Accounting for economic drivers in forest modelling: a spatially explicit bio-economic model of the French forest sector

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Objectives

Given the importance of anthropogenic determinants in forest growth within Europe, the objective of this work is to link the evidence arising from biological models of climatically-induced variations in forest ecosystems with socio-economic determinants, where the expected returns of forest investments represent the main drivers.
Hence first an adequate spatial scale is adopted to facilitate models linkage and then a management module is introduced to account for expected climatically-induced variations in forest investments.
With both climate and economic drivers considered we can assess the opportunities and risks for the French Forest Sector, both in terms of adaptation strategies that forest managers may apply as well as in terms of mitigation effects of sequestrated or substituted carbon.

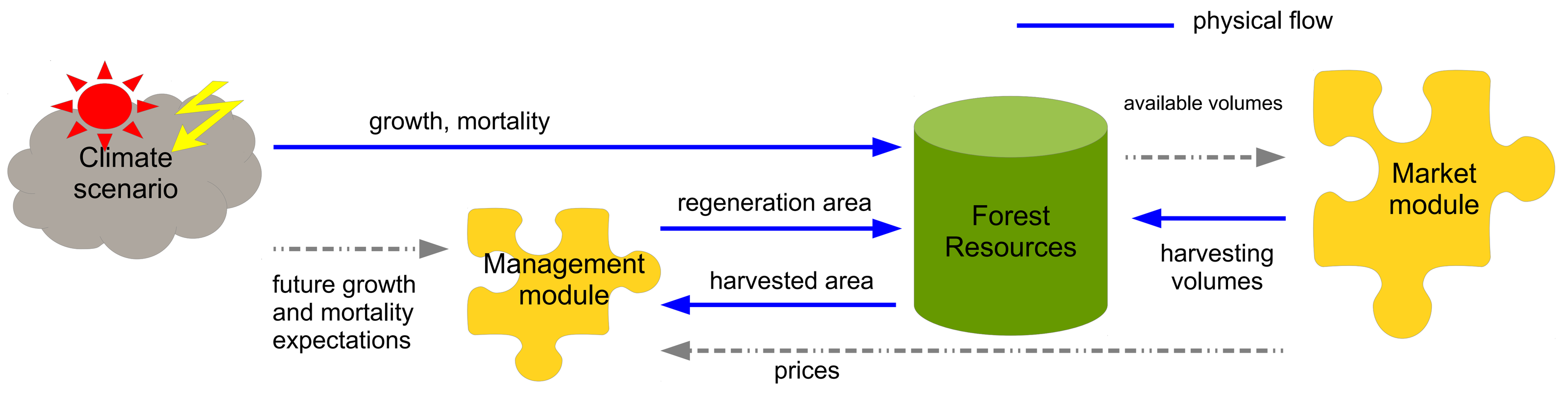
Methods

FFSM++ is a dynamic recursive model composed of three modules: the (partial-equilibrium) ***market module*** (KM) determines wood market prices, demand, supply and trade, the (inventory-based) ***resource module*** (RM) simulates the forest dynamics, and the (micro-based) ***management module*** (GM) determines investments in specific forest types.
While a regional scale is reasonably adequate for KM, it is not for RM and GM: hence an high-scale, GIS based approach has been implemented for RM and GM where climatically-induced variations produced from the (exogenous) biological models can be accounted at a pixel level.
The GM module endogenises forest wood regeneration (depending on harvesting levels), incorporates forest managers expectations and finally determines forest investments (replanting).
The unmanaged forest area is treated according to a probability of presence (of forest species) derived from the biological models.

Results

Running long-term simulations (until 2100) we show the implication on the forest composition of an active management: when the most profitable option drives forest investments, coniferous forests are generally preferred over broadleaved ones. This result is however reappraised when the risk aversion of forest owners is explicitly considered in the model, given the higher risk associated with the former.
When the spatial framework is employed to simulate the effects of an increased coniferous mortality in lowlands of southern France, that is at the lower or souther edge of their distributional range, we show that the impact on forest resources strongly depends on the regional difference in relative forest profitability: when such difference is high and the climate impact remains low, coniferous forests remain the most profitable choice and market forces that react to a reduced coniferous production may cause an increased harvesting rate of broadleaved forests and hence an increased rate of conversion toward coniferous forests that mitigate, and in certain conditions offsets, the substitution effect driven by the change in relative profitability.
When forest mortality is gradually increasing, a myopic attitude of forest managers, where investments are driven by mortality observed at investment time, would exacerbate such effect as it would reduce the expected climatic impact in comparison to an attitude that anticipate future mortality in investment decisions.

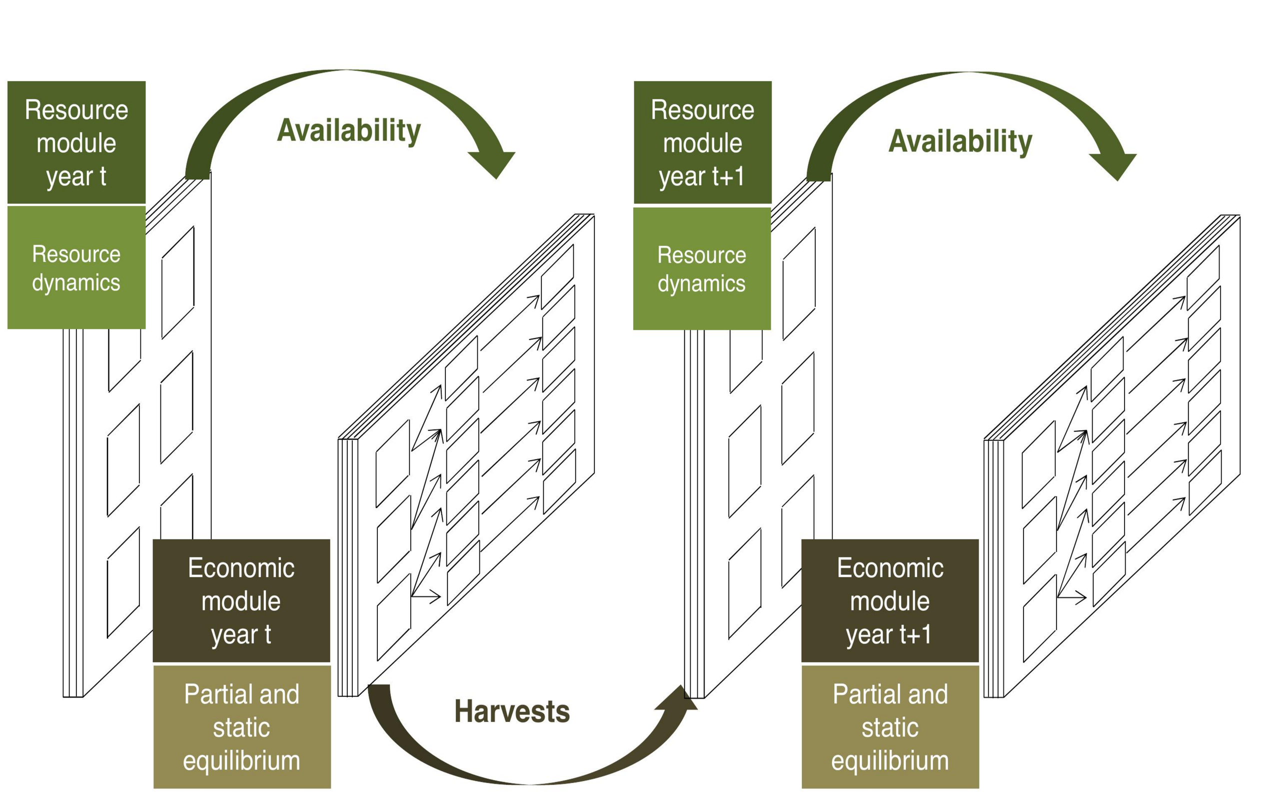
At a glance



Module	Spatial Levels	Var Input	Var Output
Market	Countries, regions	$Inv_{r,pp,t}$, $Price_{wrd,pp,t}$	$Supply_{r,pp,t}$, $Price_{r,pp,t}$
Resource	Counties, regions, pixels	$Supply_{r,pp,t}$, $RegArea_{px,ft,t}$	$Inv_{px,pp,t+1}$, $HArea_{px,ft,t}$
Management	Countries, regions, pixels	$Price_{r,pp,t}$, $HArea_{px,ft,t}$	$RegArea_{px,ft,t}$

indices

Model dynamic



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

Forest investments and regeneration

- Expected returns (in Equivalent Annual Income form) from a given forest type depend from both market price of related wood products and biological parameters:

$$expReturns_{px,ft,t}=\max_{dc,pp}\frac{PW_{r,pp,t}*vHa_{px,ft,dc,t}*finHrFlag_{ft,dc}*sflag_{ft,dc,pp}*r}{(1+r)^{cumTp_{px,dc,t}}-1}$$

- Each year an harvested area for each f.t. is computed from the harvested volumes (in turn derived from market demand)

$$harvestedArea_{px,ft,dc,t} = hV_{px,ft,dc=finharv,t} \;/\; vHa_{px,ft,dc,t}$$

- The regeneration area for each forest type is equal to the unmanaged share of the harvested area of its own type :

$$regArea_{px,ft,t} = \sum_{dc} harvestedArea_{px,ft,dc,t}*(1-mr)$$

- The managed share of the total harvested area is allocated as the regeneration area of the forest type having the highest expected return ($\mathring{ft}$):

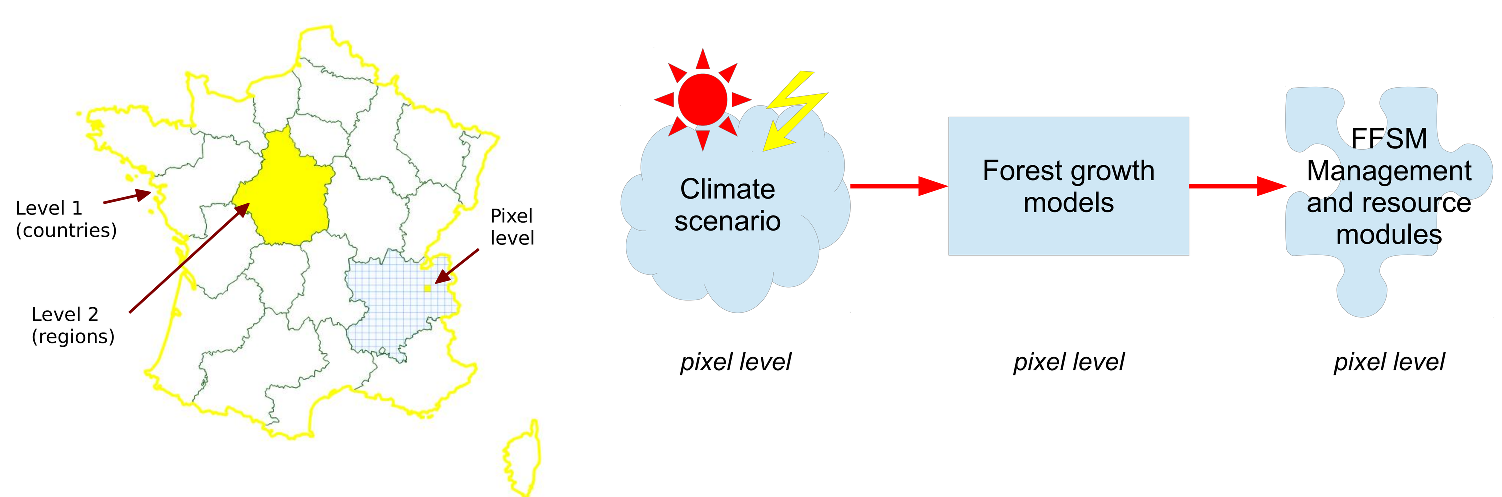
$$regArea_{px,\mathring{ft},t} \mathrel{+}= \sum_{ft}\sum_{dc} harvestedArea_{px,ft,dc,t}*mr$$

- A time leg exists between harvesting/regeneration and availability of wood resources

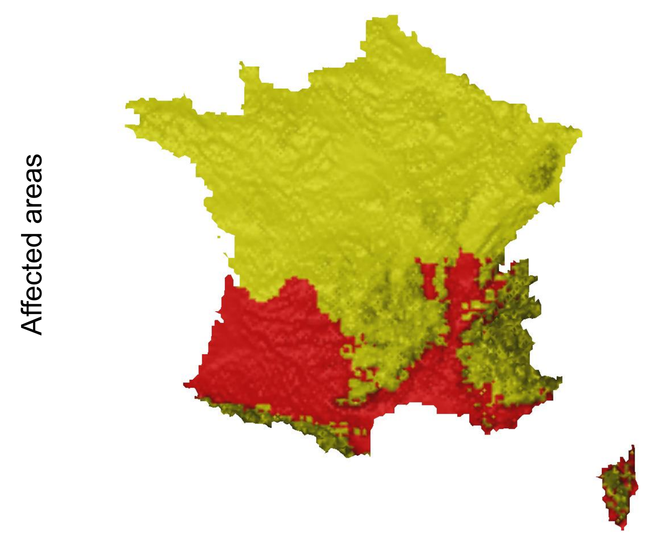
$$vReg_{px,ft,t} = regArea_{px,ft,\tau} * vHa_{px,ft,dc15,\tau} \qquad \tau = t-tp_{px,ft,dc0,t}$$

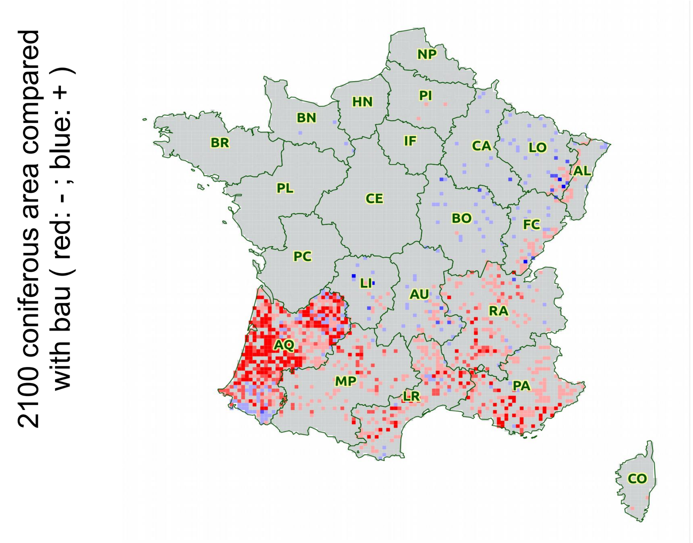
Spatial Representation

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



Allocation effects of an increased coniferous mortality in southern France





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equation indices

t	time	[2005-2100]
c	country	{France}
r	region	[22 administrative regions in France]
px	pixel	
sp	forest species group	{Broadleaves, Coniferous}
mt	forest management type	{High forests, Mixed forests, Coppers}
ft	forest type (including management)	[sp × mt]
dc	diameter class	{0, 15, 25, 35, 45, 55, 65, 75, 85, 95, 150}
pp	primary product (that is, deriving directly from forest resources)	{Hardwood Roundwood, Softwood Roundwood, Pulpwood and Fuelwood}
tp	transformed products	{Fuelwood, Hardwood Sawnwood, Softwood Sawnwood, Plywood, Pulpwood, Pannels}
prd	products (pp È tp)	

further information

http://www7.nancy.inra.fr/lef/recherches/ffsm

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