End of Project Report

Projections of Agricultural Land Use and the Consequent Environmental Implications

Jasmina Behan and Kieran McQuinn

Rural Economy Research Centre

Project No. 4822

December 2002

Summary

The research conducted under the project no. 4822 resulted in an extension of the FAPRI-Ireland econometric model of Irish agriculture, established by Rural Economy Research Centre, to include an environmental dimension. The original model was first extended by a forestry component. As a result, the standard output is now enhanced with the additional projections of agricultural land area allocated to forestry. In the next stage the model was developed to enable the conversion of standard agricultural and forestry output into environmental indicators associated with global warming. Therefore, the model currently provides projections of greenhouse gas emissions and carbon sequestration from Irish agriculture and forestry.

Objectives
The general objective is to generate projections of net greenhouse gas emissions from Irish agriculture. In order to achieve this objective we extend the existing model to generate projections of:

1. farmers' uptake of forestry on farmland
2. carbon sequestration from on-farm forests
3. greenhouse gas emissions from agricultural activities.

Methodology
The forestry component was added to the existing FAPRI-Ireland modelling system. An econometric technique is used to model farmers' forestry planting decision. The greenhouse gas emissions are calculated following the guidelines provided by the Intergovernmental Panel on Climate Change, which have been adjusted for Irish specific conditions. Carbon sequestration levels are generated by applying a methodology developed by COFORD, Ireland.

Key findings
The projections were generated under two policy scenarios. First, it was assumed that there would be no change in agricultural or forestry policy over the projection period. Second, the assumption was made that policy measures are introduced to encourage further extensification of agricultural practices.

If there was no policy change, the results suggest that afforestation on farmland would exceed 10,000 ha per annum; However the uptake would not, at any point, reach the level of planting recorded in 2001. As forests planted on farmland mature, carbon sequestration levels are projected to continuously increase in the coming years. On the other hand, greenhouse gas emissions from agriculture are expected to decline as a result of the projected contraction in the national cattle herd and sheep flock.

If policy was reformed to include further extensification of livestock production, it is expected that less agricultural land would be allocated to forestry. The reduction in planting, however, would not be sufficient to significantly affect the

carbon uptake levels projected under the no policy change scenario. However, further extensification would lead to further contraction in livestock numbers, which would result in more pronounced reductions in greenhouse gas emissions.

Introduction

Climate change and global warming have been the subject of increased debate in an agricultural policy context in recent years. In 1997, the United Nations Framework Convention on Climate Change (UNFCCC) adopted the Kyoto Protocol (see UNFCCC (1997) for details). The Protocol outlines targets and timetables for the reduction of human induced sources of global warming. It was agreed that by 2012, global emissions of greenhouse gases[1] (GHGs) expressed in carbon dioxide (CO_2) equivalents should be five percent less than emission levels recorded in 1990. Ireland's commitment under the protocol is to limit its emissions of greenhouse gases to not more than 13 percent above 1990 levels.[2] In order to achieve this target, the Irish Department of the Environment has published the National Strategy on Climate Change (NSCC) (Department of the Environment (2000)), which proposes measures for the mitigation of greenhouse gas emissions across different sectors of the economy. The strategy emphasises that the contribution of agriculture towards reaching the target should come from both a reduction in emissions and an increase in sequestration by on-farm forestry.

Ireland is unusual in that more than one third of its human induced greenhouse gas emissions originate in agriculture. In 1998, it was estimated that agriculture, at 35 percent, was the single largest producer of GHGs (Department of the Environment (2000)). This is primarily due to the structure of Irish agriculture, where the livestock sectors[3] typically account for over 80 percent of agricultural output value. Between cattle and sheep, Ireland has more than 14 million ruminant animals. These animals represent the main source of methane, a gas with a relatively high global warming potential. Consequently, one of the proposed strategies in the NSCC is to target agriculture as a source of greenhouse gases. The objective is to achieve a reduction in agricultural emissions of 2.2 million tonnes (Mt) carbon dioxide (CO_2) equivalents by the end of the commitment period 2008-2010 (Department of the Environment (2000), p. 5) from a 'business as usual' projected level of 18.7 Mt CO_2 equivalents.

On the other hand, forestry plays an important role in the reduction of greenhouse gases. Afforestation, reforestation and deforestation that have taken place since 1990 are identified in the Article 3.3 of the Protocol as acceptable greenhouse gas sinks.[4] Because Irish climatic conditions are relatively conducive for tree growth, there is considerable potential for the expansion of forest cover in Ireland. Currently, only nine percent of Irish total land area is classified as woodland, placing Ireland at the low end of EU forest cover ranking. Along with the relevance that forests have as a natural resource for timber industry, their importance is also identified with respect to rural development and environmental

[1] The main greenhouse gases considered under the Protocol are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs) and sulphur hexafluoride (SF_6).
[2] Ireland's allocation was as part of a total EU reduction target of eight per cent.
[3] The beef, pig, sheep and dairy sectors.
[4] Greenhouse gas sinks are defined as reservoirs in which sequestered CO_2 is stored.

protection. In this context, in its strategic plan for forestry, the government sets out an objective of increasing the forest cover to 17 percent by 2030. This is to be achieved by annual afforestation targets of 20,000 ha, with the emphasis on private planting by farmers (Department of Agriculture, Food and Forestry 1996).[5] This afforestation is hoped to ensure, *inter alia*, that by the end of the commitment period, the sequestration target of 1 Mt CO_2 equivalents outlined in the national strategy is reached. However, despite considerable increases in the incentives introduced to engage farmers in afforestation, planted area is consistently falling short of the national target.

The objective of our study is to provide information on the likely future evolution of net greenhouse gas emissions (including removals by forest sink) from Irish agriculture, for a set policy environment. The results will provide an indication as to whether the emission reduction targets for agriculture are likely to be achieved without additional policy stimulus. In addition, we examine how the results change if agricultural policy is reformed to encourage more extensive agricultural practices.

1. Greenhouse gases from agriculture

Greenhouse gases are gaseous constituents in the atmosphere, which have the ability to absorb the heat that subsequently resides in their molecules for a specific time period. An increased concentration of these gases in the atmosphere changes the radiative energy balance between the Earth and space by retarding the energy transfer between the two. This produces a greenhouse effect, hence their name: greenhouse gases.

The Kyoto protocol (Annex A) defines the source categories of greenhouse gas emissions from agriculture. The sources applicable to Ireland include:

- Enteric fermentation
- Manure management
- Agricultural soils.

These source categories result in the production of the two most significant GHGs in an Irish context - methane (CH_4) and nitrous oxide (N_20). Methane is released following the decomposition of organic matter in the digestive tract of ruminant animals i.e. enteric fermentation. In Ireland therefore, the emission levels of CH_4 depends directly on the size of the national cattle herd, since the most significant source categories of CH_4 are dairy and non-dairy cattle. The decomposition process of organic matter in animal waste results in the further release of both CH_4 and N_20. In Ireland, most cattle manure is left on the pasture, while some is managed in liquid systems and solid and dry lots. Given the climatic conditions conducive for fermentation, manure left on pasture represents a significant source of greenhouse gases (Department of the Environment

[5] This figure was initially set at 25,000 ha per annum and was revised downwards to 20,000 ha in 2000.

(1998)). Agricultural soils are the main source of N_20. Direct emissions arise from the application of fertilizers, both organic and synthetic, as well as from livestock production. In Ireland, given the nature of agricultural production, fertilisers are mostly used on pasture. The indirect soil emissions of nitrous oxide are a product of nitrogen leaching and atmospheric deposition of nitrogen.

2. Methodology

The projections on greenhouse gas emissions, on-farm forestry and sequestration are based on the projections of numerous agricultural variables provided by a large scale econometric model developed under the FAPRI-Ireland Partnership. The original FAPRI-Ireland model is extended to include an environmental dimension. First, an extension to the model is added in order to produce information on future farm afforestation levels. Subsequently, the projections on various source and sink categories generated by the models are converted into emission and sequestration levels.

Since its inception in 1997, the FAPRI-Ireland model has been used to generate projections and analyse the implications of likely policy changes for Irish agriculture over a ten-year horizon. The model compiles a series of interlinking commodity economic models for the Irish beef, sheep, dairy, crops and inputs sectors and under this project is extended to include on-farm forestry. The projections are generated, first, by assuming that there would be no policy change over the projection period. This is referred to as a baseline result and is used as a benchmark for the analysis of alternative policy scenarios.

The FAPRI-Ireland model provides projections on all of the key agricultural variables used to generate emissions of GHGs. This includes projections of animal numbers across source categories, as well as the quantities of synthetic nitrogen fertilizer applied. This 'raw' agricultural data is then converted into greenhouse gas emission levels by applying a methodology developed by the Intergovernmental Panel on Climate Change (IPCC (2001)), which is adjusted for Irish specific characteristics by the Irish Environmental Protection Agency (EPA (2002)). An example of this approach is provided in Behan and McQuinn (2002).

In order to ensure that greenhouse gas removals by on-farm forests are included in the assessment of progress in achieving national emissions targets, it is necessary to generate projections of farm afforestation levels. The original FAPRI-Ireland model which included a land share system for traditional agricultural enterprises, such as cereals and livestock, is now expanded to allow agricultural area to include forestry. The area allocation between traditional agricultural enterprises and forestry is based on an econometric analysis of the factors which underlie farmers' involvement in forestry. Those factors include financial revenues and costs associated with both forestry and mainstream agricultural enterprises. The projections of future farm afforestation levels are generated using a panel data analysis for five regions[6] in the country. A regional

[6] The regions are the mid-east, the north-west, the west, the south-west and the south-east.

approach ensures that geographical, as well as the production differences across regions are accounted for.

The projected on-farm afforestation areas are converted into carbon sequestration levels by applying conversion factors developed by COFORD[7] (2002). The calculations take into account the differences in carbon storage capacity across tree species. They also allow for differences in growth increments at various maturity stages. For instance, the total biomass expansion for a mature conifer tree is almost four times greater than that for a young one. Hence, the capacity to act as a carbon sink and assist in reaching the Kyoto target, depends, at any given year, on the age and species structure of the farm forests.

3. Results

Two sets of results for both agriculture and forestry are presented. The first is based on the assumption that over the projection period 2001-2010, there is no change in the EU CAP policy environment. It is also assumed that the current premium and other forest subsidy schemes for farmers will remain in place in their existing form. We refer to the projections generated under this assumption as the baseline projection.

A second series of projections are subsequently generated under an alternative series of policy assumptions – the scenario result. The policy scenario analysed in this context is an extensification scenario, which quantifies the impact on Irish agriculture of moves towards more extensive production practices in the livestock sector. Full details of this scenario are in Binfield *et al.* (2002b).[8] The effects of this scenario are measured with respect to the baseline result.

a. Baseline results

Emissions

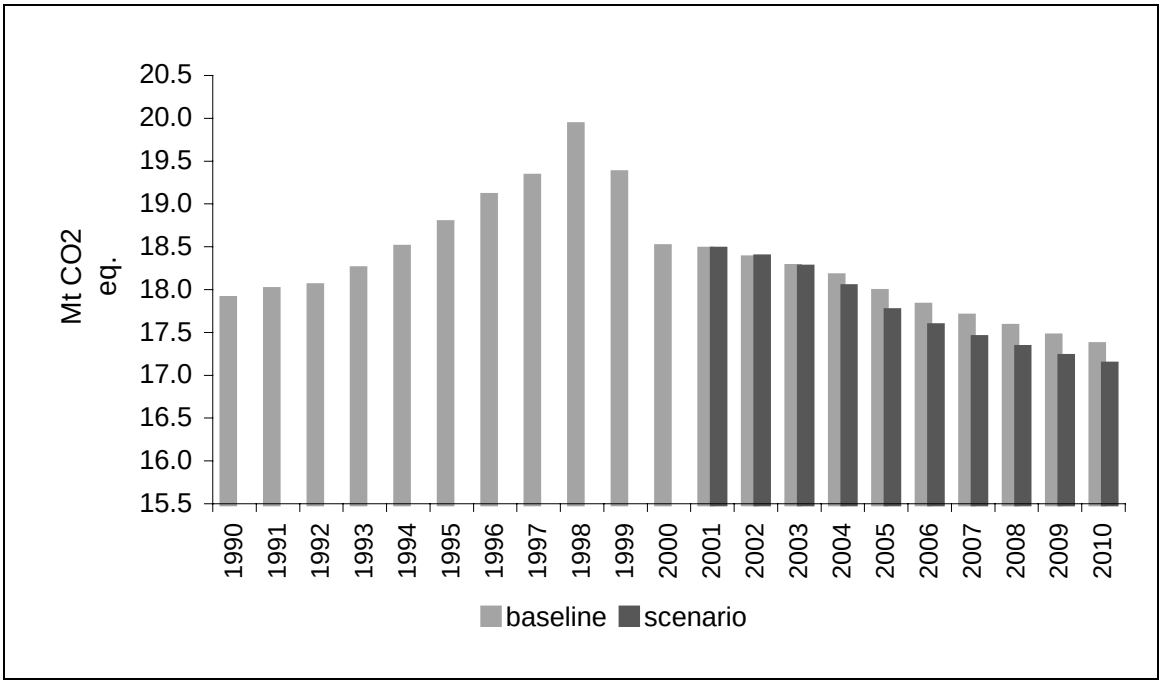
Assuming no policy change, the emissions from agriculture are expected to decline by 0.54 Mt CO_2 equivalents relative to the 1990 level. The reduction arises from the expected fall in animal numbers over the projection period, which in turn reflects the long-term decline in per capita beef consumption (Binfield *et al.* (2002a). The reduction in dairy cow numbers is associated with the persistence of milk quota and the expected increases in individual animal productivity. It is also expected that the non-dairy herd will contract as a result of the decline in profitability of that sector, as well as the implementation of extensification measures guaranteed under the reform of the CAP under Agenda 2000. As a result, methane emissions from enteric fermentation and manure

[7] COFORD is the Irish Council for Forest Research and Development and it provides estimates of carbon sink coefficients for national communications to the UNFCCC.

[8] This scenario was initially devised in February of 2002 as a possible CAP Mid-Term Review (MTR) policy scenario. The actual MTR proposal, announced in July 2002, went a step further by advocating the full decoupling of direct aid payments.

management are expected to decline. The decline in animal numbers is also expected to lead to lower levels of fertiliser application, which in turn leads to a reduction in nitrous oxide emissions from agricultural soils. The baseline projections of emission levels are shown in Figure 1.

Figure 1. Greenhouse gas emissions from Irish agriculture

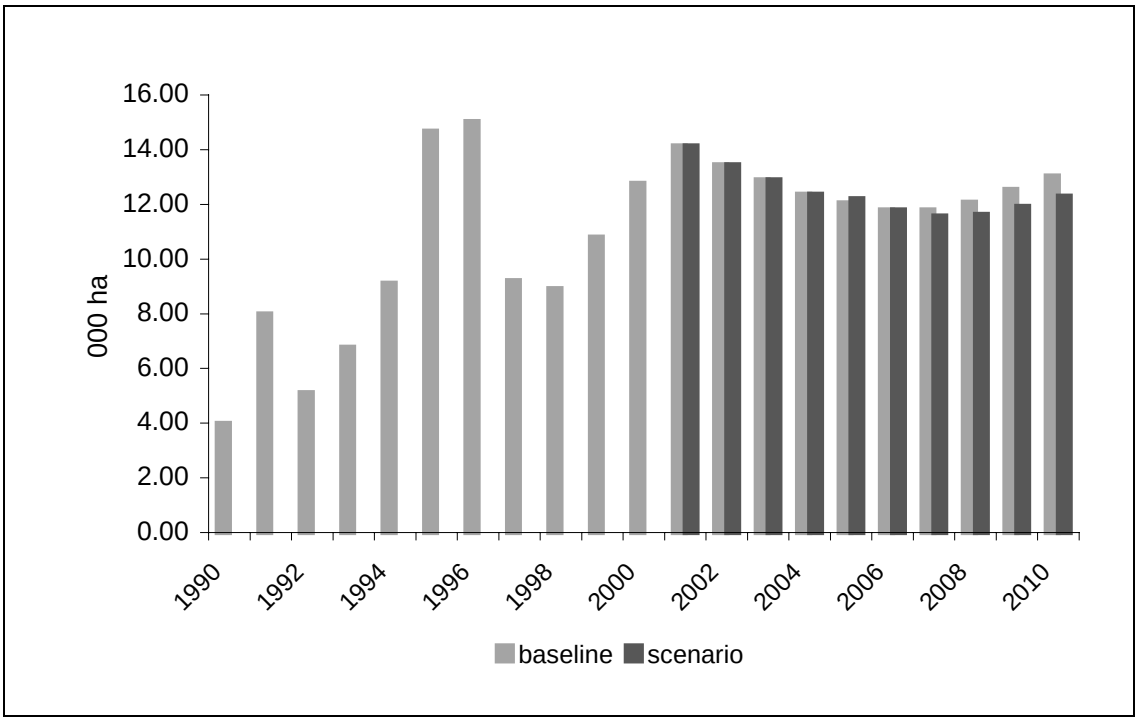


Source: FAPRI-Ireland Model

On-farm afforestation

Over the projection period, it is expected that on-farm afforestation will remain above 10,000 ha per annum. Figure 2 illustrates the evolution of farm afforestation for the period 1990-2010. Following the initial fall in planting rates relative to those recorded in 2001, afforestation is expected to increase later in the projection period. The initial decline is a result of increased competition between forestry and traditional agriculture, particularly beef production. In the first half of the projection period, the recovery of the beef sector from the BSE crisis in 2000 improves its competitiveness in the contest for land. However, farm forestry is expected to regain its competitiveness in later years, as beef consumption and prices return to their long-run pattern of decline.

Figure 2. On-farm afforestation in Ireland



Source: FAPRI-Ireland Model

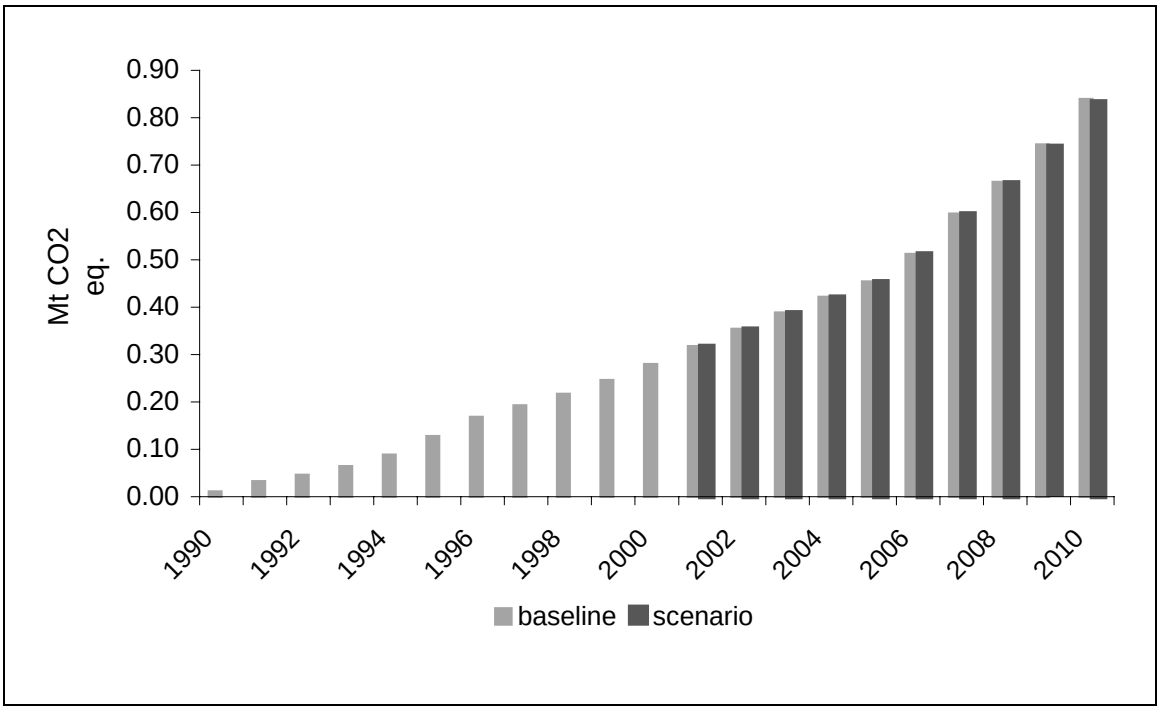
Carbon sequestration

Carbon sequestration from farm forests planted since 1990 is expected to reach 0.84 Mt CO_2 equivalents by 2010. The sequestration levels become more pronounced towards the end of the projection period. As forests planted in the early 1990s mature, their capability to store carbon increases. Projected carbon sequestration levels are presented in Figure 3.

b. Scenario results

Under the Agenda 2000 reform, two extensification limits were introduced to influence the level and type of EU beef production. The basic concept behind extensification is to provide incentives for beef producers to hold fewer animals per hectare of land. Producers are compensated for the loss of receipts from these animals by the introduction of extensification payments, which are on a per animal basis. The payments introduced under the extensification scheme are conditional on adherence by the producer to two different stocking density limits. In an Irish case, producers have the option to stock their farms at either less than 1.4 livestock units (LU) per hectare or between 1.4 and 1.8 LU per hectare. The lower the stocking density rate the higher the payment.

Figure 3. On-farm carbon sequestration in Ireland



Source: FAPRI-Ireland Model

Under a scenario performed on the FAPRI-Ireland model (see Binfield *et al.* (2002b) for more details), the two extensification limits of 1.4 and 1.8 LU per hectare are reduced by 0.2 LU. Thus, the new limits for receipt of extensification payments are at a stocking density level between 1.2 and 1.6 LU per hectare and a stocking density of less than 1.2 LU per hectare. By lowering the stocking density limits and increasing the associated payments, the aim of the scenario is to quantify the reduction in beef animals likely to be associated with these new limits.

Emisions

A significant number of producers are expected to reduce their herd size, in order to comply with the more constraining livestock density limits. The reduction in herd size is particularly observed in the beef and sheep sectors. The additional decline in greenhouse gas source categories for agriculture translates into further reduction in emissions. The results from the scenario analysis suggest that a further reduction in emissions, of up to 0.23 Mt CO_2 equivalents relative to the baseline, can be achieved by 2010, with the introduction of measures for more extensive animal production. Emission levels under both the baseline and policy proposal can be observed in Figure 1.

On-farm afforestation
The introduction of incentives to further extensify production has an adverse effect on on-farm afforestation levels. In order to reduce livestock density to the required limit and thus qualify for the extensification payment, farmers have the option of either reducing their herd size or increasing the area going to livestock production. Thus, the increased extensification payments increase the marginal benefit of livestock production relative to that accruing from afforestation. Therefore, the results, which are presented in Figure 2, confirm that some of the land which was projected to be planted under the baseline, is expected to remain in traditional agriculture under the extensification scenario. The expected afforestation under the extensification scenario is 6 percent below the baseline levels.

Carbon sequestration
The decline in afforestation rates relative to the baseline does not have a significant effect on sequestration levels. This result is explained by the fact that the additional area planted and registered as a carbon sink under the baseline, is accounted for by relatively young trees. Their capability for carbon storing at such an age is consequently relatively small.

c. ***Net greenhouse gas emissions***

By subtracting projected carbon sequestration levels from the projected greenhouse gas emission level we obtain the net greenhouse gas emissions position from Irish agriculture. Under the baseline, the projected net greenhouse gas emissions for 2010 are 16.5 Mt CO_2 equivalents. This is 1 Mt CO_2 equivalents above the national target for agricultural sector. Under the scenario analysis, net greenhouse gas emissions from agriculture are projected to be 0.2 Mt CO_2 equivalents less than levels projected under the baseline.

d. ***Cost implications***

The extensification scenario (in detail outlined in Binfield *et al.* (2002b)) had the cumulative effect of increasing incomes by 4 per cent relative to the baseline level. Therefore, while the emissions were reduced relative to the baseline level for the scenario, incomes increased, thereby resulting in an actual *marginal benefit* to the agricultural sector of emission reduction in this particular case.

However, there is a budgetary implication for the EU Commission of this extensification scenario. Assuming no loss of income on the part of producers under the scenario requires an additional annual subsidy payment of €52 million. Given that the scenario resulted in an additional 0.2 Mt CO_2 equivalents reduction in net emissions relative to the baseline, implies that there is a *marginal cost* in a budgetary sense of €229 per tonne of CO_2 equivalents per annum by 2010.

4. Conclusions

Along with the standard annual output, the FAPRI-Ireland model is now able to project the levels of emissions of greenhouse gases from Irish agriculture, as well as the on-farm afforestation levels and the associated carbon sequestration. The extended model has been simulated to analyse the impact of two policy scenarios on net greenhouse position (including on-farm sequestration) of the agricultural sector. First, the projections are generated assuming current CAP measures will persist in the future. In this case, a reduction of eight per cent is projected in net greenhouse gas emissions (including on-farm forest sequestration) between 1990 and 2010. Second, projections are generated assuming a change in policy measures in the livestock sectors, which seek to encourage more extensive production practices. The overall position under this scenario is a further decline in net emissions relative to the baseline level. Significantly, reductions in emissions of greenhouse gases under the scenario, occur with a simultaneous increase in agricultural income, thereby suggesting a win-win outcome for Irish agriculture in an emissions reduction context. However, in a budgetary sense, the scenario, as defined in our example, would require additional EU budgetary expenditure, resulting in a marginal cost of reduction in emissions.

References

Behan, J. and McQuinn, K. (2002). Projections of greenhouse gas emissions from Irish agriculture, *Outlook 2002: Medium term analysis for the agri-food sector*, Teagasc: Rural Economy Research Centre, Dublin, pp. 77-86.

Binfield, J., Donnellan, T. and McQuinn, K. (2000). An econometric model of Irish agriculture, Paper presented at the 65th EAAE Seminar, Bonn, Germany.

Binfield, J., Donnellan, T., Hanrahan, K., Hennessy, T., McQuinn, K. and Westhoff, P., (2002a). The mid-term review: an analysis of impact of changes to extensification regime, *Outlook 2002: Medium term analysis for the agri-food sector*, Teagasc: Rural Economy Research Centre, Dublin, pp. 59-76.

Binfield, J., Donnellan, T., Hanrahan, K., McQuinn, K. and Westhoff, P. (2002b). The baseline outlook for the agricultural sector in the EU and Ireland, *Outlook 2002: Medium term analysis for the agri-food sector,* Teagasc: Rural Economy Research Centre, Dublin, pp. 13-47.

COFORD (2002). Hendrick E., Personal communication.

Department of Agriculture, Food and Forestry (1996). Growing for the Future: Strategic Plan for the Development of the Forestry Sector in Ireland.

Department of the Environment (1998). *Limitation and reduction of CO_2 and other greenhouse gas emission in Ireland*, Environmental resources management in association with Byrne O Cleirigh and ESRI, Dublin: Stationery Office.

Department of the Environment (2000). *National climate change strategy Ireland*, Dublin: Stationery Office.

Environmental Protection Agency (EPA) (2002). McGettigan, M., Personal communication.

Intergovernmental Panel On Climate Change (IPCC) (2001). *Revised 1996 IPCC Guidelines for national greenhouse gas inventories: reference manual,* http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch4ref1.pdf

McQuinn K, Riordan B. (1998). *Agricultural Incomes Outlook for Ireland*. Proceedings Agri-Food Economics Conference. Dublin: Teagasc.

United Nations Framework Convention on Climate Change (UNFCC) (1997). *Kyoto Protocol to the United Nations Framework Convention on Climate Change*, http://www.unfccc.de/resource/docs/convkp/kpeng.html

Output

Behan, J. *'Forestry as a land competitor in Ireland'* – presentation to Agricultural Research Forum, Tullamore, March 2002

Behan, J. *'Projecting private forestry in Ireland'* – poster session at Agricultural Economics Society Conference, Aberystwyth, UK, April 2002

Behan, J and McQuinn, K. *'Projection of greenhouse gas emissions from Irish agriculture'* – paper presented at the FAPRI, Outlook Conference (published in the proceedings), Dublin, April 2002

Behan, J. and McQuinn, K *'The effect on greenhouse gas emissions from Irish agriculture of further extensification in the Irish beef sector'* – poster presented at the European Association of Agricultural Economists Congress, Zaragoza, Spain, 27-30 August 2002

Behan, J. and McQuinn, K *'The effects of potential reform of the CAP on greenhouse gas emissions from Irish agriculture'* – paper presented at the Business Strategy and the Environment Conference (published in the proceedings), Manchester, UK, 16-17 September 2002

Behan, J. *'Economics of farm forestry vs. other farm enterprises'*, presentation at the IFA Farm Forestry Conference, Limerick, 8 November 2002

Behan, J. **and McQuinn, K.** *'Projecting net greenhouse gas emissions from Irish Agriculture'*, paper presented at the ESRI Environmental Conference (published in the proceedings), Dublin, 11 December 2002

Behan, J. **and McQuinn, K.** *'Projecting farm forestry in Ireland'*, Teagasc, working paper (forthcoming)

Behan, J. **and McQuinn, K.** *'Projecting net greenhouse gas emissions from Irish agriculture and forestry'*, Teagasc, working paper (forthcoming)