5	-0.4	-3.1	-1.0
- west & central	2.8	1.9	1.3	-1.8	2.9	4.9	1.2	1.3	2.7	0.0	1.3	-3.8
<b>Europe</b>	0.1	0.4	1.0	0.1	0.6	0.4	0.9	0.2	-4.9	0.9	1.5	-0.9
- Italy	9.8	4.5	3.1	3.0	10.3	4.7	3.1	3.0	7.6	3.5	3.1	3.0
- France	3.8	-2.0	2.5	2.4	5.9	3.7	3.5	3.4	-11.5	-50.8	-16.7	-20.2
- Germany	0.5	0.3	0.2	0.1	0.5	0.3	0.2	0.1	0.0	0.0	0.0	0.0
- Sweden	0.3	0.2	-0.5	0.0	0.4	0.2	-0.5	0.0	0.0	0.0	0.0	0.0
<b>North and central Am.</b>	-0.4	-0.1	0.3	0.7	-0.5	-0.1	0.3	0.0	0.7	-0.1	-0.1	6.1
- central	-10.3	-4.2	-3.7	-2.0	-13.1	-5.4	-5.3	-3.6	3.3	0.3	2.5	4.0
- caribbeans	19.1	9.1	-0.5	5.3	17.9	7.2	6.4	6.7	24.7	17.3	-28.8	-3.2
- north	-0.1	0.0	0.4	0.7	-0.2	0.0	0.4	0.1	0.1	-0.4	0.3	6.4
<b>Oceania</b>	0.4	-0.6	-2.5	141.5	0.5	-0.7	-2.5	0.9	-2.6	-0.5	-0.7	3953.7
<b>South America</b>	-3.8	-2.0	-1.6	-1.0	-4.3	-2.5	-1.9	-1.2	-0.8	1.0	0.4	0.2
<b>World</b>	<b>-1.9</b>	<b>-0.4</b>	<b>0.1</b>	<b>4.3</b>	<b>-1.8</b>	<b>-0.5</b>	<b>-0.4</b>	<b>-0.4</b>	<b>-2.5</b>	<b>-0.1</b>	<b>2.1</b>	<b>23.6</b>

Source: FAO FRA 2015



# Forest resources

## - trends (2)

	Primary forest				Natural regeneration				Plantations			
	2000	2005	2010	2015	2000	2005	2010	2015	2000	2005	2010	2015
<b>Africa</b>	-4.3	-2.2	-2.4	-2.1	-5.3	-2.6	-2.8	-2.5	9.3	8.8	10.2	6.3
- east & south	-8.5	-3.8	-4.9	-2.3	-6.2	-2.9	-3.3	-2.9	5.1	5.0	7.1	14.0
- north	-7.4	-4.0	-4.2	-4.3	-6.8	-2.8	-1.8	-4.2	7.7	5.0	4.7	4.7
- west & central	-4.1	-2.1	-2.3	-2.1	-4.2	-2.2	-2.4	-1.9	26.8	30.9	32.3	0.8
<b>Asia</b>	78.0	-1.1	0.4	-1.3	27.2	-0.6	-0.2	-1.1	30.5	19.6	9.3	7.3
- east	12.2	-2.3	5.9	-1.5	6.6	1.4	1.8	0.4	26.3	18.9	7.2	6.8
- south & south-east	139.7	-0.7	-1.6	-1.3	48.4	-2.3	-1.6	-2.1	50.0	22.9	15.4	9.1
- west & central	0.4	0.9	-4.2	1.1	0.6	4.2	1.8	-0.4	22.6	15.3	12.8	6.7
<b>Europe</b>	6.7	-1.0	7.1	-0.4	0.4	-0.3	0.5	0.0	13.1	10.8	11.3	-2.1
- Italy	0.0	0.0	0.0	0.0	10.7	4.8	3.1	3.0	6.8	3.1	3.2	2.9
- France	0.0	0.0	0.0	0.0	6.2	-0.3	5.0	4.8	3.8	39.0	-5.4	-5.7
- Germany	0.0	0.0	0.0	0.0	0.4	2.8	0.2	0.1	0.5	-2.5	0.2	0.1
- Sweden	0.0	0.0	0.0	0.0	-12.8	-7.6	-11.0	-9.0	33.0	12.8	13.2	9.3
<b>North and central Am.</b>	-1.1	0.8	-0.1	0.0	-1.5	0.3	0.3	-0.3	40.4	13.3	10.1	6.2
- central	-27.7	21.3	22.7	3.9	-7.8	42.3	11.6	-2.8	-4.3	10.0	37.9	-34.9
- caribbeans	-0.9	-0.4	-0.4	-0.4	20.4	6.7	4.4	5.9	1.5	16.7	31.7	14.8
- north	-0.7	0.6	-0.4	-0.1	-1.5	-0.6	0.0	-0.3	41.8	13.3	9.5	6.7
<b>Oceania</b>	-16.6	16.8	-9.1	-9.3	0.2	355.3	-2.7	0.8	26.0	15.1	5.9	3.1
<b>South America</b>	-3.7	-1.8	10.9	-0.8	-4.5	-2.6	3.5	-1.4	20.7	9.4	25.1	13.2
<b>World</b>	<b>3.3</b>	<b>-0.5</b>	<b>4.2</b>	<b>-0.9</b>	<b>0.5</b>	<b>2.5</b>	<b>0.3</b>	<b>-0.9</b>	<b>23.9</b>	<b>14.8</b>	<b>10.7</b>	<b>4.5</b>

Source: FAO FRA 2015

• a

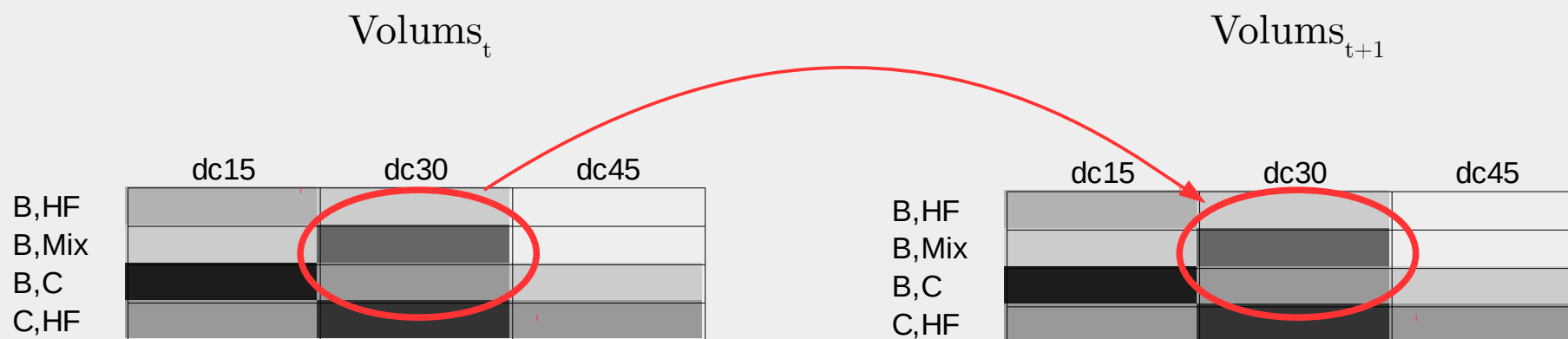


# Forest resources

## - FFMSM implementation (forest dynamics module)

- **Resource module:** inventory based, Markov transition matrix model, 10 diameter classes, 2 species groups (coniferous, broadleaved). 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

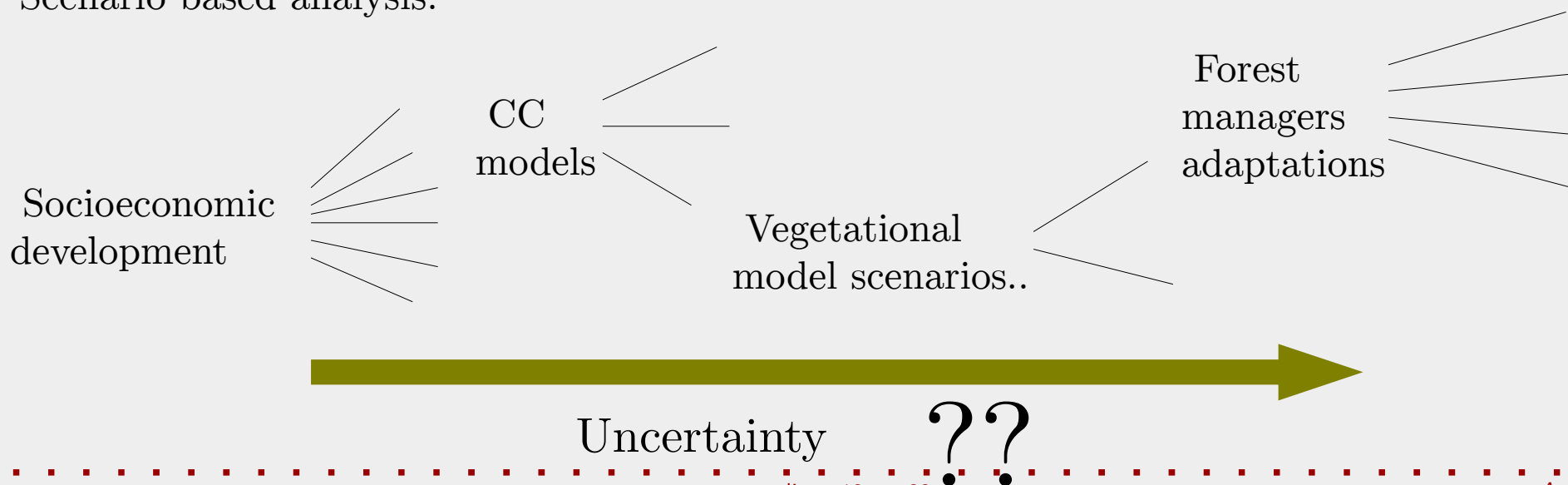
CC effects on the forest dynamics are exogenous to FFSM. Conversely, consequences on the management of the forest are explicitly accounted for.

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  $forestChangeAreaIncrementsHa_{sc,r,t}$ )

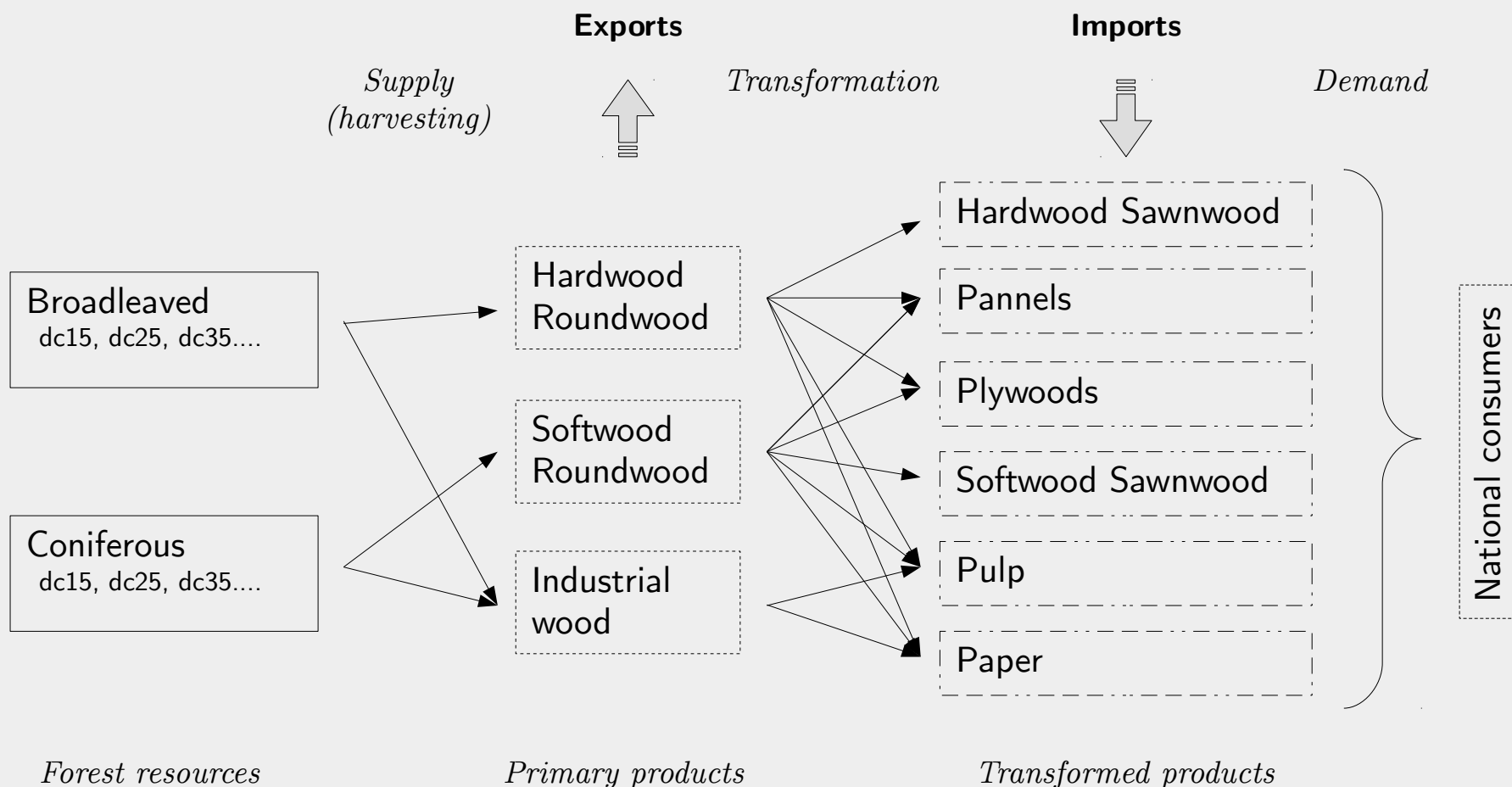
Scenario based analysis:





# HWP markets

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







# HWP markets

## Supply

It depends from own price and availability of the resource:

$$\frac{\text{supply}_{r,pp,t}}{\text{supply}_{r,pp,t-1}} = \left( \frac{P_{r,pp,t}}{P_{r,pp,t-1}} \right)^{eSP_{pp}} \left( \frac{\text{inv}_{r,pp,t}}{\text{inv}_{r,pp,t-1}} \right)^{eSI_{pp}}$$

## Demand

It depends uniquely from the own price (recently a cross-price elasticity has been added):

$$\frac{\text{demand}_{r,pt,t}}{\text{demand}_{r,pt,t-1}} = \left( \frac{P_{r,pt,t}}{P_{r,pt,t-1}} \right)^{eDP_{pp}}$$

## International trade

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:



# Forest investment decisions

## - Net Present Value

### Net Present Value

The Net Present Value (NPV) is the sum of all the benefits and costs involved during the investment, each discounted at the indicated interest rate from the planned time to the starting time of the investment.

It is therefore computed as:

$$NPV = \sum_{t=0}^T \left( \frac{B_t - C_t}{1+i} \right)^t$$

where  $T$  is the total length of the forest investment (its rotation period),  $B_t$  are the total benefits coming from the activities planned at time  $t$  in current prices, and  $C_t$  are the total costs arising from such activities and  $i$  is the interest rate.

A NPV value greater than zero means that the investment is profitably at the given interest rate.

However it is not directly comparable between investment of different length.



# Forest investment decisions

## - Soil Expected Value

### Soil Expected Value

The Soil Expectation Value (SEV) is the maximum amount that you would pay for the bare land holding the forest, given the expected flow of incomes and costs of the project under analysis. It is effectively the Net Present Value of an infinite series of identical forest rotation for the project under analysis

It is computed as:

$$SEV = \frac{NPV * (1+i)^T}{(1+i)^T - 1}$$

Where  $NPV$  is the Net Present Value of a single rotation (the production cycle),  $T$  is the rotation length (typically the number of years) and  $i$  is the market interest rate.

Differently from the NPV, it allows to compare forest investments of different duration.



# Forest investment decisions

- CBA analysis to retrieve NPV, SEV and IRR

The computation of the NPV or SEV (and the closely related Internal Rate of Return - IRR, that is the value of interest rate that lead the NPV to zero) is often done numerically and in discrete form: following “guidelines” for the specific forest investment, each year are reported the expected operations that will generate revenues or costs and then the NPV is the actualised present value of both of them.

This easily allows to include in the analysis also externalities and compute a separate profitability for the forest owner (“Financial Analysis”) or for the society as a whole (“Economic Analysis”) and to include risk analysis.

### Pine plantations in Southern Brazil - 15 years rotation

Submitted by Alan Ferreira B... on Mon, 04/15/2013 - 12:29

Cost / Benefits analyses of Pine plantations in Southern Brazil. As case studies was appraised investments on Pinus taeda plantations in the states of Paraná and Santa Catarina, for average site quality, and high technology silviculture techniques applied. The rotation was defined as 15 years for pulp production, without thinnings. The timber yield was calculated by the Sispinus management simulation software.

Species: Pinus taeda

**Project size:** 1.00 ha  
**Real interest rate:** 6.00%  
**Periodicity:** Years  
**Monetary unit:** € (EUR)  
**Periods:** 15  
**Country:** Brazil  
**Region:** Parana

**FINANCIAL AND ECONOMIC REPORTS**  
 The following tables summarise the main financial and economic variables for this investment project. Analysis is performed for both the given interest rate and for ± 1% of it.

Variable	Ir -1%	Value	Ir +1%
Net Present Value (NPV)	2097.87	1669.98	1300.11
Equivalent Annual Income (EAI)	192.489	162.213	133.407

### Economic Table

Variable	Ir -1%	Value	Ir +1%
Net Present Value (NPV)	2097.87	1669.98	1300.11
Equivalent Annual Income (EAI)	192.489	162.213	133.407
Soil Expectation Value (SEV)		2865.76	
Benefits-Costs ratio (BC ratio)		2.04406	
Internal Rate of Return (IRR)		12.4496 %	
Modified Internal Rate of Return (MIRR)		11.1746 %	

**NPV trend:**

Range: 0.0 to 15.0

**Activities cashflow:**  
 All values are in Euro (discounted values). Economic activities are in *italic*.

Activities	Unit	Periods			
		0	1	2	3
<b>Costs</b>					
- Seedlings	unit	-147.00	0.00	0.00	0.00
- Fertilization	Kg	-95.00	0.00	0.00	0.00
- Ant insecticide	kg	-14.40	-3.40	-3.20	-3.00
- Herbicide	liters	-15.30	-5.77	-5.45	-5.15
- Management	Team	-32.00	-15.09	-14.24	-13.40
- Mechanized Labor / Soil preparation (tractor 75cv)	hour	-52.00	0.00	0.00	0.00



# Forest investment decisions

## - FFSM implementation (area allocation module)

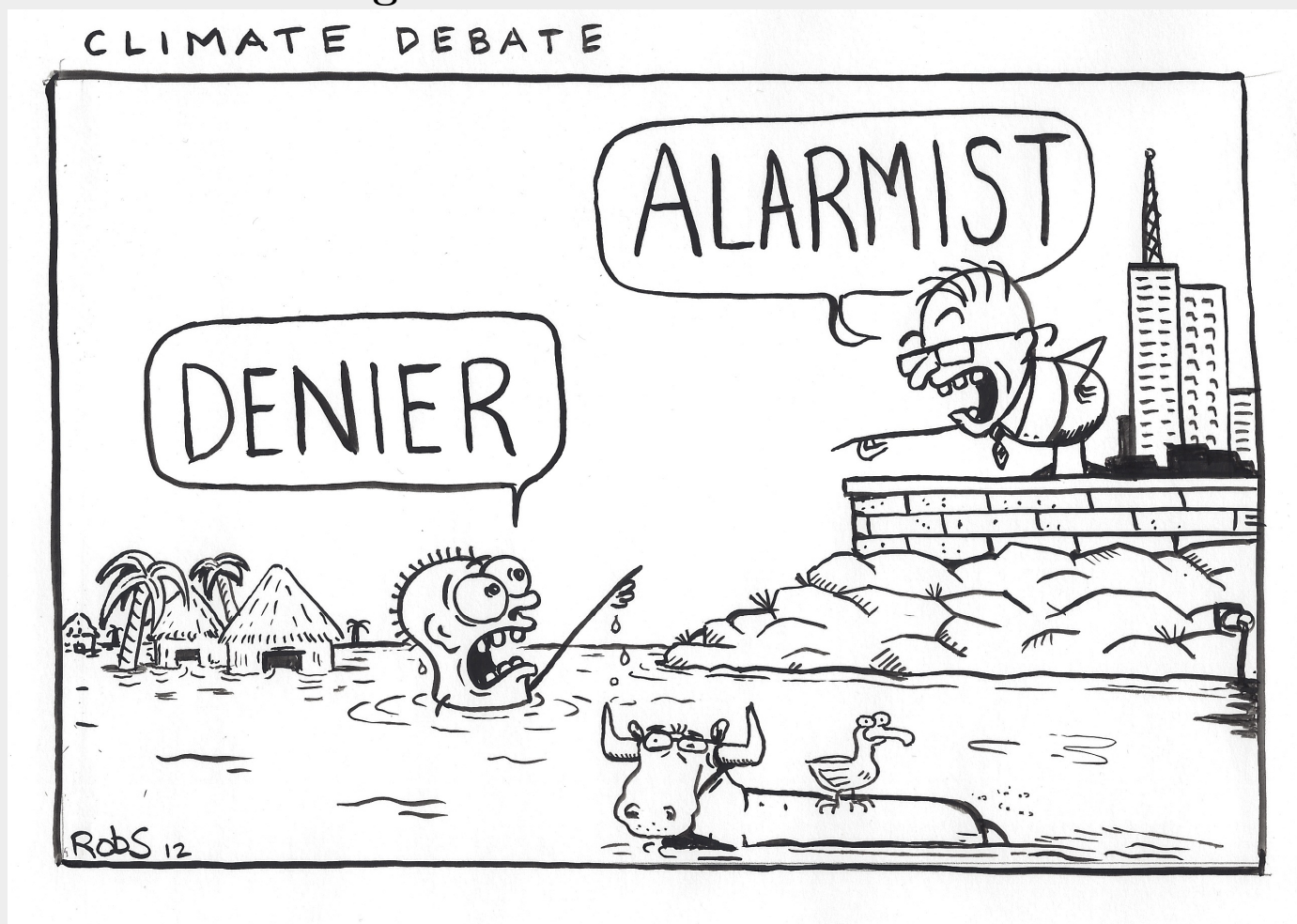
- **Area allocation module:** agent based micro-economic model; area allocation endogenised; regeneration =  $f(\pi(\text{prices, growth, mortality}))$ ; forest managers heterogeneous for (a) managed forest resources, (b) degree of risk-aversion (prices and growth vs. mortality), (c) level of expectations (observed vs. future prices, growth, mortality);
- Forest investments are chosen based (comparing) on the SEV.
- 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 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 !



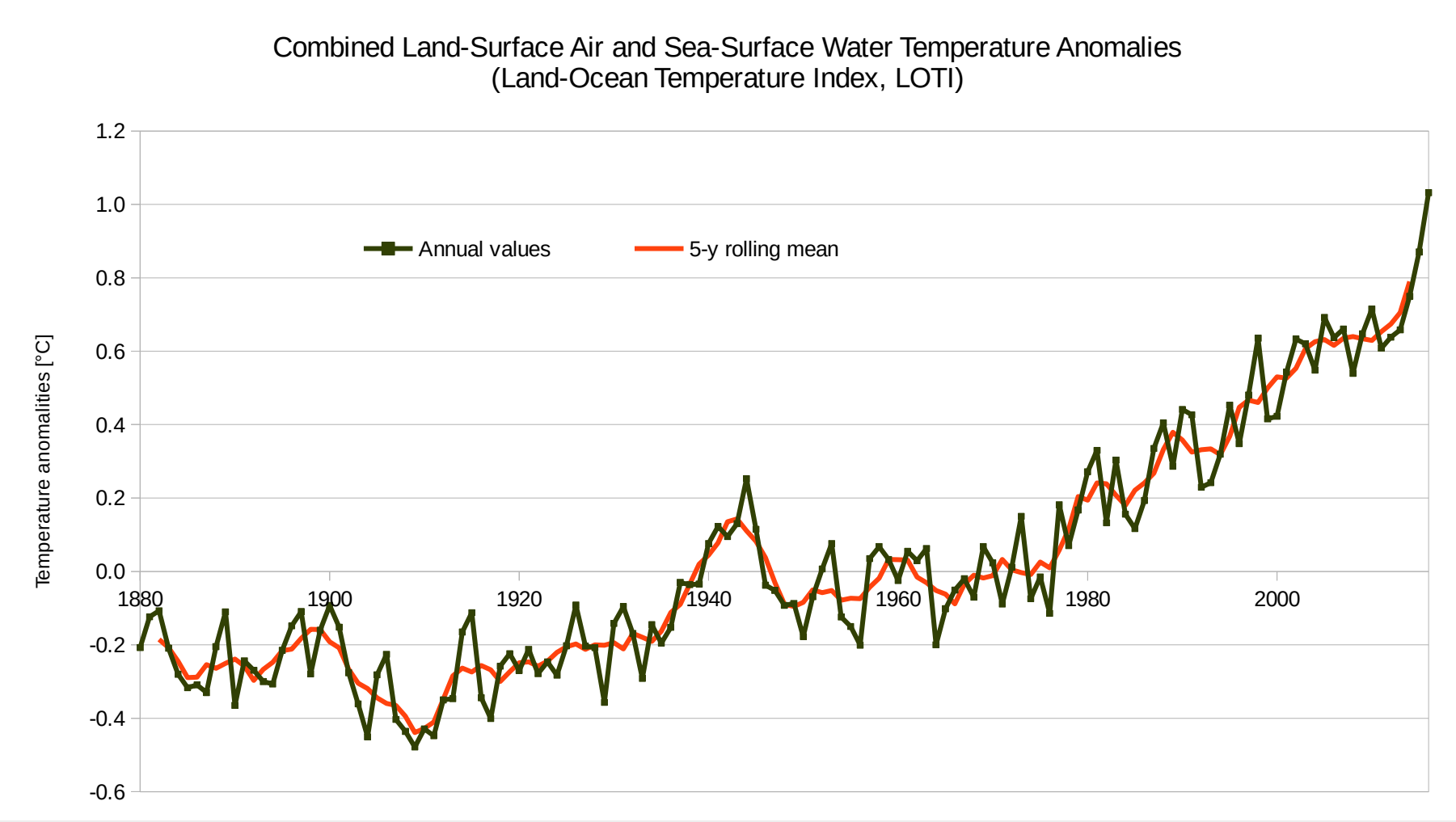




# Climate change

- introduction

## Global Annual Mean Surface Air Temperature Change

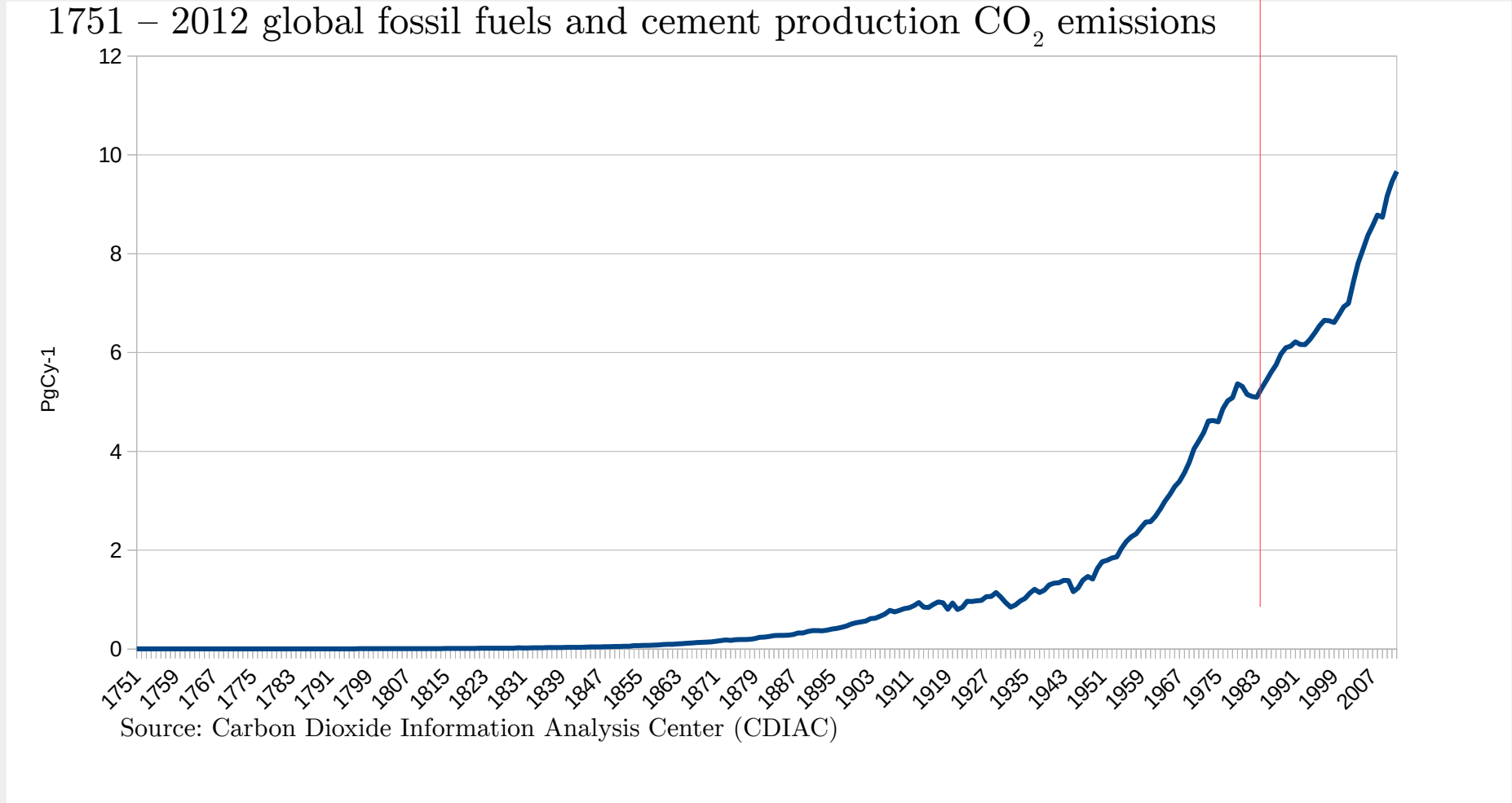


Source: NASA GISS Surface Temperature Analysis



# Climate change

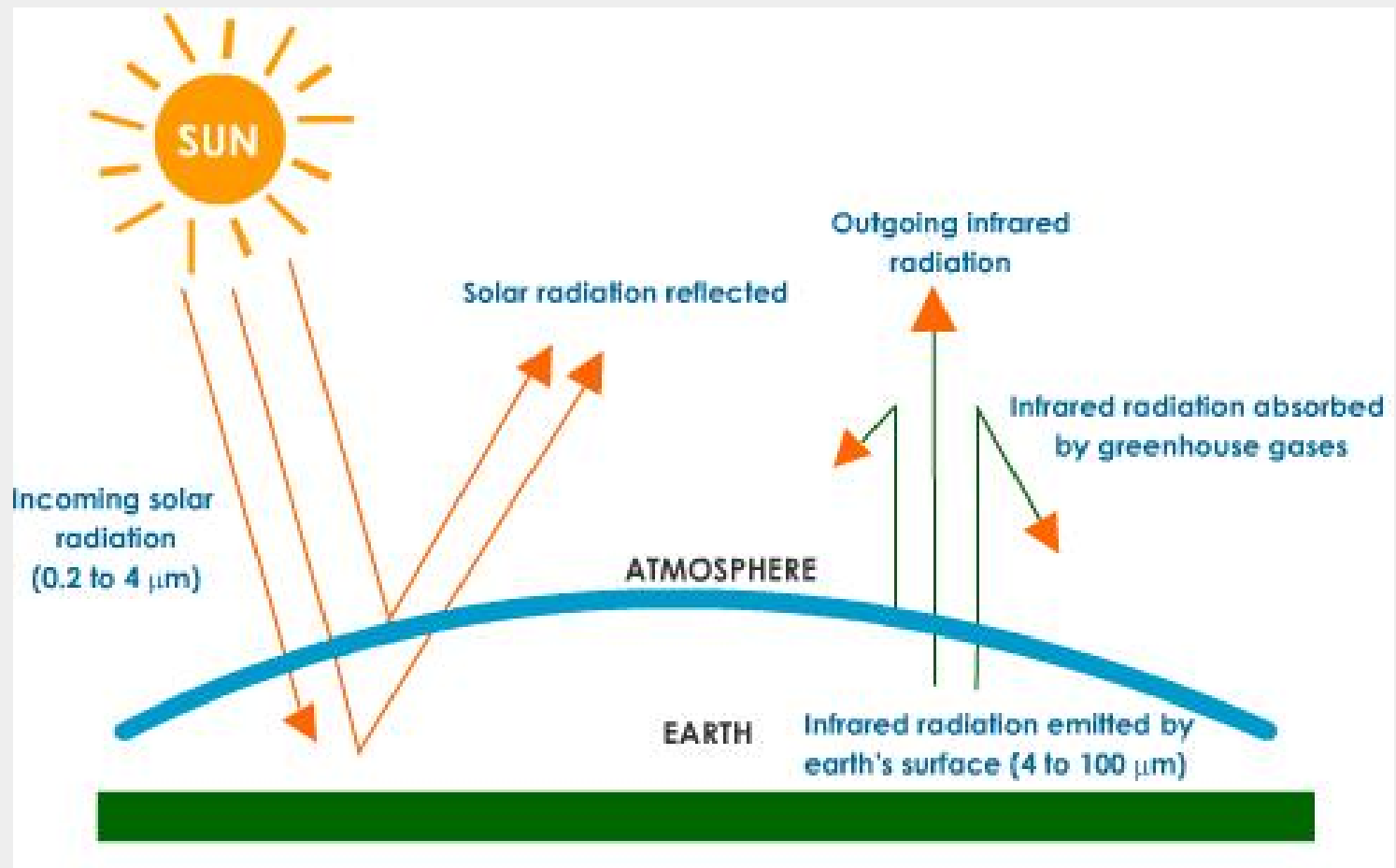
- introduction





# Climate change

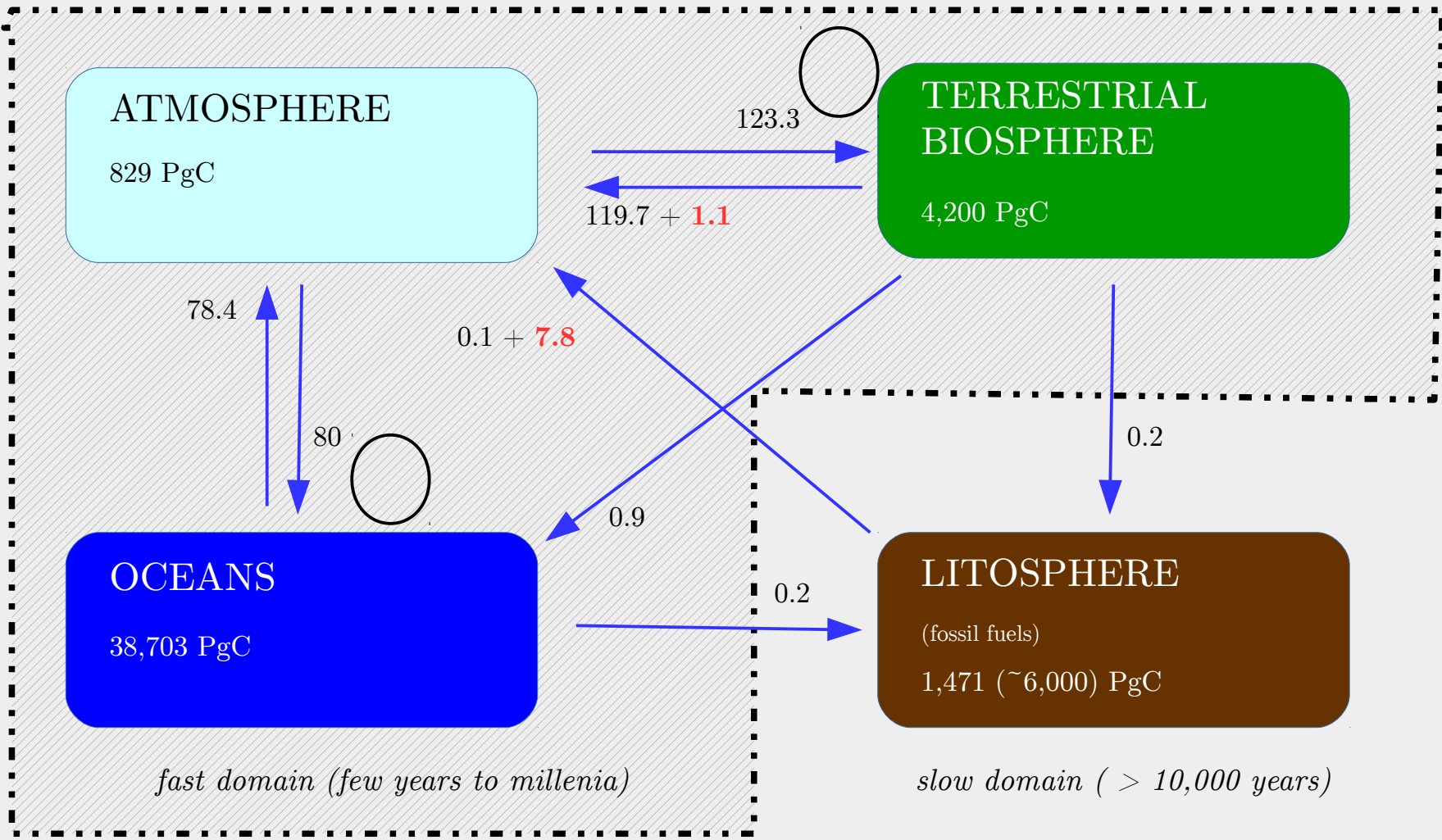
- introduction





# Climate change

- forest mitigation potential



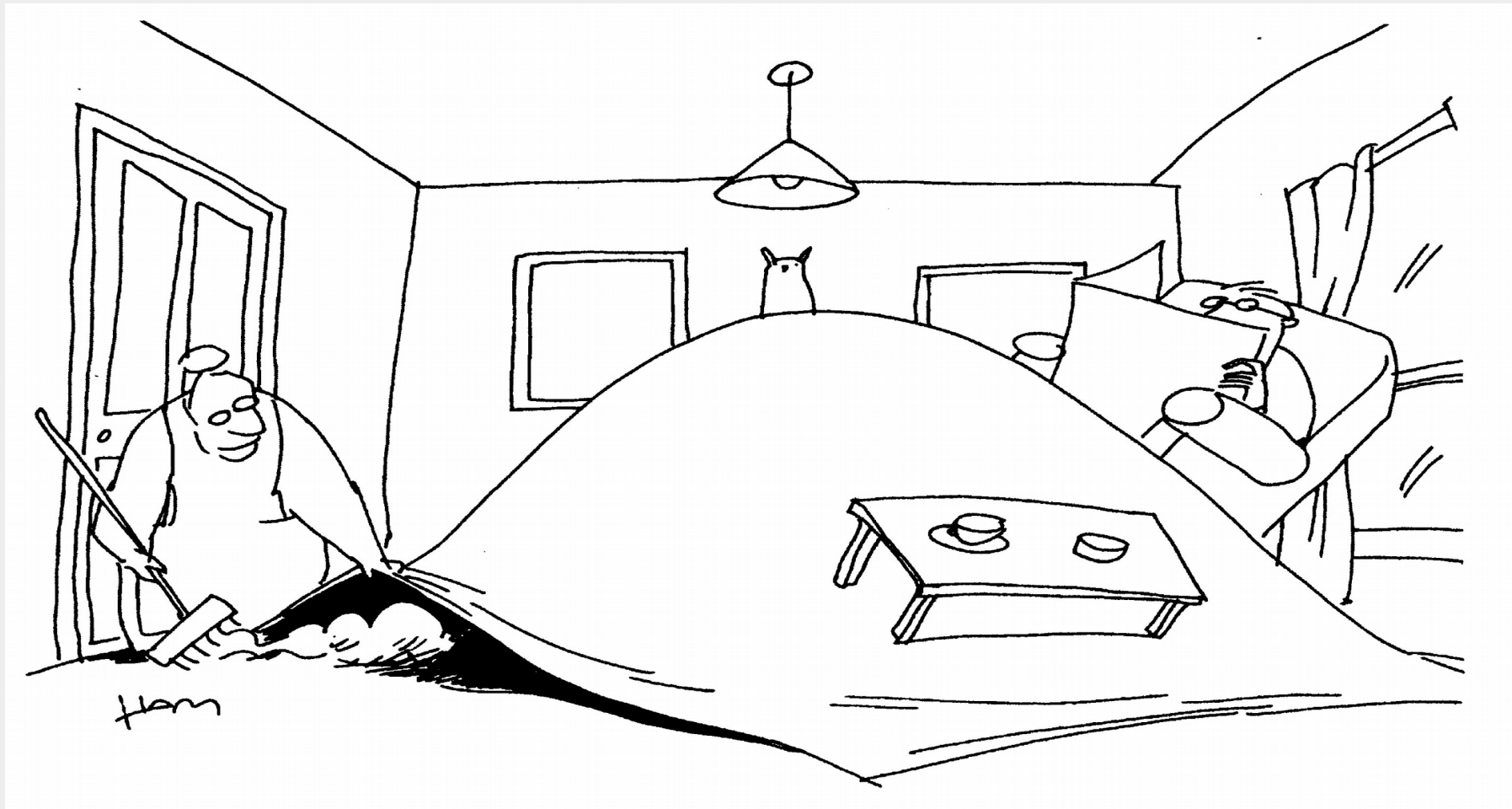
Source: Lobianco et al. (2016), adapted from Ciais and Sabine (2013)



# 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*

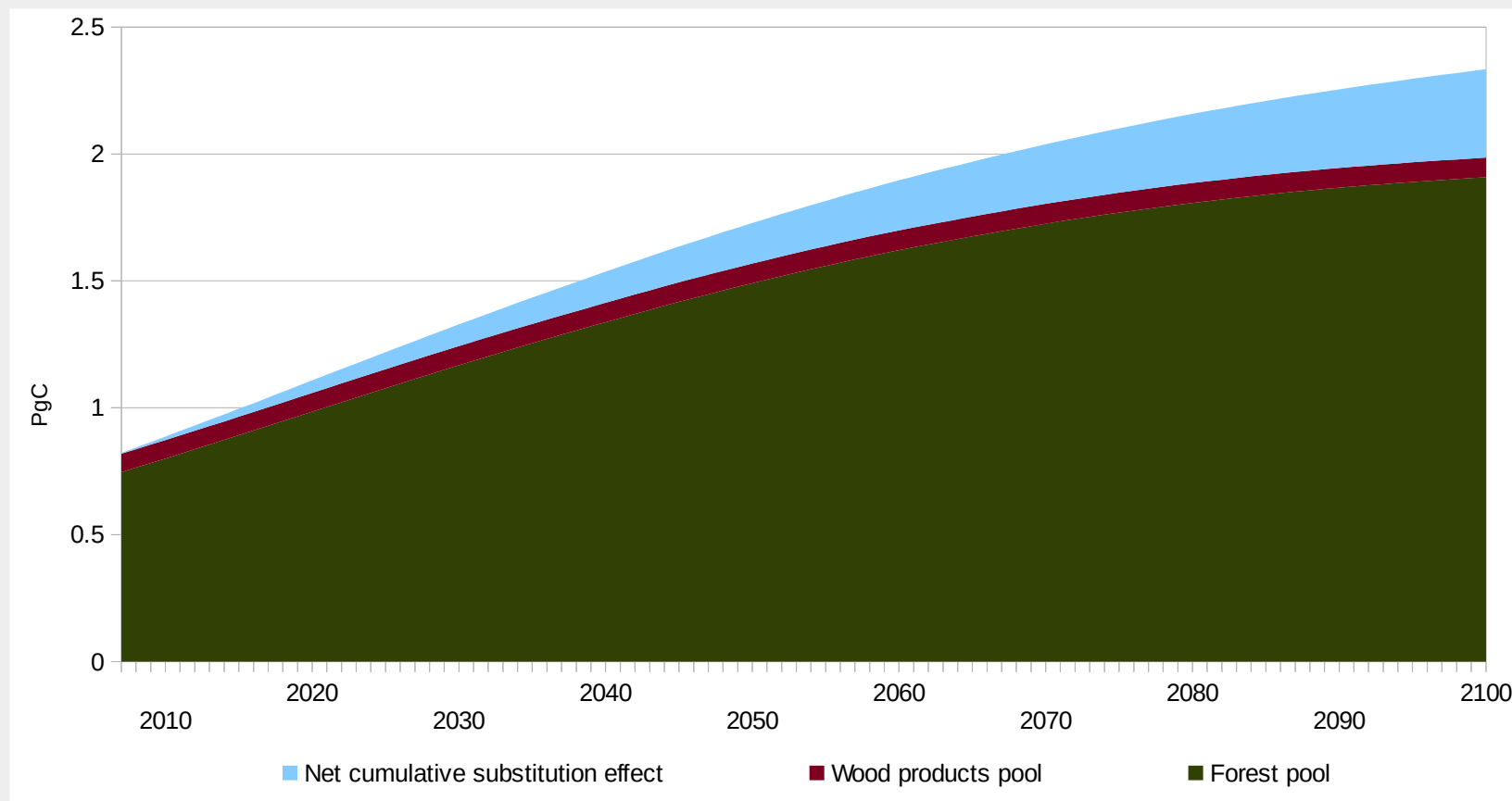




# Climate change

- forest mitigation potential

## Simulation of carbon stocks in the French forests



There is large scientific evidence that the pool is becoming saturated – hence it will be less able in the future to absorb additional CO<sub>2</sub> from the atmosphere

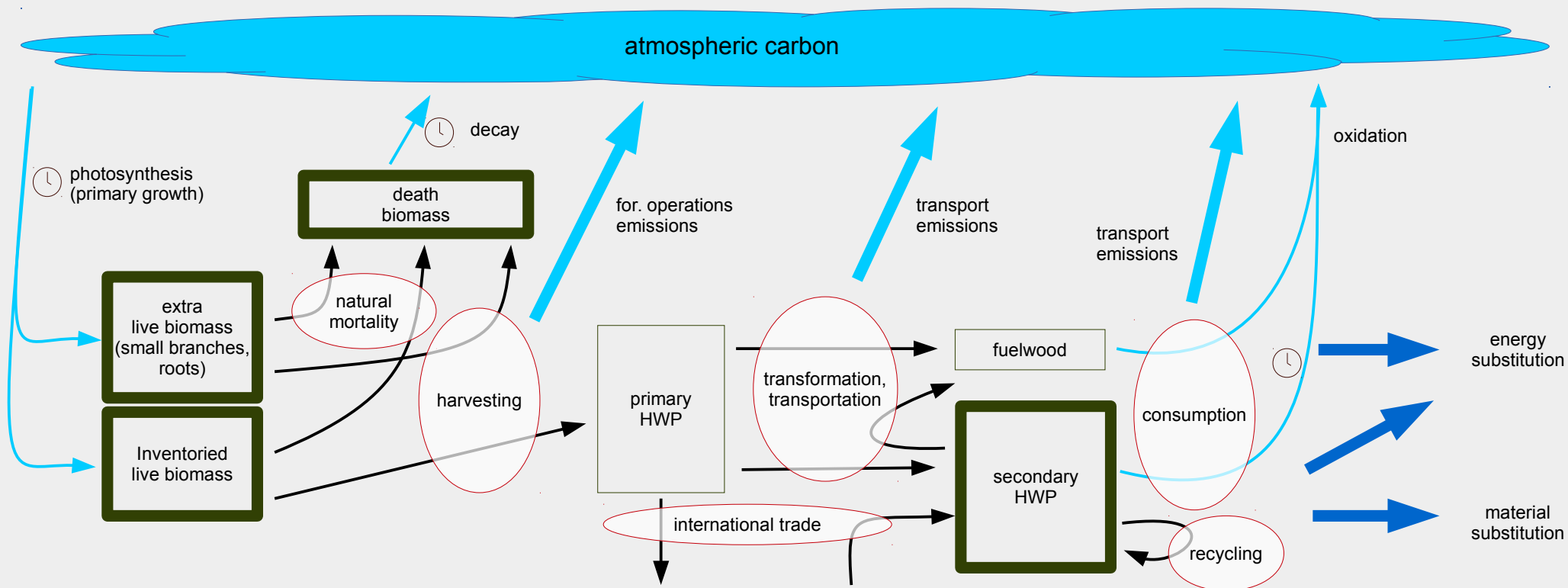




# Climate change

## - FFSM carbon module

- **Carbon module:** “registers and accounts” forest and forest sector carbon emitted/sequestered/substituted;



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



# Contacts

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