EVALUATION OF CLIMATE CHANGE MITIGATION POLICIES IN AGRICULTURE

Kahil, M.T.[a], Tapia, J.[a], Orús, F.[b] and Albiac, J.[a]

[a] Centro de Investigación y Tecnologia Agroalimentaria de Aragón (CITA-DGA), Avda. Montañana 930, 50059, Zaragoza
[b] Centro de Transferencia Agroalimentaria (CTA-DGA), Avda. Montañana 930, 50059, Zaragoza

1. Introduction

The impacts of climate change on the human society and the environment have been the subject of wide discussions and social concern during recent decades. Several studies indicate that the South of Europe and the Mediterranean basin will sustain large negative effects from climate variability, with considerable damages on food production. Appropriate climate conditions for cultivation are expected to move northwards, resulting in more frequent and severe droughts in the Mediterranean area (Olesen and Bindi 2002, IPCC 2007 and 2011).

Agriculture is a source of GHG emissions such as methane (CH_4) and nitrous oxide (N_2O), coming from nitrogen fertilization in cultivated soils, large animal production facilities, and nitrogen pollution loads in rivers and water streams. In Aragon, agricultural GHG emissions represent 20 percent of total emissions, which is above the national average (EACCEL 2011). Spain is committed by the Kyoto Protocol to reduce GHG emissions. However, emissions have been increasing during the last decade well above the binding threshold. The agricultural sector has an important potential to reduce GHG emissions, and enhance carbon sequestration by using adequate mitigation policies. This study analyzes the GHG emission sources linked to agricultural production activities, and evaluates the cost-effectiveness of several mitigation policies in the Huesca province of Aragon.

2. Methodology

The paper analyzes cultivation and livestock activities in four counties of Huesca: Barbastro, Cinca Medio, Huesca and Monegros. This area includes almost half of the irrigated acreage in Aragon (181,000 ha), and more than 2.5 million heads of swine herd. The analysis covers the main cultivation activities and the bovine and swine livestock herds.

A linear programming model has been developed to assess the cost-effectiveness of several climate change mitigation measures. The model maximizes the private benefits of farmers from cultivation and livestock activities, subject to technical and production constraints, such as land endowment, water and labor availability, and livestock facilities. In the model, it is assumed a Leontief production function, and fixed input and output prices, where farmers are price takers.

Biophysical and economic data specific for the study area have been collected and used in the model: use of land, water, fertilizers and labor, and revenues and costs of crops and livestock production activities. The method used to assess agricultural GHG emissions follows the approach of the Intergovernmental Panel on Climate Change (IPCC 1996). This method combines the use of emission factors per activity unit, and the regional-specific activity data on crop acreage, fertilizer use, animal numbers, manure management systems, and historical Spanish emission data.

3. Results and discussion

Agriculture contributes to GHG emissions through four main gas-emitting processes: direct and indirect N_2O emissions from agricultural soils, N_2O emissions from manure management, CH_4 emissions from manure management, and CH_4 emissions from enteric fermentation. The emissions in the four counties studied are estimated at about 727.000 t CO_2eq, which are 20 percent of agricultural emissions in Aragon. Manure management is the main source of emissions with 65 percent of emissions, given the large concentration of swine herd in this area. Moreover,

around half of emissions are from Monegros, which is also the county generating the largest quasi-rent (30 million €). In terms of emission intensity, Monegros is the most intensive (80 €/t CO_2eq) followed by Cinca Medio, Huesca and Barbastro.[1] The study area is quite intensive in emissions (91 €/t CO_2eq) compared to the emission intensity of the agricultural sector in Aragon (339 €/t CO_2eq) (Table 1).

GHG mitigation policy measures have been widely studied in the literature during the last decade (Bates 2001, IPCC 2007). The model is used to analyze the effects of some of these GHG mitigation measures from the agricultural sector in the study area. The environmental policies examined are emission taxes, input-based taxes (irrigation water and nitrogen), reduction of irrigation water by 25 percent, improved feed of swine herd, and reduction of swine herd by 15 percent (Table 2).

The first best instrument of taxing emissions achieves the maximum social welfare (+37% over the baseline) with a level of GHG emissions that is socially acceptable. The emission tax is 25 €/t CO_2eq, and embodies the environmental damage.[2] This instrument is difficult to implement because agricultural pollution cannot be easily observed and monitored, and its abatement involves cooperation among farmers.

Besides, all studied measures generate high abatement costs between 42 and 3,000 €/t CO_2eq. This range is above the threshold abatement cost of 20 €/t CO_2eq recommended by the European Climate Change Program (2003). Among measures, the largest emissions reduction (-10%) is obtained by reducing the swine herd, although this measure generates large losses in terms of farmers' quasi-rent and social welfare (4 and 2%, respectively).

The improved feeding of the swine herd is a measure proposed by the IPPC directive to reduce emissions from swine production. This measure has a slight effect on social welfare, and its abatement potential is quite low. Nevertheless, it generates positive ancillary effects by reducing ammonia emissions and phosphorus pollution loads in water courses.

The market-based instrument of taxing water and nitrogen reduces emissions between 2 and 5 percent, but the cost to farmers is very large, with reductions in quasi-rent ranging from 13 to 36 percent. The decrease of irrigation water reduces GHG emissions by 3 percent, with positive effects on the nitrogen pollution loads of water streams. However, the acreage of crops is also reduced.

4. Conclusions

The spatial assessment of GHG emissions complements the national and regional GHG inventories, since inventories do not reflect the spatial distribution of pollution from agriculture. Results show that the emission intensity is very different among locations. This spatial information is important for the design and implementation of GHG mitigation policies adapted to local conditions.

The analysis of the GHG mitigation measures in the agricultural sector indicates that there is not a unique preferred measure. The choice of measures depends on the objective of the decision-makers, and the availability of biophysical and economic information. Local characteristics and social acceptability have to be considered in the design of abatement measures, because enforcement requires the support of stakeholders to be legitimate. In Aragon, more attention has to be paid to manure management in order to find solutions for a better use of this waste that could

[1] The lower is the value of the emission intensity, the more emission intensive is the production within an area.
[2] The value of the environmental damage is assumed to be equal to the price of the emission allowance in the European Trading Scheme.

become a resource if properly managed. Manure management is also an important aspect for the implementation of the existing environmental legislation.[3]

Table 1. Agricultural GHG emission by source and the related economic activities

	Barbastro	Cinca Medio	Huesca	Monegros	Total study area
N_2O direct emission from agricultural soil (10^3 t CO_2eq)	16	12	20	45	93
N_2O indirect emission from agricultural soil (10^3 t CO_2eq)	10	7	12	27	56
N_2O manure management (10^3 t CO_2eq)	3	8	5	9	25
CH_4 manure management (10^3 t CO_2eq)	63	88	45	246	442
CH_4 enteric fermentation (10^3 t CO_2eq)	15	32	17	47	111
Total emissions (10^3 t CO_2eq)	**107**	**147**	**99**	**374**	**727**
Crops' quasi-rent (10^6 €)	9	8	5	17	39
Livestock's quasi-rent (10^6 €)	4	6	5	13	28
Total quasi-rent (10^6 €)	**13**	**14**	**10**	**30**	**67**
Emission intensity (€/t CO_2eq)	**122**	**95**	**100**	**80**	**91**

Table 2. Results of GHG mitigation policies

Scenarios	Welfare (10^6 €)	Quasi-rent (10^6 €)	Environmental damage (10^6 €)	GHG emissions (10^3 t CO_2eq)	Crop acreage (10^3 ha)	Swine herd (10^3 heads)
Baseline	49	67	18	727	134	2,050
Emission tax (t_e=25 €/t CO_2eq)	67	49	18	700	136	1,940
Water tax (t_w=0.02 €/m^3)	48	57	18	711	119	2,050
Water tax (t_w=0.05 €/m^3)	47	43	18	706	117	2,050
Reduction of irrigation water (25%)	43	61	18	709	114	2,050
Nitrogen tax (t_n=0.5 €/kg N)	48	58	17	694	114	2,050
Nitrogen tax (t_n=1 €/kg N)	48	51	17	690	111	2,050
Improved feed	46	64	18	726	134	2,050
Swine herd reduction (15%)	48	64	16	655	134	1,746

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[3] The availability of nitrogen from manure in Aragon could cover up to 80 percent of the nitrogen requirements of arable crops. Manure has the potential of reducing the use of mineral fertilizer, saving costs, and abating GHG emissions. There are also problems with the implementation of the Nitrates Directive, where the enforcement is based on penalties on individual farmers drawn by chance, and not on measured total pollution loads coming from the irrigation district. The current organic fertilization limits from the Nitrates Directive are excessive compared to crop requirements.