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."

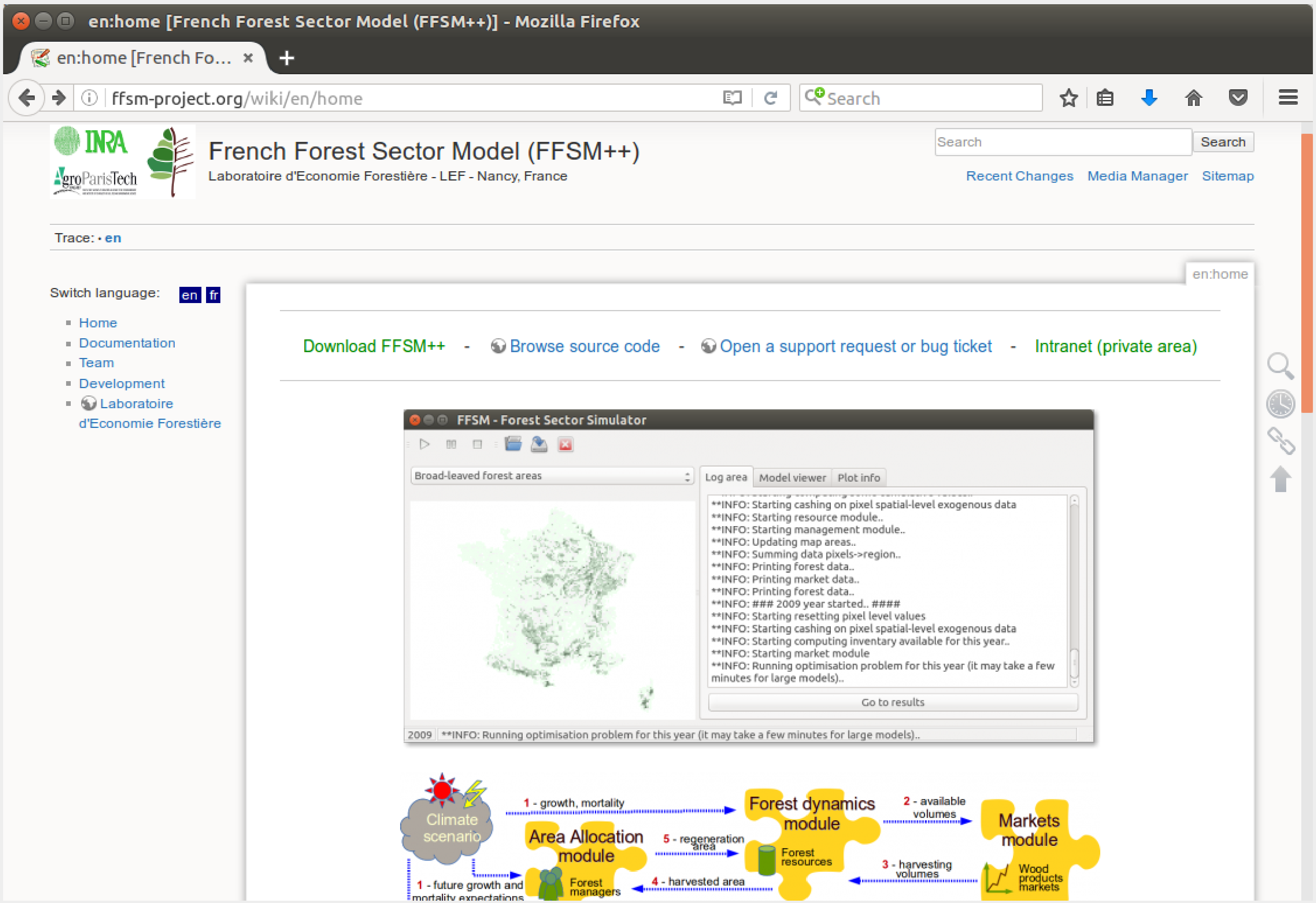
-- Theodore Roosevelt (26th President of the United States from 1901 to 1909, naturalist and Nobel Peace Prize winner)

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)



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

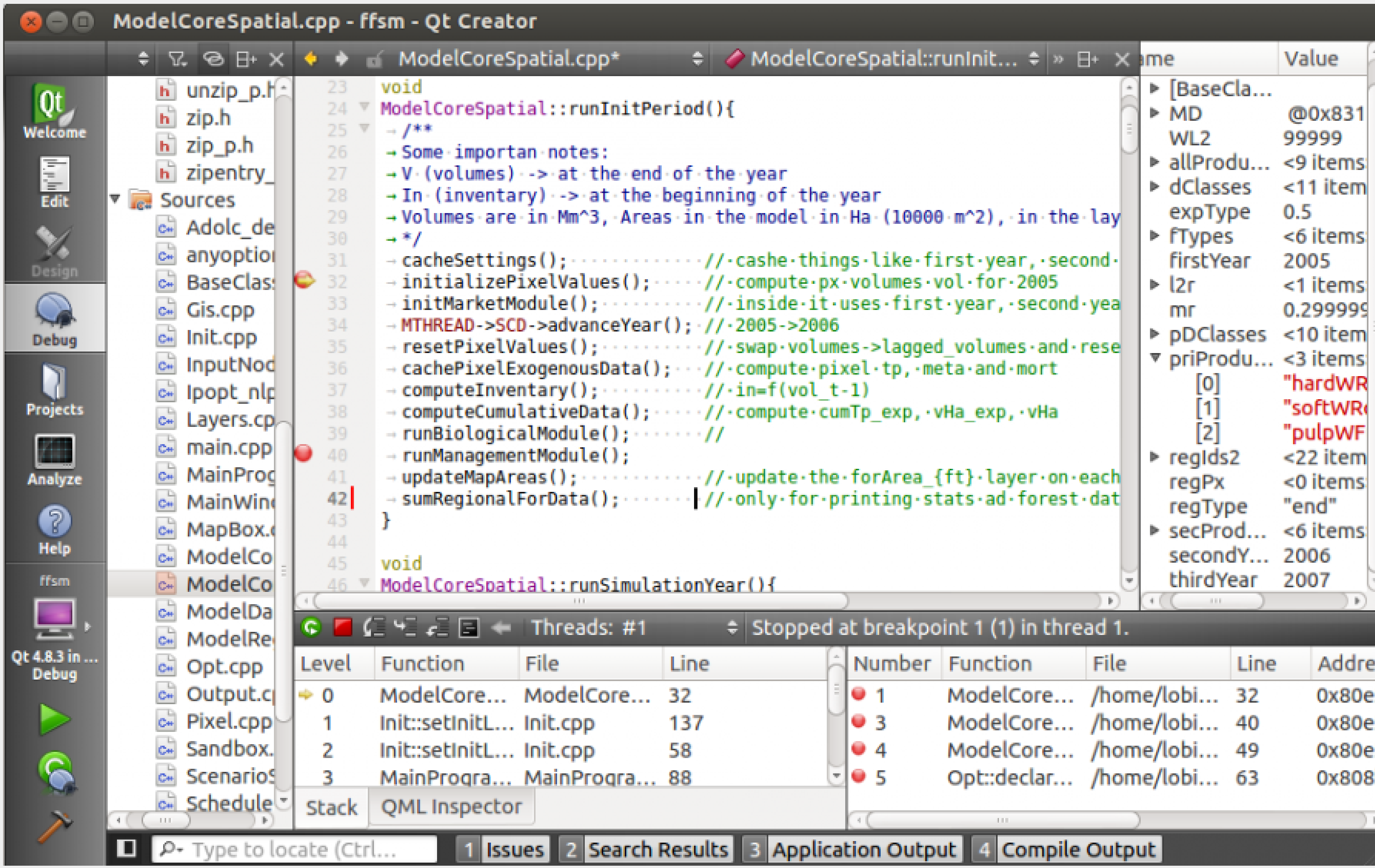
Past members

- 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)

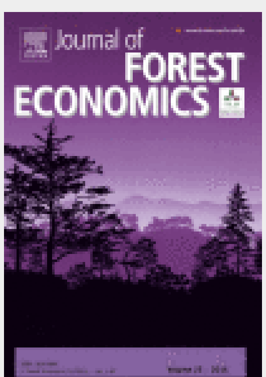
FFSM++ development

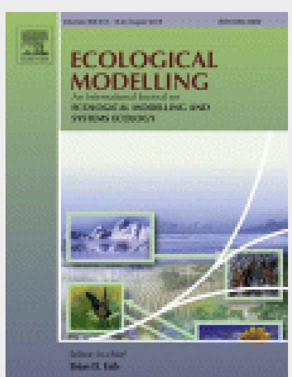


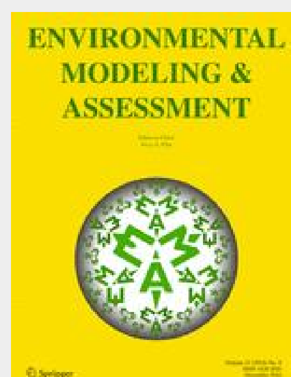
Uses

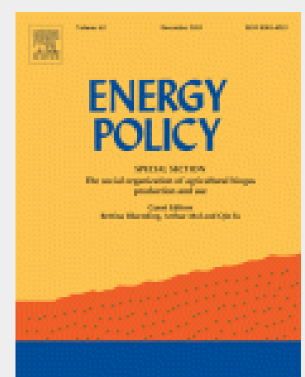
FFSM has bee used for a wide range of analysis, of both positive and normative nature:

- 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 ?



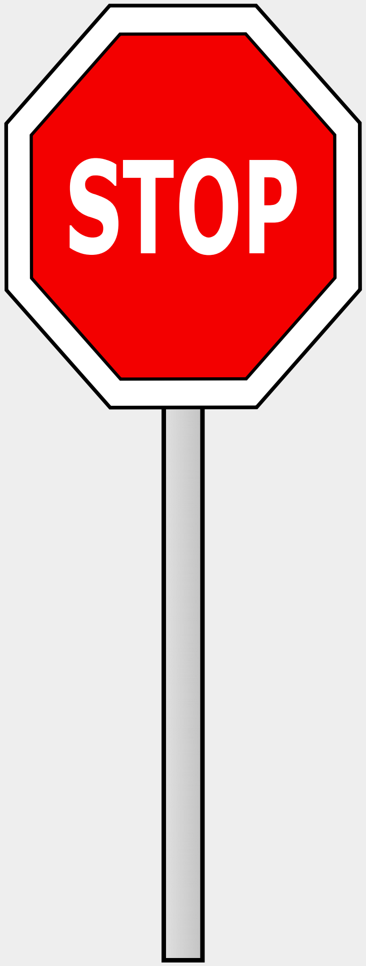


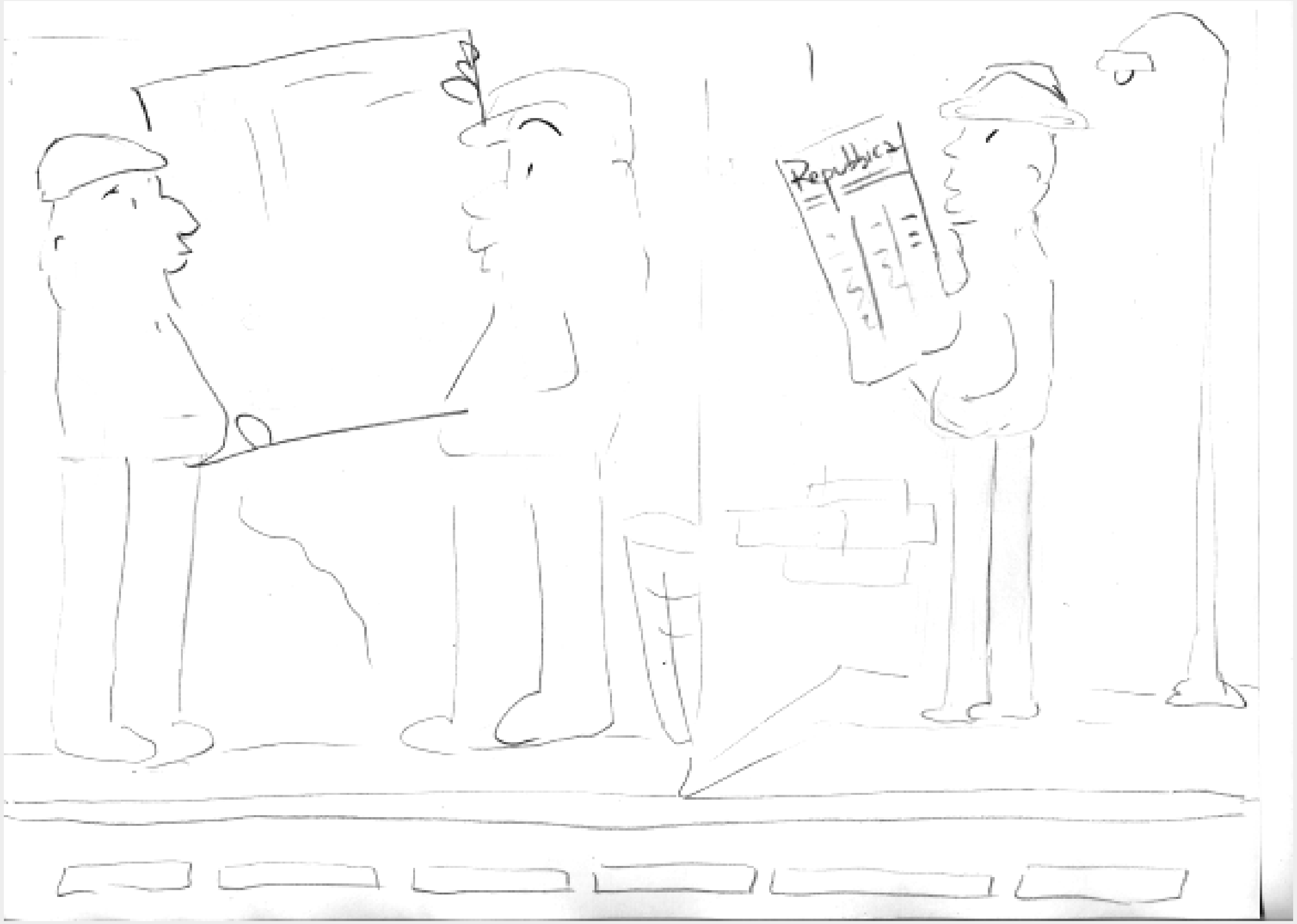




Ok, we developed a model.. but what is a *model* ??

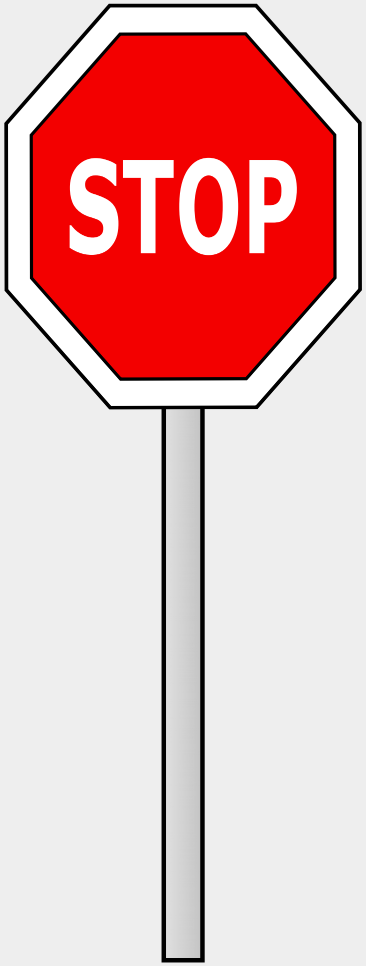
Reality $\rightarrow$ model $\rightarrow$ math. form.

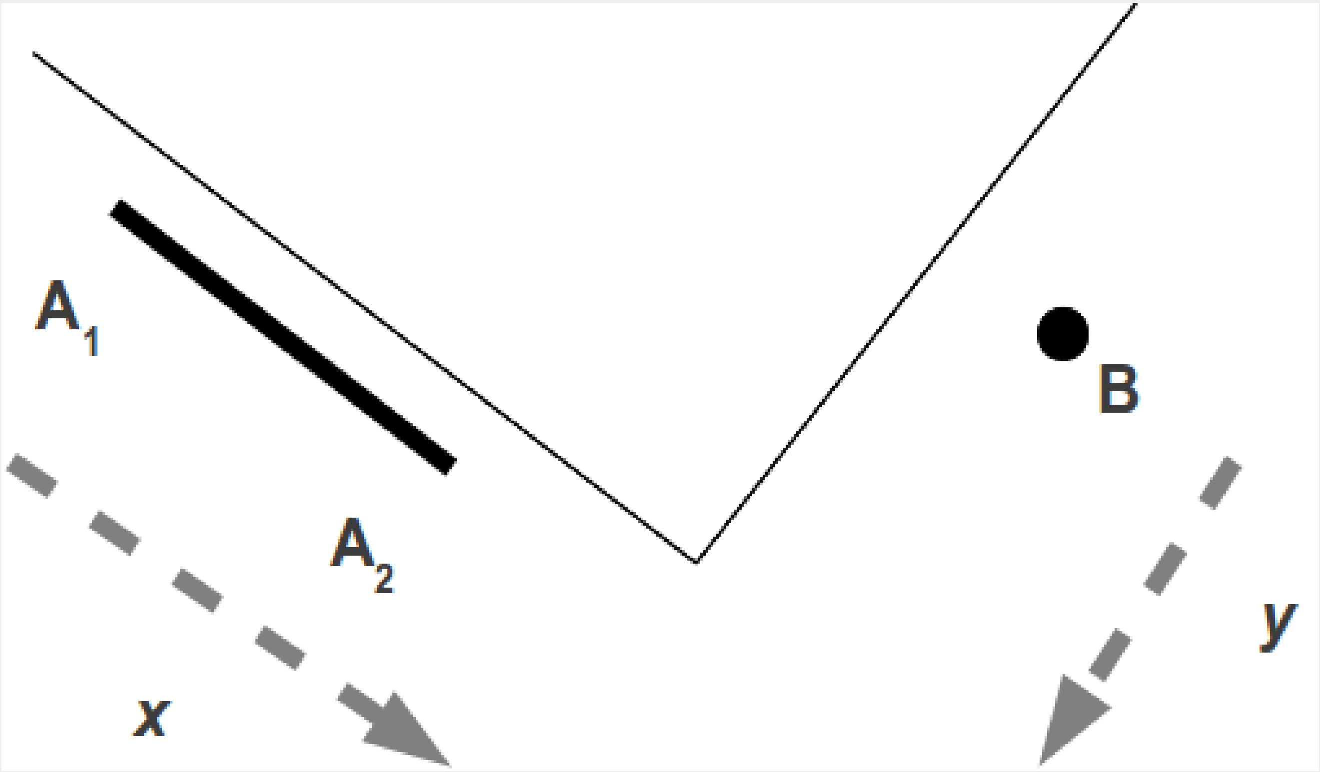




Ok, we developed a model.. but what is a *model* ??

Reality → <u>model</u> → math. form.

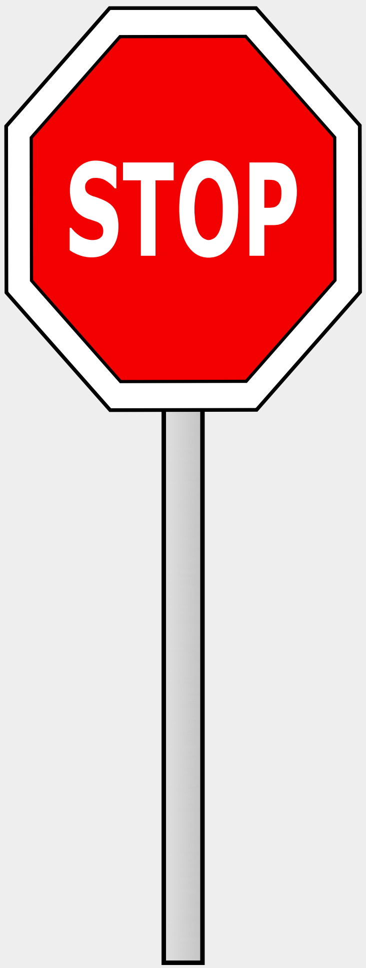




A model is useful if it helps us to predict something, in this case if a crash will happen.

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

Reality → model → <u>math. form.</u>



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

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

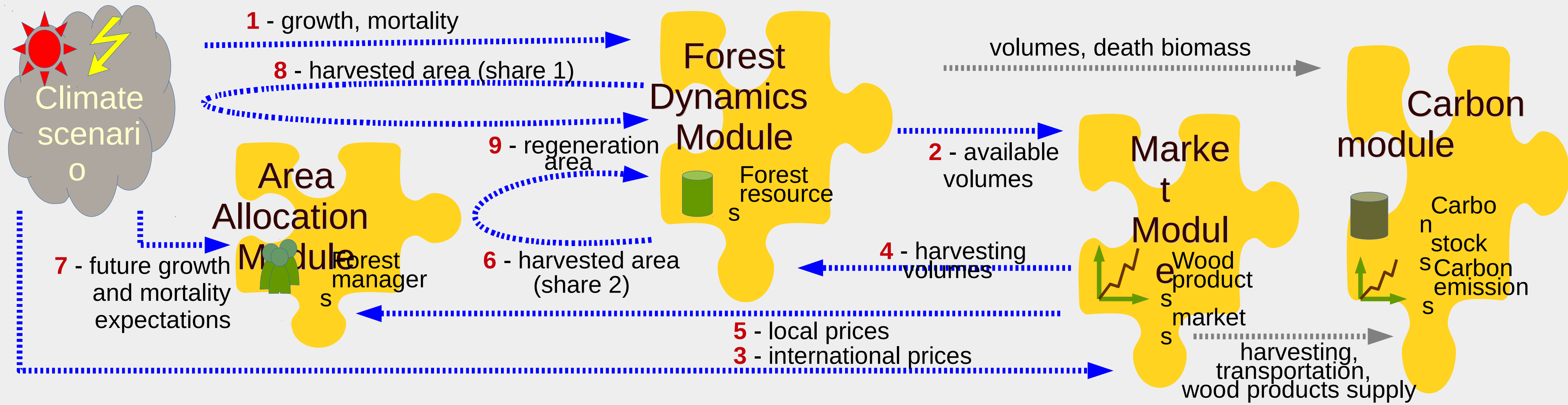
$$t_B=\frac{x_B}{v_B}$$

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

```
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

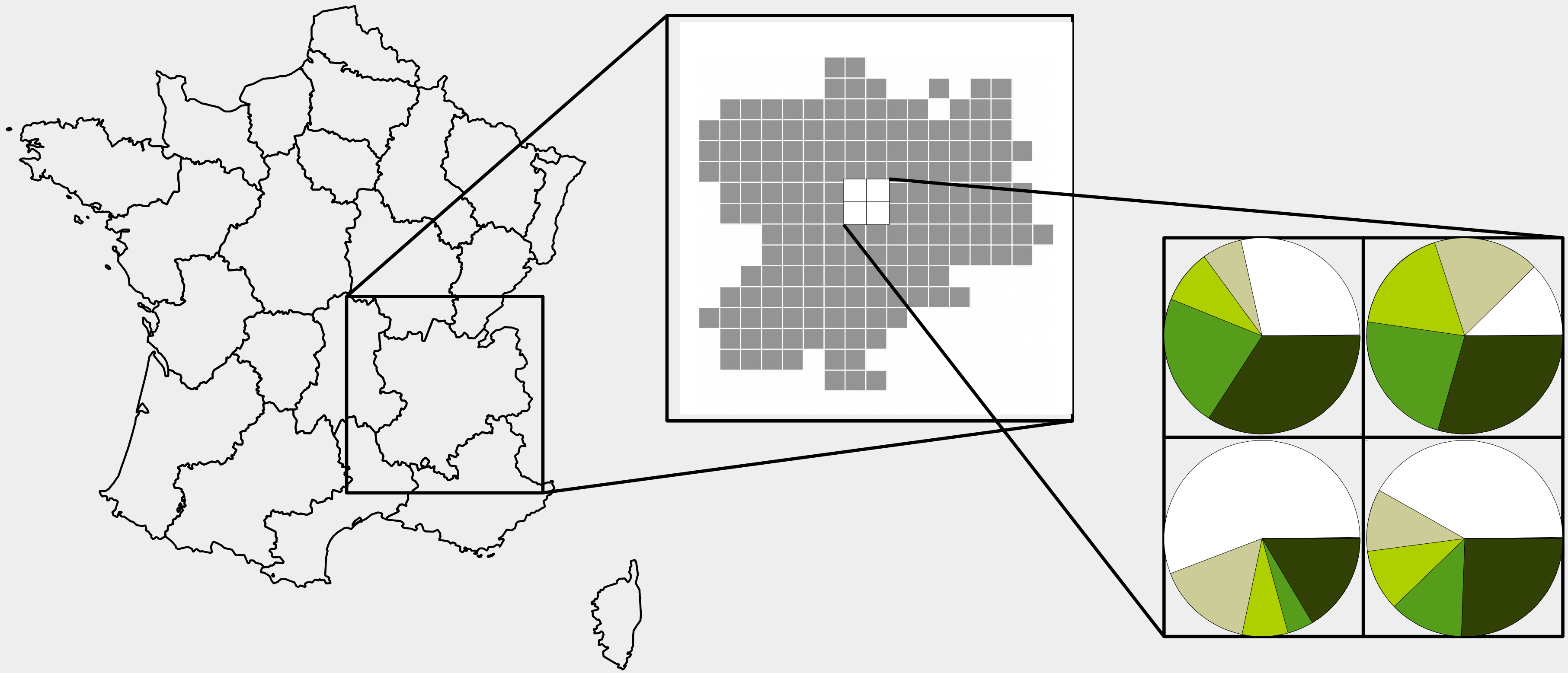


Recursive bio-economic model with coupled biological forest growth model and partial equilibrium market of forest products.

Four interconnected modules:

Forest dynamics module:	model forest resources
Market module:	HWP markets (supply, demand, trade..)
Area allocation module:	forest investment choises
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

Forest	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.
Other wooded land	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.
Other land with tree cover	All land that is **not** classified as forest or other wooded land is called '*other land*'. Of this, '*other land with tree cover*' 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	Type %			Oth. wooded land	Wooded land		
	1000ha	Primary	Nat. reg.	Plantation	1000ha	% land area	ha cap.	% world
Africa	624,103	*21.6*	*71.5*	*2.6*	367,041	*33.2*	0.86	*19.0*
- 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*
Asia	593,362	*19.8*	*58.1*	*21.7*	234,729	*26.6*	0.19	*15.9*
- east	257,047	*12.9*	*51.3*	*35.7*	108,762	*31.6*	0.23	*7.0*
- south & south-easth	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*
Europe	1,015,482	*27.3*	*64.0*	*8.1*	100,014	*50.4*	1.51	*21.4*
- 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*
North and central Am.	750,653	*42.6*	*51.6*	*5.8*	89,049	*39.3*	1.48	*16.1*
- 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*
Oceania	173,524	*15.5*	*81.7*	*2.5*	257,208	*50.7*	10.96	*8.3*
South America	842,011	*47.6*	*43.7*	*1.8*	156,429	*57.2*	2.42	*19.2*
World	3,999,134	*31.9*	*58.5*	*7.2*	1,204,471	*39.9*	0.72	100.0

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
Africa	-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
Asia	-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-easth	-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
Europe	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
North and central Am.	-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
Oceania	0.4	-0.6	-2.5	141.5	0.5	-0.7	-2.5	0.9	-2.6	-0.5	-0.7	3953.7
South America	-3.8	-2.0	-1.6	-1.0	-4.3	-2.5	-1.9	-1.2	-0.8	1.0	0.4	0.2
World	**-1.9**	**-0.4**	**0.1**	**4.3**	**-1.8**	**-0.5**	**-0.4**	**-0.4**	**-2.5**	**-0.1**	**2.1**	**23.6**

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
Africa	-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
Asia	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-easth	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
Europe	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
North and central Am.	-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
Oceania	-16.6	16.8	-9.1	-9.3	0.2	355.3	-2.7	0.8	26.0	15.1	5.9	3.1
South America	-3.7	-1.8	10.9	-0.8	-4.5	-2.6	3.5	-1.4	20.7	9.4	25.1	13.2
World	**3.3**	**-0.5**	**4.2**	**-0.9**	**0.5**	**2.5**	**0.3**	**-0.9**	**23.9**	**14.8**	**10.7**	**4.5**

Source: FAO FRA 2015

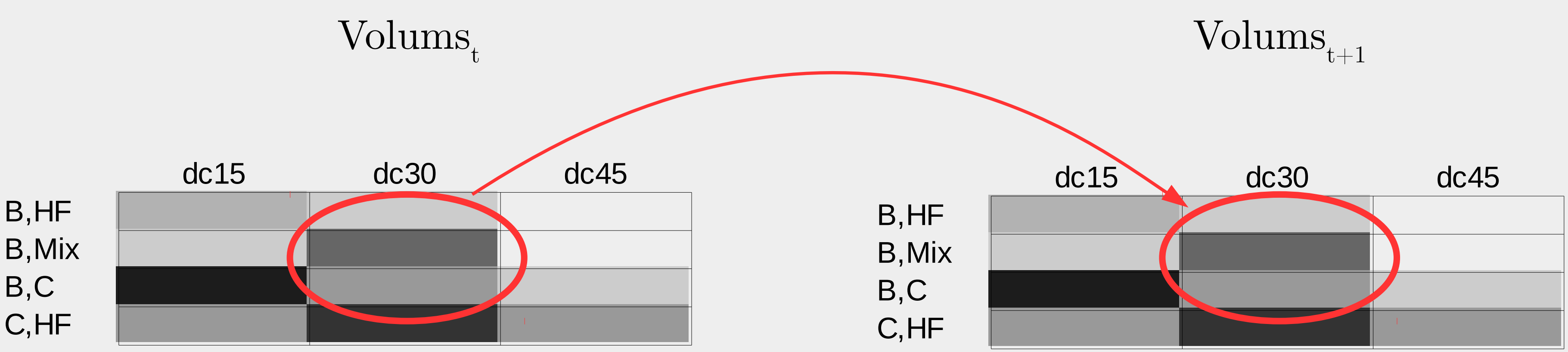
- a

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:

$$\begin{aligned} Vol_{dc,t} = {} & (1-1/timeOfPassage_{dc,t}-mortality_{dc,t}-harvestedRate_{dc,t})*Vol_{dc,t-1} \\ & +(1/timeOfPassage_{dc-1,t-1})*beta_{dc}*Vol_{dc-1,t-1} \end{aligned}$$



Forest resources

- modelling CC effect on forest resources

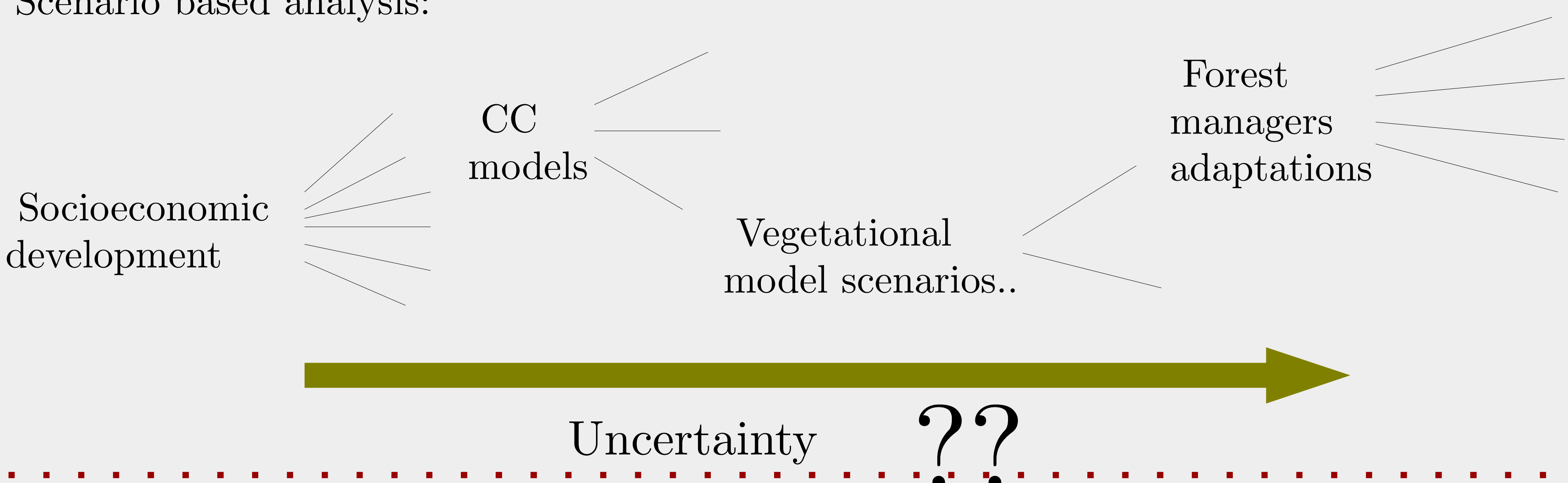
CC effects on the forest dynamics are exogenous to FFSM. Conversely, consequences on the management of the forest are explicitly accounted for.

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: $mort_{sc,px,ft,dc,t} = mort_{r,ft,dc,t=0} * mort_{sc,px,ft,t}$

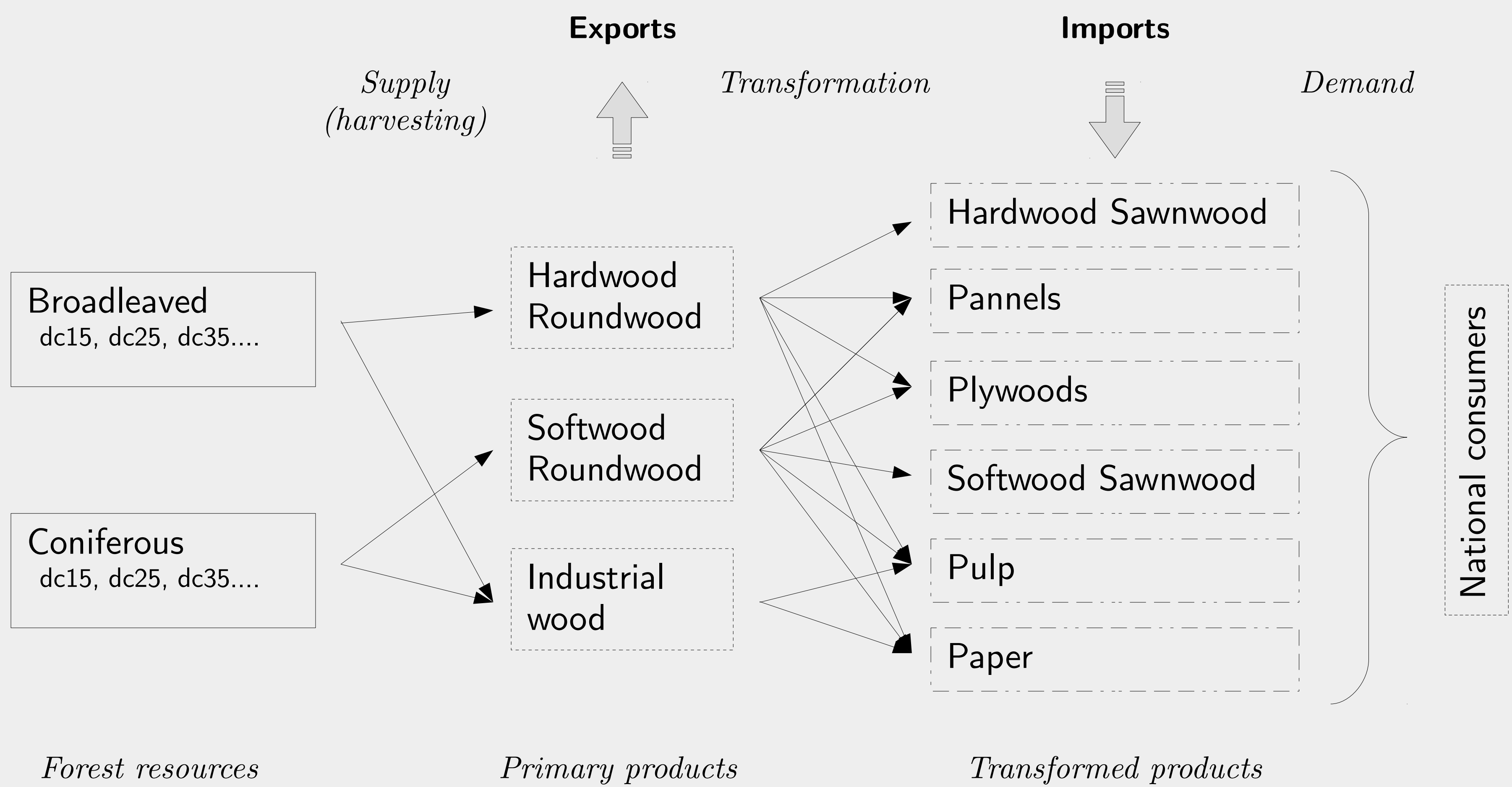
An exogenous parameter allows the model to consider (again, exogenously) land use changes with reference to the forest ($forestChangeAreaIncrementsRel_{sc,r,t}$ or $forestChangeAreaIncrementsHa_{sc,r,t}$)

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:

$$\frac{supply_{r,pp,t}}{supply_{r,pp,t-1}} = \left(\frac{P_{r,pp,t}}{P_{r,pp,t-1}}\right)^{eSP_{pp}} \left(\frac{inv_{r,pp,t}}{inv_{r,pp,t-1}}\right)^{eSI_{pp}}$$

Demand

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

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

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 it 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.

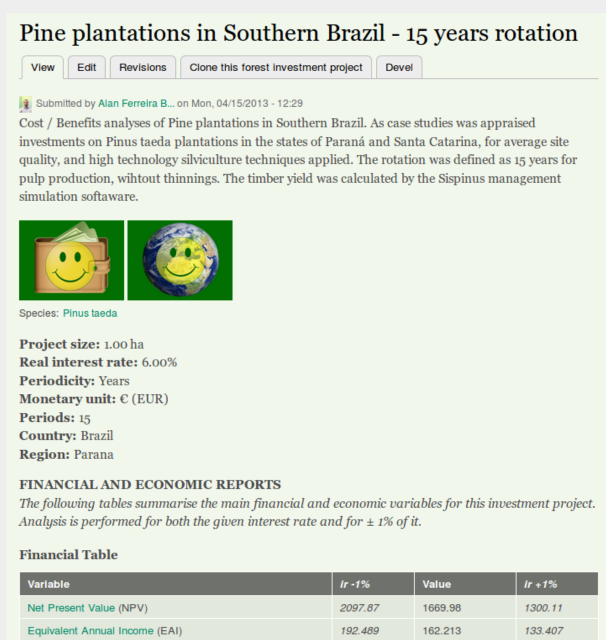
Differently from the NPV, it allows to compare forest investments of different duration.

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

View | Edit | Revisions | Clone this forest investment project | Devel

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, wihtout thinnings. The timber yield was calculated by the Sispinus management simulation softaware.

Species: Pinus taeda

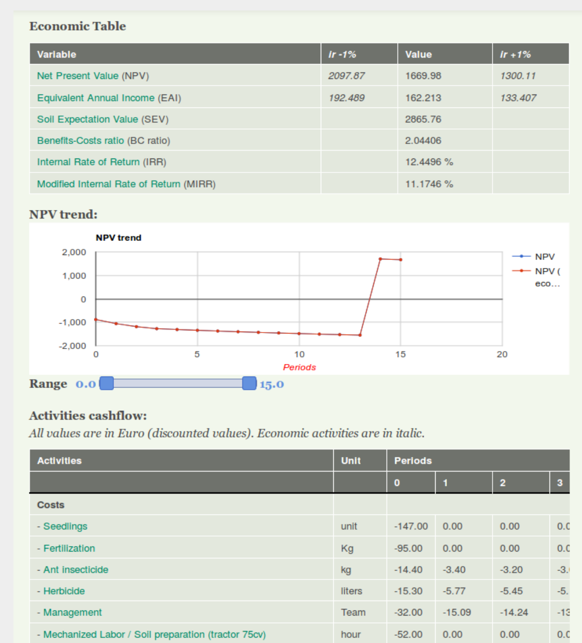
Project size: 1.00 ha
Real interest rate: 6.00%
Periodicity: Years
Monetary unit: € (EUR)
Periods: 15
Country: Brazil
Region: Parana

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.

Financial 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*



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:

Activities cashflow:

All values are in Euro (discounted values). Economic activities are in italic.

Activities	Unit	Periods			
		0	1	2	3
Costs					
- Seedlings	unit	-147.00	0.00	0.00	0.0
- Fertilization	Kg	-95.00	0.00	0.00	0.0
- Ant insecticide	kg	-14.40	-3.40	-3.20	-3.
- Herbicide	liters	-15.30	-5.77	-5.45	-5.
- Management	Team	-32.00	-15.09	-14.24	-13
- Mechanized Labor / Soil preparation (tractor 75cv)	hour	-52.00	0.00	0.00	0.0

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.
- 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:

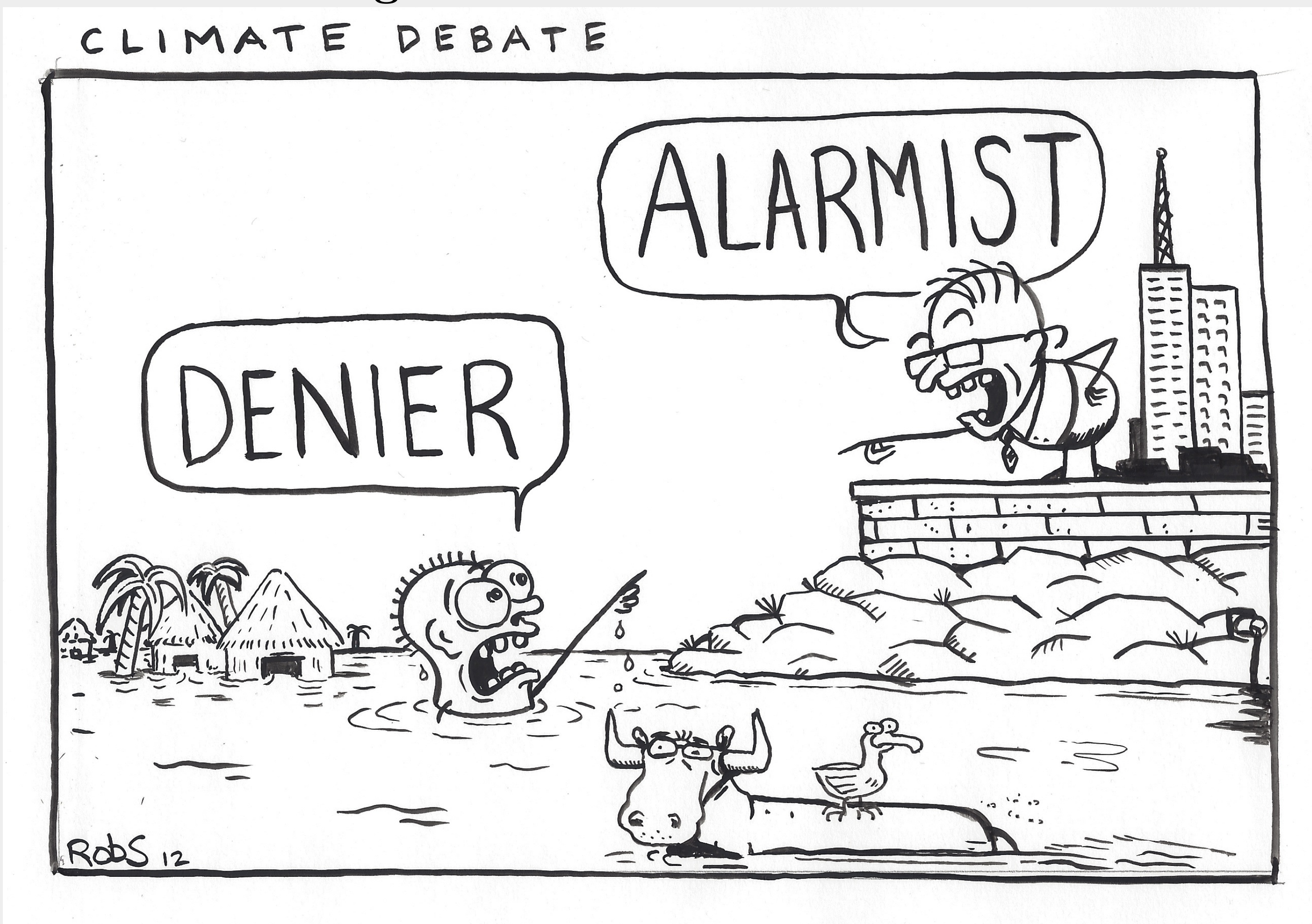
    $$CESEV_{i,j} = SEV_i * (1 - ra_j * cumMort_i)$$

    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)

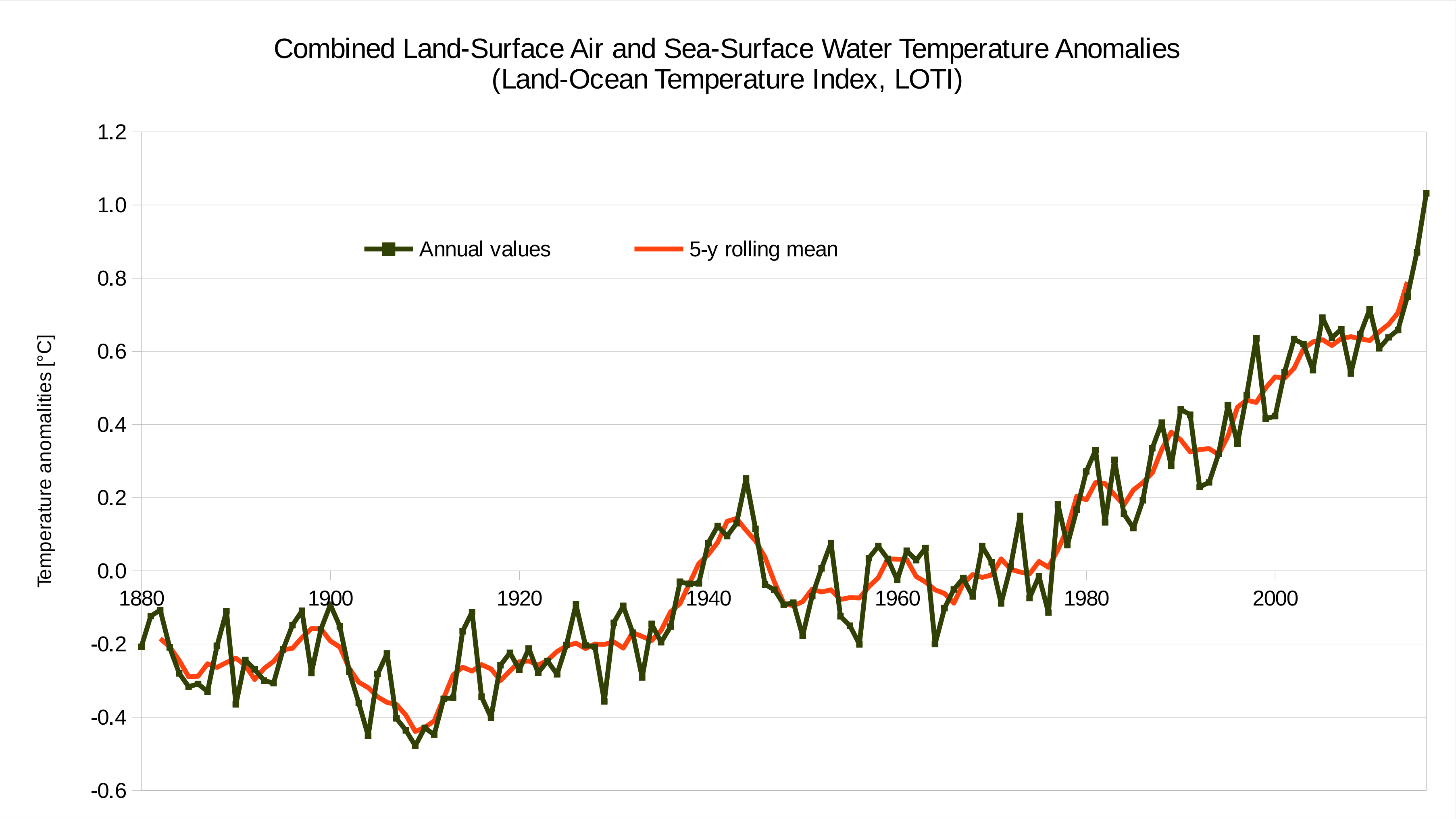
Heterogeneous expectations are important as.. **we don't all have the same opinion about climate change !**



Climate change

- introduction

Global Annual Mean Surface Air Temperature Change

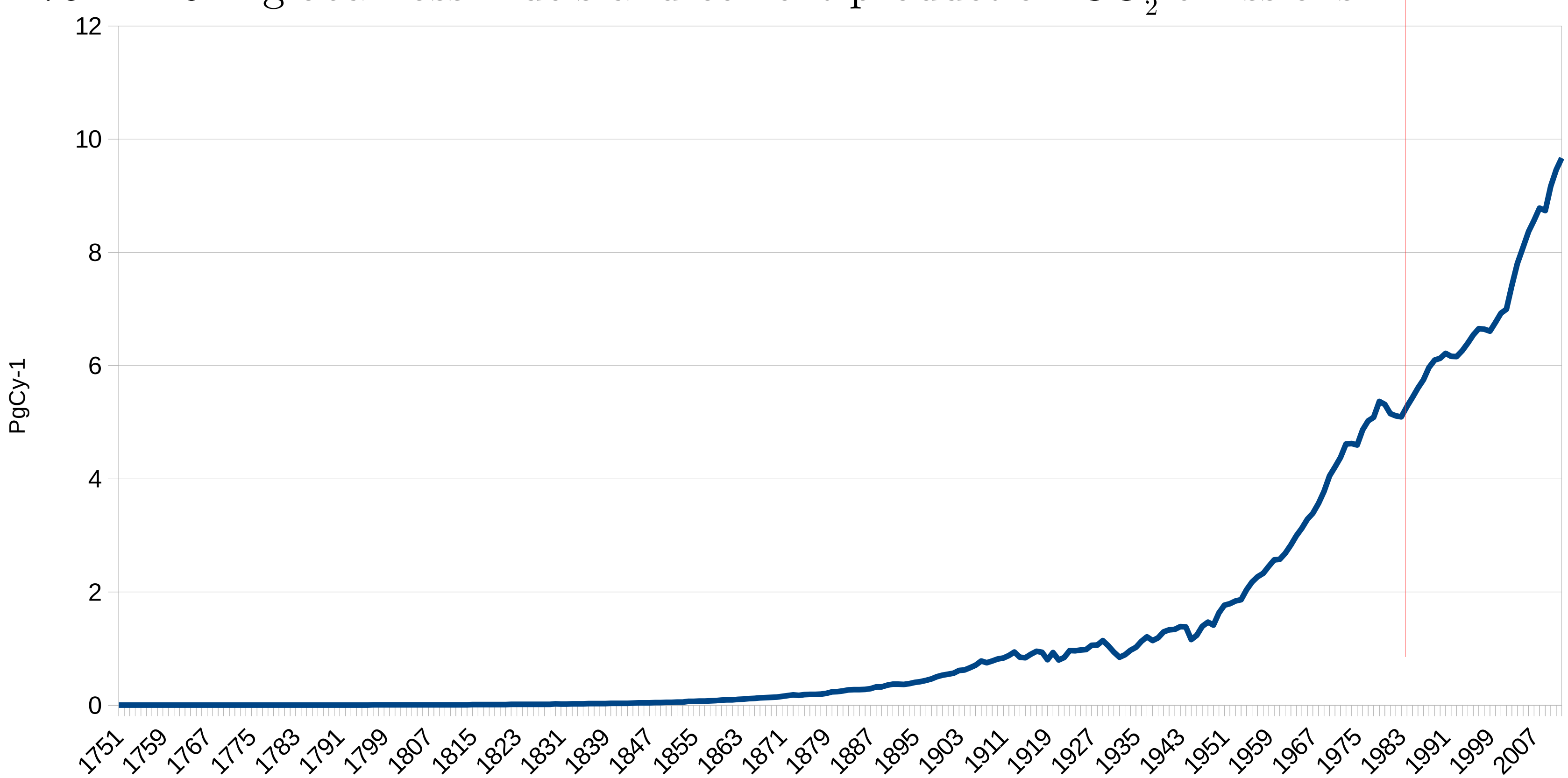


Source: NASA GISS Surface Temperature Analysis

Climate change

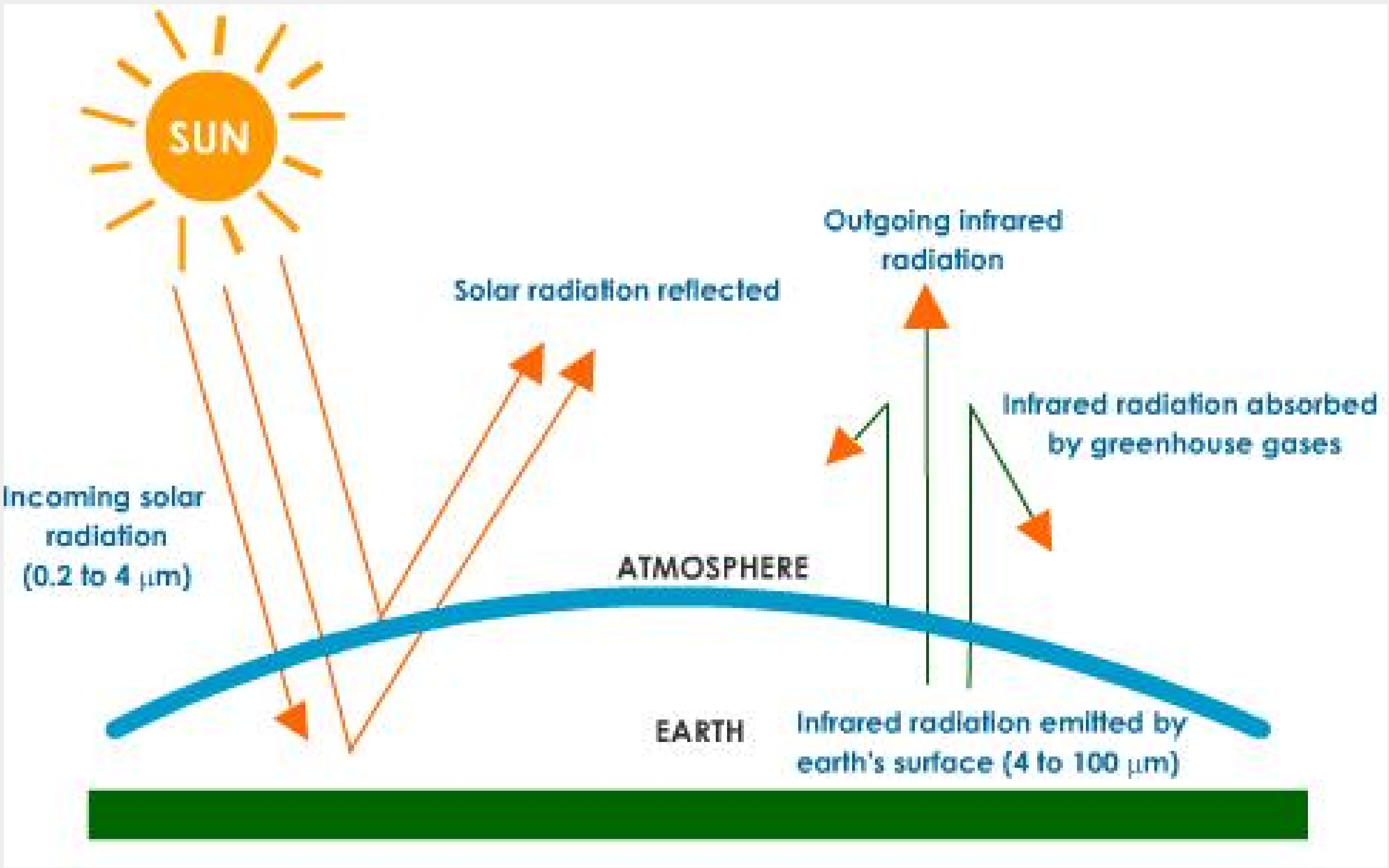
- introduction

1751 – 2012 global fossil fuels and cement production CO_2 emissions



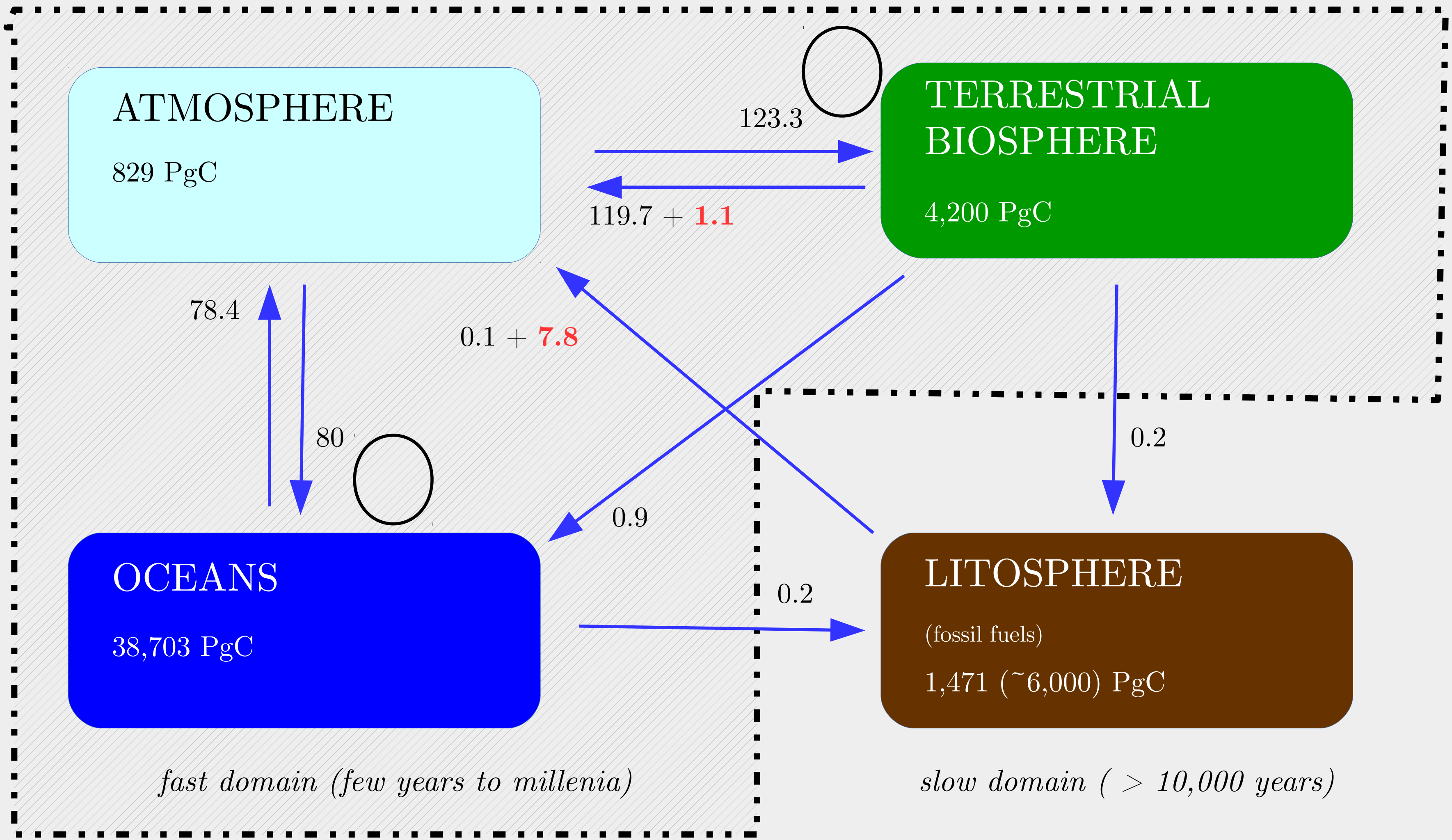
Source: Carbon Dioxide Information Analysis Center (CDIAC)

Climate change
- introduction



Climate change

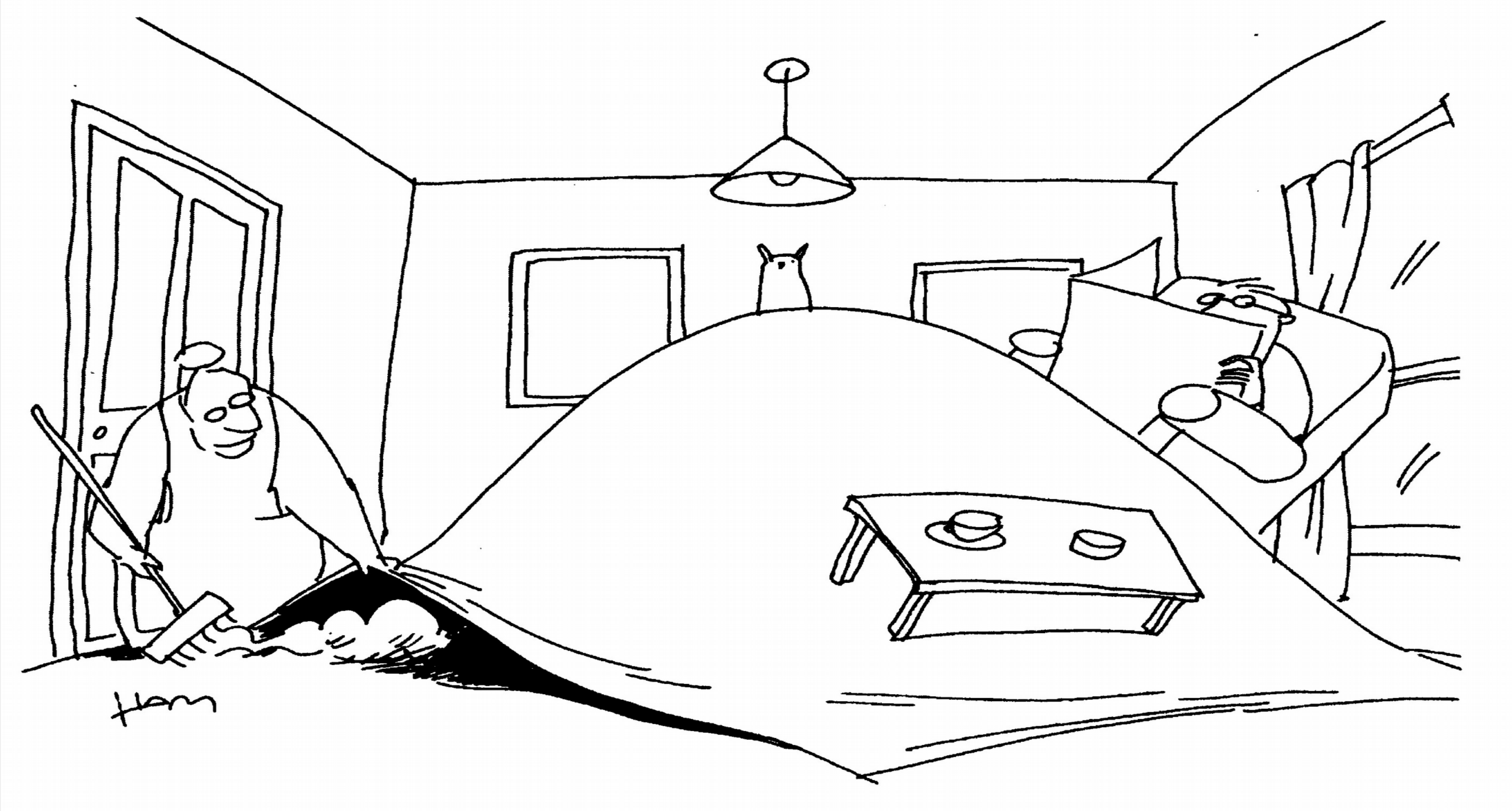
- forest mitigation potential



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

Climate change
- forest mitigation potential

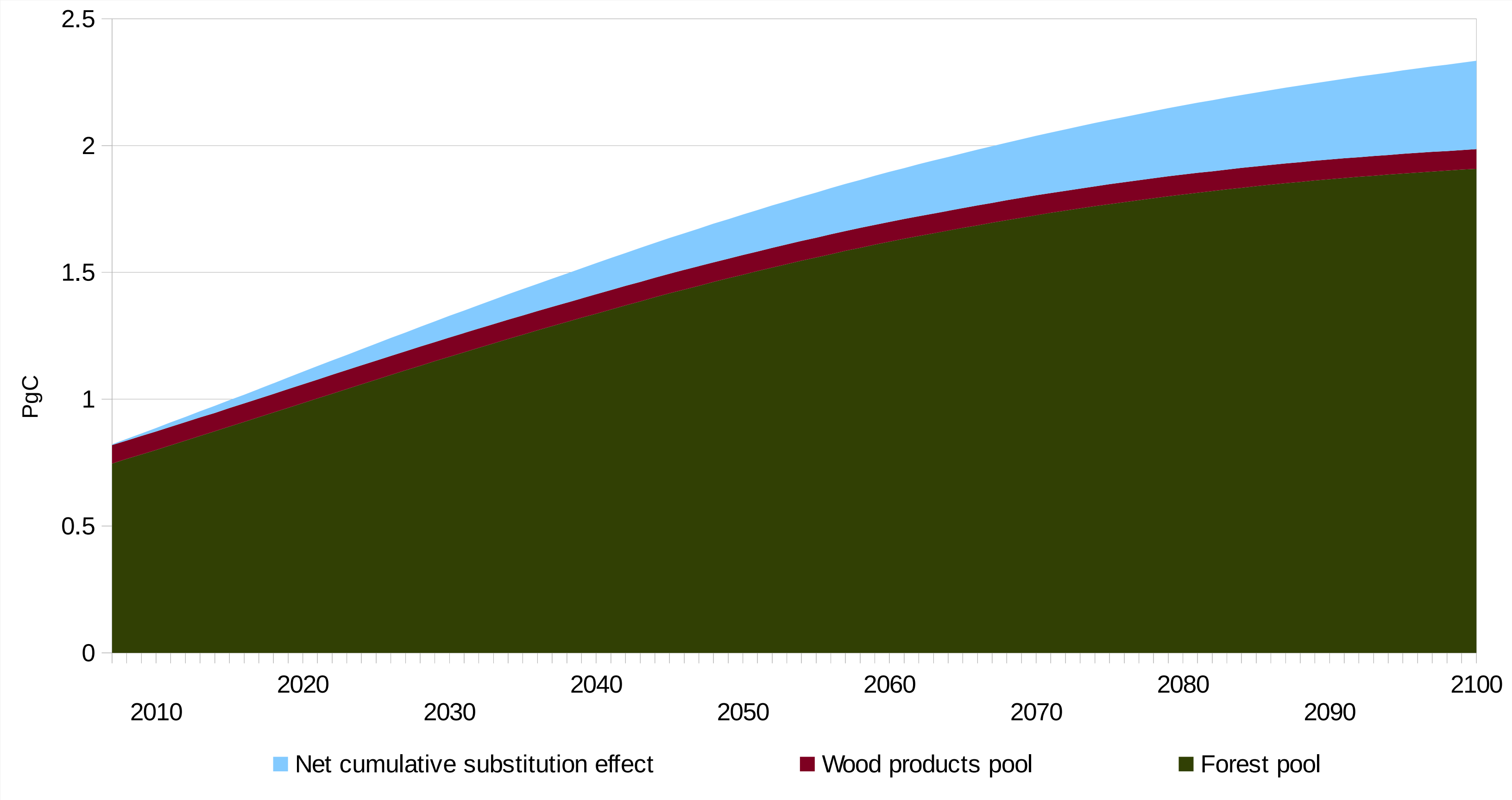
Storing carbon in the terrestrial biosphere, within the fast domain sinks is a bit like ***sweeping the dirt under the carpet***



Climate change

- forest mitigation potential

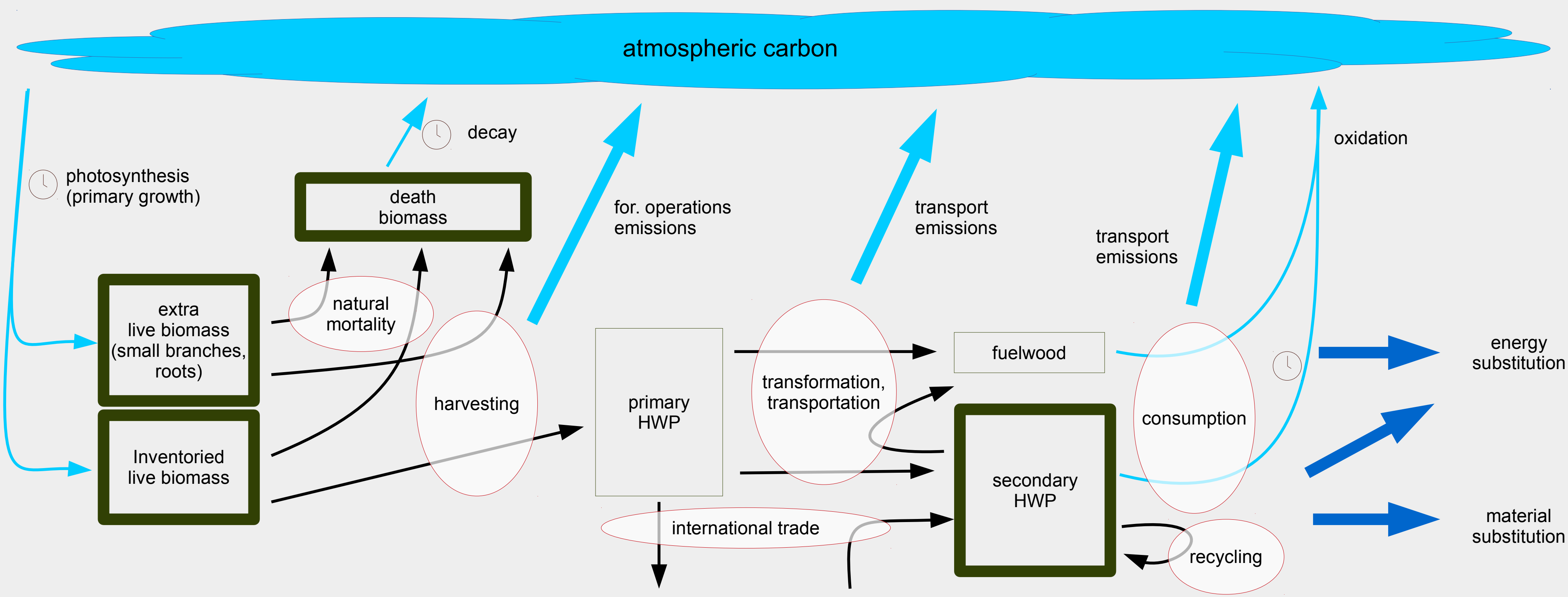
Simulation of carbon stocks in the French forests



There is large scientific evidence that the pool is becoming saturated – hence it will be less able in the future to absorb additional CO2 from the atmosphere

Climate change
- FFSM carbon module

- **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.

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