Agricultural practices with greenhouse mitigation potential in Mediterranean countries: Evaluation and policy implications

Felipe Medina[a] and Ana Iglesias[b]

[a]Department of Agricultural Economics, Union of Farmers Associations (COAG), Spain; fmedina@coag.org
[b]Department of Agricultural Economics and Social Sciences, Universidad Politécnica de Madrid (UPM), Spain; ana.iglesias@upm.es

Abstract: *The landscape of Mediterranean rural areas is shaped with crops well adapted to semi-arid zones, such as cereals and olives. In this paper we aim to understand the opportunities of agricultural systems in the Mediterranean to reduce greenhouse gas emissions and the management interventions with a special focus on policy development. We use the mitigation potential of a range of agricultural practices to pre-select the ones that may bring some opportunities in traditional Mediterranean farming systems. These practises are then evaluated by a range of stakeholders to define the barriers and opportunities for their implementation. Our results show that farmers have substantial information on the relative importance of agricultural practices that are environmentally sustainable, in consequence responding to the critical need for knowledge on agricultural response to mitigation of greenhouse gases. Nevertheless, the implementation of these agricultural practices needs to be policy-driven. We evaluate the role of the EU agricultural and environmental policy in the implementation and calculate the economic incentive for the range of practices and crops. The results are delivered to the stakeholders in a matrix of simple recommendations. While simple recommendations will never provide the level of mitigation possible with more complex choices, the direct interpretation of the results by farmers and policy-makers may be of great value to achieve emission control targets and to the process of policy development.*

Keywords: *Climate change, greenhouse gas mitigation, agricultural practices, Mediterranean countries, cereal, olives.*

Introduction

Cereals and olives shape the landscape of rural Mediterranean areas. Since they are well adapted to semi-arid zones, olives and cereals cover over 60% of the agricultural areas where they contribute to the social and environmental stability. Mediterranean countries have about one fourth of the total world area of olives whereas cereals are part of the agricultural system in all regions. A significant change in the area cultivated by these crops in European countries since the mid 1980s was driven by the direct price support of the Common Agricultural Policy of the European Union (CAP). After 2000 the agro-environmental measures of the CAP have contributed to a shift in the view of farmers on their role in protecting the environment. However, the CAP is undergoing far-reaching changes, emphasizing the role of agriculture to provide environmental services and foster rural development. The CAP environmental targets are supported by non-agricultural EU policies.

The potential role of agriculture in the mitigation of greenhouse gas emissions is currently being explored. The large surface occupied by olives and cereals in Mediterranean countries guarantees that changes in the agricultural practices will have a very high potential impact on the environment (Smith et al., 2008; Quiroga and Iglesias, 2008; Guzman and Alonso, 2008). Reductions of the fertiliser residues in the environment are anticipated due to the implementation of the EU Water Framework Directive and the Nitrogen Directive; therefore an adjustment in the nitrogen fertiliser applied is required for sustainable production systems (Guzman and Alonso, 2008. There are many environmental benefits expected from the policy changes; social consequences are a challenge and require a closer emphasis on risk management to make agricultural systems more robust without direct support.

To achieve reduction targets of greenhouse gas emissions and aiming to reduce farmers' vulnerability to climate, the Common Agricultural Policy is now considering the introduction of incentives focused on climate change mitigation agricultural practices (European Commission resolution on the CAP 'Health Check' (European Council, 2008). To respond to this challenge, policy makers need to identify the value of changes in agricultural practices for achieving mitigation targets. An important step is to understand the interactions between agricultural practices and farmers response. The practical application of mitigation practices in agriculture depends on environmental conditions (soil quality, water conditions, and temperature), technology, type of crops and livestock, economic and social issues (acceptance, costs, administration needs). Therefore, it is necessary to analyze possibilities for their practical implementation as well as existing barriers, measures supporting their application and, finally, costs and benefits from their practical use. In this paper we aim to evaluate the current and potential mitigation measures in Mediterranean agriculture in order to make some simple recommendations for environmental and climate change future policies for Mediterranean agriculture.

Methods

The methodological framework developed for evaluation mitigation measures includes three components (PICCMAT, 2008) as it can observed in Figure 1. First, the experimental evidence of the mitigation potential. Second, the practices evaluation of stakeholders. These criteria are above all the interest for farmers, the existing barriers and limitations for the implementation and policy synergies. The incentive needed is estimated taken into account the cost of implementation. Finally, the third step includes the selected practices for policy recommendations according with the results of all analysis commented.

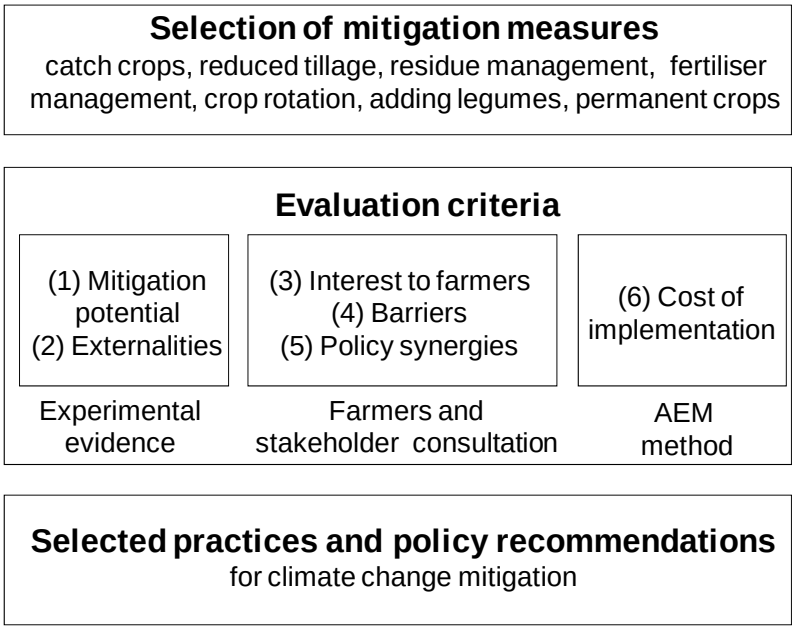

*Figure **1**.* Outline of the methodological framework.

The interviews (20) with farmers were carried out thanks to the main farmers union in Spain called COAG (Coordinadora de Organizaciones de Agricultores y Ganaderos). Their answers have been analyzed in detail trying to identify the most acceptable measures for farmers who will have to implement them in the feature. Then, a workshop with stakeholders was organized in order to compare farmer`s opinion and take into account the possible policy synergies of the measures implementation. This workshop was made up of 12 people from the Ministry of Agriculture, farmer`s unions and research centres. Table 1 summarises the sources of information and data.

Table 1. Evaluation criteria of the methodological framework.

Evaluation criteria	Data
1. Mitigation potential	Publication (pre-selection)
2. Effects and impacts	Publications and own work
3. Barriers and limitations for the implementation	Questionnaires, interviews, and own work
4. Interest for farmers	Interviews and questionnaires
5. Policy recommendations and compatibility with other Policies	Interviews and own work
6. Cost of implementation	Own work

Table 2. Data and information sources.

Type of information	Research and technical documents source
1. Statistical data	Ministry of Agriculture
2. Experimental data	Research farm "La Higueruela" situated in the region of Toledo
3. Interviews with farmers	Primary information about measures implementation possibilities Number of interviews: 20
4. Interviews with technical experts, policy makers and other stakeholders	Ministry of agriculture (5 persons) Farmers Union (5 persons) Research Centres (2 persons)
5. Publications	Review of specific papers in scientific publications.

The implementation of new practices may decrease the final yield of each crop, increase the costs but not affect the yield, or the two previous at the same time. In addition, the implementation of new practices may need control of implementation, so it is necessary to have an account notebook in the farms (new cost for many farmers). It may also need control of effectiveness, based on indicators (i.e., European Environmental Agency EEA, The International Renewable Energy Agency IRENA). Therefore the implementation of new practices may need economic incentives. The method developed is based on the premium calculation for agro-environmental measures. The data needed for the calculation include: average yield or productivity (kg/ha), average price (€/ha), calculated income (€/ha), need of an account notebook, the estimated cost of the account notebook (€/ha) and the cost of control analysis (€/ha). Production cost of implementation without any additional incentives or payments as agri-enviromental payments have been calculated.

Results and discussion

Selection of mitigation measures

The measures that have been pre-selected for their ease of implementation according to interviews and workshops conducted for this purpose are: catch crops, zero/reduced tillage, residue management, optimization of the fertilization application/type, rotation species, association with legumes, and permanent crops. These are the seven measures pre-selected for cereal production and five for the olive production studies. The definitions of the measures are summarised in Table 3.

Table 3. Definition of the mitigation measures selected adequate for cereal and olive productions.

Selected measures	Definition for the cereal and olive production studies
1. Catch crops	Cereal: Cultivating simultaneously in the exploitation of other plant species in addition to the crop that is supplemented, so that the interactions that occur between them exert a stimulating effect on them, resulting in better yields and retention of nutrients. Ex: fallow seeds or spontaneous vegetation, interspersed summer crops (sunflower), maintaining the stubble of the crop in the ground until its incorporation in the autumn. Olive: Maintenance of spontaneous vegetation or planting mix of herbaceous plant species or legumes among the trees in order to retain nutrients in the soil and reduce emissions of GHG.
2. Zero/Reduced tillage	Cereal: Tillage surface, perpendicular to the slope or no tillage with the aim of reducing the decomposition, increasing quantities of C in soil and reduction of GHG emissions by reducing aeration and incorporation of crop remains on the floor and retail use of heavy machinery. Olive: Tillage surface, perpendicular to the slope or no tillage with the aim of reducing the decomposition, increasing quantities of C in soil and reduction of GHG emissions by reducing aeration and incorporation of crop remains to the ground.
3. Residue management	Cereal: Incorporation of crop remains (straw and / or stubble) to the ground by means used for better water conservation, return and integration of C to the ground providing sequestration C. Olive: Incorporation of the remains of pruning to the ground by means used for better water conservation, return and integration of C to the ground providing sequestration C.
4. Fertiliser application/type	Cereal: Changes in the amounts of application in the location or the type of fertilizer such as the implementation in areas of cracks or rupture. Olive: Changes in the amounts of application in the location or the type of fertilizer such as the implementation in areas of cracks or rupture.
5. Rotation species	Cereal: Introduction of different crops in the same plot against time in order to improve the utilization of soil nutrients. Linked to the association of crops and optimizing the use of fertilizers
6. Adding legumes	Cereal: Cultivation in the same parcel of grain legumes with the aim of increasing the fixation of N in the soil and improve utilization of nutrients. Olive: Cultivation of legumes in the streets between rows of trees with the aim of increasing the fixation of N in the soil and improve the utilization of nutrients.
7. Permanent crops	Cereal: Transition from arable crops to timber. Examples: restoration of hedges and edges with tree species or reforestation of farmland

Mitigation potential

Many agricultural techniques contribute to the fixation CO2 and N2O in the soil avoiding their emission to the atmosphere and contributing in addition to a greater retention to water and a smaller erosion (Kurkalova, 2004). The extension of these practices to the different agricultural spaces increases the potential considerably to palliate the effects of GHGs due to their capacity of absorption. Table 4 details some estimations of the mitigation potential of different agricultural practices that can be developed with the objective of climate change mitigation.

Table 4. Mitigation potential of agricultural practices.

Measure	Media (t CO_2-eq. ha^{-1} $year^{-1}$)	Range(t CO_2-eq. ha^{-1} $year^{-1}$)	Mitigation potential
Catch crops	0.33	(-0.21; 1.05)	++
Reduced tillage	0.17	(-0.52; 0.86)	+
Residue management	0.17	(-0.52; 0.86)	+
Fertilizer use/type	0.33	(-0.21; 1.05)	++
Crop rotation	0.39	(0.07; 0.71)	+++
Adding legumes	0.39	(0.07; 0.71)	+++
Permanent crops	0.17	(-0.52; 0.86)	+

Source: PICCMAT, 2008

Externalities

The IPCC (2007) and Smith et al (2007a; 2007b) reviewed in detail the environmental effects of a full range of potential mitigation measures. Here we present the results of the evaluation of the possible environmental effects of the measures pre-selected for Mediterranean agriculture. The evaluation

was based in a literature review and informal discussion of the implications with the stakeholders that participated in the study. There are many environmental benefits that entail the implementation of these measures. Increased biodiversity, reduced soil erosion, increasing the effective precipitation and lower loss of minerals are some examples. Table 5 summarizes the possible effects of the measures implementation. However, some times, the introduction of these measures may result in certain environmental problems such as increased energy expenditure involved in the process of cutting up and incorporation into the soil of the remains of harvesting or the potential for contamination of bad management manures in animal production among others. The possible negative effects of the implementation of the measures are also summarized in Table 4.

Table 5. Possible additional effects of measures implementation.

Measures	**Possible positive effects in the environment**	**Possible negative effects in the environment**
1. Catch crops	Reduction of CO2 release to the atmosphere Decreased soil erosion Reduction or pests Reducing water pollution by herbicides	Minor problem of washing salt (only in olives)
2. Zero/Reduced tillage	Reduction of the oxidation processes and thus the release of CO2 into the atmosphere Increasing effective rainfall (less runoff)	Minor problem with soil erosion Pests and diseases proliferation in cereals and increase of pests associated with stubble in olives
3. Residue management	Reduction of CO2 release to the atmosphere Lower pollution levels Lower cost of transportation and energy saving Lower energy consumption for the production of agrochemicals	Energy cost of chopping the straw and fitted (only for cereals)
4. Fertiliser application/type	Lower pollution levels Slowing the loss of minerals (leaching) through appropriate timetables Closed cycle (take advantage of farm waste) Lower cost of transportation Reduced use of fertilizers Energy saving Improved water quality Saving the energy required in the production of agrochemicals	Animal manure can be highly polluting (if there is good management and storage
5. Rotation species	Increase of the biodiversity Better use of nutrients in soil Fixing atmospheric N Helps reduce the losses of soil N Increased below-ground biomass (holding capacity C) Energy saving	Minor specific pests: Pest Control (polyculture) Minor depletion of soil fertility
6. Adding legumes	Increased C in soil and atmospheric N by the crop (rizobium) Energy savings (no use of synthetic fertilizer N)	Minor contamination of waters and the atmosphere
7. Permanent crops	Increase of CO2 Positive effects on biodiversity Decreased soil erosion Enhanced land conservation Closed-cycle power	None

Interest for farmers

The results of the consultation to stakeholders show that all these measures are being developed by most of the organic producers that currently are receiving aid by Agri-Environmental Masures (AEM). Table 5 summarizes the results of the consultation to farmers in relation to the implementation of various measures. Reduced tillage and optimization fertilizers use/type are the easiest ones to implement according to the opinion of the producers interviewed. However, rotation species, residue management, adding legumes and catch crops are more difficult to be developed by producers as they affirm. These are techniques that require a greater degree of knowledge and

training. In the opinion of farmers, the most difficult measure to implement is the change of culture towards permanent crops, since weather conditions do not allow it in some of the cases.

Table 6. Interest to farmers. Range: (-1/3).

Measures	Reasons (legal, habits, feasibility, etc.)	Changes considered	Perception of measure implementation
Catch crops	Environmental	Environmental	+
Zero/ reduced tillage	Economic	Economic	+++
Residue management	Habits and environment	-	+
Fertiliser application/ type	Energetic efficiency	Environmental, Economic	++
Rotation species	Environmental	Biodiversity, Economic	+
Adding legumes	Environmental	Biodiversity, Economic	+
Permanent crops	Economic	Economic	-

Barriers and limitations

The barriers for the implementation of the measures have been quantified with data obtained from interviews and questionnaires (qualitative information) trying to assign the value 0 when there is no problem of implementation, 0,5 when problems are not relevant and 1 when there is a real problem of implementation. These results are shown in Table 6. The economic feasibility, the cross compliance and the environment are the most important reasons that lead to farmers to take the decision of introducing or developing most of the measures. The growing prices of inputs and the stagnation of prices received by farmers make many producers search new techniques of cheaper production.

Table 7. Barriers for new measures implementation (Range 0 -1) Cereals production.

Measure	Social	Political	Technical	Economic	Training	TOTAL
CEREAL						
1. Catch crops	0	0	1	1	0	2
2. Zero/Reduced tillage	1	0	0,5	0	1	2,5
3. Residue management	1	1	1	1	0	4
4. Fertiliser application/type	1	0	1	1	1	4
5. Rotation species	0	1	1	1	1	4
6. Adding legumes	1	1	1	1	1	5
7. Permanent crops	1	1	1	1	1	5
OLIVES						
1. Catch crops	0	0	1	1	1	3
2. Zero/Reduced tillage	0	0	0,5	0	0,5	1
3. Residue management	1	1	1	1	1	5
4. Fertiliser application/ type	1	0	1	1	1	4
6. Adding legumes	0	0	1	1	1	3

0: No barriers; 0,5: Some barriers, low intensity 1: Barriers and high intensity

In general the existing rules are perfectly fit the selected measures in the agro-environmental measures or cross compliance, but it should be taken into account the constraints of the budgets of the Common Agricultural Policy. Some measures reflected in the regulations of cross compliance, as optimizing the use of chemical fertilizers, are mostly the same that are envisaged in the regulation of organic farming. All these measures have a clear positive influence in emissions of greenhouse gases reduction and storing C in the soil.

Evaluation of current policy instruments and synergies

Combat soil erosion, conserve biodiversity, reduce pollution and the protection of the landscape are common goals that make the implementation of the measures described is perfectly compatible with the implementation of these regulations. There are currently no support tools for farmers who develop actions aimed at protecting the climate. However, some requirements of environmental measures and cross-compliance suggestions are so similar to the selected measures (Table 9). All the measures could be implemented in organic farming in our country. However, measures related to reduced tillage, optimizing the use/type of fertilizers and catch crops should be primarily supported.

Table 8. Compatibility of each measure with agro-environmental measures (AEM) and cross-compliance.

Measures	Affected by cross-compliance?	Affected by agro-environmental measures?	Current Premiums for AEM, Organic farming measure
CEREALS			
1. Catch crops	Yes	Yes	46 €/ha
2. Zero/Reduced tillage	Yes		
3. Residue management		Yes	
4. Fertiliser application/type		Yes	100 €/ha
5. Rotation species		Yes	
6. Adding legumes		Yes	
7. Permanent crops	Yes	Yes	
OLIVES			
1. Catch crops		Yes	26 €/ha
2. Zero/Reduced tillage	Yes		
3. Residue management		Yes	
4. Fertiliser application/ type		Yes	38 €/ha
6. Adding legumes		Yes	36 €/ha

Cost of implementation

The impact and the cost of implementation of individual measures are summarized in Table 7. The implementation of the new measures may lead to a decrease of the crop yield, an increase of production costs, both possibilities at the same time or neither. Moreover, as it has been explained at methodology chapter, it becomes necessary to use a count-book on the farm to take control of the expenses that are incurred. Similarly, obtaining public funding requires inspections and analysis based on indicators to verify that they are actually reducing emissions of greenhouse gases. In some cases, the implementation of these measures requires the establishment of some incentives with the objective of having a big area of application.

Table 9. Impact and estimated cost of implementation in cereals production.

Measure	Yield decrease (%)	New management	Estimated cost of implementation without incentives (€/ha)
CEREALS			
1. Catch crops	Insignificant in irrigated zones. 1-5% in dry lands	Hampers control of adventitious, disease and pests and the introduction of the next crop, Planting and maintenance of the ground cover	54
2. Zero/Reduced tillage	7	Hampers control of adventitious reduction of the use of machinery with regard to conventional tillage	8
3. Residue management	-	Increased cost of operation, management and machinery	44
4. Fertiliser application/type	10	Changes in the types and quantities of fertilizer times involve alterations in the management of the crop	74
5. Rotation species	Induction of some crops (5-10%)	Increased training and skills implies increased costs. Lower profitability by introducing new crops	56
6. Adding legumes	It must increase in a long term	Planting and maintenance of legumes. Complicates the management and separation needed at harvest	43
7. Permanent crops	-	Planting and maintenance of new permanent crops	45
OLIVES			
1. Catch crops	Insignificant in irrigated zones. 1-5% in dry lands	Mowing in spring Sowing in autumn. Makes the management of water resources	71
2. Zero/Reduced tillage	7	Reducing the use of machinery with regard to conventional tillage	118
3. Residue management	-	Increase in the cost of handling and management	72
4. Fertiliser application/ type	10	Changes in the times / amounts of fertilization involves alterations in the development of the crop	146
6. Adding legumes	It must increase in a long term	Planting and maintenance of legumes. Complicates the management and training needs	75

Conclusions

Many actions on the practices of agricultural production and livestock can be made with the aim of reducing the emission of greenhouse gases into the atmosphere. Starting with specific agricultural techniques such as those cited above, through the management of manures and pastures in livestock, and ending with the fuel savings inherent in the various activities linked to production, there are numerous strategies that can be developed for climate change mitigation through agricultural activity.

The main criteria for the selection of the various steps in the analysis have been three in particular: the mitigation potential, the barriers of a possible implementation and the economic cost of implementation. Under these criteria, within the specific strategies of agricultural production, and more specifically those relating to the production of cereal in Mediterranean countries are reduced tillage, fertilizers use optimization and catch crops seems to be more appropriate, although taking into account that the effects of catch crops have a major limitation in time.

In the case of the olive grove, taking into account that this crop has already a great potential for fixing nutrients in the soil, it should be noted that the most appropriate measures to be implemented

based in the results of the analysis are reduced tillage measure, adding legumes and catch crops, even with the same limitation than in the case of cereal production. These actions, including all of them within organic production, can play a great role in reducing the emission of greenhouse gases into the atmosphere if a high level of implementation happens in our agriculture.

However, there are few barriers for the implementation of most of these measures, which are mainly technical and related with formative training. There is a need of more training and information among farmers, good incentives to rich a large area of application and, the most important, the occurrence of a series of gradual changes in the mindset of the producers, key players in this process.

In many cases, the implementation of some of these measures can carry other negative consequences for the initial production, either purely productive (yields, pests, diseases, etc.) or whether an economic (increased costs, profitability). For this reason, series of necessary support to escort incentives or training processes aimed at producers seems to be necessary, that is, it seems more appropriate support policies through incentives to these techniques, than coercive policies to carry out the cross compliance internalizing the environmental cost in the income of farmers.

This bring us to suggest the use of article 68 (articled created to aim sector with specific problems that can contain till 10% of direct payments budget of each member state) of the proposed regulation of the European Commission for the health check of the CAP introduced in 2008, to encourage these measures aimed at mitigating climate change. In addition, support for these measures can come through the allocation of additional funds from the modulation for combating climate change through agro-environment measures.

The agro-environment measure of organic farming seems a very interesting way to achieve the desired degree of implementation of all these techniques in view of its enclave within the existing rules relating to cross compliance and the agro-environmental measures set by the European Union. In addition, the inclusion of these commitments in all environmental measures could greatly contribute to achieve the targets set in terms of reduction of GHG emissions from agricultural activity, which might even need to change the system of calculation in premiums and reconsider their commitments in that measure of organic farming because, as it has been observed, some of these techniques are not considered in the premium calculation.

Most of main Mediterranean crops as olive grove or vineyards, are working as carbon fixers into the soil. In most of the cases, their greenhouse gas emissions balance is negative. Actually, data offered by IPCC related with GHGs emissions from Mediterranean crops is being questioned in our country. Some research studies are demonstrating that these crops are nowadays contributing so much to the climate change mitigation by agriculture.

References

CE 2003. Reg. 1782/2003. Direct payments of Common Agricultural Policy (CAP).

CE 2004. Reg. 796/2004 about cross compliance in European Agricultural Policy.

European Council (2008) Reg 16049/08. Propuesta de reglamento del consejo en el marco del chequeo médico de la PAC.

Guzmán, G. and M. González de Molina y E. Sevilla (Eds). (2000) Introducción a la agroecología como desarrollo rural sostenible. Mundi-Prensa. Madrid.

IPCC (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group. II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Chapter 12 and Summary for Policymakers.

Junta de Andalucía (2007) Agro-evironmental measures regulation.

Junta de Andalucía (2008) Rural Development Program of Andalucía period 2007-2013.

Junta de Castilla la Mancha (2008) Rural Development Program of Castilla la Mancha period 2007-2013.

Junta de Castilla la Mancha (2008) Agro-evironmental measures regulation.

Kurkalova, L., Kling C.L. and J. Zhao (2004) Multiple benefits of carbon friendly agricultural practices: empirical assessment of conservation tillage. Environ. Manage. 33, 519-527.

MAPA (2002) Real Decreto 1322/2002 de aplicación de la condicionalidad de la PAC.

MAPA (2007) Real Decreto 1470/2007 de aplicación de las ayudas directas de la PAC.

Medina, F. (2008) La gestión del riesgo y las políticas de cambio climático en la agricultura ecológica. COAG, Madrid, Spain.

PESETA (2008) (Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis). http://peseta.jrc.ec.europa.eu (last visited 22 Nov 2008)

PICCMAT (2008) Policy Incentives for Climate Change Mitigation Agricultural Techniques. European Commission, DG Agriculture, Specific Support Action. Brussels, October 2008

Quiroga, S. and A. Iglesias (2008) Projections of economic impacts o climate change in agriculture in Europe. *Economía Agraria y Recursos Naturales* 7(14): 65-82.

Schneider, U.A. and B.A. McCarl (2006) Implications of a carbon based energy tax for US agriculture. Agric. Res. Econ. Rev. 34: 264-278.

SEAE (2006) Contribución de la agricultura ecológica a la mitigación del cambio climático en comparación con la agricultura convencional. Informe técnico.

Smith, P. (2004) Carbon sequestration in croplands: the potential in Europe and the global context. European Journal of Agronomy 20: 229–236.

Smith, P., Somogyi, Z., Trines, E., Ward, M. and Y. Yamagata (2007a) Greenhouse gas mitigation in agriculture. Philosophical Transactions of Royal Society, 363(1492):789-813.

Smith, P., Daniel Martino, Zucong Cai, Daniel Gwary, Henry Janzen, Pushpam Kumar, Bruce McCarl, Stephen Ogle, Frank O'Mara, Charles Rice, Bob Scholes, Oleg Sirotenko, Mark Howden, Tim McAllister, Genxing Pan, Vladimir Romanenkov, Uwe Schneider and Sirintornthep Towprayoon (2007b) Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. Agriculture Ecosystems and Environment, 118: 6-28.