PROJECTING NET GREENHOUSE GAS EMISSIONS FROM IRISH AGRICULTURE AND FORESTRY

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Abstract

This paper presents a holistic approach to the projections of greenhouse gas emissions from Irish agriculture and forestry. Results from a large-scale econometric model of Irish agriculture are combined with those from a recently developed model of Irish forestry, in order to calculate the net emissions of carbon dioxide equivalents from the Irish agricultural and forestry sectors. The expected future paths of net emissions are then derived under two different policy scenarios.

1. 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 UNFCC (1997) for details). The Protocol outlines targets and timetables for the reduction of anthropogenic 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 5 per cent 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 per cent 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

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[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 8 per cent.

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 anthropogenic greenhouse gas emissions originate in agriculture. In 1998, it was estimated that agriculture, at 35 per cent, 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 per cent 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.

On the other hand, forestry plays an important role in the protection of the environment. Afforestation, reforestation and deforestation that have taken place since 1990 are identified in 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 9 per cent of Irish total land area is classified as woodland, placing Ireland at the low end of EU forest cover ranking. In its strategic plan for forestry, the government sets out an objective of increasing the forest cover to 17 per cent by 2030. This is to be achieved by annual afforestation targets of 20,000 hectares, with the emphasis on private planting by farmers (Department of Agriculture, Food and Forestry, 1996).[5] This afforestation is hoped to ensure 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. In order to accomplish these objectives we generate projections of:

1. greenhouse gas emissions from agriculture,
2. on-farm afforestation levels,
3. carbon sequestration levels from on-farm forests.

The paper proceeds by first elaborating on the methodologies used to generate these projections and this is followed with a results and discussions section. The last section offers some concluding comments.

[3] The beef, pig, sheep and dairy sectors.

[4] Greenhouse gas sinks are defined as reservoirs in which sequestered CO_2 is stored.

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

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, which is described in the next section. This paper describes how this original FAPRI-Ireland model is extended to include an environmental dimension. A further 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.

FAPRI-IRELAND MODEL

The FAPRI-Ireland model of the Irish agricultural sector is a joint effort of the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri, Columbia and Teagasc.[6] It is a dynamic, partial equilibrium model consisting of 200 econometrically estimated equations (for more on the model see Binfield *et al.* (2000)). The model compiles a series of interlinking commodity models for the Irish beef, sheep, dairy, crops and inputs sectors. Since 1998 the model has been used to generate an annual series of projections referred to as a baseline result. This result serves as a benchmark as it represents the projection of key agricultural variables in the absence of any policy change. In tandem with the baseline result is the analysis of the effects of a particular policy change on the Irish agri-sector. The continued collaboration between FAPRI at the University of Missouri and Teagasc, gives the FAPRI-Ireland model the considerable advantage of being linked both to the FAPRI EU and World modelling systems. This enables changes in world markets to be traced down through to the equivalent domestic Irish markets. Therefore, in generating projections the following is ensured:

- the projections of agricultural outputs in Ireland are generated taking formal account of international market developments, and
- the most relevant policy levers associated with the EU Common Agricultural Policy (CAP) are fully incorporated within the projections.

The projections of agricultural variables are then used to generate projections of greenhouse gas emissions from agriculture.

3. Greenhouse Gas Emissions from Agriculture

The Kyoto protocol defines the source categories of greenhouse gas emissions from agriculture. Those applicable to Ireland are:

- enteric fermentation
- agricultural soils
- manure management.

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). CH_4 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

[6] The Irish Agriculture and Food Development Authority.

national cattle herd, since the most significant source categories of CH_4 are dairy and non-dairy cattle.

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.

The decomposition process of organic matter in animal waste results in the further release of both CH_4 and N_20. The degree to which fermentation advances in animal waste depends on the manure management system practiced. In Ireland, most cattle manure is left on the pasture range, while some is managed in liquid systems and solid and dry lots. The manure from pig production is almost entirely kept in liquid systems.

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).

ON-FARM AFFORESTATION

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 more mainstream agricultural enterprises. The projections of future farm afforestation levels are generated using the following panel data model for five regions[7] in the country:

$$y_{i,t} = \alpha_i + \beta_1 y_{i,t-1} + \beta_2 x_{i,t} + \varepsilon_t$$

where,

i – one of five regions observed across Ireland
t – time period from sample covering 1986-2001
y – afforestation level (hectares)
x – returns from forestry relative to returns from traditional agriculture[8]

[7] The regions are the mid-east, the north-west, the west, the south-west and the south-east. The counties in each region are summarised in Table A.1 of the Appendix.

[8] The explanatory variable, a returns ratio, was calculated for each region *i* and time period *t*, as a ratio of discounted forestry return (DFR) per hectare to discounted agricultural return (DAR) per hectare.

ε – residual.

The intercept and slope coefficients are estimated using a fixed effects panel data estimation technique. The specification of the model is such that it allows for the intercept to be region specific. This ensures that the geographical, as well as the production differences across regions are accounted for. The estimation results are presented in Table 1.

Table 1: Forestry Model Estimation Results

Regions	Coefficient	Estimate	t-prob
Mid-east	α_1	-0.10	-0.864
North-west	α_2	0.03***	0.000
West	α_3	0.28***	0.000
South-west	α_4	0.42***	0.000
South-east	α_5	0.22***	0.000
	β_1	0.57***	0.000
	β_2	0.83***	0.000

N = 75

CARBON SEQUESTRATION

The projected on-farm afforestation levels are converted into carbon sequestration levels by applying conversion factors developed by COFORD[9] (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.

4. 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 the 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. The introduction and subsequent increase in the use of extensification by the EU Commission has prompted considerable interest amongst domestic policy makers in potential changes in this relatively new EU policy lever. It is important to note that the scenario was not performed for the explicit purpose of achieving reductions in greenhouse gas emissions or changes in

$$x_{i,t} = \frac{DFR_{i,t} ha^{-1}}{DAR_{i,t} ha^{-1}}$$

Discounting period was assumed to be 40 years, the time from the planting to clear fell for most plantations in Ireland. The discount rate was 5 per cent.

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

afforestation levels. Therefore, motivation for the scenario arose from an agricultural, rather than an environmental, policy perspective. However, as will be seen, the scenario has associated or knock-on effects for agricultural emission levels. Full details of this scenario are in Binfield *et al.* (2002b).[10] The effects of this scenario are measured with respect to the baseline result.

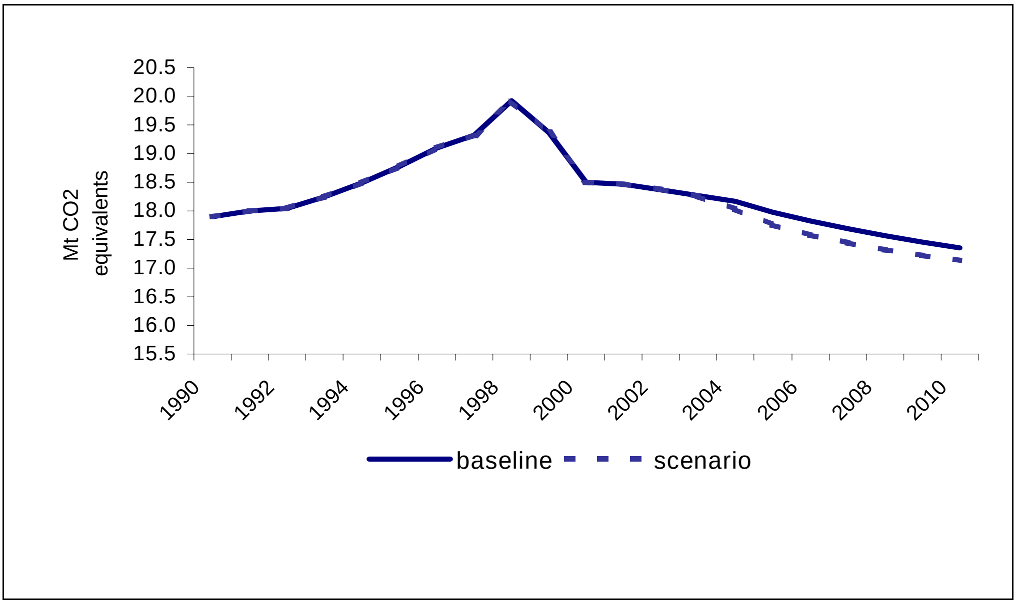
Baseline Results

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 the Agenda 2000. As a result, methane emissions from enteric fermentation and manure 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.

Over the projection period, it is expected that on-farm afforestation will remain above 10,000 hectares.

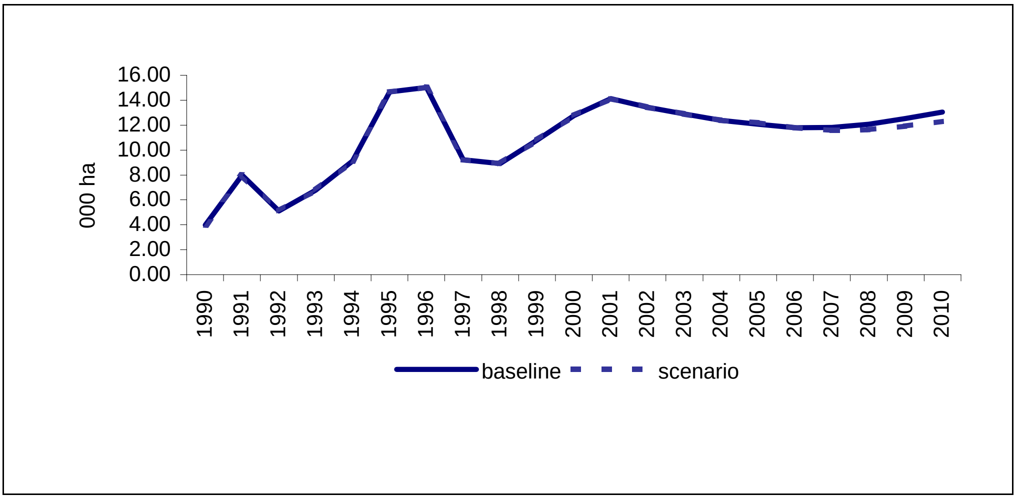
Figure 1: Greenhouse Gas Emissions from Irish Agriculture

[10] 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.



Source: FAPRI-Ireland Model.

Figure 2: On-farm Afforestation in Ireland

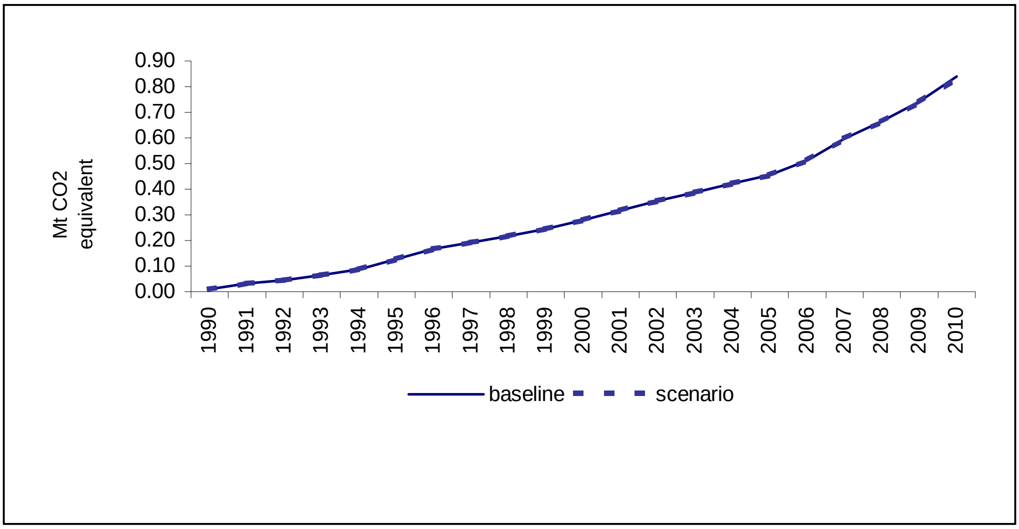


Source: FAPRI-Ireland Model.

Figure 2 illustrates the evolution of farm afforestation. 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.

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.

Figure 3: On-farm Carbon Sequestration in Ireland



Source: FAPRI-Ireland Model.

Overall, assuming no policy change, total net emissions from Irish agriculture and forestry are expected to be 16.5 Mt CO_2 equivalents in 2010. This represents an 8 per cent decline from the level recorded in 1990.

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.

The scenario performed on the FAPRI-Ireland model reduced the two extensification limits of 1.4 and 1.8 LU per hectare 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.

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.

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 per cent below the baseline levels. The decline in afforestation rates relative to the baseline does not have a significant effect on sequestration levels. Under the scenario, the net emissions position from Irish agriculture and forestry is a further 1 percentage point decline (additional 0.2 Mt CO_2 equivalents reduction) relative to the level projected under the baseline.

An additional component of the FAPRI-Ireland model introduced in Section 2 is the facility to generate projections of total agricultural income for each scenario result (see McQuinn and Riordan (1998) for an example). The extensification scenario outlined in Binfield *et al.* (2002b) had the cumulative effect of increasing incomes by 4 per cent relative to the baseline level. Consequently a "win-win" situation exists *vis-à-vis* emission reductions and agricultural incomes. Even though 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.

There is however, the budgetary implication for the EU Commission of this extensification scenario. The full details of the additional payments required under the scenario are detailed in Binfield *et al.* (2002b). Assuming no loss of income on the part of producers under the scenario[11] requires an additional subsidy payment of €52 million. Taking the change in emissions

[11] The scenario explicitly assumes that producers are at least in an income neutral situation following the implementation of the scenario. Consequently, even though livestock numbers decrease under the scenario, the extensification payment on the remaining animals is increased to leave all producers at the very least in an income neutral position.

of 0.2 Mt CO_2 equivalents yields a *marginal cost* in a budgetary sense of €229 per tonne of CO_2 equivalents per annum by 2010.

5. Conclusions

The link between the impacts of agricultural policy and the attainment of national greenhouse gas targets has been forcibly demonstrated with previous applications of the FAPRI-Ireland model (see Behan and McQuinn (2002) for example) in this paper. An example is provided which illustrates how changes in an agricultural policy lever such as extensification can have implications for the level of emissions from Irish agriculture.

In the example, projections of greenhouse gas emissions and carbon sequestration for Irish agriculture and forestry are presented for two different sets of policy assumptions. First, the projections are generated assuming current CAP measures will persist in the future. In this case, a reduction of 8 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, however, as a result of the scenario, reductions in emissions of greenhouse gases occur with a simultaneous increase in agricultural income thereby suggesting a win-win outcome for Irish agriculture in an emissions reduction context. In an EU budgetary sense, the additional cost of achieving the reduction in emissions relative to the baseline is approximately €52 million a year by 2010.

Future work in this area will address the effects of the proposed "decoupling" of EU support payments on the levels of greenhouse gas emissions.[12] One interpretation of decoupled payments is that agricultural producers would no longer have to maintain livestock in order to be eligible for support payments. Initial FAPRI-Ireland analysis of the proposed MTR (see Behan *et al.* 2003) suggests that Irish beef cow numbers could fall by up to 30 per cent under such a policy. The knock-on effects for agricultural emission levels under this proposal, could well therefore, exceed those under the hypothesised changes to the extensification regime.

APPENDIX A

Table A.1. Regional Breakdown by County

Mid-East	North-West	West	South-West	South-East
Dublin	Longford	Clare	Cork	Carlow
Kildare	Leitrim	Galway	Kerry	Kilkenny
Laois	Sligo	Mayo	Limerick	Wexford
Louth	Cavan	Roscommon		Wicklow
Meath	Donegal			Tipperary
Offaly	Monaghan			Waterford

[12] As per the EU Commission's July 2002, proposed Mid Term Review (MTR) of the EU Common Agricultural Policy. Details of the proposed MTR are available online at: http://europa.eu.int/eur-lex/en/com/cnc/2002/com2002_0394en01.pdf

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