Atténuation des émissions de GES dans l'agriculture

Potentiels et coûts d'atténuation, implications pour l'efficacité des politiques publiques et perspectives pour la recherche

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Key messages

Mitigation of agricultural GHG emissions

1. Not so small
2. Not that expensive (if done right)
3. Not much is currently done to get it right
4. Not only about reductions in emissions within the ag sector
5. Not only about the supply side

Questions

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   - How to compute MAC in agriculture?
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   - Do MRV costs impede the implementation of climate policy instruments in the agricultural sector?
3. Emerging questions

MAC of agricultural GHG emissions in the literature

- Variety of modeling approaches
  - 'Engineering' approach [Pellerin et al., 2013]
  - Supply-side micro-economic models [De Cara and Jayet, 2011, De Cara et al., 2017]
  - Equilibrium models [Schneider and McCarl, 2003]

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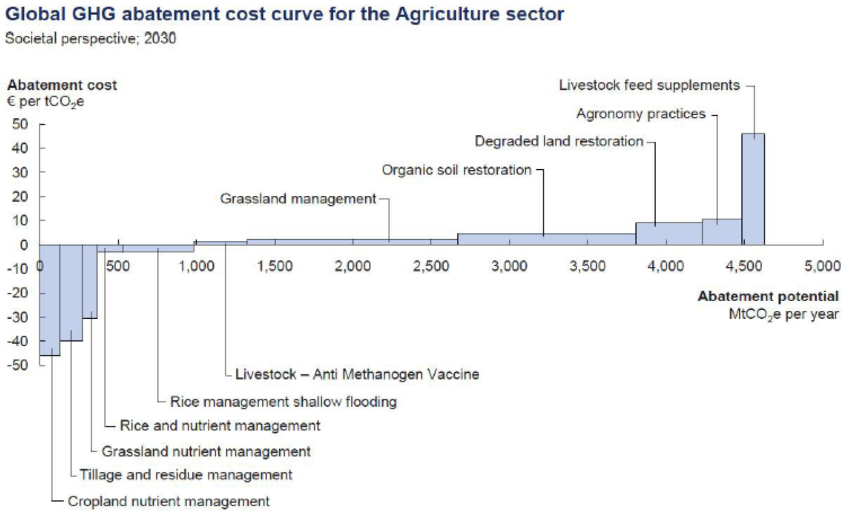
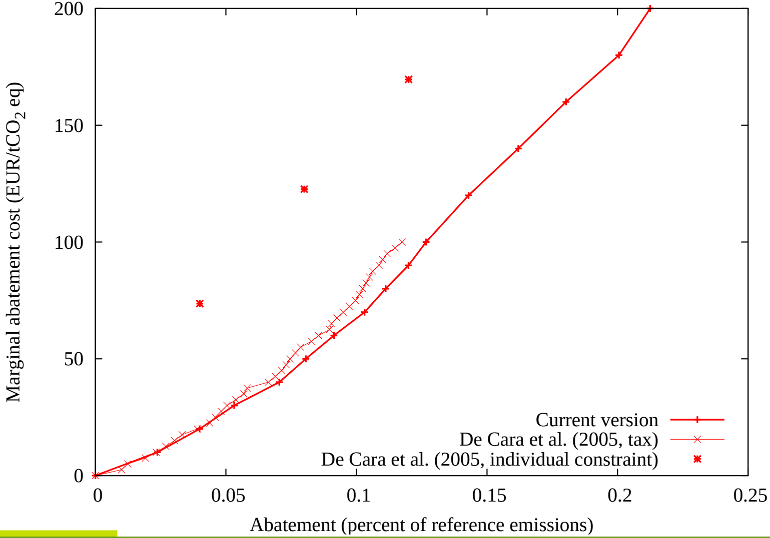
  - Equilibrium models [Schneider and McCarl, 2003]
- Variety of assumptions
  - Source/sink coverage, mitigation options, spatial scale and resolution, baseline year, etc.

Engineering approach

[McKinsey & Co, 2009]

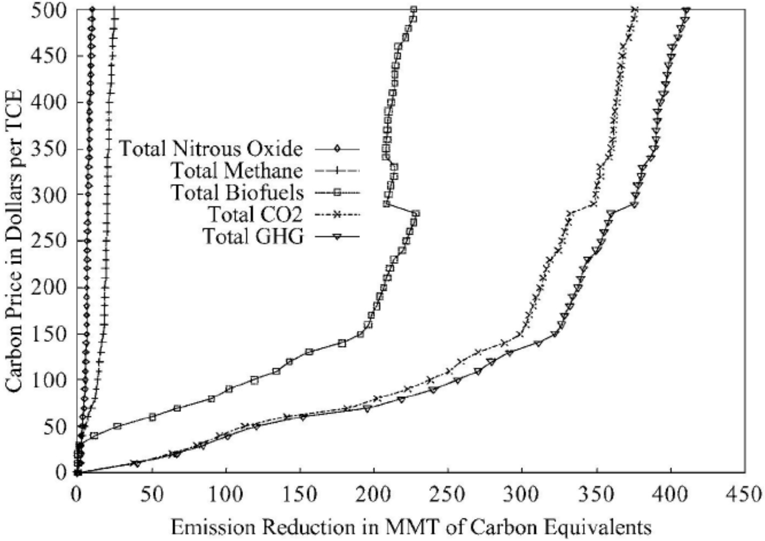


Supply-side microeconomic models *[De Cara et al., 2005]*

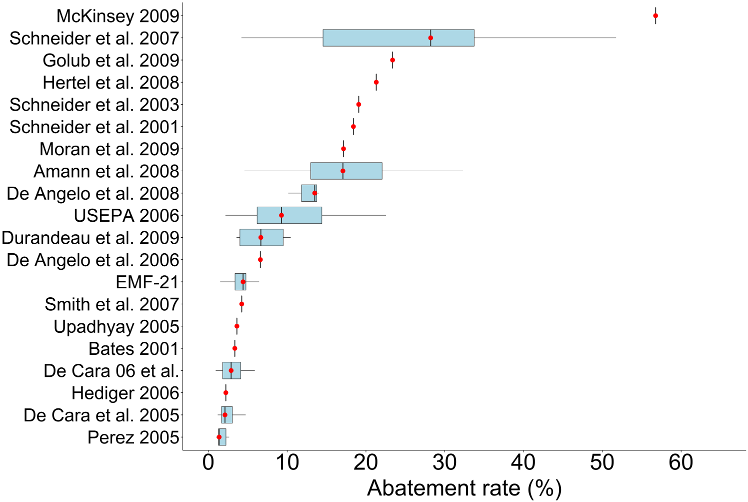


Equilibrium models

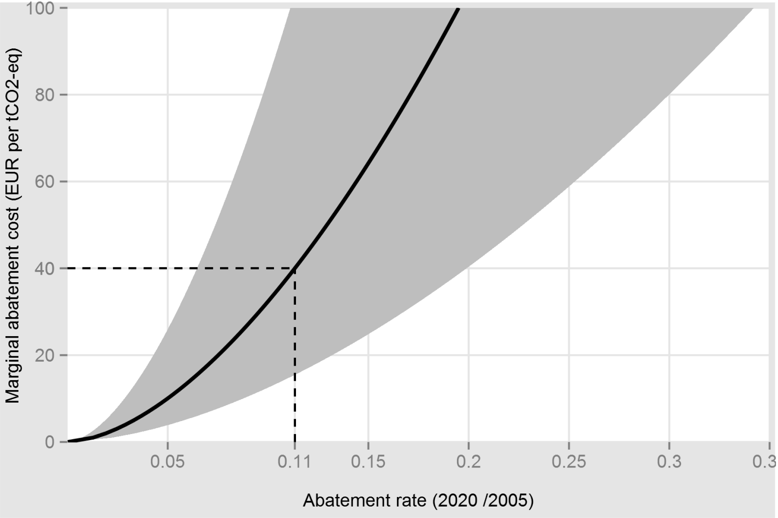
[Schneider and McCarl, 2003]



Abatement at 20 €$_{2005}$/tCO_2eq [Vermont and De Cara, 2010]

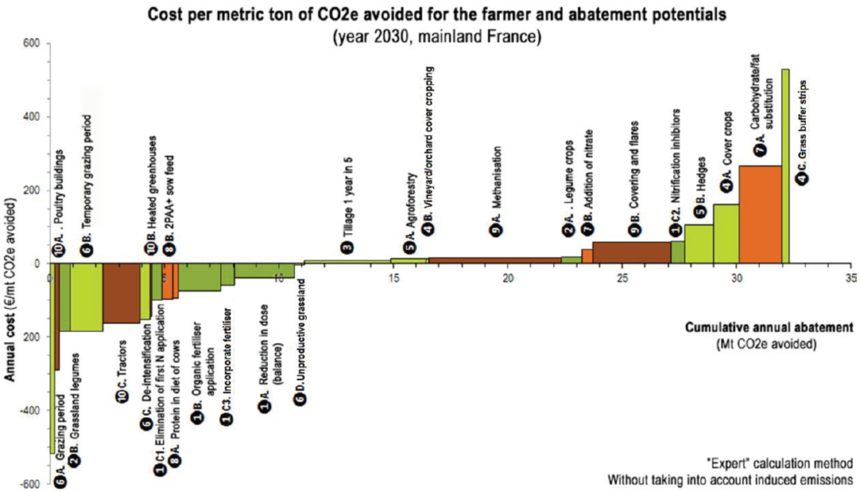


Meta-model (EU, 2020) [Vermont and De Cara, 2010]



Engineering approach

[Pellerin et al., 2013]



Engineering approach

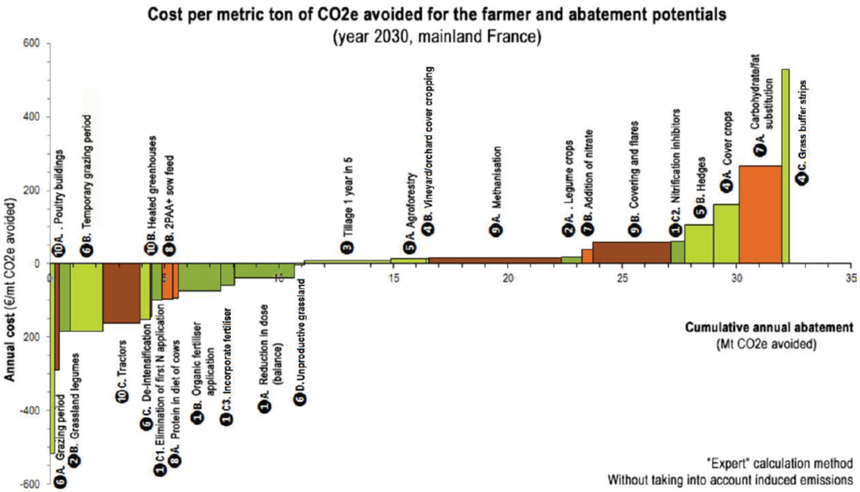
- List of candidate mitigation options
- Assessment of
  - Unit mitigation potential
  - Unit mitigation cost
  - Potential extent
- Options are then ranked by increasing unit costs

Engineering approach

- List of candidate mitigation options
- Assessment of
  - Unit mitigation potential
  - Unit mitigation cost
  - Potential extent
- Options are then ranked by increasing unit costs
- Not really marginal abatement costs
- Assumptions on baseline and potential extent are critical
- Interactions between abatement activities are difficult to take into account
- Accounting for spatial variability in abatement costs

Engineering approach

[Pellerin et al., 2013]



Engineering approach

What do we learn from it?

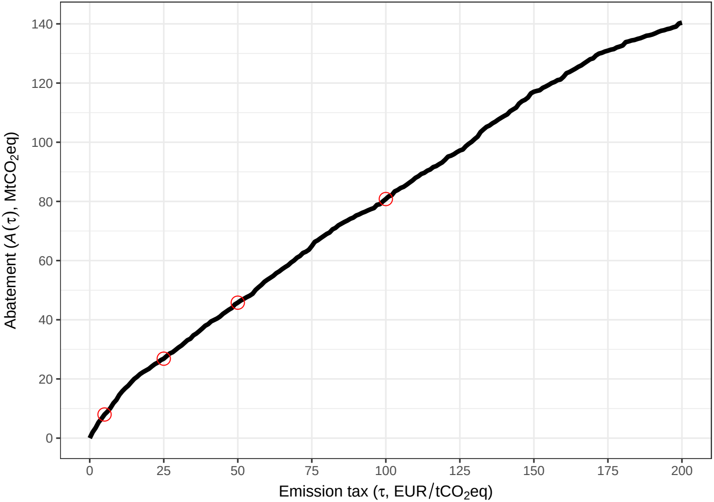
- Existence of a technical mitigation potential at low cost ("low hanging fruits")
- The accounting method plays an important role
- The presence of "negative-cost" options raise economic questions
  - Why is there a $100 bill lying on the floor?
  - Similar issues as in the energy efficiency gap debate
  - Methodological issues: aggregation bias, competition between actions
  - Other: Risk, credit constraints, behavioural, etc...

Supply-side microeconomic models *[De Cara and Jayet, 2011]*

- Farm level, supply-side model of EU agriculture
- Detailed description of agronomic and CAP-related constraints
- Major annual crop and livestock activities are represented
- Regional resolution for the EU
- Explicit modelling of the relationships between activity variables and emissions (N_2O, CH_4) at farm level

Supply-side microeconomic models

Abatement supply curve, EU-27, year 2009 [De Cara et al., 2017]

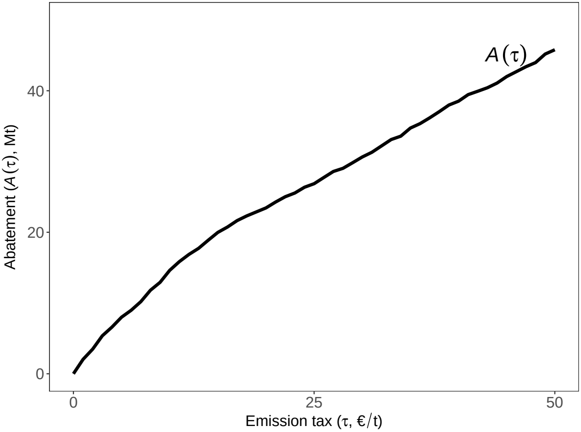


Supply-side microeconomic models

Use for the assessment of climate policy

- Cost-efficiency gains permitted by market-based relative to uniform instruments
  - Flexibility accross farms [De Cara et al., 2005]
- Market-based instruments vs. Effort Sharing Agreement
  - Flexibility accross countries [De Cara and Jayet, 2011]
- Cost-efficiency gains of including agriculture into the EU-ETS
  - Flexibility accross sectors [De Cara and Vermont, 2011]

Sector-level abatement supply curve and MRV costs [De Cara et al., 2017]



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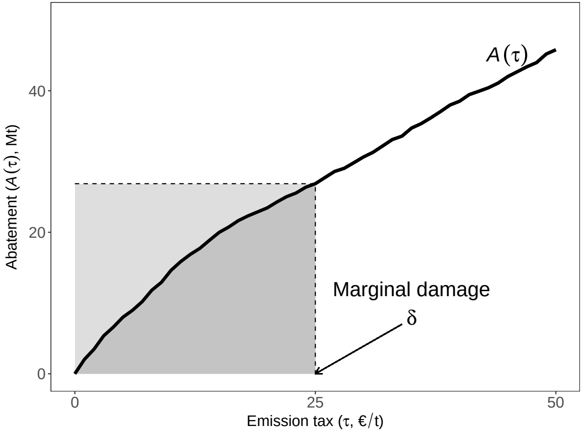

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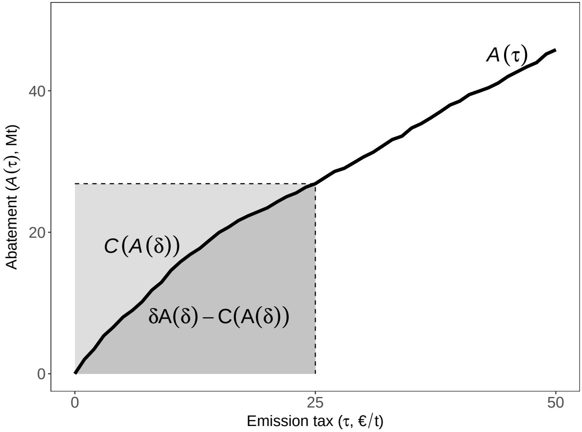

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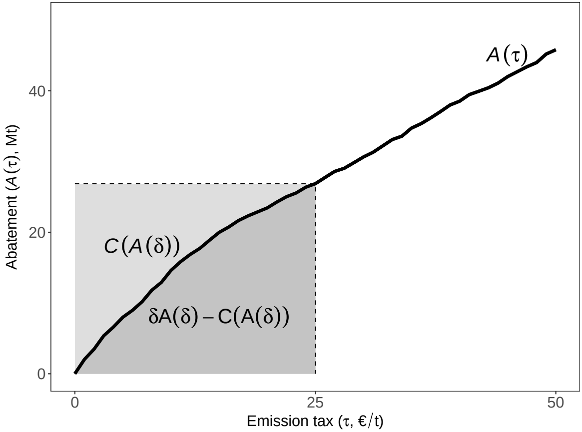
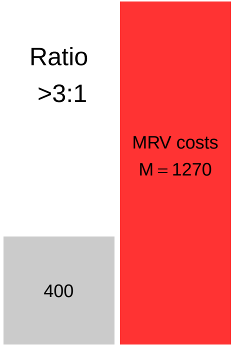
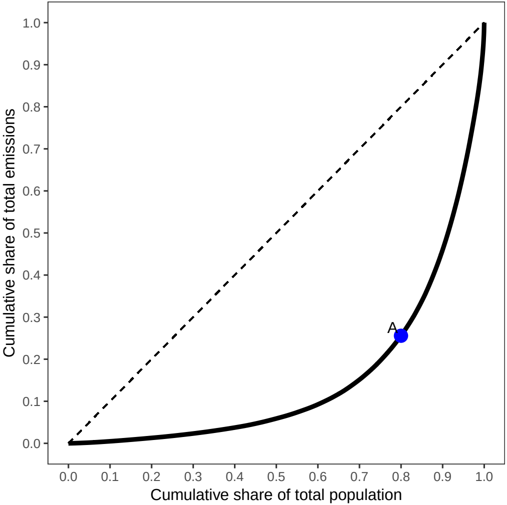


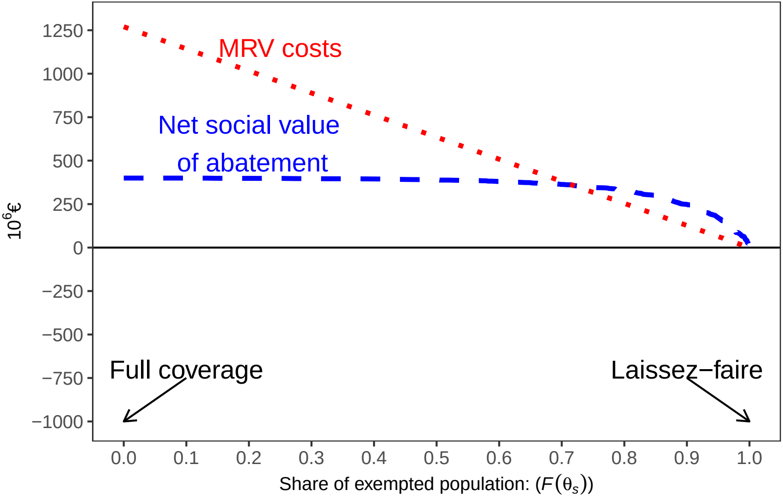


Lorenz curve of emissions



Social benefit in the benchmark configuration

Social value of emissions: $\delta = 25€/tCO_2$; MRV costs: medium + constant per-farm



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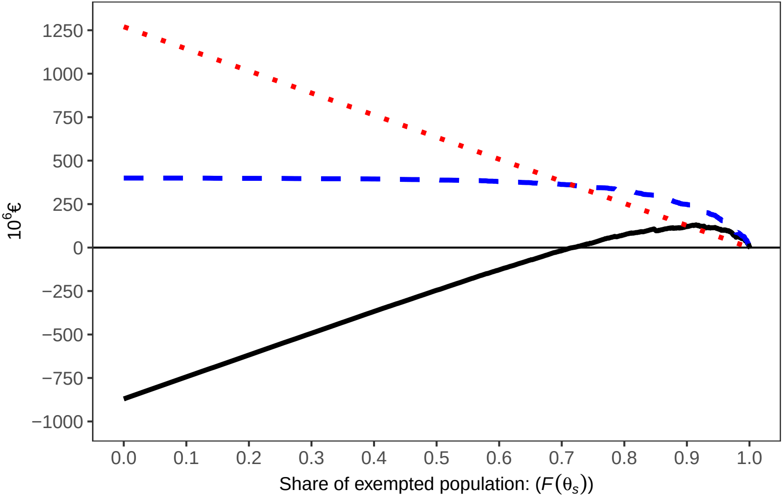

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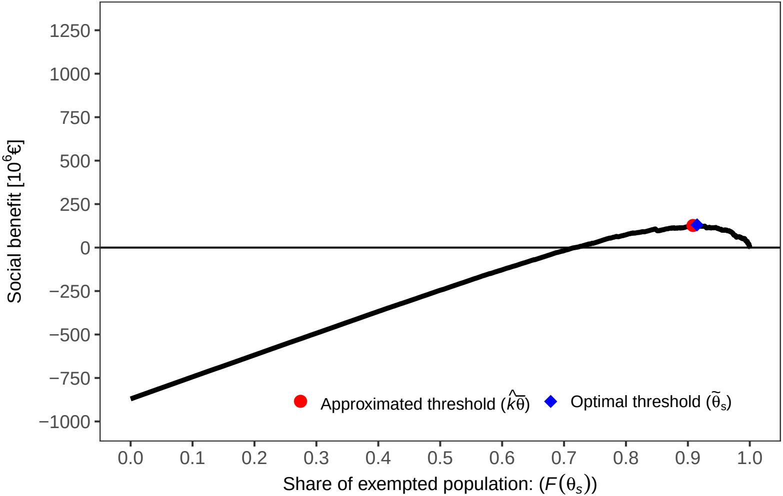
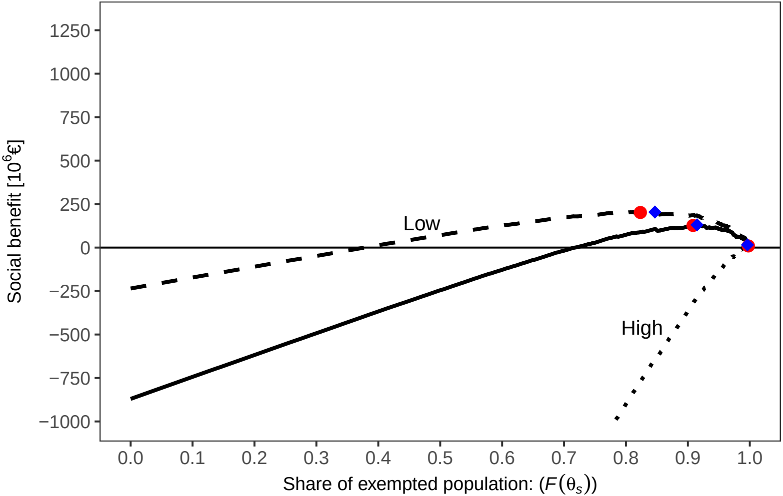


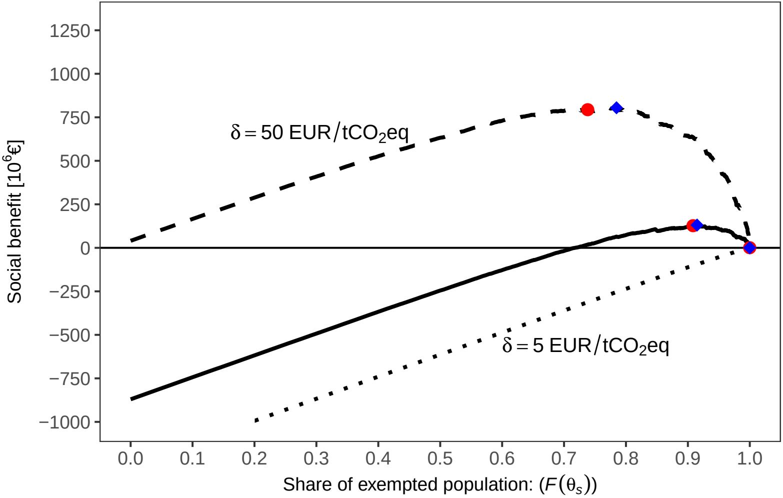
Effect of the magnitude of MRV costs

Social value of emissions: $\delta = 25€/tCO_2$; MRV costs: constant per-farm



Effect of the social value of emissions

MRV costs: medium + constant per-farm

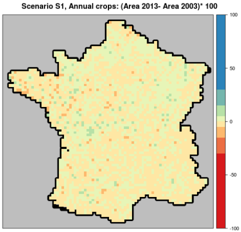


Emerging questions

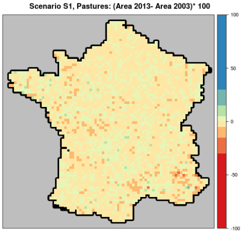
- Articulation of agricultural and climate policies
  - Interactions between CAP and climate policy instruments [Grosjean et al., 2016]
  - Farms' income inequality
- Interactions between the mitigation of GHG ag emissions and land-use related emissions
  - Indirect (price-induced) land-use effects [Chakir et al., 2017]
- Demand-based mitigation
  - Relative locations of farmers and end consumers, local food [De Cara et al., 2016]
  - Diet shifts, food tax based on GHG content, feedbacks on land use
- Determinants of the (non) adoption of mitigation technologies
- Land use as an adaptation levier [**?**], mitigation vs. adaptation [**?**]

S1: Land use developments (2013-2003)

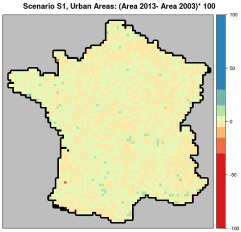
Cropland (CR)



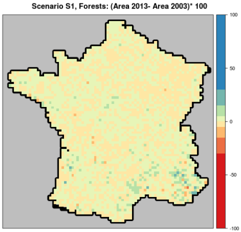
Grassland (GR)



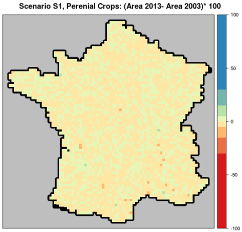
Urban (UR)

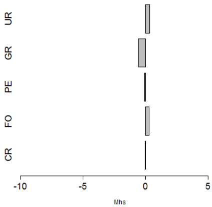


Forest (FO)



Perennial crops (PE)





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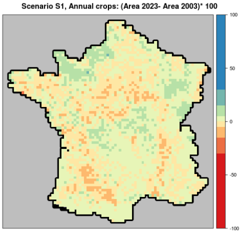

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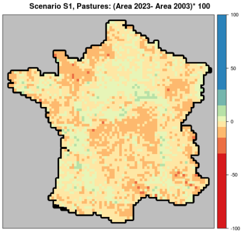

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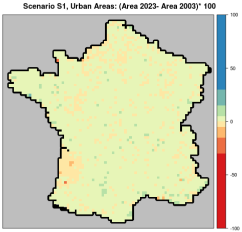

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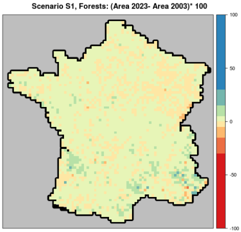

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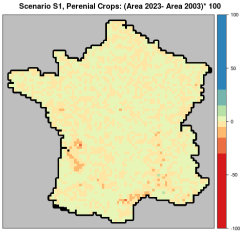

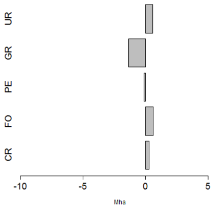

S1: Land use developments (2033-2003)

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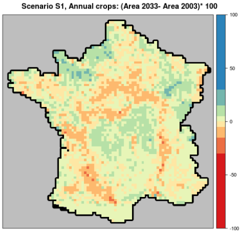
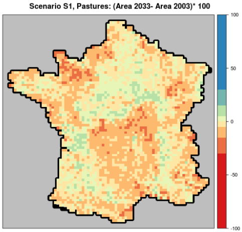
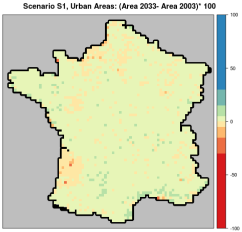


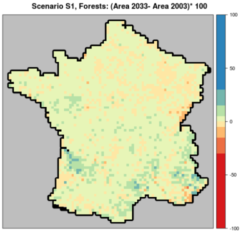
Grassland (GR)



Urban (UR)



Forest (FO)



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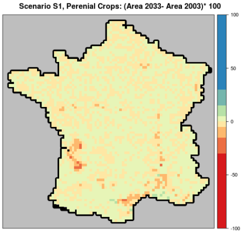

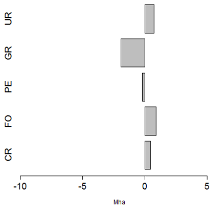

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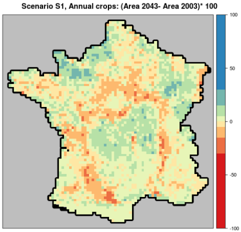
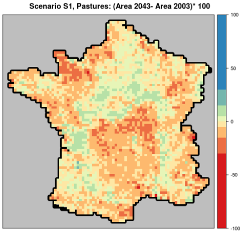
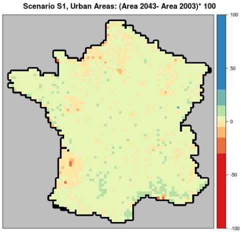


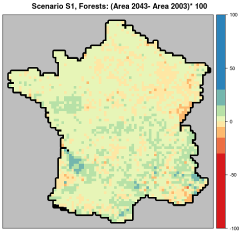
Grassland (GR)



Urban (UR)



Forest (FO)



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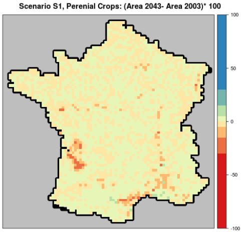
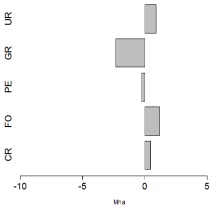
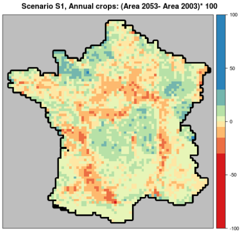


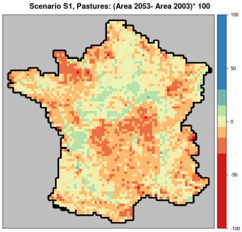


S1: Land use developments (2053-2003)

Cropland (CR)



Grassland (GR)



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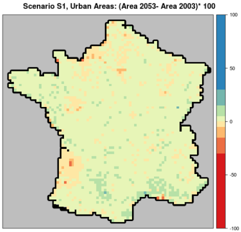
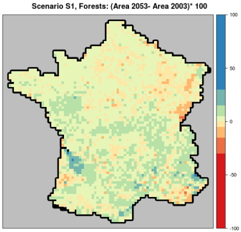


Forest (FO)



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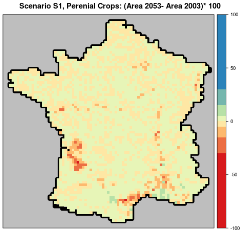
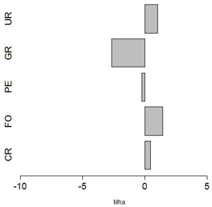
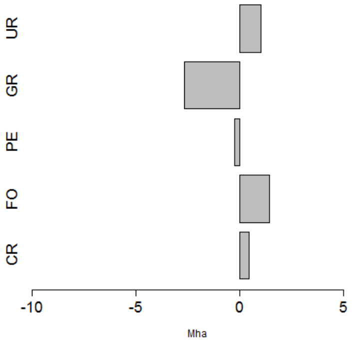




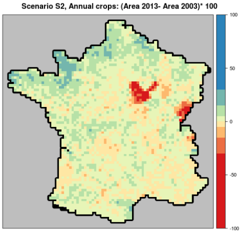
S1: Land use developments (2053-2003)

Urban (UR)	+1.0 Mha
Grassland (GR)	-2.7 Mha
Perennial crops (PE)	-0.2 Mha
Forest (FO)	+1.4 Mha
Cropland (CR)	+0.4 Mha

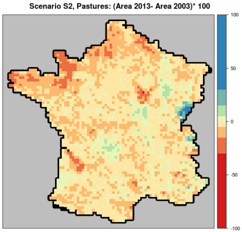


S2: Land use developments (2013-2003)

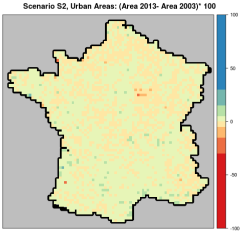
Cropland (CR)



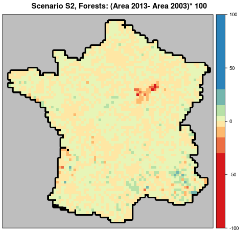
Grassland (GR)



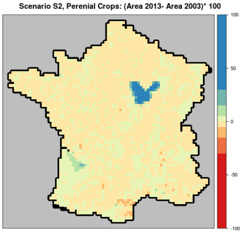
Urban (UR)

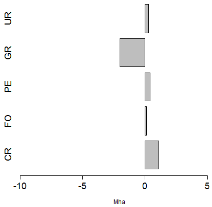


Forest (FO)



Perennial crops (PE)





S2: Land use developments (2023-2003)

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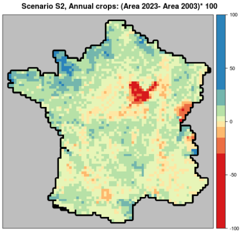
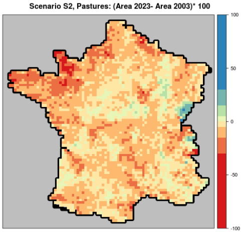
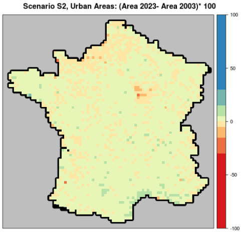


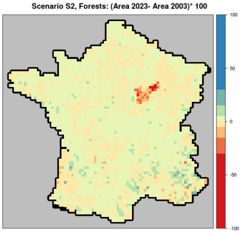
Grassland (GR)



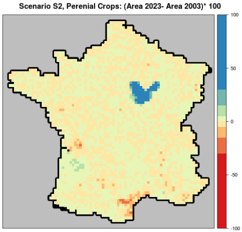
Urban (UR)

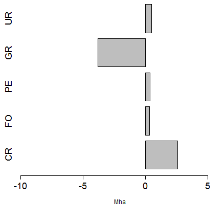


Forest (FO)



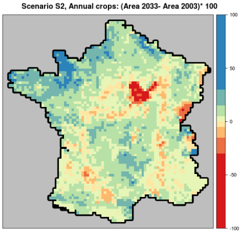
Perennial crops (PE)



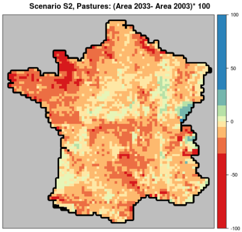


S2: Land use developments (2033-2003)

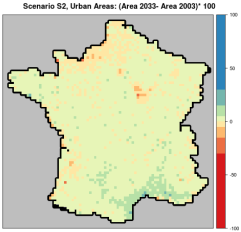
Cropland (CR)



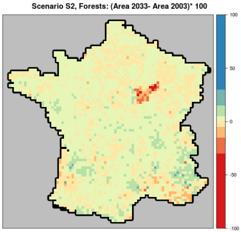
Grassland (GR)



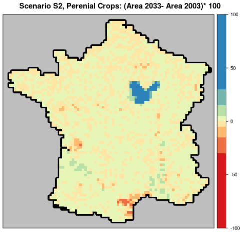
Urban (UR)

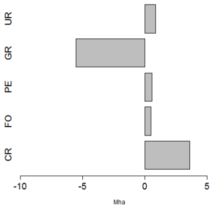


Forest (FO)



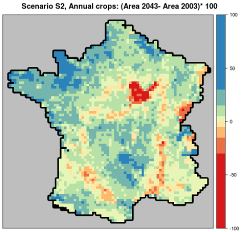
Perennial crops (PE)



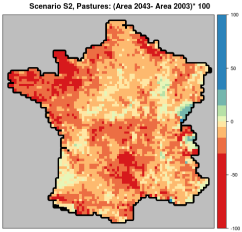


S2: Land use developments (2043-2003)

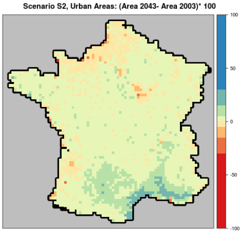
Cropland (CR)



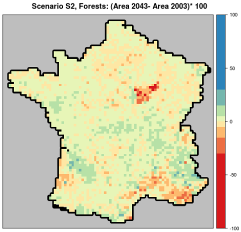
Grassland (GR)



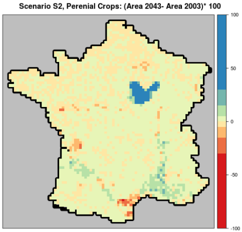
Urban (UR)

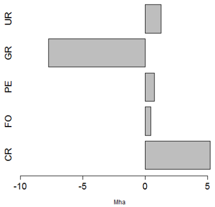


Forest (FO)



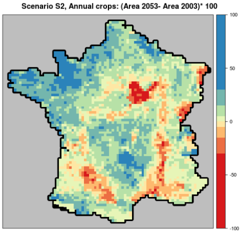
Perennial crops (PE)



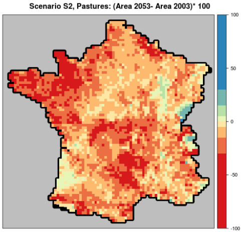


S2: Land use developments (2053-2003)

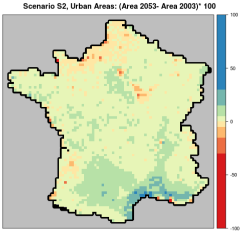
Cropland (CR)



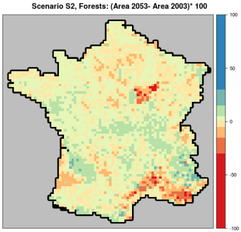
Grassland (GR)



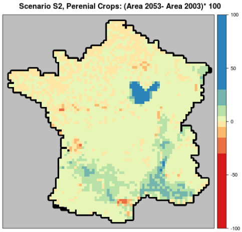
Urban (UR)

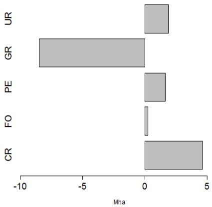


Forest (FO)



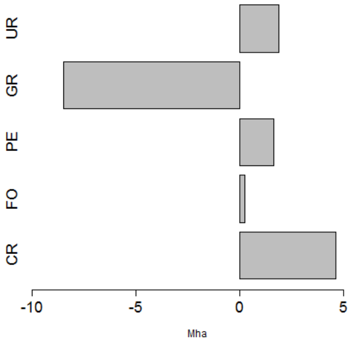
Perennial crops (PE)





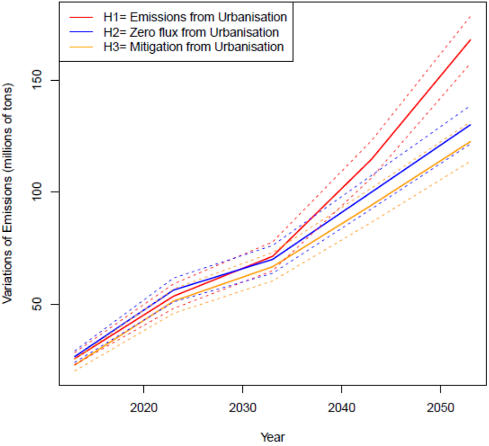
S2: Land use developments (2053-2003)

Urban (UR)	+1.9 Mha
Grassland (GR)	-8.4 Mha
Perennial crops (PE)	+1.6 Mha
Forest (FO)	+0.3 Mha
Cropland (CR)	+4.6 Mha

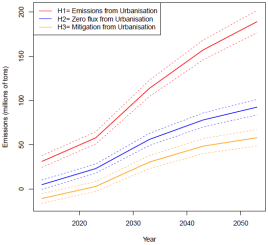


Cumulative carbon developments

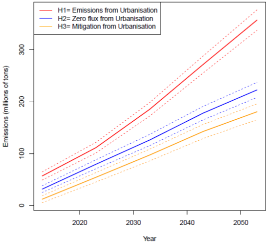
S2 - S1



S1



S2



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Co-direction avec P.-A. Jayet.

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Land-use change as an adaptation strategy

- Climate change is likely to impact yields/land productivity [Brisson and Levrault, 2010, IPCC, 2013]
- Adaptation to climate change may take various forms, with consequences on :
  - Irrigation, input use, choice of cultivar, timing, rotation, etc.
  - Crop allocation within agriculture [Leclère et al., 2013]
  - Agricultural vs. alternative land uses [Haim et al., 2011]
- Ricardian assumption [Mendelsohn et al., 1994]
  - All these (expected) changes are capitalized in land rent value
  - Changes in land returns will drive land use
  - The resulting land-use changes may vary in space and time [Chakir et al., 2011]

Climate-induced land-use change and GHG emissions

- The majority of adaptation studies in land-based sector focus on only one sector (either crops, livestock, or forestry), thus largely ignoring land-use changes
- Soils and biomass contain more carbon than the atmosphere
- LULUCF is a major contributor to the release of CO_2 emissions into the atmosphere

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- The modification in climate conditions may induce modifications in land use (extensive margin)
- A previous study for France has shown that these land use changes can be significant [Ay et al., 2014]
- To asses the impacts on carbon stocks, it is important to account for:
  - Current land use and land use dynamics
  - Microeconomic decisions of land-owners
  - Spatial variability

Economic return model

- Land price $v_{\ell t}$ for use ℓ is equal to the net present value of all expected futures rents

$$v_{\ell t} = \sum_{s=0}^{\infty} \frac{\mathbb{E}[r_{t+s}]}{(1+\rho)^s} = \frac{\mathbb{E}[r_{t+1}]}{\rho - g}$$

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- Ricardian model: Economic returns of land as a function of climate and soil characteristics

$$\log(r_{i\ell t}) = y_\ell(\mathbf{c}_{it}, \mathbf{x}_i, \mathbf{z}_i) + \gamma_\ell t + \varepsilon_{i\ell t}$$

  - $r_{i\ell t}$: net returns
  - $y_\ell(\cdot)$: spline-based smooth function with endogenous structure for land use ℓ
  - $\mathbf{c}_{it}$ and $\mathbf{x}_i$, $\mathbf{z}_i$: climate, biophysical, and geographic variables

Land use model

- Random utility model
  - A landowner i chooses the use ℓ^*_{it} on plot i if this provides the highest utility from all uses that are possible.

$$u_{i\ell t} = \alpha_\ell + \mathbf{r}_{it}\beta_{1\ell} + \mathbf{c}_{it}\beta_{2\ell} + \mathbf{x}_i\beta_{3\ell} + \mathbf{r}_{it}(\mathbf{c}_{it} + \mathbf{x}_i)\beta_{4\ell} + \mathbf{h}_{it-1}\eta_\ell + \epsilon_{i\ell t}.$$

  - Conversion costs between land uses are implicitly taken into account by including dummy variables representing previous land use $\mathbf{h}_{i,t-1}$.

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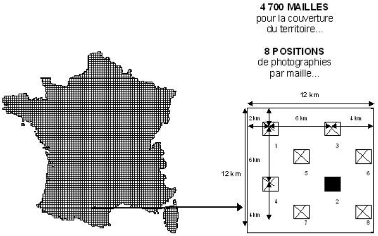
  - Conversion costs between land uses are implicitly taken into account by including dummy variables representing previous land use $\mathbf{h}_{i,t-1}$.
- Multinomial logit [McFadden, 1974, Train, 2009]:

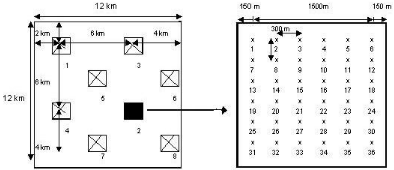
$$p_{i\ell t} = \frac{\exp(\bar{u}_{i\ell t})}{\sum_k \exp(\bar{u}_{ikt})} = f_\ell(\mathbf{r}_{a_i t}, \mathbf{c}_{it}, \mathbf{x}_i, \mathbf{h}_{it-1}).$$

where $p_{i,\ell,t}$ is the probability that plot i is in use ℓ at t

Land use data

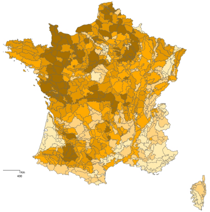
- Based on Teruti
- About 550,000 points surveyed each year (1992-2003)
- 81 land uses grouped into 5 main uses
  - Annual crops (CR)
  - Grassland (GR)
  - Perennial crops (PE),
  - Forest (FO)
  - Urban (UR)

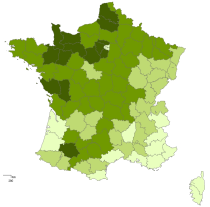




Economic returns of land data

- Land prices (1990-2005) from SAFER / French Ministry of Agriculture
  - Annual crops and grassland at the *Petites Régions Agricoles* resolution (PRA, $n = 713$)
  - Perennial crops at the *Départements* resolution ($n = 93$)
- Proxies for expected returns
  - Forest: per ha output value (production, prices, and forest area) at the *Départements* resolution
  - Urban: population densities at the municipalities resolution ($n \approx 35,500$)





Climate and soil data

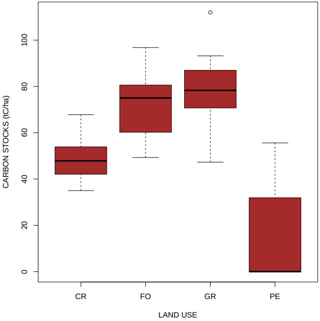
- Regionalized climate scenarios based on the IPCC A1B scenario from Arpège climate model (Météo France).
  - Historical (1990–2010) and projected (2010–2053) climate data, downscaled at a 8-km resolution (Safran)
  - Annual mean, min, max, seasonality of temperature, precipitation, solar radiation, relative humidity, wind

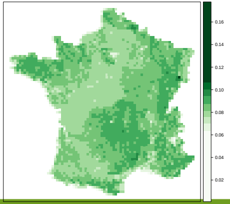
Variable	2053-2003	St.Dev.
Mean Temperature	+2.01°C	0.23
Cum. Precipitations	-13.4mm	6.34
Relative Humidity	-1.69%	1.23
Solar Radiation	+17.1J	14.4

- Soil data: INRA Orleans (mean, min, max of depth and WHC) + Digitalized Elevation Model (IGN)

Soil carbon data

- Top-30 cm soil carbon contents obtained from CITEPA and INRA-Orléans by land use and region (22 regions) [Arrouays et al., 2001, Martin et al., 2011, Martin et al., 2014]
- Assumptions
  - The release or sequestration of the difference in C stocks between two uses is spread over 20 years





Scenario design

Scenario	Climate	Drivers of economic returns of land
S1	2003	Historic trend 1993-2003
S2	2003-53 (A1b)	Historic trend 1993-2003 + Climate
S2-S1	2003-53 (A1b)	Climate

Estimation: Ricardian models

The model (1) is estimated separately for each use using Gaussian Generalized Additive Models (GAM) [Wood, 2006].

$$\log(r_{i\ell t}) = y_\ell(\mathbf{c}_{it}, \mathbf{x}_i, \mathbf{z}_i) + \gamma_\ell t + \varepsilon_{i\ell t} \tag{1}$$

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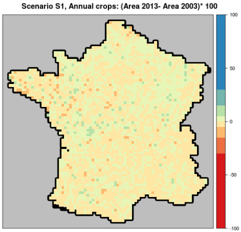
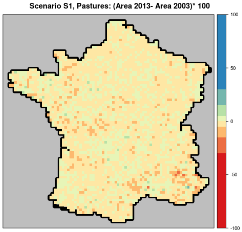
	F-test of joint significance			Trend	Sample size	Quality of fit
	Climate	Soil	Coord.			
	F-$\mathbf{c}_{tq}$	F-$\mathbf{x}_q$	F-$\mathbf{z}_q$	γ_ℓ	(n, t)	Adj.R^2
CR	4.95**	11.6**	14.8**	.028**	(713, 3)	.785
GR	4.13**	11.6**	6.11**	.012**	(713, 3)	.766
PE	3.62**	0.43	20.6**	.007*	(93, 2)	.914
FO	6.46**	1.68	19.9**	.000	(93, 3)	.361

S1: Land use developments (2013-2003)

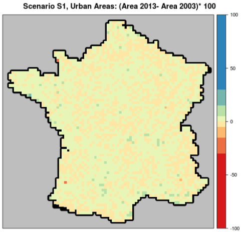
Cropland (CR)



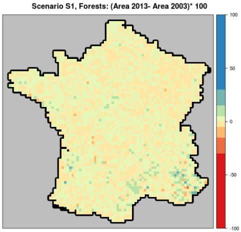
Grassland (GR)



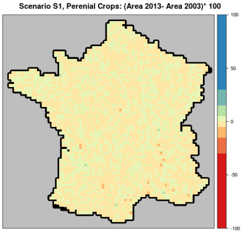
Urban (UR)

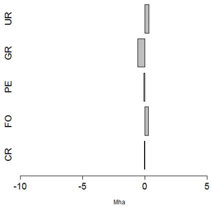


Forest (FO)



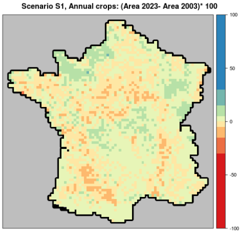
Perennial crops (PE)



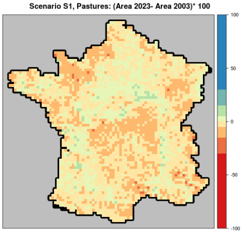


S1: Land use developments (2023-2003)

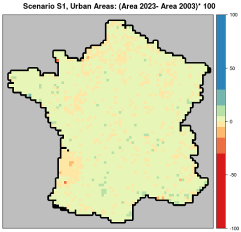
Cropland (CR)



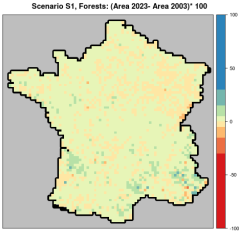
Grassland (GR)



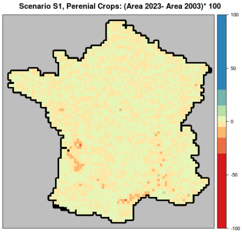
Urban (UR)

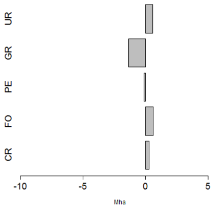


Forest (FO)



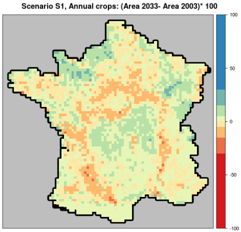
Perennial crops (PE)



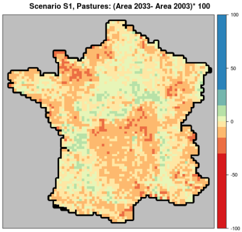


S1: Land use developments (2033-2003)

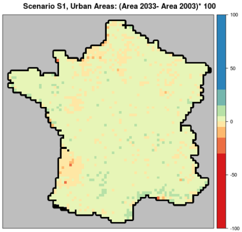
Cropland (CR)



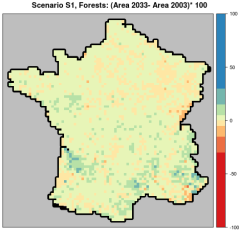
Grassland (GR)



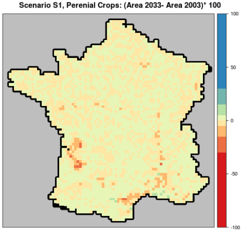
Urban (UR)

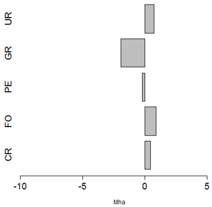


Forest (FO)



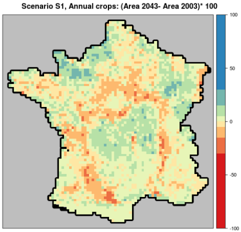
Perennial crops (PE)



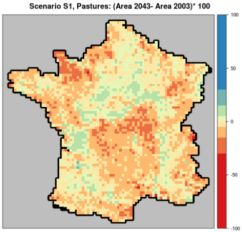


S1: Land use developments (2043-2003)

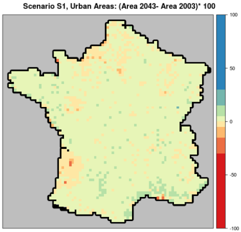
Cropland (CR)



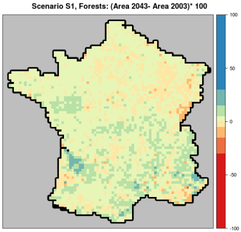
Grassland (GR)



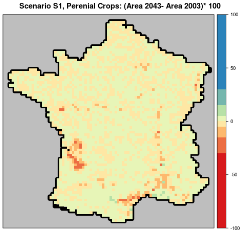
Urban (UR)

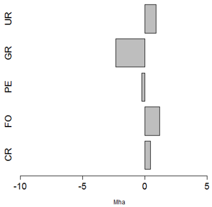


Forest (FO)



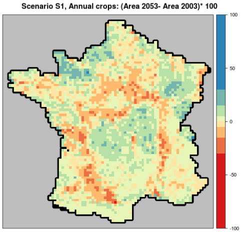
Perennial crops (PE)



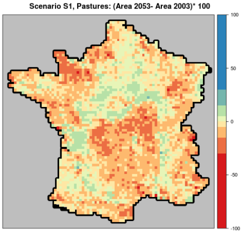


S1: Land use developments (2053-2003)

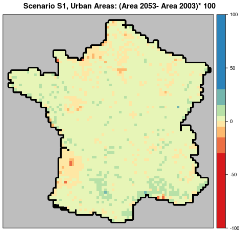
Cropland (CR)



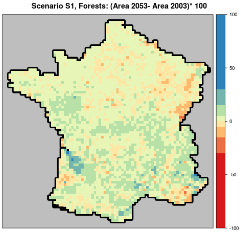
Grassland (GR)



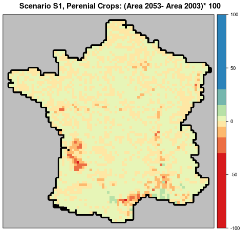
Urban (UR)

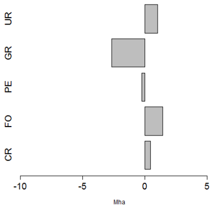


Forest (FO)



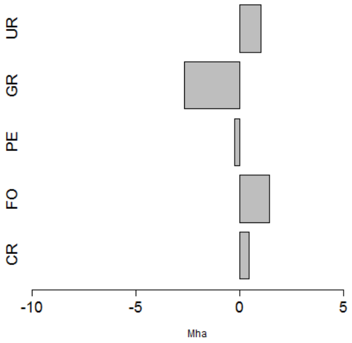
Perennial crops (PE)





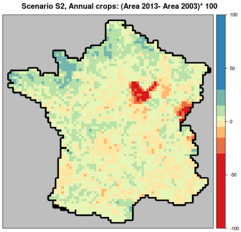
S1: Land use developments (2053-2003)

Urban (UR)	+1.0 Mha
Grassland (GR)	-2.7 Mha
Perennial crops (PE)	-0.2 Mha
Forest (FO)	+1.4 Mha
Cropland (CR)	+0.4 Mha

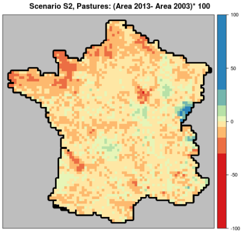


S2: Land use developments (2013-2003)

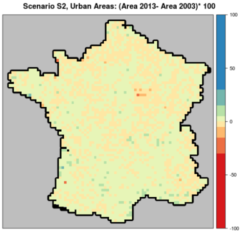
Cropland (CR)



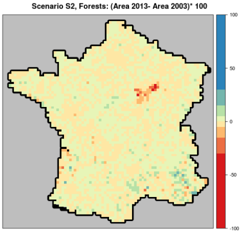
Grassland (GR)



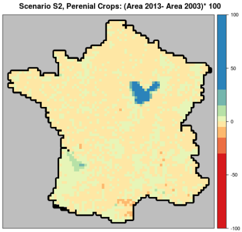
Urban (UR)

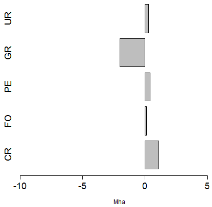


Forest (FO)



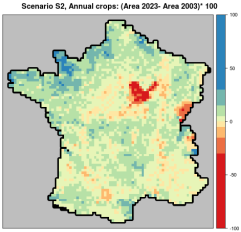
Perennial crops (PE)



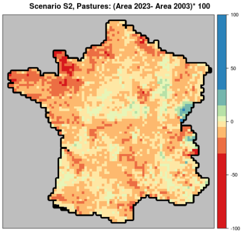


S2: Land use developments (2023-2003)

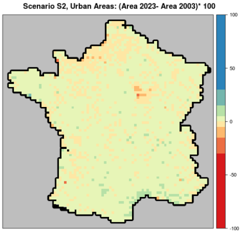
Cropland (CR)



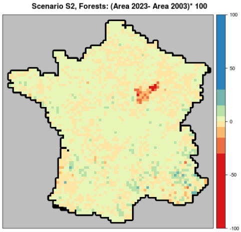
Grassland (GR)



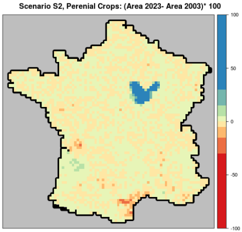
Urban (UR)

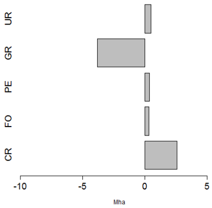


Forest (FO)



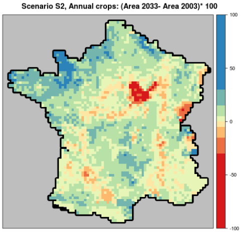
Perennial crops (PE)



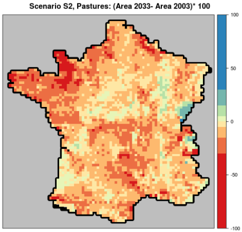


S2: Land use developments (2033-2003)

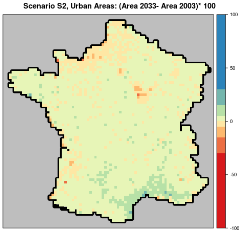
Cropland (CR)



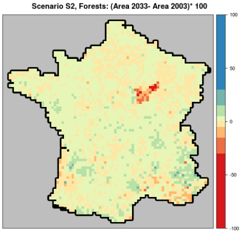
Grassland (GR)



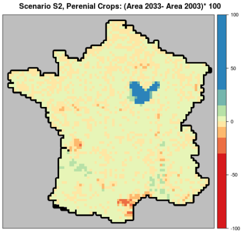
Urban (UR)

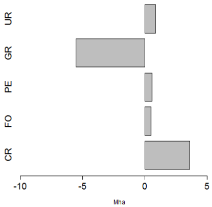


Forest (FO)



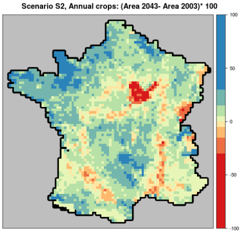
Perennial crops (PE)



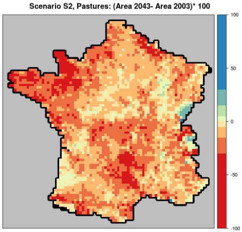


S2: Land use developments (2043-2003)

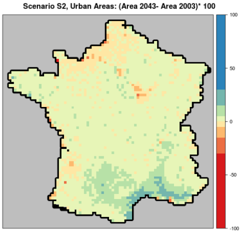
Cropland (CR)



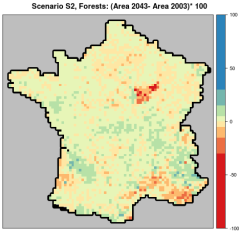
Grassland (GR)



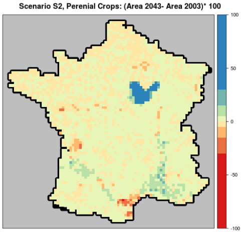
Urban (UR)

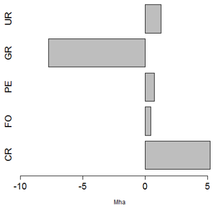


Forest (FO)



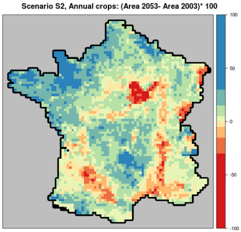
Perennial crops (PE)



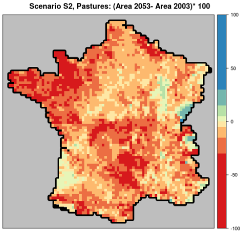


S2: Land use developments (2053-2003)

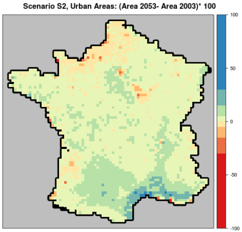
Cropland (CR)



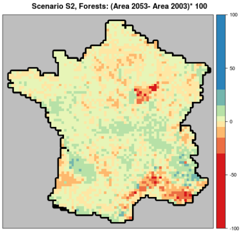
Grassland (GR)



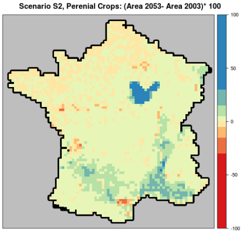
Urban (UR)

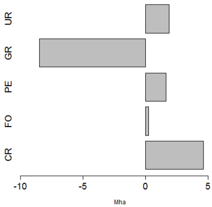


Forest (FO)



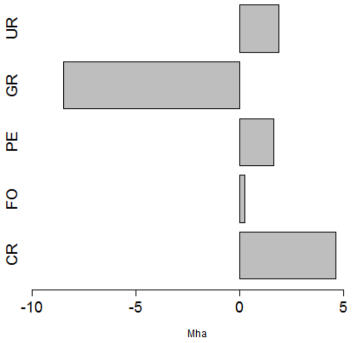
Perennial crops (PE)





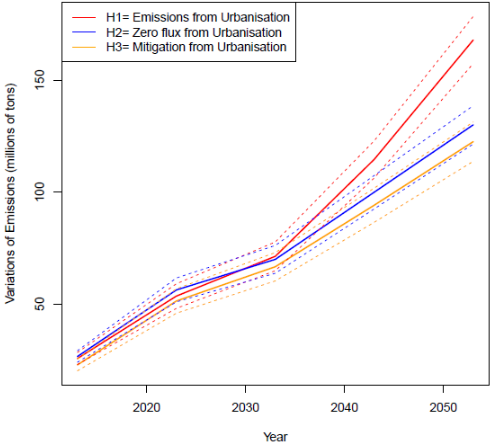
S2: Land use developments (2053-2003)

Urban (UR)	+1.9 Mha
Grassland (GR)	-8.4 Mha
Perennial crops (PE)	+1.6 Mha
Forest (FO)	+0.3 Mha
Cropland (CR)	+4.6 Mha

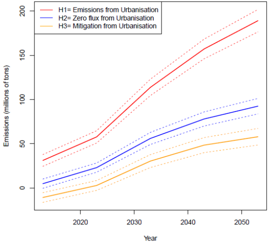


Cumulative carbon developments

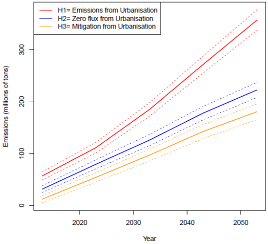
S2 - S1



S1



S2



Discussion

- Market-based instruments have the potential to provide large cost-effectiveness gains through increased flexibility
- Current (and future?) state (and prospects of) the EU ETS
- The EU CAP now embarks the issue GHG emissions from agriculture
  - Practice-based rather than emissions-based instruments
  - Not ideal to realize the full cost-effectiveness gains
- Are "low-hanging fruits" sufficient?

Discussion

- Full inclusion into the ETS?
  - Large number of farmers (several millions vs. 11,000+ installations in the EU ETS)
  - MRV
  - Transaction costs
- Leakage (internal and external)
- Adaptation and mitigation