Climate induced land use change in France: impacts of agricultural adaptation and climate change mitigation

Anna LUNGARSKA & Raja CHAKIR
INRA-AgroParisTech UMR Économie Publique

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Overview

Introduction

The model

Data

Estimates

Climate change and public policy simulations

Motivations

- IPCC R5 states that climate change effects are now clearly manifesting and the pace of warming is unprecedented.
- In December 2015, the first legally-binding global climate agreement was reached during the United Nations Climate Change Conference (COP 21).
- It builds on ambitious commitments:
  - The European Union announced a 40% reduction in greenhouse gases (GHG).
  - France pledged a 75% emission cut by 2050.
  - Agriculture is to reduce its GHG emissions by half comparing to 1990.
- Climate change adaptation and mitigation in agriculture can lead to land use change (LUC).
- Here, we evaluate the combined effect of these two factors on GHG and LUC in France.

CC impact on agriculture and land use: literature

- Assessing CC impacts on agriculture:
  - mathematical programming (Adams et al., 1990, 1995; Leclère et al., 2013);
  - econometric methods (Mendelsohn et al., 1994; Schlenker et al., 2005; **?**).
- Assessing impacts on land use:
  - Crops vs. pastures (Fezzi and Bateman, 2011);
  - With other land demanding sectors (Haim et al., 2011; Ay et al., 2014).
- These studies are build on the econometric methods for predicting climate change impacts on the economic activities.
  They do not account for spatial autocorrelation.

CC mitigation from agriculture: literature

- Two main techniques for assessing CO_2 abatement costs for agriculture (Vermont and De Cara, 2010):
  - General equilibrium models: comprises all sectors but lack details;
  - Supply-side models: a more detailed representation but no price feed-backs;
  - Engineering models: best detail but low scope of the models.
- Except in general equilibrium models, no feed-back on land use has been considered.

Objectives

In this paper:

- We simulate different tax levels for GHG emissions from agriculture;
- We evaluate the effects of climate change and the tax on land use and on the overall GHG emissions from farming.
- We show that a GHG tax can lead to land use allocations deemed desirable by policy makers: preservation/extension of pastures and forests.

Methodology

- We propose a methodology for the study of the impacts of CC on land use for four main classes : i) agriculture; ii) forests; iii) urban; and iv) other.
- We use land rent data from sector-specific mathematical programming models for agriculture (AROPAj) and forestry (FFSM++).
- We combine these data via an econometric land-use share model accounting for spatial autocorrelation.
- The model is developed at the scale of a 8 km × 8 km homogeneous grid covering metropolitan France.
- This methodology has two main advantages:
    1. It allows us to take into account some adaptation measures available to economic agents.
    2. We can simulate the effects of different public policy scenarios.

Modeling strategy

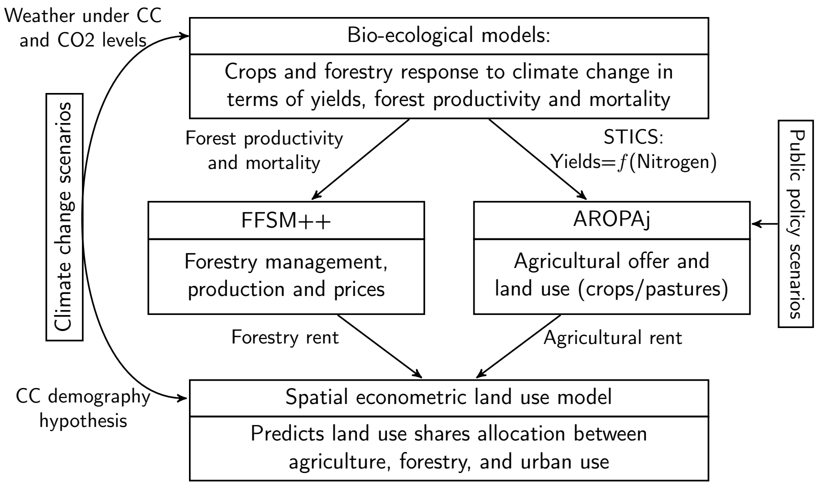

Figure : Modeling scheme

Econometric model

- A land use shares model and a logistic specification for the share functions:

$$y_{ki} = p_{ki} + \epsilon_{ki} \tag{1}$$

$$p_{ki} = \frac{e^{\beta_k' X_i}}{\sum_{j=1}^{K} e^{\beta_j' X_i}} \tag{2}$$

  - y_{ki} is the share of land use k in the grid cell i ;
  - p_{ki} is the the expected share;
  - X_i are the explanatory variables and their effects β_k'.

Applying Zellner and Lee (1965) approximation, y_{Ki} being the land use of reference:

$$\tilde{y}_{ki} = ln(y_{ki}/y_{Ki}) = \beta_k' X_i + u_{ki} \tag{3}$$

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Choice of spatial model specification

- In a previous study (Chakir and Lungarska, 2016), we compare different spatial specifications for the land use share model.
- We opt for a spatial Durbin error model with two neighborhood matrices depending on the scale of the explanatory variables.

Spatial autocorrelation

- Spatial autocorrelation is modelled as a spatial error model (SEM).

$$\begin{aligned}\widetilde{y} &= X\beta + W_1X'\beta' + W_2X''\beta'' + \varepsilon \\ \varepsilon &= \lambda W_1\varepsilon + u\end{aligned} \tag{4}$$

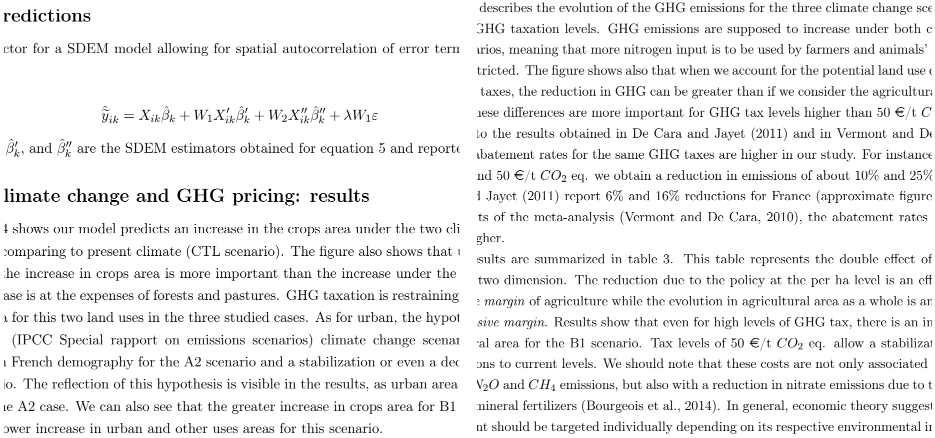
  W_1 being the weight matrix of the grid cells (contiguity queen rule);
  W_2 is the weight matrix of administrative regions.
  X', β' are the variables available at the grid scale level and the associated coefficients;
  X'', β'' are the variables available at the administrative region level and the associated coefficients.
- Spatial autocorrelation can originate from:
  - Omitted variables;
  - Artificial grid;
  - Spatial phenomena at a scale other than the one studied.

Estimated with `R` package `spdep`, `Matrix` option.

Data

- **Land use shares** are derived from the Corine Land Cover 2000 database: *agriculture, forestry, urban* and *other* (used as reference); original scale 1 ha.
- **Forestry revenues** are estimated by the FFSM++ partial equilibrium model (Lobianco et al., 2015) for the administrative region.
- **Urban rent** is approximated by the population density and revenues for the *commune* (INSEE).
- **Agricultural rent** is approximated by AROPAj (agricultural supply-side model, Jayet et al., 2015) at the scale of the administrative region.
- **Relief and soils**: we use information on the slope and the texture of soils (GTOPO30 and JRC European soils database).

Estimates



redictions

ctor for a SDEM model allowing for spatial autocorrelation of error tern

$$\hat{\hat{y}}_{ik} = X_{ik}\hat{\beta}_k + W_1 X'_{ik}\hat{\beta}'_k + W_2 X''_{ik}\hat{\beta}''_k + \lambda W_1 \varepsilon$$

$\hat{\beta}'_k$, and $\hat{\beta}''_k$ are the SDEM estimators obtained for equation 5 and reporte

limate change and GHG pricing: results

4 shows our model predicts an increase in the crops area under the two cli
comparing to present climate (CTL scenario). The figure also shows that u
he increase in crops area is more important than the increase under the
ase is at the expenses of forests and pastures. GHG taxation is restraining
a for this two land uses in the three studied cases. As for urban, the hypot
(IPCC Special rapport on emissions scenarios) climate change scenar
a French demography for the A2 scenario and a stabilization or even a dec
io. The reflection of this hypothesis is visible in the results, as urban area
ie A2 case. We can also see that the greater increase in crops area for B1
ower increase in urban and other uses areas for this scenario.

describes the evolution of the GHG emissions for the three climate change sce
GHG taxation levels. GHG emissions are supposed to increase under both c
arios, meaning that more nitrogen input is to be used by farmers and animals'
tricted. The figure shows also that when we account for the potential land use
taxes, the reduction in GHG can be greater than if we consider the agricultura
hese differences are more important for GHG tax levels higher than 50 €/t C
to the results obtained in De Cara and Jayet (2011) and in Vermont and De
abatement rates for the same GHG taxes are higher in our study. For instance
nd 50 €/t CO_2 eq. we obtain a reduction in emissions of about 10% and 25%
l Jayet (2011) report 6% and 16% reductions for France (approximate figure
ts of the meta-analysis (Vermont and De Cara, 2010), the abatement rates
gher.

esults are summarized in table 3. This table represents the double effect of
two dimension. The reduction due to the policy at the per ha level is an eff
e *margin* of agriculture while the evolution in agricultural area as a whole is an
sive margin. Results show that even for high levels of GHG tax, there is an in
al area for the B1 scenario. Tax levels of 50 €/t CO_2 eq. allow a stabilizat
ons to current levels. We should note that these costs are not only associated
V_2O and CH_4 emissions, but also with a reduction in nitrate emissions due to t
mineral fertilizers (Bourgeois et al., 2014). In general, economic theory suggest
nt should be targeted individually depending on its respective environmental i

↪

Figure : Estimated coefficients and significance.

Climate change and public policy simulations

We evaluate two climate change and/or two public policy scenarios.

Climate change:

- IPCC SRES scenario **A2** – a pessimistic scenario, temperature increase between 1.4 and 6.4°C; demographic increase;
- IPCC SRES scenario **B1** – an optimistic scenario, temperature increase between 1.1 and 2.9°C; slower demographic increase and even a decrease towards the end of the XXIst century.

Public policy:

- **Tax** on GHG emissions from agriculture varying from 0 to 200 €/tCO_2 equivalent.

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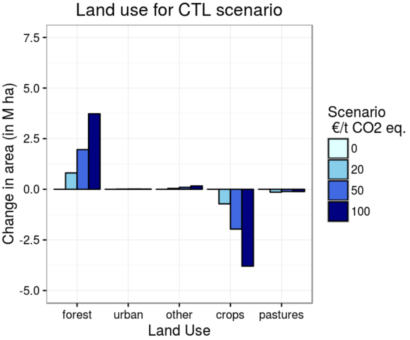
Effects of the GHG emissions taxation on land use

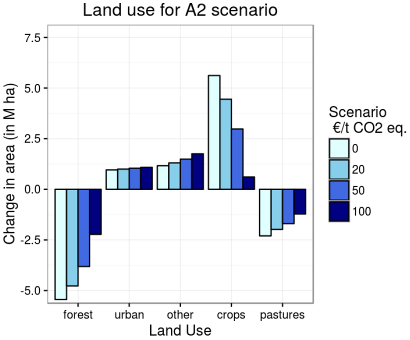


Climate change scenario	GHG taxation (€/tCO_2 eq.)	All GHG evolution (%)	GHG emissions per ha (tCO_2 eq.)	Utilized agricultural area evolution (%)
CTL	0	100.00	3.453	100.00
	20	90.11	3.190	97.54
	50	76.41	2.805	94.08
	100	63.76	2.478	88.85

*Utilized agricultural area equals the sum of land devoted to crops and to pastures.

Table : Emission abatement, change in agricultural area, and abatement costs.

Effects of the GHG emissions taxation, A2 scenario

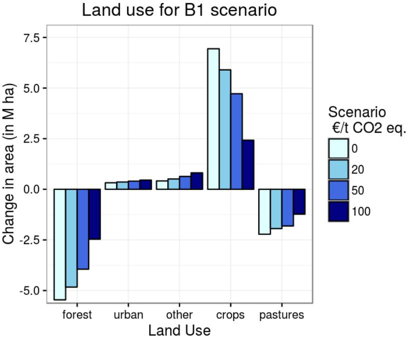


Climate change scenario	GHG taxation (€/tCO_2 eq.)	All GHG evolution (%)	GHG emissions per ha (tCO_2 eq.)	Utilized agricultural area evolution (%)
A2	0	127.04	4.008	109.47
	20	115.18	3.716	107.05
	50	98.36	3.277	103.65
	100	81.49	2.864	98.26

*Utilized agricultural area equals the sum of land devoted to crops and to pastures.

Table : Emission abatement, change in agricultural area, and abatement costs.

Effects of the GHG emissions taxation, B1 scenario

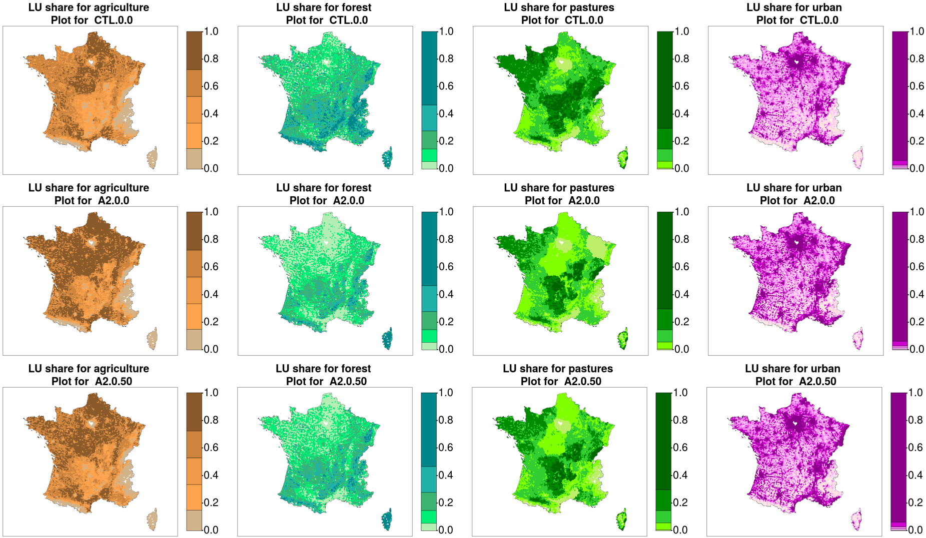


Climate change scenario	GHG taxation (€/tCO_2 eq.)	All GHG evolution (%)	GHG emissions per ha (tCO_2 eq.)	Utilized agricultural area evolution (%)
B1	0	125.80	3.829	113.47
	20	115.47	3.583	111.29
	50	99.85	3.184	108.30
	100	84.89	2.835	103.41

*Utilized agricultural area equals the sum of land devoted to crops and to pastures.

Table : Emission abatement, change in agricultural area, and abatement costs.

Land use effects, A2 scenario



LU share for agriculture
Plot for CTL.0.0

LU share for forest
Plot for CTL.0.0

LU share for pastures
Plot for CTL.0.0

LU share for urban
Plot for CTL.0.0

LU share for agriculture
Plot for A2.0.0

LU share for forest
Plot for A2.0.0

LU share for pastures
Plot for A2.0.0

LU share for urban
Plot for A2.0.0

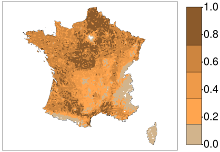
LU share for agriculture
Plot for A2.0.50

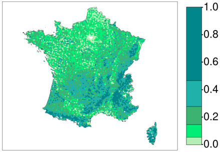
LU share for forest
Plot for A2.0.50

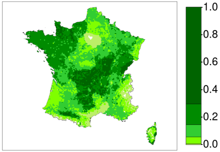
LU share for pastures
Plot for A2.0.50

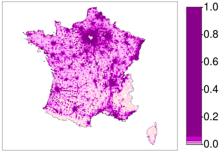
LU share for urban
Plot for A2.0.50

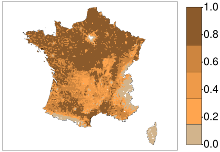
Land use effects, B1 scenario

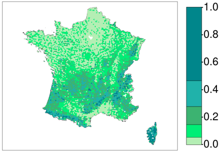

LU share for agriculture
Plot for CTL.0.0

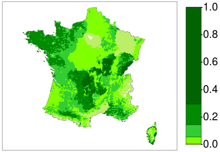

LU share for forest
Plot for CTL.0.0

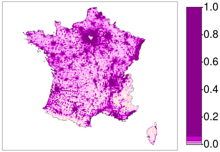

LU share for pastures
Plot for CTL.0.0

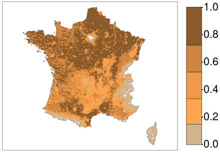

LU share for urban
Plot for CTL.0.0

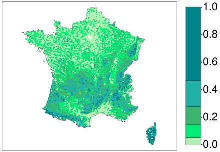

LU share for agriculture
Plot for B1.0.0

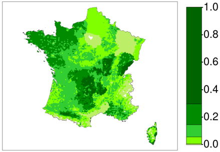

LU share for forest
Plot for B1.0.0

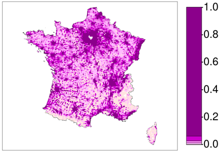

LU share for pastures
Plot for B1.0.0


LU share for urban
Plot for B1.0.0


LU share for agriculture
Plot for B1.0.50


LU share for forest
Plot for B1.0.50


LU share for pastures
Plot for B1.0.50


LU share for urban
Plot for B1.0.50

Accounting for land use change in GHG policy

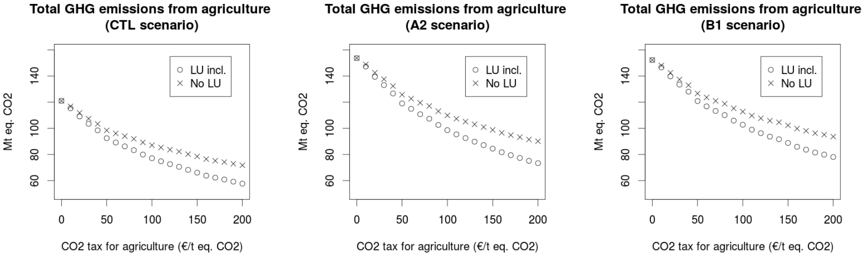


Figure : National GHG emissions from agriculture when accounting for LUC.

Conclusion

- Both CC scenarios lead to an increase in crop area at the expense of forests and pastures.
- Taxing GHG emissions can curtail this progression.
- Accounting for land use change resulting of the GHG taxation results in lower abatement costs for agriculture.
- Potential synergies between environmental objectives are to be identified and measured:
  - CO_2 and NO_3 objectives;
  - Internalization of the negative externalities and increase in forest area.

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Thank you for your attention!

`Anna.Lungarska@inra.fr`
`Raja.Chakir@inra.fr`