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# The economic issues

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Ensuring sufficient food production in the context of climate change: economists explore the trade-offs between land use, greenhouse gas emissions, and agricultural production using integrated approaches.

With close to 6 gigatons of carbon dioxide equivalent released globally each year (just under 50 gigatons of carbon dioxide were emitted in 2010), greenhouse gas emissions from agriculture are higher than those from the transportation sector. When including emissions from land-use change (primarily due to deforestation), land-based sectors are together among the highest contributors of greenhouse gas emissions at the global level. Agriculture and forestry are thus poised to play an essential role in both mitigating emissions and adapting to climate change.

The need to reduce greenhouse gas emissions while both adapting to climate change and responding to a growing food demand raises the following questions: How can agricultural production (and in a broader sense, land use) be optimized to address this trade-off? How can producers and consumers be encouraged to efficiently change their behavior? What environmental impacts can be expected from these changes? These questions are not only of interest to agricultural, ecological or climate sciences. They also call for integrated assessments that encompass the economic impacts from the micro-economic level (farms, for example) to the macro-economic level (intersectoral distribution of mitigation efforts, consequences on global markets). Several types of economic models have been used to address these issues at these various scales. Together, they shed some quantitative light on the latitude of public policies aimed at mitigation and adaptation.

How can a given mitigation target be met at a minimal cost to society? This question of cost-effectiveness is at the core of environmental economics. Cost-effective mitigation means prioritizing for mobilization the most cost-effective potential mitigation actions possible. As production conditions, and hence mitigation costs, vary from one agent to the other, cost-effective mitigation efforts are not necessarily uniformly distributed among individuals, regions, or sectors. The difficulty is therefore ensuring that all individual actions or decisions are compatible with a cost-effective mitigation plan at the aggregated level. Environmental economics has shown that economic instruments provide powerful incentives in this respect. The rationale is simple: by transmitting a price signal (in the form of a tax or a market price in the cap-and-trade system) that reflects the value of the damage caused by his/her emissions, all agents are encouraged to integrate this value in their decisions about production or consumption and cost-effectively mobilize their mitigation potential.

**Assessing the costs and potential mitigation measures**

To analyze cost-effective distribution of the mitigation effort within the agricultural sector, mitigation costs and potential need to be measured. Microeconomic, supply-side agricultural models can provide such quantitative assessments. These models describe the economic behavior of a wide range of farmers operating in a variety of contexts and production conditions. These models account for farmers' revenues and costs, as well as for the constraints imposed by agricultural policy measures, agronomy, and animal production. They give the opportunity to simulate the impacts of a public policy on production, emission levels, and revenue.

This type of model has been applied to the French agricultural sector, which, despite a contribution of about 20 percent to total emissions in France, is largely absent from French mitigation policy measures currently in place. In 2011, we were able to show that, even under rather conservative assumptions regarding the mitigation potential, French agriculture could reduce its emissions by up to 10 percent lower than levels in 2005 at a cost of around 35 euros per ton of carbon dioxide equivalent. This cost is of the same order of magnitude of those prevalent in other sectors of the economy. This indicates that agriculture has an important role to play in ensuring that France reaches its mitigation objectives at the lowest possible cost.

The same model was applied to the European agricultural sector to assess the gains that can be expected from the implementation of a cap-and-trade system for agricultural greenhouse gas emissions in the context of the objectives defined by the EU climate energy package. This package adopted by the European Union in 2009 aims to increase the share of renewable energy, reduce carbon dioxide emissions, and increase energy efficiency. In addition, it sets an ambitious mitigation target for the 'non-ETS' sectors (the sectors not covered by the European carbon trading scheme, i.e., mainly agriculture, residential sectors, transport). The overall reduction in non-ETS sectors was distributed among Member States according to the 'effort sharing' agreement.

Our results show that, for the 10 percent mitigation target implied by the effort sharing agreement, the total mitigation cost could be reduced by half if mitigation is distributed cost-effectively among EU Member States compared to the strict implementation of the national targets implied by the effort sharing agreement. This


### What role does the consumer play?

Food production in France, which accounts for about 30 percent of "greenhouse gas emissions", has both positive and negative effects on water, biodiversity and land use. According to a "life cycle" approach of the food chain which includes agricultural production, storage and food processing, transportation, distribution, consumption and waste management, agricultural production is the main contributor to these effects.

Life cycle inventories of agricultural products highlight very different impacts per kilogram of product, depending on the type of commodity (plant or animal products, different types of meat), but also according to the production method (in open fields or in heated greenhouses, using extensive or intensive livestock systems). However, each food, responding to different nutritional needs and varied economic and social expectations, may have its place in a balanced diet.

What role can consumers play? First, they can be educated about how their food and the environment are linked. A first action, both simple and economical, is to reduce food waste, which represents approximately 30 kilograms per person per year of discarded food: including food that was produced, transformed and stored in vain. Further, they can change their diet: over-consumption of food rich in animal products and Western-style food, sugar and fats, consumption of alcohol or sweet drinks, all increase the environmental footprint for food consumption, but are also health risk factors. Finally, consumers can support certain methods and locations of production, by selecting products with recognized labels and by avoiding fruits and vegetables sold out of season.

Sarah Martin and Vincent Columbus, ADEME reduction could be achieved at a price between 30 and 40 euros per ton of equivalent carbon dioxide.

The implications of cost-effectiveness are not restricted to the agriculture sector alone. Mitigation achieved in the agricultural sector could, in part, substitute to the most costly mitigation measures in other economic sectors, therefore offering additional opportunities to lower overall mitigation costs. Our results show for instance that extending the scope of the EU ETS to include agricultural emissions could reduce the mitigation costs faced by the other sectors of the economy by roughly 30 percent (or an annual savings of more than two billion euros) for the same EU mitigation target by 2020.

Agriculture can also participate in mitigation by providing biomass as a substitute to fossil fuel energy. In response to high energy costs, biofuels were introduced in the early 2000s as a means of diversifying the energy supply while offering market opportunities for farmers and reducing greenhouse gas emissions in the transportation sector. However, the indirect impacts of the development of biofuels on land use have raised a fierce debate about the net effect of biofuels on emissions (see opposite box). Beyond this debate, this illustrates the complex interactions between mitigation of greenhouse gases emissions and land use change related emissions. This alone underlines the need for comprehensive and integrated economic modeling approaches encompassing all land uses, particularly agriculture and forestry.

The results discussed above underscore the importance of well-designed economic incentives to encourage farmers to make cost-effective modifications to their production. Without such incentives, the total mitigation cost might appear too large, which in turn might favor inaction, while mitigation potentials do indeed exist.

Agriculture and forestry are influenced by the climate. Climate projections made for different time horizons are conditioned by techniques that we are actively further developing for greater efficiency. These improved techniques, at an initial cost to fund the necessary research project, will ultimately lower the cost of energy per unit.

In agriculture, for example, we are anticipating increased efficiency through the use of inputs (energy, fertilizers, plant protection products, seed, irrigation), within the framework of sustainable agriculture. In models designed to favor the environment, we are working on creating systems to limit inputs. However, modeling becomes more complex when tasked with predicting contributions of genetic progress, development of GMOs or developing new varieties. This area of adaptation depends on policies in research and development. Yet, as a result of climate change, farmers (and other economic agents), will adapt their agronomic practices to the new conditions, as they will adapt to any changes in public policy. This change will take place independently and will be difficult to integrate into global economic models.

## Biofuels in question

The contribution of first generation biofuels to mitigating climate changes, for many years, has generated lively debates in the scientific community and in political circles. This potential was evaluated by life cycle analysis, which included greenhouse gas emissions from the production phase up to consumption phase. However, it was considered to be incomplete because it did not take into account the indirect effects in developing the sector. Indeed, as demand for raw agricultural materials used to produce the biofuels increases, this causes tension in the markets and a rise in prices, an incentive for production, and therefore potential conversion of agricultural land parcels originally not intended for such uses. This change in use releases carbon stored in soils and in the developed biomass.

Calculating the amounts of released carbon, combined with the balance of biofuels, is complex and involves a number of uncertainties. It requires the use of various models, especially economic models. Different estimations of these emissions around the world vary, and the balance in terms of greenhouse gases released through these channels could be significantly lowered, as confirmed by the assessment published in 2012 by INRA at the request of ADEME. According to half of published evaluations which took into account emissions associated with changes in land use, emissions related to the use of first-generation biofuels would be higher than those of fossil fuels. Ongoing research continues to refine these assessments and identify routes for improvement. Beyond biofuels, it will be necessary to integrate greenhouse gas emissions linked to indirect effects of different policies of land use, for example other energy crops, the development of livestock systems, or urbanization of agricultural land.

Antonio Bispo, ADEME

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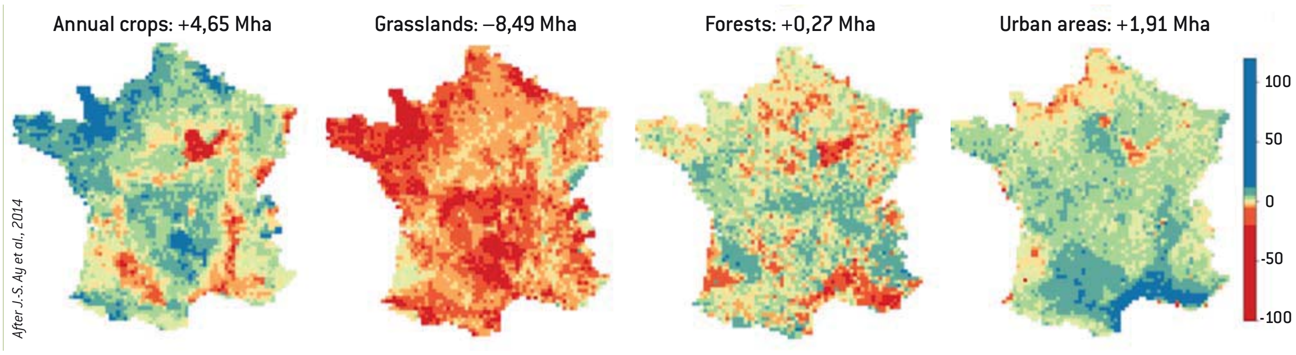
*Sugar cane can be used to produce biofuels.*




*Planned changes in land use according to of the scenarios used to model the consequences of climate change. These variations illustrate changes between 2003 and 2053 for surfaces dedicated to four uses (from left to right: annual crops, grasslands, forests and urban areas). On these maps, the surfaces are expressed in tens of hectares in each 12 km by 12 km grid box.*

**The economics of adaptation**

In 2013, David Leclère and his colleagues at the French National Institute for Agricultural Research (INRA) and the Laboratory of Climate and Environmental Science (LSCE), highlighted the effects of autonomous adaptation by farmers across the European Union in two climate scenarios. Production levels of agricultural land and their locations would change, as well as local greenhouse gas emissions, with a marked change in water needs. It is possible that, if current prices are sustained, European farmers would benefit from these changes. This is even the scenario associated with the sharpest increase in temperatures, which appears to be the most favorable. In the South as in the North, the availability of water resources could become the primary issue. Inevitably, this will pose the problem of accessing the water in the right place and at the right time. In addition, with an increased demand for food, agricultural prices could rise, as it has already been observed for some years. Although favorable at the outset for producers, this change will slow with increasing costs of inputs.

The impacts of climate change on production conditions are likely to modify revenues from different land uses, whether for agricultural, forestry or urban purposes. In addition to impacts on agricultural systems and forestry, climate changes will have consequences on land markets and on land use. Jean-Sauveur Ay and his colleagues at INRA studied these questions. Using historical data of French land use, they evaluated existing links between expected revenues of five uses (annual crops, grassland, forests, perennial crops and urban use) and climatic conditions. Their results indicate that climate change expected for 2050 will significantly alter uses in France (see figure above). They show a decrease in grasslands (with a loss of roughly 8.5 million hectares) with an increase of annual crops (gaining close to 5 million hectares). Grasslands store large quantities of carbon and such changes would have significant consequences on emissions due to land use.

Thus, through adaptation, systems will change significantly, resulting in lower or higher greenhouse gas emissions. It is estimated that, for many European farmers, higher yields could result in an increase in nitrogen oxide ($N_2O$) emissions, which is related to increased use of nitrogen amendments. This will affect mitigation strategies, which in themselves are likely to cause an adaptation dynamic.

This dynamic depends in large part on the emissions and their delayed effect on the climate. Depending on how long greenhouse gases remain in the atmosphere and other influential factors, they contribute to make the analysis of this dynamic particularly complex. From an economic perspective, we will also need to compare today's efforts and benefits to those we will need to agree on for the future.

But the complexity should not serve as a pretext for inaction. If we understand the difficulties involved in implementing pollution regulation, even when it is as simple as characterizing water quality by its nitrate levels, and regardless of how confident we are in technological advances, a basic precautionary principle should push us to move quickly to limit the impacts of climate change, impacts which remain uncertain in a local context but are certain to have global effects.

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