A Climate for Change

Opportunities for Carbon-Efficient Farming

Thursday, 24 and Friday, 25 June 2010
The Mansion House, Dublin

Organised by: Teagasc, GHG Working Group

Teagasc
Agriculture and Food Development Authority

CLIMATE FOR CHANGE

Opportunities for Carbon-Efficient Farming

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INTRODUCTION

- Is the global debate on Climate Change a threat to Irish farming, or can we turn it into an opportunity?
- Will efforts to curb national Greenhouse Gas Emission necessarily equate to curbing agricultural productivity?
- Can carbon-efficient farming give Ireland a competitive edge on the global food market?
- Which on-farm measures are practical and cost-effective in further improving carbon-efficiency on tillage, dairy and beef farms?
- How can we exploit the potential for forestry, biofuels and land-use change to offset Greenhouse Gas Emissions?
- How can we get acknowledgement for future gains in production efficiencies within the ridig framework of Kyoto reporting?

These are the central questions which were being asked at the Tasgasc Agri-Environmental Policy Conference which was held from 24–25 June at the Mansion House, Dublin.

This conference brought together scientists, policy makers, farmers, students and stakeholders to discuss first-hand how we can transform the threat of GHG emissions forum to contextualise the Irish Agricultural Greenhouse Gas challenge in an international science and policy setting.

CONTENTS

SPEAKER PROFILES

Mr Mark Gibson

Teagasc, Ireland

Mark Gibson is an Environmental Specialist at Teagasc. His main areas include water quality and conservation, nutrient management and agri-environmental schemes. He is a council member of the Irish Agricultural Science Association and is former president of the Irish Society for Information Technology in Agriculture. He is secretary af the Teagasc Climate Change and Water Framework Directive Working Groups.

Professor Gerry Boyle

Teagasc, Ireland

Professor Boyle is the Director of TEAGASC, the Irish Agriculture and Food Development Authority, the principle State Body involved in agri-food reseach. Professor Boyle joined TEAGASC from the National University of Ireland (NUI), Maynooth where he was a former Head of its Economic Department. He is also a former member of the Governing Authority of NUI Maynooth and is a Director and Secretary of the Maynooth University Foundation. He is Co-chairman of the FAPRI-Ireland Partnership and the founding Director of the National Institute of Regional and Spatial Analysis. He is also a member of the Senate of the NUI and holds Adjunt Professorships at the University of Limerick and at the University of Missouri, Columbia.

Dr Alistair R McCracken

Agri-Food and Biosciences Institute, Northern Ireland

Dr. McCracken is the Principle Scientific Officer and project leader in the Agri-Food and Biosciences Institute, Northern Ireland. He is a plant physiologist who has been involved in research and development on growing Short Rotation Coppice (SRC) willow (*Salix* spp.) since the mid 1980's. His work on the use of *Salix* spp. Genotype mixtures for rust disease management has resulted in the normal commercial practice of planting at least six diverse genotypes. For the past ten years, Dr. McCracken has been investigating the use of SRC willow as a route for the disposal of effluents or biosolids.

Dr John Gilliland

Rural Generation Ltd

Dr Gilliland OBE has extensive international political experience in the sustainable energy sector and a strong farming background. He is a former president of the Ulster Farmers' Union (2002–2004) and a Fellow of the Royal Agricultural Societies of the UK. Dr. Gilliland was appointed Northern Ireland Sustainable Development Commissioner in 2005. He is co-chair of the Defra Rural Climate Change Forum and participated in the Joint EU Agriculture and Environment Informal Council under the UK Presidency. In 2004, he was awarded an OBE for services to the environment for his work on willow biomass and bioremediation of sewage sludge. He has recently been awarded an Honourary Doctorate of Science from the University of Ulster for his services to agriculture and renewable energy. He is also currently a director of the Scottish Agricultural College. He lives in Derry where he runs Rural Generation Ltd., a company that designs sustainable renewable energy and waste management systems and manages a 200 hectare arable and willow estate.

Mr John McCarthy

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Mr McCarthy is the Assistant Secretary in the Department of Environment, Heritage and Local Government heading the Environment Division. His current responsibilities include climate change policy and sustainable development.

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Dr Montgomery is a policy analyst in the Natural Resources Group. He has an undergraduate degree in Geography and a Post Graduate Diploma of Science in Geography from the University of Auckland.

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Teagasc, Ireland

Dr O'Donoghue is Head of Teagasc's Rural Economy Research Centre. He studied at UCC, UCD, Oxford and the London School of Economics, taking degrees in Mathematics, Statistics, Economics and Social Policy. Prior to joining RERC Cathal spent a number of years at the Department of Economics at NUI Galway, Ireland.

Professor Roger Sylvester-Bradley

ADAS, Boxworth, Cambridgshire

Prfoessor Slyvester-Bradley is a Principal Research Scientist with ADAS, and a special professor with the University of Nottingham, specialising in temperate crop physiology. His research in 'predictive agronomy' has delivered canopy management and fertiliser recommendations, and growth stage keys, all used internationally by cropping industries. He has reviewed research on nitrate and genetic improvement for Government, and has published over 150 scientific papers on the resource capture by crops, disease impacts, crop stature and yield determination.

Dr Phillip O'Brien

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Dr O'Brien is a researcher at NUI, Galway. His research interests focus on greenhouse gas emissions, quantification and inventory procedures related to agriculture, land use and soil; greenhouse gas atmospheric measurements and inverse modelling; and, climate change impacts.

Mr Donal O'Brien

Teagasc, Ireland

Donal is a graduate of University College Dublin with an honours degree in agricultural and environmental science in 2008. Currently, he is conducting a postgraduate on greenhouse gas emissions from dairy farming systems in Teagasc, Moorepark. The aim of the work is to identify strategies that reduce greenhouse gas emissions while simultaneously maintaining farm profitability.

Dr Frank O’Mara

Teagasc, Ireland

Dr O’Mara is a graduate of University College Dublin with a first-class honours BAgSc in 1987. He lectured in UCD for 13 years and was appointed Associate Professor of Animal Nutrition in 2006. He nationally and internationally recognised for his research on animal nutrition, feed evaluation, management of beef and dairy cattle and nutritional effects on methane emissions. His research has been published in over 75 peer-reviewed papers; he has also published numerous technical articles and addressed many national and international scientific and industry conferences. He joined Teagasc in 2006 and was appointed Director of Research in 2009.

Dr Frank McGovern

Environmental Protection Agency, Ireland

Dr. McGovern is Senior Manager Climate Research Programme with the Environmental Protection Agency. He has more than twelve years research experience in the areas of climate change and air pollution, including work on international research projects funded by the European Commission and World Meteorological Office. He joined the EPA in 2000. He is a member of EU Expert Group on Climate Science and is a regular delegate to meetings of the UN Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC).

Dr Chris Grainger

Department of Primary Industries, Ellinbank, Australia

Dr Grainger has worked in dairy nutrition research at DPI Ellinbank for over 20 years. He has specialist expertise in dairy cow nutrition and grazing management systems, and is internationally recognised for his research into dairy cow modelling and milk processing. He has well-developed project leadership and management skills, and has a strong commitment to see the industry improve milk yield and cow performance measures. He is currently managing a large project investigating extended lactations of dairy cows and developing project work in feed conversion efficiencies across livestock industries.

Dr James Humphreys

Teagasc, Ireland

Dr Humphreys is a researcher at Teagasc’s Dairy Production Research Centre. His research interests focus particularly on sustainable grassland systems. He work involves close collaboration with UCC, WIT, AFBI and international research institutes.

Dr Bob Rees

Scottish Agricultural College, Scotland

Dr Rees is a soil and environmental scientist, with research interests in nutrient cycling and soil management in a range of crop and soil systems. His current research focuses on climate change and the role that soils play in contributing to the release and uptake of greenhouse gases (carbon dioxide, methane and nitrous oxide). He has significant involvement in EU-funded research programmes, co-ordinating an EU Framework project on the role of legumes in farming systems (Legume-Futures), and is an activity leader (arable farming) in NitroEurope. Dr Rees is also a member of SAC’s newly formed climate change research group.

Dr Oene Oenema

Wageningen University and Research Centre, the Netherlands

Oene Oenema is research leader of environmental assessment studies and part-time professor in soil fertility and nutrient management at Wageningen University and Research Center.

Dr Eugene Hendrick

Department of Agriculture, Fisheries and Food

Dr. Hendrick is the head of COFORD (National Council for Forest Research and Development) and was previously research manager within the organisation. He joined the Forest Service in 1976 and worked for a year in forest management. In 1977 he moved to research branch where he worked mainly on establishment of forests on peats, podsols and wet mineral soils. Shortly after the establishment of Coillte in 1989 he became head of growth and yield, and wood quality research in 1990. In 1991 he moved to the marketing arm of Coillte and dealt with marketing statistics and product development. He became Director of COFORD in May 1999 - he previously held the position of research manager within the organisation. Eugene sits on the Forestry Sector Group of the Forests and Forestry Products Technical Committee of COST, an EU funded initiative promoting co-operation in science and technology.

Dr Gary J Lanigan

Teagasc, Ireland

Dr. Lanigan is a Research Officer with Teagasc based in the Environmental Research Centre, Johnstown Castle Wexford. He studied at UCD and Cambridge and his areas of work include quantifying and drawing up mitigation strategies for gaseous emissions associated with agricultural practices. These emissions include the major greenhouse gases; carbon dioxide, methane and nitrous oxide, as well as non-greenhouse gas emissions, such as ammonia. His particular research interests include the effects of land-use change on GHG's and the use of natural abundance stable isotopes in constraining ecosystem fluxes.

Dr Laurence Shalloo

Teagasc, Ireland

Dr. Shalloo graduated from the faculty of agriculture in UCD with a first-class honours degree in 1999. He completed a PhD. on the development of the Moorepark Dairy Systems Model. Current research interests centre around the development of the Moorepark Model, the development of a milk processing sector model, the development of a grass growth model, the development of a GHG emissions model and the development of an animal intake model as well as the development of economic-based grass selection index, the development of milk pricing systems, the development of futuristic systems of milk production and developing mitigation strategies to reduce GHG emissions and to increase Nitrogen-use efficiency.

Professor Mike Jones

Trinity College, Dublin, Ireland

Professor Jones is a Plant Ecophysiologist and holds the Chair of Botany at Trinity College, Dublin. His main area of research is in the study of climate-plant interactions, particularly the effects of climate and future carbon dioxide effects on photosynthesis, growth and primary productivity. He was regional co-ordinator of CarboEurope IP in relation to grassland Carbon balances.

Greenhouse gas emissions from agriculture: The story so far

By MARK GIBSON[1] and GARY LANIGAN[2]

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[2]*Teagasc, Johnstown Castle Environmental Research Centre, Wexford, Ireland*

Abstract

Ireland is unique among the EU countries for the proportion of its greenhouse gas (GHG) emissions which originate in agriculture. It is currently estimated that agriculture contributes 17.5 million tonnes of CO_2 equivalents representing 26.1% of national emissions. This large proportion contribution to national GHG and transboundary emissions arises because of the dominance of livestock production in Irish agricultural output, with methane emissions primarily due to livestock enteric fermentation and manure management while nitrous oxide (N_2O) emissions result from chemical/organic fertilizer application and animal deposition in the field and during housing periods. Whilst national emissions have risen by almost a quarter since 1990, agricultural emissions have been reduced by 1.7 million tonnes. This represents an 8.6% decrease relative to 1990, or 16.5% relative to peak emissions in 1998; the largest decrease in emissions across all sectors.

Despite these reductions, considerable challenges lie ahead for the sector. The EU 20–20–20 Climate and Energy Package envisages a 20% reduction in EU emissions by 2020, rising to 30% in the event of a comprehensive global agreement. More importantly, under the Effort Sharing Decision (406/2009/EC), Irish emissions from sectors not included in the EU Emission Trading System (EU ETS) – such as transport, buildings, agriculture and waste will have to be curtailed by 20% (the EU-wide target is 10%). As agriculture makes up 40% of non-ETS emissions, the sector may be required to shoulder a large share of the burden. Set in the context of current world food demand, target-led reductions in Irish agricultural output could simply be balanced by increased production in countries with higher emissions – giving rise to Carbon leakage.

In addition, quota abolishment combined with higher global demand may limit any reductions. In this context of increased food demand, there may be a paradox between the need to meet world food demand and emission reduction. However, the answer may lie in optimising the amount of greenhouse gases emitted per unit product. Adoption of this metric could drive future agricultural efficiency wand reduce emission, whilst maintaining production potential.

Green house gas emissions, food security & the market place

By JOHN GILLILAND

Chairman, Rural Climate Change Forum, London
Farmer, Derry

Abstract

In the 20 years I have been a participant in the Agri Food Industry, no issue has accelerated to prominence at such a speed as the collective issue of Climate Change and Food Security. Many drivers prevail, but three key drivers; National, European and International Policy Development; Media fascination; and Retailer economics; will make sure that this is not just another passing fad.

Over the years I have participated in many Industry meetings, whether it was with Farmers, Processors, Retailers or Consumers, one issue has really started to float to the surface, Food Security and how will we feed the future billions on this Planet. A year ago, I was in Paris to witness the signing of a historic accord, between the French and British Governments, two Governments known for being poles apart when it comes to Agriculture, yet agreeing to work together to help agriculture protect itself from Climate Change. Why? Because our changing climate will make delivering on Food Security an impossible task, unless we mitigate our emissions now and make our agricultural systems more resilient for the future.

Key to mitigating our emissions is our understanding where Greenhouse Gases are emitted, what is the state of our evidence base and what are the economics of reducing these gases. Driving domestic food production out of business, while increasing imports of food from other areas of higher emissions, will not deliver in reducing Global Green House gas levels and will definitely not deliver on Global Food Security.

Over the last 18 months, the Media have become more and more interested in this topic. Headlines quoting famous musicians calling for a “Meat Free Monday,” to certain Government Departments calling for a “Cull of 30% of Farm Livestock,” have started to really galvanise the minds of the big GB retailers. We in Ireland ignore this at our peril. As an Island, we export 80% of the food we produce, of which GB Retailers buy approximately 60% of these exports. We can not ignore the new raft of market place developments, occurring in our main market place.

A raft of new first Generation, food product, carbon calculators have now appeared. They are crude calculators which point a direction of travel for developing a low carbon product, but only measure emissions and ignore the sequestration which occurs naturally right across our farming industry.

The threat of these and the raft of new Policy ideas emerging will need a vigilant and well engaged Irish Agri Food Industry. The Market Place, the Media and our Policy Makers all have limited knowledge in this area. If we as an Industry do not engage, someone else will lead the agenda and Irish Ruminant Agriculture will be the Loser!

Economic issues associated with greenhouse gas emission reductions in agriculture

By JAMES BREEN, TREVOR DONNELLAN, KEVIN HANRAHAN, PATRICK GILLESPIE, CORINA MILLER[1] and CATHAL O'DONOGHUE

Teagasc Rural Economy Research Centre
[1]*Teagasc Rural Economy Research Centre, Department of Economics TCD*

Abstract

As a major agricultural producing nation, with a concentration on animal production, Ireland has a disproportionate production of agricultural based greenhouse gas emissions (GHG) in the EU. While Ireland has only 0.89% of the EU-27 population, it has 3.84% of the agricultural emissions, reflecting the fact that Ireland is a substantial net exporter of agricultural products that is centred on ruminant animals. While significant research is being undertaken to reduce the level of emissions per unit of agricultural output produced, there have been a number of commentaries that have suggested the reduction of herd numbers as a mechanism to reduce GHG emissions within Ireland.

In this paper, we shall assess the economic implications of some of these proposals to reduce emissions as well as other policy interventions targeted at reducing emissions. In the first part of the paper, we use the FAPRI-Ireland aggregate model to examine the implications of reductions in herd numbers on overall agricultural output and gross value added from the sector.

Agricultural in Ireland is highly integrated within the national economy, with substantial inputs from local suppliers and with output acting as an important input into food production and into the wider food supply chain, which is in turn a major export earner. Utilising the IMAGE Computable General Equilibrium model of the Irish economy, we describe these upstream and down stream linkages and assess the impact on the wider economy of potential changes to the national herd size being proposed.

We conclude by discussing potential policy interventions that could be used to achieve these goals both at the level of the output from the sector such as emissions trading schemes, regulation and carbon taxes and at the level of inputs such as carbon taxes. We shall discuss the potential implications of these alternative policy mechanisms on the sector.

Mitigation of agricultural greenhouse gas emissions

By FRANK O'MARA

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Abstract

According to IPCC (2007), agriculture accounts for about 11% of global anthropogenic GHG emissions. In contrast, FAO (2006) estimates that livestock agriculture alone contributes 18% of total anthropogenic emissions. This higher figure is based on a Life Cycle Analysis (LCA) approach and therefore allocates several additional GHG sources to agriculture compared to the IPCC estimate. These include land-use change and the energy costs involved in the production and transport of agricultural products and inputs. Globally, land use change is a bigger emitter than agriculture (UNFCCC, 2008).

The trend in agricultural emissions has been upwards with growth of 17% between 1990 and 2005, and without mitigation, this trend is projected to continue as the world's population increases and requires more food production (IPCC, 2007; US EPA, 2006). Most of this growth has occurred in developing regions, and these regions are expected to see most of the growth in future years.

IPCC (2007) identified a large technical mitigation potential for agriculture of 5.5 to 6 Gt of CO_2 equivalent per year, mostly associated with agricultural soils (cropland and grazing land management, restoration of degraded soils and restoration of cultivated organic soils) and with 70% of the mitigation potential in developing regions. However when the cost of mitigation is considered, the potential is only about one third of the technical potential at 1.5–2 Gt of CO_2 equivalent at a C price of up to $20 per tonne of CO_2 equivalent.

There is little scope for agricultural soils based mitigation in Ireland due to limited possibility for improved cropland or grazing land management, and a virtual absence of degraded lands to restore. Most Irish agricultural emissions are related to livestock production, with the main sources being methane from enteric fermentation, nitrous oxide from soils, and methane and nitrous oxide from manure management. Livestock production has a relatively small mitigation potential in the IPCC (2007) assessment, which suggests that reducing Ireland's agricultural emissions will be difficult without new mitigation technologies. With current technology, most mitigation options relate to improving the efficiency of agricultural production. These include improved nitrogen use efficiency, extending the grazing season, and improving the genetic merit of the national herd. These can certainly improve emissions per kg of agricultural product, but it is a big challenge to significantly reduce total emissions from the sector.

Reporting agricultural greenhouse gas emissions and sinks

By PHILLIP O'BRIEN

Research Specialist
Climate Change Research Programme
Environmental Protection Agency

Abstract

A brief overview of the current methodologies and data sources used to estimate greenhouse gas emissions and sinks associated with agricultural activities in Ireland is provided. Estimated emissions of greenhouse gases are robust, in terms of acceptance of the methods used which are based on GPG and are subject to regular y international review. However, there is always room for improvement. Estimates of emissions of Nitrous Oxide (N_2O) have a high level of uncertainty and is therefore major focus of inventory development in Ireland and internationally. The key issues and challenges are outlined.

An over arching challenge to better quantification of national greenhouse gas emissions is a lack of knowledge of farming practices, and more especially changes in farming practicing which impact negatively or positively on emissions (and sinks). Robust activity data are require to verifiably incorporate mitigation options, demonstrated by research and on a farm scale, into the national inventory. This is essential for policy development and implementation including use of fiscal incentives.

There has been much attention on the potential of sequestration and storage of carbon to soils. EPA and DAFF funded research by Teagasc, UCD, UCC and elsewhere, and European research point to a potentially significant ongoing uptake of CO_2 from the atmosphere, via biomass, to the agricultural grassland soils.

These findings are promising, from an GHG emissions reporting perspective, but caution is required as carbon sinks are subject to a range of reporting and accounting rules. Not all land use activities are accountable towards meeting Ireland's emissions targets under international agreements. However, this may represent a future opportunity but information and analysis of this is required.

Policy *versus* the Environment? IPCC *versus* LCA?

By D O'BRIEN[1,2], L SHALLOO[1], J PATTON[1], M BUTLER[1], C GRAINGER[1] and M WALLACE[2]

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[2]*School of Agriculture, Food Science and Veterinary Medicine, University College Dublin, Belfield, Dublin 4, Ireland*

Abstract

The objective of this study was to compare two methodologies, Intergovernmental Panel on Climate Change (IPCC) and life cycle analysis (LCA), for quantifying greenhouse gas (GHG) emissions from dairy farms. The IPCC method quantifies emissions from specific sources related to dairy farming. The LCA method estimates all emissions associated with the dairy production system up to the point milk leaves the farm gate. Both methods were applied to model GHG emissions from a pasture and total mixed ration based dairy farm as well as to estimate the emissions from nine pasture based dairy farms varying in strain of Holstein-Friesian cow (differing in genetic potential for milk production and fertility) and type of grass-based feed systems (differing in stocking rate and level of concentrate per cow). The physical performance used to quantify emissions from these farms was obtained from previously published work (Horan *et al*., 2005; McCarthy *et al*., 2007; Butler, 2010). The milk production systems were modelled using an economic-GHG farm model. The model calculated GHG emissions using both the LCA approach as well as using the IPCC method. The study found that GHG emissions of dairy farms were greater when calculated using the LCA method rather than the IPCC method. Both methods found that low input dairy systems reduced GHG emissions per hectare by 10–20%. When emissions were expressed per unit of product the methodologies did not rank farming systems in the same order. The effect of feed system on emissions per unit of product was inconsistent between methodologies because the IPCC method excludes indirect GHG emissions from farm pre-chains, i.e. concentrate production. For instance, using the IPCC method high input dairy systems i.e. total mixed ration dairy farms reduced emissions per unit of product by 3% but when the LCA approach was used these systems increased emissions by 8%. Thus, producers could implement strategies which comply with policy methodology (IPCC method) and reduction targets, but when a holistic analysis is conducted the net effect of complying with policy is to increase emissions to the environment. Both methodologies agreed that animals selected solely for milk production (HP) had higher GHG emissions per unit of product (5–12%). The results indicate that if abatement strategies targeting a net reduction in global GHG for projected increases in meat and milk production are to be developed, a holistic approach such as LCA, should be used to quantify emissions on a per unit product basis.

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The way forward

By GERRY BOYLE

Director, Teagasc, Oak Park, Carlow, Ireland

Abstract

The agri-food sector accounts for over half of Ireland's indigenous exports and represents one-tenth of the Irish economy. Indeed the wider bio-economy contributes an estimated 30% of total national net exports and in 2008 accounted for 179,200 jobs.

Agriculture also comprises a quarter of national greenhouse gas (GHG) emissions that contribute to climate change. As such, reducing emissions from the sector is often considered as a strategy to meet our emission reduction targets. However, world food security has emerged as a critical global challenge. This sets a significant challenge for Teagasc and its national and international collaborators – namely reducing emissions while increasing food supply. Delivering this will ensure that the Irish agri-food sector can and will play a key strategic role in our economic recovery whilst achieving our legally binding emission reduction targets. In addition, these challenges can provide the opportunities to drive efficiencies that will ultimately reduce costs and drive profitability in the sector.

Teagasc recognises both the scale and urgency of the challenge presented by climate change legislation. Since 2005, organisation has been engaged in a large programme of research across all centres comprising 14 projects and almost four million euro in order to elucidate the potential of some of these future mitigation options. Recognising the large body of cross-centre research, the Climate Change Working Group was established in 2009 in order to co-ordinate both research and dissemination. Already, the group has been crucial for providing policy advice for the Cabinet Committee on Climate Change and liaising with other reports on agricultural emissions. Into the future, Teagasc will be co-leading a pan-European project studying livestock abatement strategies.

Any proposed reductions in GHG emissions from farming must be considered in a world-wide context. Global emissions from the sector have risen by 17% between 1990 and 2008 with a larger increase (32%) for Non-Annex 1 countries. In contrast, Irish agricultural emissions have fallen by 8% over the same time period. As a consequence, any policies that reduces agricultural activity countries with a high production/GHG quotient, such as Ireland, in at a time of increased demand for food and renewable-energy sources, is likely to be counter-productive in the context of reducing global GHG's. Indeed, in order to optimise global agricultural emissions abatement, food production should be focussed as far as possible in those countries where GHG emissions per unit product are lowest, and existing agricultural land should be used to the maximum before new land is brought into production through deforestation.

The way forward for agriculture will be to maximise the amount of produce per unit GHG emitted. Already, this has been recognised in the retail sector and there is a market-driven demand for thorough and accurate life-cycle assessment of all agricultural practices. Part of the challenge for Teagasc will be to provide a not only an accurate greenhouse gas-based analysis, but a full sustainability index incorporating the requirements of other Directives. It has been demonstrated that the application of best management practices can provide opportunities to both reduce emissions whilst optimising production efficiency, both in terms of maximising output

per livestock unit and minimising inputs, notably N fertilisers. The identification of further ‘best practice’ strategies is urgent, not only for meeting emissions targets, but in optimising resources and reducing costs.

Future challenges must also include the assessment of climate change impacts and climate adaptation on agricultural production. Climate adaptation will potentially touch on every aspect of the industry, but also provide opportunities as climate impacts on Irish agricultural production are forecast to be relatively small compared to other countries. However, the sector must be prepared and research into areas such as future pest control and the opportunities provided by longer growing seasons will be vital.

In conclusion, global milk and beef demand have risen considerably over the last twenty years and the long-term outlook for agricultural commodity markets is positive. Climate change legislation poses challenges which ultimately may provide the opportunities to drive efficiencies that will ultimately reduce costs and drive profitability in the sector.

Reducing enteric methane from ruminant livestock - a snapshot of the research being done by different organisations around the world

By C GRAINGER

Visiting scientist based at Teagasc, Moorepark Dairy Production Research Centre, Fermoy, Co. Cork, Ireland

Abstract

The purpose of this paper is to provide a snapshot of the areas of research into reducing enteric methane production from ruminant livestock, that research organisations are currently focused on. It is not intended to cover every organisation around the world that is working in the area of reducing enteric methane from ruminant livestock. The focus is on enteric methane emissions from livestock in pasture-based systems of production. The groups (including contact person) that have contributed are:

- Teagasc-Moorepark - (Matthew Deighton)
- Teagsac-Grange - (Padraig O'Kiely)
- AFBI Hillsborough - (Tianhai Yan)
- UCD - (Tommy Boland)
- AgResearch NZ - (Simone Hoskin)
- DPI Ellinbank Victoria - (Peter Moate)

The six scientists listed above have provided information on their current areas of research into reducing enteric methane production from ruminant livestock. It is not the intent to present detailed results of research from these different organisations, but more to outline the broad areas of research that are being studied. Information was also provided on future research plans into reducing methane emissions from ruminant livestock.

Mitigation strategies for lower carbon dairy and beef production

By LAURENCE SHALLOO[1], DONAL O' BRIEN[1], PAUL CROSSON[2], PADRAIG FOLEY[3] and CHRIS GRAINGER[1]

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Abstract

Livestock farming is a major contributor to greenhouse gas (GHG) emissions. Even though temperate grass based systems of milk and beef production result in lower emissions per unit of product (Gerber *et al*., 2010) there will be a requirement to reduce emissions in order to meet agreed reduction targets (e.g. Kyoto Protocol). A number of mitigation strategies such as the application of nitrification inhibitors (Dobbie & Smith, 2003), anaerobic digestion of stored manure (Amon *et al*., 2006) or supplementation of livestock diets with protein hormones (Capper *et al*., 2008) have been identified as methodologies to reduce GHG emissions from livestock farms. However, many proposed mitigation strategies have only been assessed by considering on-farm emissions. The objective of this paper is to determine the effect of differing mitigation strategies on both dairy and beef production systems. In the case of dairy systems, the computations of the potential reduction in emissions were obtained using a modelling methodology incorporating the Moorepark Dairy Systems Model (MDSM) (Shalloo *et al*., 2004) to define the dairy production system and a GHG model (O'Brien *et al*., 2010) to define the sources and quantities of CO_2 equivalents (CH_4, N_2O and CO_2) and the GHG sinks. A similar approach was used for suckler beef production systems and is described by Foley *et al*. (2010) used for modelling beef production systems. Total national emissions for dairy and beef production systems were 16.06 kg CO_2e kg^{-1} milk solids (MS) and 22.70 kg CO_2e kg^{-1} carcass, respectively. Mitigation strategies investigated for the dairy systems included; increasing milk yield per cow, increasing milk solids concentration, increasing overall herd fertility, changing calving date, increasing grazing season length and increasing the efficiency of nitrogen use based on the expected rate of technological adoption. For suckler beef production systems, the main drivers of GHG emission reductions were level of animal performance and beef carcass output as well as efficiencies in utilisation of grazed grass and inorganic fertilisers (Foley *et al*., 2010). Dairy emissions could be reduced by 28.4% based on current research and were projected to be reduced by 16.5% based on expected technical change by 2020. For beef production systems, potential reductions of 18.5% based on current research performance were obtained by increasing farm beef output and level of production efficiency.

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The role of N-efficiency in lowering nitrous oxide emissions from agriculture in Ireland

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Abstract

Agriculture is the single largest contributor (26%) to greenhouse gas (GHG) emissions (primarily methane and nitrous oxide) in Ireland. Agriculture accounted for 92% of national nitrous oxide emissions in 2008. Sources of nitrous oxide from agriculture include (in declining order of magnitude): Excreta (primarily urine) deposited during grazing, fertilizer N, indirect emissions associated with nitrate leaching and ammonia, soils, managed manures and crop residues. Emissions of nitrous oxide (in CO_2 equivalents) from agriculture steadily increased from 7.045 Mt in 1990 to a peak of 8.304 Mt in 1999 and subsequently declined to 6.619 Mt in 2008. While the last decade has seen a decline in GHG emissions from agriculture, this has not been true for other sectors of the economy. There is pressure to lower emissions from all sectors of the economy including agriculture. The objectives of this study are (i) to determine the factors contributing to declining nitrous oxide emissions from agriculture in recent years, (ii) to ascertain whether these factors are likely to contribute future reduction and (iii) to evaluate the potential of other factors coming on stream to lower emissions.

Part of the decline in nitrous oxide emissions in recent years can be explained by lower ruminant livestock numbers. Ninety percent of the agricultural area of Ireland is under grassland, mostly permanent grassland, and grazed grass and grass silage comprise approximately 90% of the diet of ruminant livestock. Less ruminant livestock generate less excreta and hence lower associated nitrous oxide emissions. Lower stocking densities on grassland also necessitate lower fertilizer N input contributing to lower emissions. National fertilizer N use was 379 thousand t in 1990, increased to a peak of 443 thousand t in 1999 and declined to 309 thousand t in 2008. The escalating cost of fertilizer N and the widening gap between fertilizer N costs and relatively static farm gate product prices during the past decade has been an important contributing factor to declining fertilizer N use. This widening gap has driven up the efficiency of fertilizer N use on farms.

This gap is likely to get wider in future driving down fertilizer N use and fuelling the search for alternatives. Nitrification inhibitors have been shown to substantially lower nitrous oxide emissions associated with applications of fertilizers and manures and from urine deposited during grazing. However, there is little or no evidence of improved agronomic performance associated with the use of nitrification inhibitors and, hence, no economic incentive for their use on farms; the cost associated with its use exceeds any economic benefit to the farmer. Modern slurry application techniques such as trailing shoe and injection into the soil can increase N-use efficiency and improve agronomic performance compared with more traditional splash-plate. However, these techniques are associated with higher nitrous oxide emissions mainly because a greater quantity

of N is effectively delivered to the soil. Furthermore, the costs associated with these application techniques (higher capital investment and lower work rates) tend to negate the economic benefits of the improved agronomic performance and there is little incentive for adoption on farms.

Rhizobia in association with white clover have the capacity to generate approximately 100 kg ha^{-1} of plant-available N in the soil by biological fixation of atmospheric N. Escalating fertilizer N costs have improved the profitability of using white clover in grassland in recent years. Clover-based systems of dairy production can be as profitable as more conventional fertilizer-N-based systems. From the perspective of nitrous oxide emissions and GHG emissions generally, the clover-based system entails two additive advantages (i) there is lower reliance on fertilizer N and (ii) the same level of profitability can be achieved at lower stocking densities. Lower fertilizer N use and lower stocking densities (and less excreta) both contribute to lower nitrous oxide emissions, while lower stocking densities also entail lower methane emissions. At present, using the methodology of the International Panel on Climate Change no nitrous oxide emissions are attributed to white clover in grassland. Life cycle assessment comparing clover-based with more conventional dairy production has shown that use of white clover results in lower GHG emissions per litre of milk by between 12% and 22%. Furthermore, direct measurement has shown lower nitrous oxide emissions from clover-based grassland. White clover offers a solution that can maintain or increase profitability while lowering GHG emissions. This solution is particularly pertinent taking into account the importance of grassland as an agricultural land use in Ireland. Nevertheless, white clover is not in widespread use in Ireland primarily due to the lack of persistence in permanent grassland.

It is likely that fertilizer N costs will continue to increase relative to farm gate product prices. This will drive down fertilizer N use nationally and drive up the efficiency of fertilizer N use on farms. Under these circumstances the economics of using white clover become increasingly favourable offering substantial potential to lower GHG emissions if its use becomes widespread on farms.

Mitigation of greenhouse gas emissions in agriculture: A UK perspective

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Introduction

The UK is committed in law to reduce its greenhouse gas emissions by 80% from 1990 baseline. In order to achieve these demanding reductions, the government has set out carbon budgets which will decline progressively between now and 2050. An independent Committee on Climate Change has been established that is charged with the responsibility for proposing carbon budgets over a five year periods, and reporting on progress. Because of the magnitude of reduction required, it is anticipated that all sectors of the economy will contribute, although it is acknowledged that these reductions will not be evenly distributed between different sectors. Within the agricultural sector it is recognized that there are large uncertainties regarding the magnitude of emissions and that there are physical limits to the magnitude of emissions reductions can be achieved that are consistent with maintaining agricultural productivity. It is also understood that any changes introduced within the agricultural sector need to be sensitive to issues of global food security, and do so in a way which reduces other pressures on the environment. This paper examines opportunities the mitigation of greenhouse gases from UK agriculture over the first three reporting periods between 2008–2022.

Methods

A screening process was undertaken involving scientists with specialist knowledge of mitigation technologies and extensive reference to published literature to identify methods with the greatest potential to reduce greenhouse gas emissions from the agricultural sector. Mitigation potential was assessed against the National Inventory of greenhouse gas emissions in order to determine their relative importance. A shortlist of methods was produced and the abatement potential of these methods was costed using standard farm management approaches. This procedure was originally undertaken the part of a study which reported in 2008, with a further revision of the underlying assumptions provided in 2010 (see Moran *et al.*, 2008; MacLeod *et al.*, 2010*a,b*).

Results

The abatement potential of methods used to reduce greenhouse gas emissions is a function of the technical potential of individual method (i.e. its ability to reduce greenhouse gas emissions), and its adoption rate. There is uncertainty regarding both of these values and it is therefore important to reflect this uncertainty in the magnitude of predicted abatement. The abatement potential for the whole of the UK for methods that would cost less than £100 t^{-1} C was between 8,000 and 19,000 $ktCO_{2e}$ (Fig. 1). It was estimated that this could be achieved by the introduction of eight approaches.

Nutrient management

This would include improved timing of mineral and organic N applications, the separation of slurry and mineral N and full allowance for manure N in nutrient budgets.

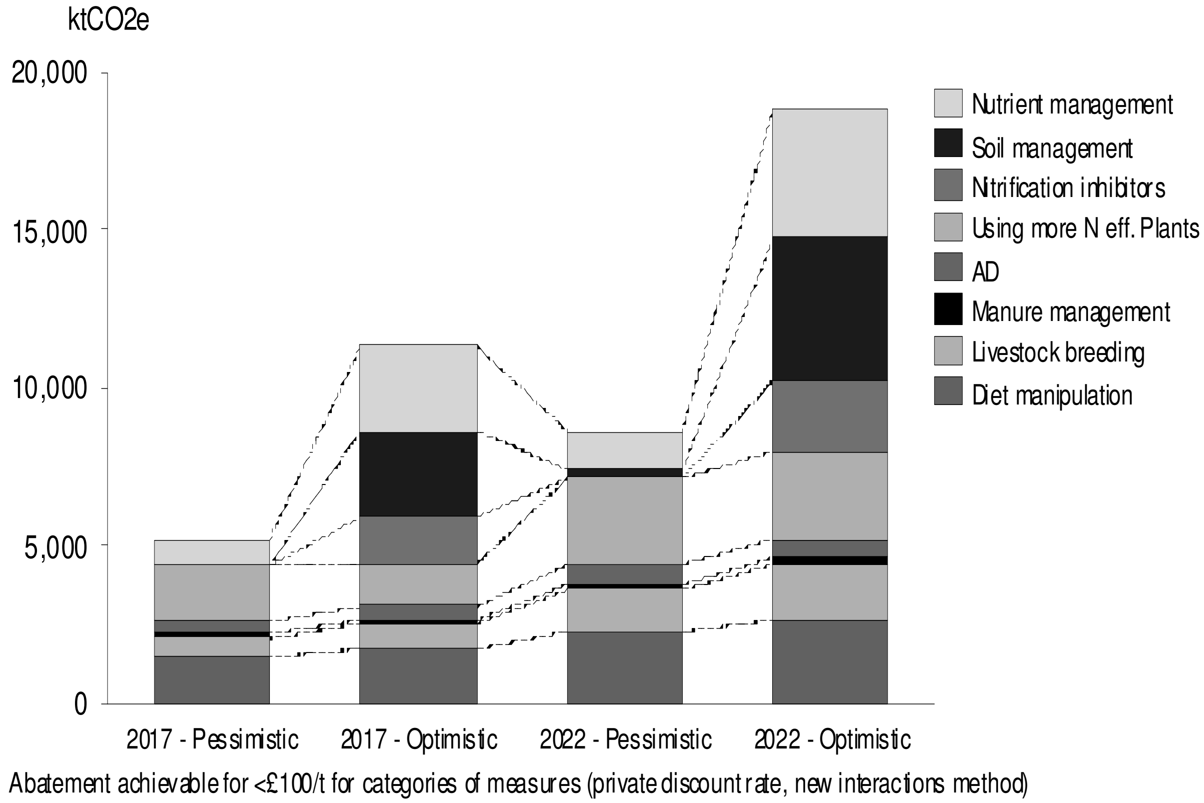

Fig. 1. The range of potential abatement in GHG emissions offered by different methods in the 2017 and 2022 reporting periods.

Soil management

Improvements in soil drainage may be particularly important here given that drainage not only produces nitrous oxide emission, but also contributes to improve crop production.

Nitrification inhibitors

New research from New Zealand indicates that abatement potential from the application of nitrification inhibitors can contribute significantly to reductions in nitrous oxide emissions from soils in grassland situations.

More efficient plants

There is a potential for plant breeding to produce varieties of crops that require less nitrogen and at the same time reduce nitrous oxide emissions.

Manure management

This method has a relatively small abatement potential, however more efficient management of manures can result in improvements both in crop yield and nitrogen losses.

Livestock breeding

The use of genetics to improve productivity and resource use efficiency by livestock can result in lower greenhouse gas emissions (particularly methane) per unit of output (meat or milk).

Diet manipulation

A range of supplements have been proposed that can contribute to reduction in methane emissions from animals. Growth promoters (Ionophores) also provide an effective abatement potential but are currently prohibited under EU legislation.

Conclusion

The mitigation of greenhouse gas emissions in agriculture will be dependant on the application of a range of methods. The relatively high levels of uncertainty associated with their mitigation potential highlights the importance of ongoing research.

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The use of whole farm nutrient budgets in driving efficiency and mitigation

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Abstract

The success of long-term food security relies to a large extent on the efficiency by which nutrient and other resources are utilized in global agriculture. Current livestock production systems have a low nutrient use efficiency. This is because of the limited biological potential of livestock to retain nutrients from feed intake and the poor nutrient management in practice. The nutrient cycle of livestock production systems is extremely complex and there are many processes that result in emissions of nutrients and greenhouse gases to the wider environment. Therefore, a whole-farm approach is needed to develop management strategies to decrease emissions and increase resource use efficiency. This holds especially for nitrogen (N).

Nitrogen output / input ratios (mass/mass ratios) and balances (input minus output, in mass per unit surface area) are the best indicators for expressing overall N use efficiency and N losses at farm level, respectively. While the ratio of total N output (via products exported from the farm) and total N input (imported into the farm) is an indicator for the N use efficiency at farm level, the N surplus (or deficit) is an indicator for the N pressure of the farm on the wider environment, assuming that ultimately all surplus N is lost via either ammonia volatilization, N leaching and/or nitrification/denitrification. Indirectly, N use efficiency and N surplus are also performance indicators for the emissions of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4), albeit different for different systems. Strategies focussed on increasing N use efficiency in general also have low risk of pollution swapping.

For dairy farming systems, a decrease of the N surplus with 1 kg decreases greenhouse gas emissions with approximately 25 kg CO_2-equivalents. Similar trends are observed for ammonia volatilization and nitrate leaching; increasing N use efficiency decreases ammonia volatilization and nitrate leaching per unit of milk, beef, mutton and egg produced. Our estimates indicate that the production of 1 kg milk, egg, chicken, pork and beef in EU-27 agriculture in 2005 had an approximate emission of 1.1; 1.3; 1.3; 3.1 and 21.2 kg CO_2-equivalents, respectively. There are significant differences between EU Member States and between farms within MS.

We conclude that nutrient use efficiency and nutrient surpluses can be used as performance indicators for commercial livestock farming at farm and regional levels. High nutrient use efficiency is indicative for low nutrient losses and low greenhouse gas emissions. The necessary benchmarks must recognize that different livestock categories have different biological potential for nutrient retention, and must consider the complexities arising from differences in livestock density and environmental conditions.

Growing returns: the role of land-use change in influencing GHG emissions

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Abstract

Biomass and biofuel can be used as a fossil fuel substitute for both oil, heat and electricity generation and may reduce the dependence on imports and/or carbon dioxide emissions. Consequently, the EU and also several EU member states have developed policies to promote the use of biomass energy sources. In order to obtain the maximum abatement benefits of bioenergy, a range of factors need to be considered. These include the end-use of the product and fossil fuel type being replaced, which will ultimately impact on the total GHG displacement. In addition, changes in the greenhouse gas (GHG) balance associated with cultivation is usually as a result of a) change in CO_2 sequestration into the soil as a consequence of vegetation type b) altered N fertiliser inputs and c) other inputs associated with cultivation (ploughing, liming, herbicides, fuel usage, grain drying, etc). However, factors such as soil type and climate heavily influence the size of the GHG source or sink. As a result, the spatial distribution of production is important for both crop productivity and the emission abatement potential.

The conversion of pasture to annual crops generally result in both a loss of soil carbon associated with both ploughing and extended fallow periods as well as increases in GHG emissions associated with field operations. This may impact on the overall sustainability index of using annual crops as biofuel or biomass. However, these effects can be limited by altered management strategies. These include the more targeted use of inputs, such as fertilisers and pesticides, reduced tillage, increased C inputs and crop type. As a result, the net GHG emissions can vary between 1–8 tonnes CO_2-eq yr^{-1}.

By contrast the cultivation of perennial biomass crops may result in net GHG abatement usually as a result of reduced fertiliser inputs, and increased CO_2 sequestration into root biomass and the soil. The extent this sequestration will be dependent on whether biomass cultivation is displacing arable land or stocked pasture, as well as crop productivity and soil type. Overall C input into the soil associated with the conversion of arable land to biomass has been estimated to increase by between 2.8 and 4.1 tCO_2 ha^{-1} $yr^{-1}$for *Miscanthus* and 1.8–2.7 tCO_2 ha^{-1} yr^{-1} for short-rotation coppice. By contrast, the conversion of pasture to biomass crops (*Miscanthus* or SRC) is assumed to have no impact on long-term net C sequestration when using IPCC Tier 1 methodologies for estimating C-stocks due to C loss associated with site preparation. However, recent measurements at under a range of soil types have shown that initial C loss after ploughing may be low (20–100kg CO_2 ha^{-1}) and that total site preparation losses can be limited to *c*. 1 tCO_2 ha^{-1} provided the fallow period is minimised. If the biomass accumulation by below-ground biomass (rhizomes and roots) is included, another 0.5–1 tCO_2 ha^{-1} yr^{-1}could be added to the total sequestration, dependant on climatic and soil factors.

The potential of SRC willow to reduce carbon emissions

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Abstract

Short Rotation Coppice Willow is grown as a source of biomass for the production of renewable energy. Yields of 10–12 dry t ha^{-1} yr^{-1} wood chip can be expected on a two or three year harvest cycle when grown on reasonable arable land. In energy terms short rotation coppice willow dry matter has an energy content of approximately 19 MJ kg^{-1} or 45% of the energy in an equivalent volume of light fuel oil. This gives a mean annual production equivalent to 3300–5700 L of oil ha^{-1} yr^{-1}. It is normally considered that willow wood chip is carbon neutral, having absorbed the same amount of carbon during growth as is released during burning. Additionally, there are significant carbon savings through the displacement of heating oil. It is estimated that 3,300 L of domestic heating oil produces 8,355 Kg CO_2. Burning wood chip will reduce the net CO_2 emissions by an estimated 90%. Expressed another way, wood produces 7 Kg CO_2 per GJ compared to heating oil which produces 79 Kg CO_2 per GJ. Furthermore, biomass does not contain many of the other noxious chemicals that are released when fossil fuels are burnt e.g. sulphur, which can cause major environmental problems.

There is considerable potential for the sequestration of carbon by SRC willow. It is estimated that willow plantations will remain in the ground for 25–30 years. The net soil sequestration for coppice willow has been calculated at around 0.22–0.39 t C ha^{-1} yr^{-1} which confirms the neutrality of biomass combustion in terms of greenhouse gas emissions. The overall carbon balances could be improved by reducing the amount of cultivation at establishment. Carbon is released from the soil during initial tillage. Work has been done to investigate the potential of planting SRC willow with a minimum-tillage approach.

SRC willow can be used to receive effluents and sludges. Treatment of waste-streams through Waste Water Treatment Works (WWTW) is very energy demanding with associated large emissions of greenhouse gases. Diverting effluents or sludges from conventional WWTW to land results in large net reductions in carbon emissions while increasing the growth of the willow.

Carbon sequestration: implications for grassland systems

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Abstract

Soil carbon sequestration in grasslands may mitigate rising levels of atmospheric CO_2 but there is still great uncertainty about the size, distribution and activity of this 'sink'. Carbon accumulation in grassland ecosystems occurs mainly below ground where soil organic matter is located in discrete pools, the characteristics of which have now been described in some detail. Carbon sequestration can be determined directly by measuring changes in carbon stocks or by simulation modelling. Both methods have many limitations but long-term estimates rely almost exclusively on modelling.

Management practices and climate strongly influence carbon sequestration rates which in temperate grasslands across Europe range from -4.5 g C m^{-2} yr^{-1} (a carbon source) to 40 g C m^{-2} yr^{-1} (a carbon sink). Due to uncertainties in location of sinks and their activity we currently only have enough information to infer the order of magnitude of soil carbon sequestration rates in temperate grasslands

Carbon losses from land to water in Northern Ireland: implications for net GHG emissions and carbon sequestration

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Abstract

Although landscape exports of dissolved organic carbon (DOC) to water are a poorly defined pathway of carbon (C) loss it is argued that they account for a significant portion of the apparent C gain in terrestrial C budgets. Uncertainties surrounding their magnitude and fate suggest that terrestrial estimates of C sequestration and net GHG emissions may have high margins of error. The significance of C exported from the landscape is further complicated depending on whether the C exported is a source or sink of atmospheric CO_2. Exported DOC will be a sink for C when buried in the sediments of lakes and oceans but it becomes a source of CO_2 when the exported DOM is bioavailable and subject to microbial respiration in the aquatic environment. Additionally CO_2 supersaturation in drainage water due to soil respiration will act as a C source during downstream transport.

The dynamics of drainage water DOC export from a variety of land use types in Northern Ireland were determined from 31 mini-catchments of 1–19 km^2 within the Upper Bann and Colebrooke river basins. Exports were also measured in 11 larger catchments of 46–1154 km^2 that are the 10 major inflowing rivers to Lough Neagh and the River Bush. The mini-catchments encompassed a range of land use types but those in the Upper Bann had a high proportion of intensively managed grasslands whereas the Colebrooke catchment has high proportions of unimproved pastures, peatlands and coniferous forestry. Grab samples for water chemistry were taken at fortnightly intervals in mini-catchments and at weekly intervals in whole catchments between September 2008 and October 2009 and analysed for DOC, dissolved organic nitrogen and five day biological oxygen demand (BOD_5).

No clear relationship was found between flow and DOC in any catchment but variation in DOC concentration was highly synchronised between sites and showed a pronounced seasonality with the highest concentrations and exports occurring in autumn. DOC exports ranged from 36–81 kg ha^{-1} yr^{-1} in the Upper Bann, 175 to 256 kg C ha^{-1} yr^{-1} in the Colebrooke and 46–138 kg ha^{-1} yr^{-1} in the River Bush and Lough Neagh rivers. In the Colebrooke DOC exports were positively related to the proportion of peatland in the catchment ($R^2 = 0.46$, $P < 0.001$) whereas in the Upper Bann DOC exports were negatively related to the proportion of natural vegetation ($R^2 = 0.30$, $P < 0.01$)

Despite lower DOC, values of BOD_5 were similar in the Upper Bann and Colebrooke mini-catchments, so that DOC normalised BOD_5 was twice as high on average in the Upper Bann. Mean organic C:N molar ratios ranged between 15–42 in the Colebrooke and 9–21 in the Upper Bann mini-catchments, but were only negatively related to BOD_5 in the Colebrooke mini-catchments. These observations are consistent with a smaller proportion of bioavailable DOM in the Colebrooke mini-catchments. Continuous recording BOD incubations over 100 days for a subset of Upper Bann mini-catchments demonstrated continued significant mineralisation of DOM equivalent to five times the BOD_5 values.

Based on an average Northern Irish grass dry matter (DM) yield of 8000 kg DM ha^{-1} yr^{-1} or 3200 kg C ha^{-1} yr^{-1} (using a conversion factor of 0.4 to convert grass DM to a C equivalent) the measured DOC export rates for the Upper Bann mini-catchments indicate that C equivalent to approximately 1–3% of grass production may have been exported annually. Applying a respiratory quotient of 1 to BOD_5 values and a factor of 5 to approximate the total BOD demand for the Upper Bann mini-catchments indicates that 40–60% of the DOC exported is re-mineralised as CO_2. This return of C to the atmosphere may therefore only represent less than 0.5% of typical annual soil CO_2 efflux but when considered against potential carbon sequestration rates of 0.4–1.0 t C ha^{-1} yr^{-1} they may represent 10% of the sequestered C.

Complexity in science; afforestation of the Irish landscape as a source of atmospheric greenhouse gas nitrous oxide

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Abstract

In order to determine the relative contribution of the greenhouse gas (GHG) nitrous oxide (N_2O) emissions to the total GHG budget of forest ecosystems, and in order to assess the impact of grassland afforestation on the production of this gas, a static chamber technique has been deployed from May 2008 to October 2009 on a Sitka spruce (*Picea sitchensis* (Bong) Carr.) forest chronosequence on mineral soil in central Ireland (Dooary forest, Co. Laois). The chronosequence consisted of four subsites representing the different stages in growth of the forest, from the grassland (year 0 site) to the 6, 14 and 20 year old sites.

Data suggest that the conversion from grassland to forest increases the emissions of N_2O to the atmosphere by an average of 80–100 fold. The increase in N_2O emissions could be due to a reduction in the water content of the soil and to the permanent lowering of the water table associated with the conversion from grassland to forest. This hypothesis however was not supported by data coming from laboratory experiments on soil cores. No clear relationship therefore could be found between soil moisture content and N_2O emissions. Other factors that could be responsible for this difference in emissions are at the moment under investigation, such as differences in mineral N and changes in microbial population activity associated with the land conversion.

The conversion from grassland to Sitka spruce forest in Ireland has a clear impact on atmospheric carbon dioxide, with the forest acting as a strong sink for this gas. The results of this study however suggest that the same is not true for N_2O, with the forest acting as a source. Any estimation of national GHG budgets should take this into consideration.

Effect of slurry type, dry-matter content and application technique on greenhouse gases and ammonia emissions from grasslands

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Abstract

Agriculture in Ireland contributes 98% of ammonia (NH_3) and 26% of greenhouse gas (GHG) emissions with the majority of these emissions associated with livestock production. This study aims at: a) measuring the effect of cattle slurry and inorganic fertiliser application on GHG and NH_3 emissions, b) investigating the impact of slurry composition and application technique on these emissions.

A field-plot experiment was carried out on a grassland site, with grass-based and maize-based slurries of high and low dry matter (DM) content. Plots were spread using splash-plate application. In addition, one of the combinations of maize-based slurry DM content was also use to spread three new plots simulating trailing shoe application to compare both slurry application techniques. Control plots include no N fertilization and two different rates of calcium ammonium nitrate (CAN) fertilization. Slurry applications were carried out on three separate dates to provide a range of contrasting weather conditions.

Continuous flux measurements were taken after slurry application. NH_3 was measured using a photo-acoustic analyzer (INNOVA 1412 Trace Gas Analyser, INNOVA Instruments, Copenhagen, Denmark) coupled to a dynamic chamber. CO_2 and N_2O were measured using static chambers and an Infra-Red Gas Analyzer (CO_2, PP Systems EGM-4, PP Systems, Hitchin, Herts, UK) or a gas chromatograph (N_2O, Varian) for the analysis of the gases respectively.

The first results show that NH_3 emissions were highest under warm dry conditions and when splash-plate applied. In terms of trace gases, indirect N_2O emissions sourced from ammonia losses comprised the largest proportion of land spreading emissions. Direct N_2O release from soils was highest in August and lowest in July. These N_2O emissions from slurry spread plots were significantly lower than those measured under CAN fertilisation.

Lowering slurry DM also led to a significant reduction in the emissions of ammonia from splash plate applied plots. This reduction of nitrous oxide release from the soil, when reducing slurry DM content, was significant for grass-derived slurry, but not when cows were initially fed with maize.

Application of slurry resulted in a significant increase in CO_2 release from soils, particularly in summer, indicating a possible 'priming effect' following the addition of relatively labile C sources. These CO_2 emissions dwarfed other emissions over the measurement period.

Measuring the impact of alternative greenhouse gas emissions policies on Irish farmers

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Abstract

The European Union's (EU) "20 20 by 2020" proposal is arguably the most significant legislation that has been introduced to date, in the challenge to reduce man-made greenhouse gas (GHG) emissions. It entails an EU commitment to reduce emissions by at least 20% by 2020 compared to 1990 levels. The target for the non-Emissions Trading Scheme (non-ETS) sector is a 10% reduction in emissions by 2020 compared to 2005, with specific emissions reduction targets for each member state. Ireland, along with Denmark and Luxembourg, was given the largest non-ETS emissions reduction target of 20%. Ireland is relatively unique amongst EU member states in that agriculture accounts for 26% of total GHG emissions and approximately 40% of non-ETS emissions. While no decision has been made to date on Irish agriculture's share, if any, of the 20 percent reduction target, this policy has the potential to impact substantially on Irish agriculture.

A number of technological abatement strategies exist for agriculture including changes in production systems, animal diet and animal genetics. Lovett *et al*. (2006) argued that adoption of these technologies would be contingent on their ability to improve farm profitability or the provision of "financial inducements" from central government. A variety of policy based mechanisms exist that could be used to achieve a reduction in GHG emissions, including input subsidies, emissions standards, emissions taxes, input taxes and tradable emissions permits.

Data from the 2006 National Farm Survey is used to construct a linear programming model of Irish agriculture. The model solves for the optimum mix of agricultural enterprises that will maximize the overall sectoral gross margin subject to farm specific constraints such as land and labour availability and sectoral constraints also. The model allows for analysis of the impact on Irish farmers of alternative GHG emissions targets or policies, relative to a baseline scenario of no emissions reduction in agriculture. This paper examines the potential impact on Irish farmers of two of these approaches, emissions standards (20% Reduction scenario) and tradable GHG emissions permits for Irish agriculture (TEPS scenario).

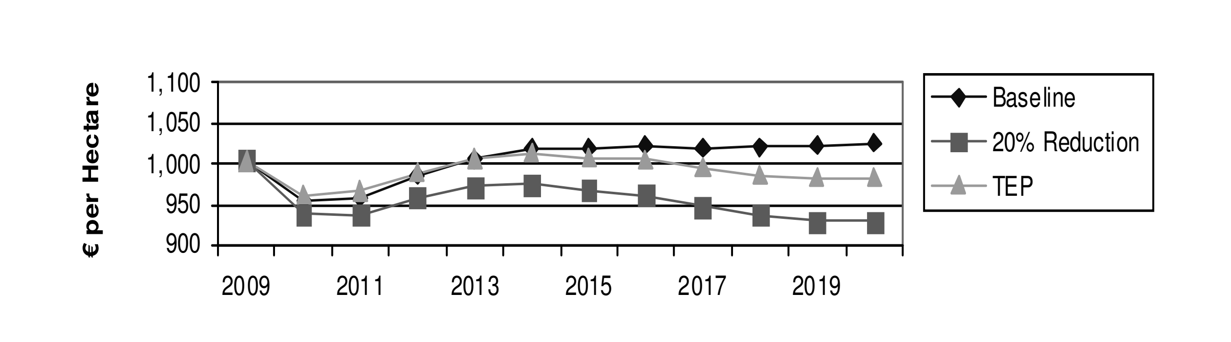

Fig.1. Impact of alternative GHG emissions scenarios on dairy farm average gross margin per hectare.

The introduction of an emissions standard equivalent to a 20% reduction in emissions across all farms would result in a reduction of €96 per hectare in the average dairy farm gross margin. In comparison, if a system of tradable emissions permits were introduced for agriculture, this loss in average dairy farm gross margin could potentially be reduced to €43 per hectare.

Reference

Lovett D K, Shalloo L, Dillon P, O'Mara F P. 2006. A systems approach to quantify greenhouse gas fluxes from pastoral dairy production as affected by management regime. *Agricultural Systems* **88**:156–179.

Cost implications of a carbon tax on fuel used in agricultural production in Ireland

By JAMES BREEN, DARAGH CLANCY TREVOR DONNELLAN and KEVIN HANRAHAN

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Abstract

In this paper we examine the implications of the introduction of a carbon tax on fossil fuels on the cost of production in Irish agriculture. The purpose of the tax is to correct a market failure by internalising the cost associated with the damage caused to the environment by the use of such fuels.

This tax applies to fuels such as petrol, auto diesel, and marked or "green" diesel all of which are used in agricultural production, but excludes electricity as electricity generators are already part of the EU's Emissions trading Scheme. The tax is levied at €15 per tonne of carbon.

The carbon tax will impact on farm production costs in Ireland in a number of ways. The carbon tax will impact agricultural production costs directly through an increase in the price paid by the farmer for these fuels. The carbon tax will also impact indirectly through increases in the prices of particular services that are purchased by farmers that are themselves affected by the introduction of a carbon tax. The most notable of these services are agricultural contracting charges such as silage making and slurry spreading and also the cost of transporting milk, animals and grain. For providers of such services fuel represents a significant portion of their costs of production and it can be expected that the increase in fuel costs experienced by these service providers arising from the carbon tax will be passed onto farmers.

Farmers will be largely unable to substitute away from these fuels by using more electricity and less diesel for example, since the appropriate electric technologies do not exist. The same is true for providers of services to farmers. As such the tax cannot be avoided as demand for fuel inputs is very inelastic. As price takers, farmers will be unable to offset the increases in production costs associated with the tax by increasing the price of the output they produce. As a result the tax will reduce farm profitability.

We use historical cost data from the National Farm Survey (NFS) (Connolly *et al*., 2009) and estimate the increase in costs associated with the tax based on our estimates of the share of fuel expenditure in various agricultural production cost categories in the NFS. The study provides results for the average farm within each farm system covered in the NFS as well as an aggregate figure for those sectors of agriculture covered by the NFS.

Based on the analysis it is found that the annual cost increase resulting from the tax amounts to about €225 on average per farm, ranging from €125 for the average sheep farm to €467 for the average tillage farm. The total cost to the dairy, drystock and tillage sectors in Ireland is estimated to be almost €24 million per annum.

Reference

Connolly L, Kinsella A, Quinlan G, Moran B. 2009. *National Farm Survey 2008*. Athenry, Ireland: Teagasc.

The effect of climate and land use change on soil respiratory fluxes

By ERICA CACCIOTTI[1*], MATT SAUNDERS[1], BRIAN TOBIN[2] and BRUCE OSBORNE[1]

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Abstract

The effect of stand age on soil respiration has been studied at three locations at the Dooary forest, County Laois, Ireland. This forest is located on a wet mineral soil and the chronosequence includes a semi-natural grassland (T_0), a 6 year old Sitka spruce and a 20 year old Sitka spruce stand.

Different rates of total soil carbon dioxide (CO_2) efflux have been found among sites where soil CO_2 efflux decreased with forest age. In this study afforestation has been shown to decrease soil CO_2 emissions. Soil respiration has been shown to be driven by certain climatic parameters such as air temperature, precipitation and soil water status.

Changing future climatic conditions may therefore change the observed rates of soil CO_2 efflux. In order to investigate the impacts of changing soil water content on rates of soil respiration, precipitation exclusion shelters have been installed at the chronosequence sites. The results show, in the short term, that the impacts of a reduction in precipitation on soil respiration differ between the different chronosequence sites with a significant reduction observed in the six year old forest stands and no significant differences observed at the other sites.

Quantification of ruminal methanogenic, fungal, cellulolytic and protozoal variation in beef heifers divergently ranked for residual feed intake (RFI) under different diets

By C A CARBERRY[1,2], D A KENNY[1,2] and S M WATERS[1]

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Introduction

Selection for improved feed efficiency in beef cattle has been shown to reduce total and feed intake corrected methane emissions without compromising animal production. However, little is known about the biological mechanisms controlling this effect. The objective of this research was to investigate whether specific ruminal microbial populations are associated with differing feed efficiencies in cattle by developing specific relative quantification real time PCR assays.

Materials & Methods

Beef heifers (n= 86) were ranked on RFI and the seven highest (HRFI; least efficient) and seven lowest (LRFI; most efficient) ranking animals were selected for use in this study. Both groups had similar mean bodyweight and average daily gain at ranking but HRFI had, on average, 20% higher dry matter intake. Following ranking on RFI all animals were allocated to a grass silage diet for six weeks (Period 1). All animals were later offered a 30:70 maize silage:concentrate TMR over a six week period (Period 2). Both silage and TMR diets were offered *ad libitum*. Ruminal fluid was sampled at the end of each period using a specialised trans-oesophageal sampling device. Total microbial DNA was isolated from the ruminal fluid and a qPCR SYBR Green assay was developed to quantify key microbial groups using specific PCR primers to target methanogens, fungi, cellulolytic bacteria and protozoa. Abundance of quantified microbes was calculated as a proportion of total estimated rumen bacterial 16S rDNA according to the equation: relative quantification = $2^{-(\mathrm{Ct\ target}-\mathrm{Ct\ total\ bacteria})}$, where Ct represents threshold cycle. Data were analysed using mixed models ANOVA (PROC MIXED; SAS, 2006).

Results

There was no evidence for an effect ($P < 0.05$) of RFI phenotype x diet interaction on the total abundance of any of the microbial species measured. There was also no effect ($P > 0.05$) of RFI phenotype on the quantity of any of the microbial populations measured, although a trend was observed toward a positive association between RFI and total fungal abundance. Dietary energy type had no effect ($P > 0.05$) on fungal abundance, however dietary energy type significantly affected ($P < 0.001$) the methanogen, cellulolytic and protozoal microbes manifested as a reduction in methanogen and cellulolytic abundance and an increase in protozoa abundance between periods 1 and 2.

Conclusions

With the exception of fungi, there was no clear evidence of differences in inherent ruminal population between animals ranked as either HRFI or LRFI. However, the abundance of ruminal microbes did correlate with differences in dietary energy type. Future research is warranted to unravel the effect of animal RFI phenotype and diet on the abundance of the ruminant microbial population at species or strain level to elucidate their potential role in the contribution to differing methane emissions

Investigating the carbon balance implications of establishing biomass crops

By ÓRLAITH NÍ CHONCUBHAIR[1,2], BRUCE OSBORNE[1] and GARY J LANIGAN[2]

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Abstract

The issue of climate change has gained critical relevance in Ireland due to global concerns regarding perturbations in climatic variables and large increases in national greenhouse gas emissions since 1990. The Kyoto Protocol has set a limit on national GHG emissions of 13% above 1990 levels for 2008–2012, while EU proposals envisage a 20% EU-wide cut in emissions relative to 1990. These targets represent a significant distance from current emissions of almost 25% above the 1990 baseline. Biomass crops, in particular perennial grasses such as *Miscanthus*, have been proposed as carbon-neutral alternatives to fossil fuels, with the added potential for sequestering carbon in vegetative pools and soil carbon reservoirs. However, the magnitude of this potential carbon sink is unknown, as is the relative strength of different crops as viable sequestration options. The aim of this research is to quantify ecosystem-scale CO_2 fluxes over plots of *Miscanthus* and Reed Canary Grass using the eddy covariance technique. Results from the first *Miscanthus* growing season show an increase in C uptake over this period and provide information on the impact of climatic factors on CO_2 exchange processes.

Accounting for uncertainty in biomass investments

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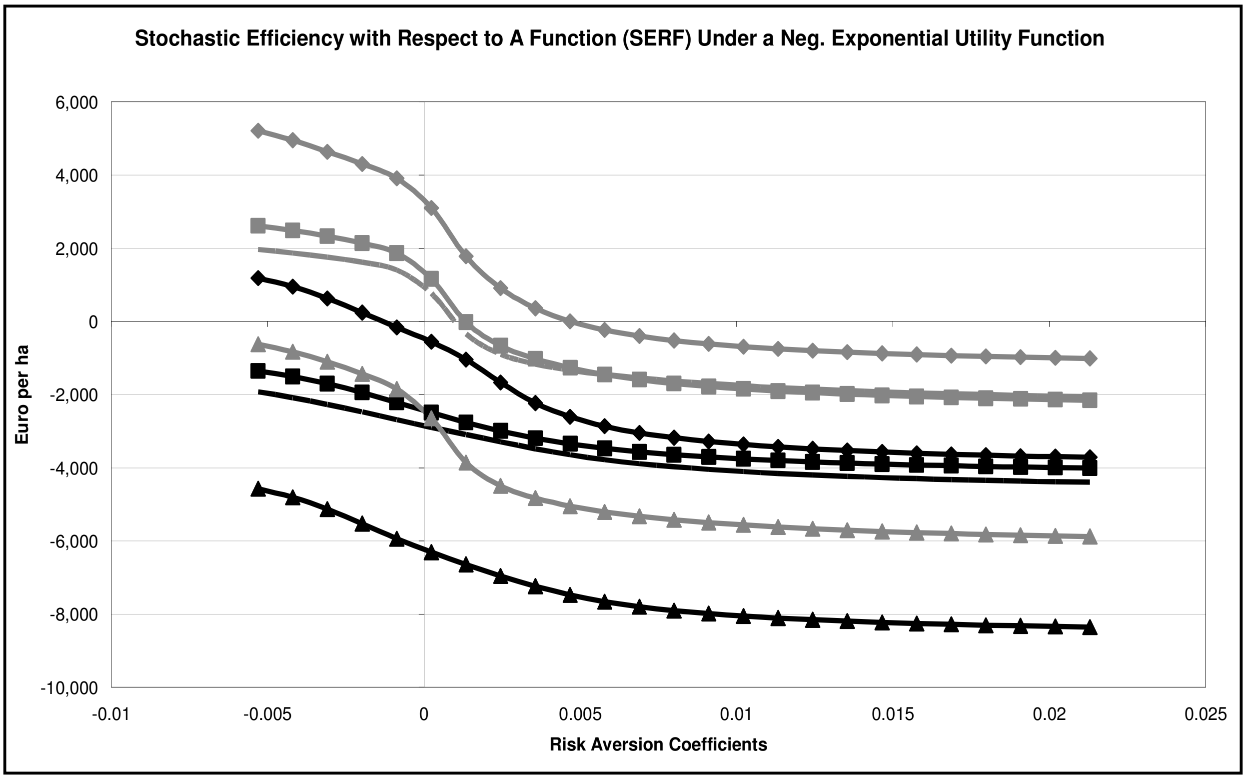
Abstract

There is increasing interest in biomass crops as an alternative farm enterprise. However the uncertainty surrounding risky variables such as the costs of production, yield level, price per tonne and opportunity cost of land make it difficult to accurately calculate the returns to biomass crops. Their lengthy production lifespan may only serve to heighten the level of risk that affects key variables. A stochastic budgeting model is used to estimate distributions of returns from willow and miscanthus in Ireland. The opportunity cost of land is accounted for through the inclusion of the foregone returns from selected conventional agricultural activities. The Net Present Value (NPV) of various biomass investment options are simulated to ascertain the full distribution of possible returns. These investment options are then ranked using Stochastic Efficiency with Respect to a Function (SERF).



SERF is a procedure for ranking risky alternatives based on their certainty equivalents (CE). The CE values show the amount of money that the decision maker would have to be paid to be indifferent between the particular scenario and a no-risk investment. A positive CE indicates that an investment is worthwhile, as the farmer would have to receive a payment in order to sell a desirable risky prospect. Farmers with a negative risk aversion coefficient are willing to take on risk in an investment if the returns from the investment are high enough. The results from the SERF analysis show miscanthus generally has higher certainty equivalents, and therefore farmers would be more likely to invest in miscanthus rather than willow. Despite this, most farmers with positive levels of risk aversion would not make an investment in either crop given the available returns.

Application of digestate on permanent grassland – Fertiliser value and environmental impact

By B DIETERICH[1], J FINNAN[2], S HEPP[1], T HOCHSTRASSER[1] and C MÜLLER[1,3]

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[3]*Institute of Plant Ecology, University of Gießen, Germany*

Abstract

The production of renewable energy via anaerobic digestion of biomass has increased considerably in recent years. The undigested residue leaving the reactor, the digestate, may be used as a fertiliser in agriculture. However, as the digestate carries an active population of methanogenic micro-organisms, negative environmental impacts in the form of methane emissions are possible. Our goal is to quantify the fertiliser replacement value and environmental impact of digestate application in Ireland.

We are conducting a trial on long-term set-aside grassland at the Oak Park station of Teagasc, Carlow, Republic of Ireland. Treatments comprise four levels of mineral N fertiliser (calcium ammonium nitrate), four levels of digestate matched to the mineral treatments, a combined mineral / digestate treatment and a control receiving no N fertiliser. The two fertilisers are compared with respect to the efficiency of N utilisation by the grass and the environmental impact from trace gas emissions after application (CH_4, N_2O). Global warming potentials are derived by converting the emissions into CO_{2eq}. (Forster *et al*., 2007). Annual emissions are calculated by adding emissions from the three fertiliser applications. Specific emissions (kg CO_{2eq}. t^{-1} DM) are then calculated by division by the respective annual yield. Results from 2009 are presented.

The yield response to mineral fertiliser nitrogen was found to be higher than to digestate nitrogen. However, the highest dry matter yield was obtained from the combined treatment. The annual greenhouse gas budget of biomass was dominated by N_2O emissions after fertiliser application while emissions of CH_4 played a minor role. As mineral fertiliser application gave rise to higher emissions of N_2O than did digestate application, the specific emissions per tonne dry matter of biomass were higher in the plots receiving mineral fertilisation. Therefore, it seems that digestate may have good potential as a fertiliser on grassland, possibly in combination with chemical fertiliser, but further research is required.

Reference

Forster P, Ramaswamy V, Artaxo P, Berntsen T, Betts R, Fahey D W, Haywood J, Lean J, Lowe D C, Myhre G, Nganga J, Prinn R, Raga G, Schulz M, Van Dorland R. 2007. Changes in atmospheric constituents and in radiative forcing. In *Climate change 2007*: *The physical science basis*, pp. 129–134. Eds S Solomon, D Qin, M Manning, Z Cehn, M Marquis, K B Aveeryt, M Tignor and H L Miller. Cambridge: Cambridge University Press.
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Impact of the economic recession on emissions of greenhouse gases from agriculture in the Republic of Ireland

By TREVOR DONNELLAN, PATRICK GILLESPIE and KEVIN HANRAHAN

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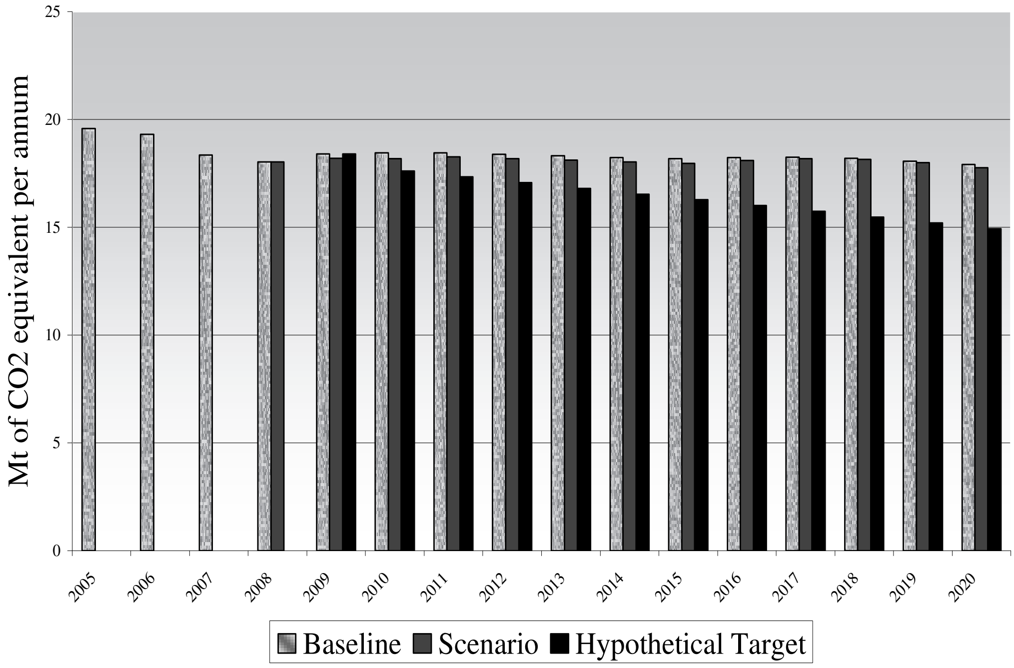
Abstract

The effects of the recession of 2009 have been felt across the economy of Ireland. The rapid contraction in economic activity has had its effect on greenhouse gas (GHG) emissions as well. With the latest international commodity price projections from Food and Agricultural Policy Research Institute (FAPRI) having been made available it is possible to model the recession's effect on agricultural GHG in the FAPRI-Ireland GHG model.

The FAPRI-Ireland GHG model creates projections of future levels of agricultural activity and then uses a mix of national and default emissions factors to convert this activity to estimates of annual GHG emissions from now to 2020.

The method of analysis used involves creating a baseline scenario in which assumptions about future policy changes are kept to a minimum, and then shocking the model by changing values of selected variables to reflect a new or different state of the world. The changes in the models outputs are then the affect of the shock, ceteris paribus.

In this analysis, the model is shocked using post-downturn price projections for a selection of exogenous prices which have been newly obtained from the FAPRI modelling system. The changes to these international commodity prices reflect the international market response to the downturn, and as such they have an impact on domestic prices, which in turn affects production and input usage levels. This will imply corresponding changes to the level of GHG emitted by the agricultural sector in Ireland.



This analysis finds that, despite the depth and breadth of the recession, the impact on GHG emissions from Irish agriculture has been muted. The impact of the shock is to reduce the projected annual emissions from the sector by only 0.14 Mt by 2020. This compares to the 2.97 Mt reduction in annual emissions which the sector would have to achieve if, for example, a reduction target of 20 percent on 2005 levels were to be imposed.

Pests, diseases and climate change: A spatio-temporal analysis of the potential impacts on Irish agricultural productivity

By CATRIONA DUFFY[1], RÉAMONN FEALY[1] and ROWAN FEALY ICARUS[2]

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[2]*Department of Geography, NUI Maynooth, Co Kildare, Ireland*

Abstract

Global environmental changes are projected to impact the productivity of agricultural systems in the future. The scientific consensus supported by the Intergovernmental Panel on Climate Change (IPCC) is that the global climate is warming. Despite the physical link between agriculture and climate, there has been limited work conducted on the potential impacts of projected temperature, precipitation and atmospheric CO_2 changes on economically important agricultural pests and diseases in Ireland. The aim of the research highlighted here is to provide an insight into the range of potential impacts of climate change on selected insect pest and pathogen incidence in the context of Irish agricultural systems. This poster incorporates three general themes: (1) Climate in Ireland, (2) the direct effects of climate change on crop and animal production and (3) the direct and indirect impacts of climate change on agricultural pests/diseases and their hosts. As an example, low winter temperatures provide a limiting factor for many pests and diseases in Ireland. However, projected increases in winter minimum temperatures could increase the severity of pest and disease prevalence, or extend the geographic range of indigenous or alien species. Latent changes in plant/crop phenology and physiology may also alter their suitability as hosts for many pests and diseases. This research seeks to analyse the possible implications for Irish agriculture under future climate change on both temporal and spatial scales in the context of pest and disease incidence and severity.

Estimating greenhouse gas emissions in the grain and sheep industries in the Upper Wimmera Catchment, Victoria, Australia

By CARLY GREEN[1] and MARINA CONWAY[2]

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Abstract

The agriculture sector is responsible for over 16% of Australia's total annual greenhouse gas emissions. With the emergence of greenhouse gas regulation in Australia, the agricultural sector is likely to be required to reduce their emissions. Very few land managers understand where greenhouse gases are emitted from on their farm, and which processes are accounted for in the National greenhouse gas account. The objective of this project was to increase landholder and community understanding of greenhouse gas emissions on farms, through capacity building and promotion of opportunities for reducing and sequestering greenhouse gas emissions within agriculture and forestry, and to demonstrate the utilisation of greenhouse gas calculators in the sheep and grain industries.

The project involved demonstrating the use of greenhouse gas calculators based on Australia's national greenhouse gas accounting system to a group of 15 sheep and grain landholders in the Upper Wimmera Catchment, Victoria, Australia. Greenhouse gas emission profiles were developed for each farm and benchmarked against each other.

This project:

- Lead to an increase in the skills and knowledge relating to greenhouse gas accounting amongst primary producers in the sheep and grain industry in the Upper Wimmera and how it directly impacts them at farm level.
- Increased land manager capacity to potentially report emissions in the future and to monitor reductions made through identified actions
- Demonstrated how greenhouse gas calculators can be used to estimate and project gas emissions in the sheep and grain industries.
- Heightened awareness of greenhouse gas risks and opportunities in the voluntary (and emerging mandatory) emissions trading schemes in Australia.
- Enhanced relationships between scientists and landholders within the upper Wimmera network through positive voluntary action.

Assessing the greenhouse gas budget of eco-tillage and other mitigation options for arable ecosystems: "Tillage managements and trace gases emissions"

By MOHAMED HELMY[1], MOHAMED ABDALLA[2] and BRUCE OSBORNE[1]

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[2]*Botany department, Trinity College Dublin, College Green, Dublin 2, Ireland*

Summary

Measurements of nitrous oxide (N_2O) and methane (CH_4) greenhouse gas fluxes form soils under different field management systems were carried out at the Teagasc, Oak Park Research Centre in Carlow. The aims were to provide a better understanding of the controlling factors for the trace gas fluxes from soils and to validate DNDC and DayCent models for the Irish croplands. The soil is classified as a sandy loam with a pH of 7.3 and a mean organic carbon and nitrogen content at 15 cm of 19 and 1.9 g kg^{-1} dry soil, respectively. Data on N_2O and CH_4 trace gas fluxes due to application of the crop straw and cover crop under conventional and reduced tillage, especially during the ploughing and fertilizers application periods, was collected. Soil temperature and soil moisture were measured at 10 cm depth simultaneously with the gas sampling. Results showed that application of crop straw to conventional tillage significantly increased N_2O fluxes during ploughing but no significant differences between all treatments were observed for methane. Significantly negative correlation between soil moisture and soil temperature was found. Soil temperature positively correlated with N_2O fluxes however, soil moisture affected the flux indirectly by modifying soil temperature.

Key words: Nitrous oxide, methane, conventional tillage, reduced tillage, ploughing, n application

Emission of N_2O from Irish groundwaters

By M M R JAHANGIR[1, 3], P JOHNSTON[1], M I KHALIL[2] and K G RICHARDS[3]

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[2]*Research Fellow, Environment Protection Agency, UCD; 3Teagasc Environment Research Centre, Johnstown Castle, Co. Wexford, Ireland*
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Abstract

It is of utmost importance to understand the production mechanisms for N_2O in groundwaters which is contributing approximately 10% of global N_2O budget, being able to cause both direct (diffusion to surface) and indirect (flux with groundwater) emission to atmosphere. A groundwater monitoring network was established on grazed grassland at research farms at Johnstown Castle (JC) and Solohead (SH), on tillage farm at Oak Park (OP) in Ireland, to quantify N_2O concentrations within the shallow groundwater zone (1.5–6.0 m mgl). Groundwater sampling was carried out monthly from February 2009 to January 2010 following the USEPA low flow sampling procedures. Dissolved groundwater N_2O was separated by degassing groundwater following the headspace equilibration method. N_2O concentrations ranged from 0.019 to 0.052, 0.003 to 0.091 and 0.014 to 0.146 mg L^{-1} over the sampling period, with corresponding mean values of 0.034, 0.023, 0.038 mg N L^{-1} in JC, SH and OP, respectively. The higher N_2O concentration in OP compared to JC and SH indicated higher N input into groundwater zone which have lower water table, residence time and DOC but higher DO and redox potential. There were considerable temporal variations at all sites with the coefficients of variation (CV) ranging from 83 in JC to 120% in OP. The N_2O emission factors (EFg) were 0.0048, 0.0083 and 0.0035 at JC, SH and OP, respectively which are considerably greater than the IPCC (2006) default value of 0.0025. It is concluded that groundwater can be a considerable source of N_2O and the IPCC default value of emission factor (EFg) required an upward revision. However, the existing biogeochemistry in groundwater zone can cause further reduction of N_2O to N_2 but can simultaneously reduce NO_3^- to N_2O as well.

Added organic material and nitrogenous fertiliser interactively reduces global warming potentials of agricultural soils

By M I KHALIL

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Climate Change Research Programme, Environmental Protection Agency, Johnstown Castle Estate, Wexford, Republic of Ireland

Abstract

Soil as a storehouse of atmospheric carbon and the reduction of greenhouse gases (GHGs: CO_2, N_2O and CH_4) from agricultural soils has received global attention to revert at least in part the changing climate. Atmospheric concentrations of potent GHGs (mainly N_2O and CH_4) during the past few decades have increased, contributing to enhanced greenhouse effect. Agricultural systems are a major source of these reactive gases, mainly as a result of application of inorganic and organic fertilisers, but may act as a sink depending on soil and environmental conditions. Any changes in sink or source strengths may result in a net increase in global warming potential (GWP). Organic matter is one of the main keys not only to improve soil productivity but also important for replenishing the soil C losses. The addition of organic residues increases the supply of carbonaceous materials as an energy source for the living microorganisms and the dead microbial biomass provides the substrate, leading to a series of biological N transformations. Organic materials having low C/N ratios show N mineralization more than those with wide C/N ratios, having characteristics to sequester more C though mostly causes N (either added or mineralized) immobilization in microbial-deficient soil during decomposition. This brings about N limitation of the microbial biomass though it may triumph over by the supply of extra-N. Application of N fertilisers has been shown to increase N_2O emissions and inhibit CH_4 oxidation in soil. Depending on the decomposability of organic materials, however, addition of N fertilisers (mainly urea and ammonium-based) during aerobic decomposition of organic materials (either in the beginning or at a later stage) stabilizes the added C at the expense of CO_2 to an acceptable limit, and helps retaining more N and re-mineralizes thereafter to make available for plant uptake. These interactive functional relations between C and N could reduce GWP substantially by trade-offs between N_2O, CH_4 and CO_2 emitting from differently managed agricultural soils. Thus, scientific knowledge on the timing and method of adding organic matter and N fertilisers to a specific soil/land use is vital towards integrated, effective management strategies for maximising nutrient use efficiency, better crop return and less environmental degradation.

Grass-legume interactions reduce N_2O emissions at low level of nitrogen application

By LAURA KIRWAN[1], TIM CARNUS[2], DAVID DEVANEY[2], JOHN FINN[2], GARY LANIGAN and KARL RICHARDS[2]

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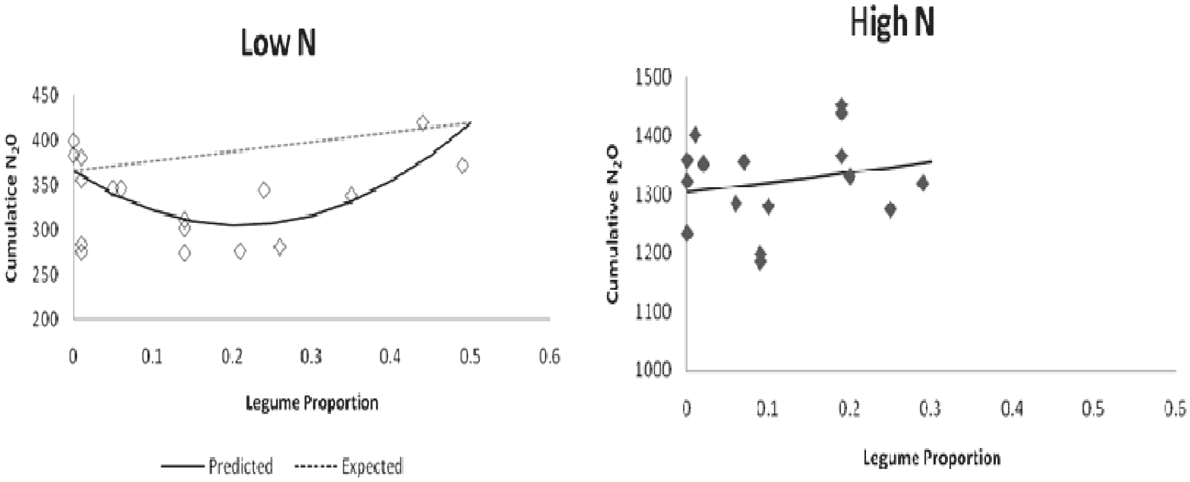
[2]*Teagasc Environment Research Centre, Johnstown Castle, Co Wexford, Ireland*

Abstract

The yield benefits of clover-based systems are well established. While nitrogen (N) input through N_2-fixation can improve biomass production, there may also be an increased risk of N losses from clover-based systems. We present results from a split-plot field experiment that was established at Johnstown Castle in autumn 2006. At the main plot level, plant species composition (relative proportions of *Lolium perenne, Phleum pratense, Trifolium pratense* and *Trifolium repens*) was varied. Compositions ranged from monocultures of each of the four species, to plots dominated by single and pairs of species and plots with equal representations of all four species. At sub-plot level, two nitrogen treatments were applied (low N = 45 kg/ha/yr, high N = 200 kg/ha/yr). Plots were harvested twice in 2008.

N_2O emissions were quantified using the static chamber method for 27 days after fertiliser application. Cumulative N_2O losses were modelled as a function of actual species proportions in 2008. At low N, individual species performances differed. Emissions from grass species were lower than from clover species (P = 0.0125). However, there were signficant interaction among the grass and clover species (P = 0.013). Emissions from grass-clover mixtures (Fig. 1a solid line) were up to 41% lower than would have been expected from species' individual performances (Fig. 1a dashed line). At high N, there were no significant differences among individual species performances and there were no significant species interactions (Fig. 1b). The lack of legume effects at high N may be due to shifts in species composition, with convergence towards dominance by grasses (max legume proportion 29%). At low N, in contrast, compositions contained up to 50% clover.



a) b)

Lysimeter study on the effect of ploughing techniques on N_2O and DON losses

By D KROL[1,2], K RICHARDS[1], Ó NÍ CHONCUBHAIR[1,3], C NARAYAN[1], B A OSBORNE[3], M B JONES[2], M WILLIAMS[2] and G J LANIGAN[1]

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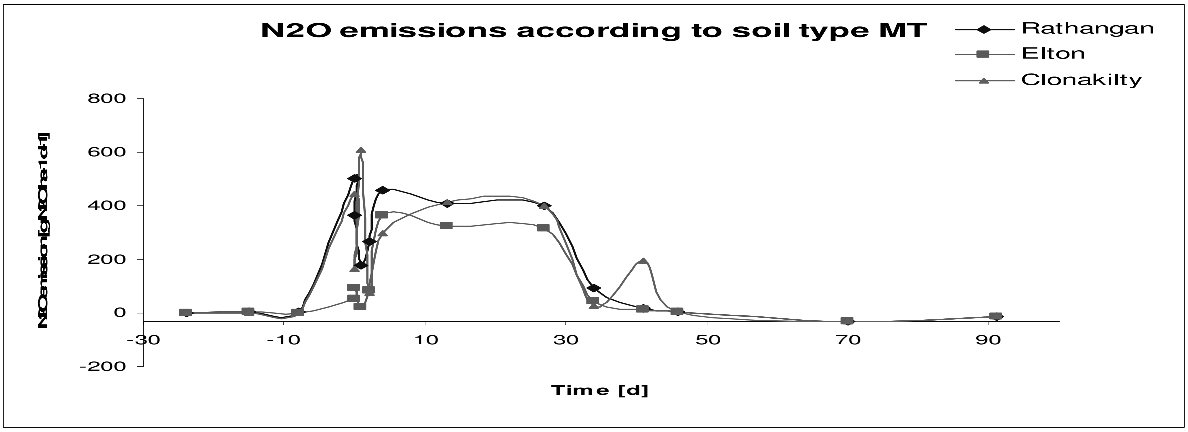
[2]*TCD Department of Botany, Trinity College Dublin, Dublin, Ireland*
[3]*UCD School of Biology and Environmental Science, University College Dublin, Ireland*

Abstract

A quarter of Irish GHG emissions are derived from agriculture therefore mitigation through alternative land use option is required to reduce them. Probable scenario for Ireland would involve grassland conversion into energy crop cultivation. Ploughing, as a first step of this land use change is associated with peak greenhouse gases emissions. Furthermore, gaseous emissions following tillage depend on the soil. Experiment was designed in Teagasc Johnstown Castle, Ireland to examine the effect of tillage on gas exchange. The experiment consisted of 18 lysimeters representing three commonly met Irish soil types characterised by different drainage properties; poorly drained Rathangan soil, moderately drained Elton soil and well drained Clonakilty soil.



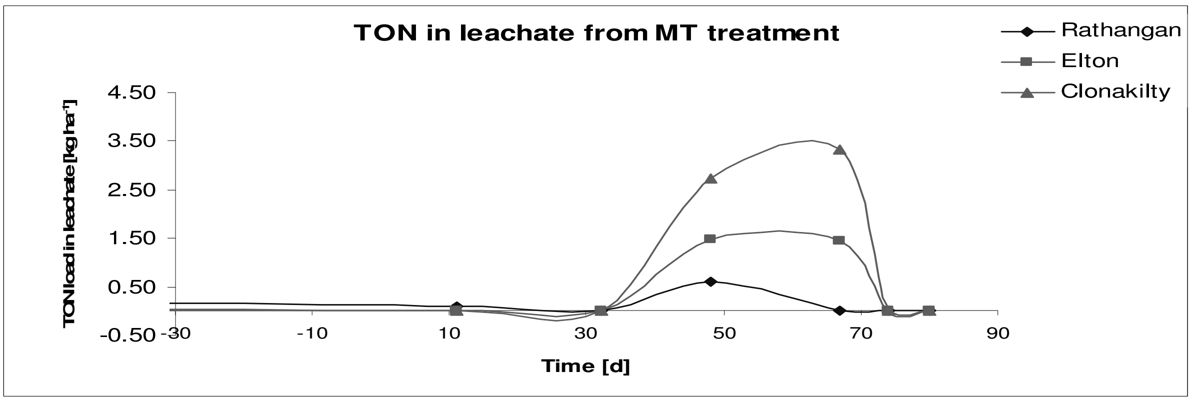


Fig.1. Temporal patterns of A) N2O fluxes and B) DON losses on lysimeters over 30 days before and 90 days after treatments application.

Two treatments were applied in mid June to examined soils: CT-conventional inversion tillage and MT-minimum tillage, both followed by fertilisation with N, P, K. and the response in terms of N_2O emissions and DON losses was studied to assess the environmental impact of this step of the land use change process. Nitrous oxide emissions were measured once a week for expected low emissions period and every day for 5 consecutive days after treatments application. Lechate was also collected and analysed to determine the load of nutrients lost through this pathway. The effects of tillage intensity on both N_2O and DON losses are shown in Fig.1. Post-ploughing, N_2O emissions remained high over a prolonged period of time for all soil types with emissions significantly higher from reduced tillage, and from poorly drained soil. Peak losses of DON were observed in leachate post-ploughing with the highest losses from well drained soil; soil effect was found significant. Combined leachate and gaseous emissions displayed effect of both soil and treatment; the highest amount of N was lost from well drained soil.

The effect of the nitrification inhibitor dicyandiamide on nitrous oxide and dinitrogen emissions from cattle slurry applied to grassland

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Abstract

The nitrification inhibitor dicyandiamide (DCD) has been shown to reduce N_2O emissions by 75–91% when applied to urea amended grazed pastures (Watson *et al*., 2009) in New Zealand. The aim of the current study was to investigate the effect of DCD on N_2O and N_2 fluxes after an application of cattle slurry (CS) to Irish grassland on three separate occasions in March, July and August 2009, using the 15 N gas flux method at Hillsborough, Co. Down.

Four treatments were applied on each occasion ± DCD at a rate of 15% NH_4-N content of CS; (i) unlabelled CS plus ^{15}N labelled KNO_3, (ii) ^{15}N labelled CS plus unlabelled KNO_3, (iii)$^{14}NH_4Cl$ plus ^{15}N labelled KNO_3 (control for (i)) and (iv) $^{15}NH_4Cl$ plus unlabelled KNO_3 (control for (ii)). CS was applied at a rate of 33 m^3 ha^{-1} and the labelled ^{15}N moieties were enriched to 50 atom %. NH_4Cl acted as a control, supplying no degradable C but the same amount of water and NH_4-N as CS. Fluxes of N_2 and N_2O were measured twice a day for approximately 5 days after the treatments were applied and thereafter one measurement was made on days 7, 9, 11 and 15. On each occasion, the static chamber technique was used and gases analysed by isotope-ratio mass spectrometry and gas chromatography.

The flux of N_2O and N_2 peaked in the first 5 days after application of treatments. CS significantly ($P < 0.001$) increased both N_2 and N_2O emissions, compared to the NH_4Cl control. Total cumulative emissions were highest in July with up to 26.5% of the available N applied being lost. DCD significantly $P < 0.05$) reduced N_2O emissions by 13% in March and 25% in July, but had no significant effect on N_2 emissions. This would suggest that DCD was inhibiting processes which produce N_2O but not N_2.

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Use of winter cover-cropping in Irish spring-barley systems as greenhouse gas mitigation action: Preliminary findings on comparative assessment of four crop types

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Abstract

The IPCC has advocated the use of cover-crops to increase soil carbon as part of its climate change mitigation strategy. Most of Ireland's 161,000 ha of spring barley only maintain a volunteer crop for the winter period, creating an opportunity to implement the IPCC's recommendation. To be effective, a cover-crop must maximise carbon assimilation over constrained winter conditions. Commonly, varieties are selected according to their winter hardiness, however, ultimately the goal of a winter cover-crop is primarily to maximise biomass accumulation rather than optimal plant condition.

A range of commonly-used cover-crops (rye, clover, mustard and wheat) were grown under greenhouse conditions to compare relative biomass accumulation rates for a defined winter period. These rates were then related to photosynthetic rates, PSII efficiency and leaf area for each crop. It was found that despite having the lowest rates of photosynthesis, lowest leaf-area to leaf mass ratio and PSII efficiency, the mustard cover-crop managed to accumulate the highest dry mass.

Given the fate of a cover-crop is incorporation into the soil, the concept of what constitutes an ecophysiologyically "successful" crop is challenged by the somewhat contradictory biomass accumulation rates in this study. The results of this trial will be used to inform a series of cover-crop field trials at Oak Park, Carlow and Lyon's Estate, Newcastle.

Methane emissions from finishing beef cattle offered ensiled feeds

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Introduction

Methane emissions from enteric fermentation comprise approximately 51% of the total greenhouse gas (GHG) emissions from agriculture in Ireland. Methane also represents a 2–15% loss of the energy ingested by a ruminant. The objective of this research was to investigate the effect of various ensiled feeds on ruminal methanogenesis in cattle and their impact on whole-farm GHG emissions.

Materials & Methods

Two *in vivo* studies determined the methane emissions of finishing beef steers offered diets based on maize and whole-crop wheat (WCW) silages, and ranked these relative to grass silage (GS) and *ad libitum* concentrates (ALC). In Study 1, maize was harvested on four dates: 13 September, 28 September, 9 October and 23 October. In Study 2, WCW was formulated at feedout to give four ratios of grain to straw plus chaff: 11:89, 21:79, 31:69 and 47:53. In both of these studies, *ad libitum* concentrates treatments were included, and a GS treatment was also included in Study 2. In Study 3, the methane output of a range of feeds including high-moisture grains, and maize and WCW silage was assessed using the *in vitro* total gas production (TGP) technique. In Study 4, a hybrid modelling approach was taken, involving a bioeconomic model and a GHG systems model, to determine both on- and off-farm emissions and also the profitability of beef production systems based on maize, WCW, GS and ALC.

Results

In Study 1, advancing maize maturity at harvest reduced methane emissions per unit intake or carcass gain. In Study 2, increasing the grain to straw plus chaff ratio of WCW silage also reduced methane emissions per unit intake or carcass gain. In both studies, cattle offered ALC exhibited lower methane emissions than those offered silage-based diets, irrespective of unit of expression. Cattle offered GS had higher methane emissions per unit intake than other treatments. In Study 3, trends in methane output identified using the TGP technique did not reliably reflect *in vivo* responses. In Study 4, finishing regimes based on maize or WCW exhibited higher on-farm and total GHG emissions than GS or ALC. Furthermore, GS exhibited the lowest GHG emissions and the highest financial performance overall.

Conclusions

Increasing the starch concentration of ruminant diets reduced methane emissions relative to DMI and carcass gain. However, whole-farm GHG emissions were lowest for GS, which also offered the greatest financial performance. Thus, it is unlikely that maize or WCW will be major mitigation strategies in the short-term.

Losses of nitrous oxide emissions following land application of high and low nitrogen pig manures to winter wheat at three growth stages

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Abstract

Pig manure can be a valuable nutrient source in cereal crop production but significant nitrogen (N) losses may occur through nitrous oxide (N_2O) emissions. In a field trial study on a winter wheat crop (cv. Alchemy) at UCD Lyons Farm, gaseous emissions of N_2O post manure application and manure N uptake (CNU) by the crop were investigated. To generate manures of high (HN) and low (LN) N content, grower-finisher pigs were assigned to one of two diets; a high crude protein (CP) diet (230 g kg^{-1}) and a low CP diet (160 g kg^{-1}). In a 2 × 3 factorial experimental design the manure products were applied to a winter wheat crop at three timings; growth stage (G.S) 25, G.S 30–31 and G.S 37–39, at a rate of 30,000 L ha^{-1} using a 6 m band spread applicator to plots 30 m × 24 m. N_2O fluxes were measured using the static chamber technique at 3 day intervals for 4 weeks post manure application. Manure application increased grain yield and CNU relative to control plots ($P < 0.001$); while similar yield and CNU levels were achieved irrespective of manure type (HN *vs* LN). Higher N_2O emissions were measured from the HN manure treatments ($P < 0.05$). A manure application timing × sampling date interaction also occurred ($P < 0.001$). This interaction was as a result of a rainfall event-nitrous oxide emission relationship evident at each spread date. It can be concluded that dietary manipulation can reduce N_2O emissions following land application of pig manure while having no adverse affect on crop performance.

Cold hardiness of the photosynthetic performance of the forage maize varieties of Ireland in early spring

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Abstract

The introduction of early maturing cultivars has enabled forage maize to be grown in climatically marginal temperate regions, but this has increased the importance of early photosynthetic vigor under cold stress. The objective of the study was to screen nine commercial maize varieties recommended for growing in Ireland without plastic mulch for early spring cold hardiness of the photosynthetic apparatus under controlled and field conditions. A combination of chlorophyll fluorescence and gas-exchange measurements were used to assess the impact of cold stress on photosynthetic performance under controlled conditions. The results show that maize seedlings under cold stress show major variety-dependent reversible reductions in photosynthetic performance, although isotope data indicate that all have a functional C4 pathway. Most of the varieties examined show no net photosynthesis at temperatures < 150°C. Maize cultivars which maintain higher Fv/Fm, ΦPSII and NPQ have a more tolerant photosynthetic apparatus during prolonged cold stress. Field trials also indicate that the cold tolerance of these varieties differs markedly and associations were found between traits evaluated under cold-controlled and field conditions. The pattern of variations among these commercial hybrids indicates that the traits associated with an enhanced performance under cold stress may need to be considered when breeding maize varieties for cool-temperate regions.

Investigating the potential to reduce in vitro rumen methane production by dietary manipulation

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Introduction

The diet fed to livestock is an important factor altering rumen microbial populations, fermentation products and, consequently, the amount of methane emitted. Therefore, modifying ruminant diets has the potential to reduce greenhouse gas (GHG) emissions in beef and dairy production systems. In this project, various feedstuffs were investigated using the in vitro rumen total gas production technique (TGP) and an artificial rumen system (Rusitec) for their potential to effect methane production, fermentation and microbial community structure. The effectiveness of two anti-methanogenic compounds to suppress methane output was also assessed.

Materials & Methods

Three experiments determined the effect of a range of grass silages (Experiment 1), legumes and grasses (Experiment 2), and grass silage, grass, red clover and hay+wheat treatments (Experiment 3) on rumen methanogenesis and other fermentation products. A further experiment (Experiment 4) examined the potential of two halogentated methane compounds, bromoethanesulphonate (BES) and pyromellitic diimide (PMDI), to suppress methane output when added to either grass or grass silage:barley (50:50 ratio). These experiments were undertaken using either the *in vitro* rumen total gas production technique (a 24 hour batch assay) or an artificial rumen system (Rusitec; continuous culture assay). Treatment effects were assessed in terms of methane production, fermentation acids and microbial community structure.

Results

In Experiment 1, silages with an extensive lactic acid dominant fermentation resulted in a lower methane output compared to silages with a reduced lactic acid content (either through extensive or restricted fermentation). In Experiment 2, autumn harvests of grasses and legumes showed a reduction in methane output compared to spring harvests. Fertilised ryegrass (150 kg nitrogen) had a lower methane output than red clover (var. Merviot). In Experiment 3, hay+wheat and red clover stimulated a higher methane output than grass or grass silage. In Experiment 4, the addition of up to 20 µM BES decreased methane output by 42 and 53% per gram dry matter digested of grass and silage+barley, respectively. The addition of up to 20 ppm of PMDI decreased methane output by 100% in both feedstuffs.

Conclusions

The potential exists to modify the diets of ruminants to reduce their methane emissions. Clearly, the findings from the above studies need to be confirmed by *in vivo* trials.

A bioenergy mapping & modelling tool as applied in Ireland

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Abstract

An information system that consists of mapping, modelling and documentation tools has been constructed to enable the Irish Bioenergy Working Group to undertake an assessment of current bioenergy resources, usage, gaps and future opportunities, and to enable modelling of future scenarios and simulations. This task is both an interesting and challenging one, and one that illustrates the potential of geographic information technologies in integration of both data and predictive models from across organisations - in this case primarily from organisations in the agriculture, forestry, waste management, and environmental management sectors.

The system is modular in structure allowing further extension of functions or complexity of calculations, including those relating to the supply chain of bioenergy sources. It also incorporates open source and selected proprietary technologies and makes extensive use of standards based web services for serving of datasets into the system and potentially into other external platforms e.g. mobile or third party systems. The system forms an information portal with the mapping system supported by a parameter editing, documentation wiki, and a metadata section. The system also spawns related corporate map viewers in other energy areas including wind and geothermal energy.

The system has been developed under contract to the Sustainable Energy Authority of Ireland (SEAI) - Ireland's national energy authority with a mission to promote and assist the development of sustainable energy. This encompasses environmentally and economically sustainable production, supply and use of energy, in support of Government policy, across all sectors of the economy. Its remit relates mainly to improving energy efficiency, advancing the development and competitive deployment of renewable sources of energy and combined heat and power, and reducing the environmental impact of energy production and use, particularly in respect of greenhouse gas emissions. SEAI, through its Low Carbon Technologies division has a significant role in the Bioenergy Working Group, which was set up by the Department of Communications, Energy and Natural Resources. This Group is charged with developing a roadmap to Ireland's 2020 bioenergy targets.

The influence of strain of Holstein-Friesian cow and feeding systems on greenhouse gas emissions from pasture-based dairy farms

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Abstract

One of Ireland's largest sources of greenhouse gas (GHG) emissions is the agricultural sector (McGettigan *et al*., 2009). Within this sector, pastoral dairy farming is estimated to be a significant source of emissions (Lovett *et al*., 2008). Therefore, to meet the targets of the Kyoto Protocol and future reduction targets, pastoral dairy farms will be required to reduce GHG emissions. The purpose of this study was to model the effect three different strains of Holstein Friesian cows in three pasture-based feed systems have on GHG emissions from dairy farms. The strains compared were high production North American (HP), high durability North American (HD), and New Zealand (NZ). The feed systems were a high grass allowance system (MP, control); high stocking rate system (HS); and high concentrate supplementation system (HC). The MP system had a stocking rate of 2.47 cows/ha and received 325 kg of DM concentrate per cow in early lactation. The HS system had a similar concentrate input to the MP system, but had a stocking rate of 2.74 cows ha^{-1}. The HC system had a similar stocking rate as the MP system, but 1,445 kg of DM concentrate was offered per cow. A newly developed integrated economic-GHG farm model was used to evaluate the milk production systems. The GHG model estimates on-farm (emissions arising within the farm physical boundaries) and total (all emissions associated with the production system up to the point milk leaves the farm gate) GHG emissions. Total GHG emissions were always greater than on-farm emissions. The ranking of on-farm and total emissions was not consistent. The exception was the NZ strain that achieved their lowest GHG emission per unit of product in the HC system when indirect emissions were excluded, but when indirect emissions were included; their lowest emission was in the HS system. Generally, the results showed that as cow strain changed from lower (HD and NZ) to higher genetic potential (HP) for milk production, the GHG emission per kg of milksolids increased. This was due to a decline in cow fertility in the HP strain that resulted in a higher number of non-productive animals leading to a lower total farm milksolids production and an increase in emissions from non-productive animals. The GHG emission per ha increased for all strains moving from MP to HS to HC feed systems and this was associated with increases in herd total feed intake. The most profitable combination was the NZ strain in the HS system and this combination also resulted in a 12% reduction in production system GHG emission per ha compared with the NZ strain in the HC system, which produced the highest emissions. This demonstrates that grass-based systems can simultaneously achieve high profitability and decreased GHG emissions.

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Reporting agricultural greenhouse gas emissions and sinks

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Abstract

A brief overview of the current methodologies and data sources used to estimate greenhouse gas emissions and sinks associated with agricultural activities in Ireland is provided. Estimated emissions of greenhouse gases are robust, in terms of acceptance of the methods used which are based on GPG and are subject to regular y international review. However, there is always room for improvement. Estimates of emissions of Nitrous Oxide (N_2O) have a high level of uncertainty and is therefore major focus of inventory development in Ireland and internationally. The key issues and challenges are outlined.

An over arching challenge to better quantification of national greenhouse gas emissions is a lack of knowledge of farming practices, and more especially changes in farming practicing which impact negatively or positively on emissions (and sinks). Robust activity data are require to verifiably incorporate mitigation options, demonstrated by research and on a farm scale, into the national inventory. This is essential for policy development and implementation including use of fiscal incentives.

There has been much attention on the potential of sequestration and storage of carbon to soils. EPA and DAFF funded research by Teagasc, UCD, UCC and elsewhere, and European research point to a potentially significant ongoing uptake of CO_2 from the atmosphere, via biomass, to the agricultural grassland soils.

These findings are promising, from an GHG emissions reporting perspective, but caution is required as carbon sinks are subject to a range of reporting and accounting rules. Not all land use activities are accountable towards meeting Ireland's emissions targets under international agreements. However, this may represent a future opportunity but information and analysis of this is required.

Effects of feeding spring calving dairy cows a perennial ryegrass pasture diet or total mixed ration diet in spring on methane emissions, dry matter intake and milk production

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Abstract

In 2007 the production of methane (CH_4) gas from enteric fermentation contributed approximately 12.8% of total GHG emissions in Ireland and there is a growing demand to reduce GHG emissions associated with dairy production. The dairy herd in Ireland is comprised of 1.1 million dairy cows that predominantly produce milk from grazed pasture, with the mean calving date coinciding with the initiation of grass growth in early spring. Very little information is available on the enteric CH_4 emissions of cows managed in this type of system.

Forty eight spring calving Holstein Friesian dairy cows were randomly assigned to one of two dietary treatments for a 10 week period in spring 2009: (1) Grass (grazing unsupplemented perennial ryegrass pasture) or (2) TMR (composed of grass silage, maize silage, concentrate, straw and molasses; offered *ad libitum* indoors). Daily CH_4 emissions were measured during weeks 4 (P1) and 10 (P2) of the trial for a 5-day period using the sulphur hexafluoride (SF_6) tracer gas technique. Milk production and dry matter intake (DMI) was also measured at this time.

TMR cows had significantly higher ($P < 0.001$) milk yield, milk solids (MS) yield and DMI. However, grass cows had significantly higher ($P < 0.01$) milk protein content. With regard to CH_4 emissions grass cows had significantly lower ($P < 0.001$) CH_4 emissions on a per cow basis (P1: grass 243 g/cow/day, TMR 384g/cow/d; P2: grass 258 g/cow/day, TMR 410 g/cow/day). Grass cows also had lower (P < 0.05) CH4 emissions per unit MS in both measurement periods (P1: grass 157g kg^{-1} MS, TMR 185 g kg^{-1} MS; P2: grass 196 g kg^{-1} MS, TMR 213 g kg^{-1} MS) and per unit DMI in the second measurement period (grass 17.1 g kg^{-1} DMI, TMR 20.1 g kg^{-1} DMI).

This study indicates that spring calving dairy cows consuming a grass diet in spring emit less CH_4 per cow, per unit DMI and per unit MS produced in comparison to cows offered TMR.

Land use regulates carbon budgets: From NEE to NBP

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Abstract

The concentration of carbon dioxide in the atmosphere is influenced by land use and management. The carbon (CO_2–C) budgets of a managed forest (spruce), a grass site and a crop site (crop rotation) have been compared to examine the effects of different management practices on net ecosystem exchange (NEE) and net biome productivity (NBP). This approach enables a more comprehensive carbon budgeting as it takes into account carbon exports (thinning, harvest) and imports (fertilization) for particular land uses.

Of the investigated sites of the Tharandt cluster in eastern Germany, the forest's annual NEE showed a variability in the net sink from −698 g cm^{-2} (1999) to −444 g cm^{-2} (2003), whereas the grassland and cropland sites exhibited small sinks between −177 g cm^{-2} (2004) and −62 g cm^{-2} (2005) and between −115 g cm^{-2} (2005) and −32 g cm^{-2} (2007 and 2008), respectively.

The forest site is a carbon source with an NBP +221 g cm^{-2} in 2002 because ~43 m^3 ha^{-1} solid wood was removed. The grassland alternated between carbon sources and sinks, with NBP ranging from +25 g cm^{-2} (2008) to −28 g cm^{-2} (2006) due to carbon export through several cuts per year. The cropland site was mainly influenced by the cultivated crop species and the application of organic fertilizer (manure), resulting in NBP values between +484 g cm^{-2} (2007) and −89 g cm^{-2} (2006).

The impacts of sub-zero temperatures on the photosynthetic performance of a Sitka Spruce forest

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Abstract

Forest ecosystems have the ability to sequester significant amounts of carbon. Sitka spruce forests in Ireland are some of the most productive in Europe assimilating between 7–10 t C ha^{-1} annually. Management activities and localised climatic conditions may, however, play an important role in inter-annual variations in the carbon sink strength of these forests. Whilst the impacts of low temperatures on the photosynthetic performance of many plant species is generally well known, the affects of prolonged periods of low temperature on the photosynthetic performance of Sitka spruce forests at the ecosystem scale is not well characterised in Ireland. Mean monthly air temperatures recorded at the Dooary forest research station between December 2009 and March 2010 were 20–65% below the 30 year mean for the same period. In addition, prolonged periods of freezing temperatures were also observed with up to 11 days of consecutive sub-zero temperatures recorded. Continuous measurements of the surface to atmosphere carbon dioxide exchange showed a significant decrease in the net stand photosynthetic performance of the forest. The net stand apparent quantum yield (AQY) and maximum rate of photosynthesis (A_{max}) were reduced from 0.041 μmol CO_2.μmol PAR and 17.09 μmol CO_2 m^{-2} s^{-1} to 0.012 μmol CO_2.μmol PAR and 6.90 μmol CO_2 m^{-2} s^{-1} after exposure to sub-zero temperatures. The time required for recovery of photosynthesis was also influenced by temperature. After a freezing event a minimum of 6 days was required before the photosynthetic performance of the forest returned to the level observed before exposure to sub-zero conditions.

Manipulating N excretion and the effect on N_2O emissions from grassland soil

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Abstract

Currently, agriculture accounts for 26% of Irish GHG emissions and of this figure 36% is due to gaseous emissions from soil. Nitrous oxide (N_2O) emissions from grassland systems have been identified as a major contributor to Irish GHG emissions. In grazed grassland, feed N utilization by the ruminant animal is low and 60–90% of ingested N is returned to the soil/pasture system as urine and dung. Nitrous oxide emissions from grazed pasture are often associated with urine deposition (Hyde *et al*., 2006). Altering animal diet constituents such as protein and energy level and amino acid supplementation have been shown to reduce the amount of N excreted (Oenema *et al*., 2005). The objective of this experiment was to investigate the effect of urinary N content on N_2O emissions from grassland resulting from dietary manipulation of cattle. Intact soil monolith lysimeters (0.5 m × 0.75 m) of one soil type were sampled using the method of Cameron *et al*. (1992). Urine was collected from dairy cows during milking and urinary N content was manipulated by dilution with water or addition of urea to give four typical urine N concentration treatments: 3, 5, 7 and 10 g total N/L (expressed as loading rates 300, 500, 700 and 1000 kg N ha^{-1} respectively). Two litres of urine were applied to lysimeters in a randomised block design with 4 replicates per treatment. N_2O emissions were sampled using stainless steel static chambers and the headspace N_2O content was quantified by gas chromatography on a Varian 3800 GC with ECD detector. Peak daily N_2O flux was 269 g N_2O–N ha^{-1} d^{-1} in the U1000 treatment 27 days after urine application. All urine treatment N_2O fluxes were higher than the control ($P < 0.0001$). N_2O emissions returned to background levels approximately 46 days after urine application. Cumulative total emissions ranged from 0.12–3.38 kg N_2O–N ha^{-1} and showed a trend to increasing N_2O loss with urine N content. Data from this experiment can be used to model N emissions from dietary manipulation trials.

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What will the climate look like for south-west England this century? UKCP09* climate change data for the North Wyke Research Institute, Devon

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Abstract

The UKCP09 state-of-the-art climate scenario data is recognized by climate modellers as a step forward, an improvement in the flexibility and delivery of such data. UKCP09 data is interactive, a user gives the interface parameters, greenhouse gas emission levels and time slices, for example, and the software calculates the data from multiple climate model combinations.

Whereas the original functionality of the climate data was for modelling use, the user group of this data has widened to include managers and policymakers who generally are not interested in the raw data but require a statistical summary in graph or visual format and reports on findings. The variety of available output formats reflect this.

Modellers need to use the climate data in applications, however extracting daily weather data can now be extremely time consuming. UKCP09 data provides a minimum of one hundred equally relevant daily weather files. Most applications using this climate data would have to be run a hundred times, and need single daily mean values. To avoid a hundred manual simulations, it is necessary to create one representative climate file for further application.

Mean values were calculated across the hundred files of each daily weather element (except precipitation) for each day of the 30 years of data. Because of its skewed distribution, precipitation means could not be taken. The monthly mean value of precipitation and the number of rain days per month were calculated, and averaged across the files; the precipitation was then distributed randomly across each month with the aid of a stochastic precipitation model and historic precipitation. Scenarios were taken, which account for rapid economic world growth using carbon intensive energy (high emissions), or decarbonization and a mix of energy sources (medium emissions).

Historic UKCP09 output compared very satisfactorily with our own observed daily weather data. Mean weekly temperatures show an overall higher increase in summer for North Wyke than in winter, and higher increases in the maxima rather than in the minima. The average weekly maximum temperature under a high GHG emissions scenario in the 2050s predicts an increase of 3.7 degrees in the summer and of 2.2 degrees in the winter, and average weekly summer precipitation to decrease by 10%, with a corresponding winter increase of 5%. We apply the climate to a soil water model and show the UKCP09 predictions of what the climate and soil moisture for North Wyke Research Institute, Devon should look like for the 2020s, 2050s and 2080s. We conclude that how long the greenhouse effect has been occurring since the baseline period has more influence on the degree of change than whether GHG emissions are medium or high.

*collaborative source of data from Met Office, Defra and many other organizations

Managing climate risk and market risk in the Irish agriculture

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Abstract

Goal of the PhD : to provide solutions to better manage market risk and production risk

The progressive *rollback* of the Common Agricultural Policy (CAP), the integration of commodities markets and the rising uncertainty created by climate change both amplify risks and let farmers more exposed. Knowing the risk preferences of farmers is crucial to address this challenge. Indeed, a more risk averse producer will tend to reduce its exposure to risk by seeking, for instance, to diversify its investments in an activity less profitable but more secure. Pillar II schemes (eg. REPS) offer such opportunities. However, as the aversion to risk decreases with the level of wealth, rising and stabilizing farm income with the Single Farm Payment (SFP) decreases the incentive to join pillar II schemes. Therefore, pillar II and the pillar I are, at least theoretically, antagonist. Furthermore, by decreasing risk aversion, the SFP tends to rise the incentive to increase production. The SFP is thus probably not as “trade neutral” as it is meant to be. In this case, the SFP doesn’t have its place in the *green box* of support policies authorised by the WTO and should therefore be abandoned at the 2013 CAP reform. To sum-up, risk preferences are a major determinant of the effect of agricultural policies. They cannot be ignored.

1st step of the PhD: risk preferences and risk exposure estimation

Most techniques of risk estimation are based on the idea that risk preferences explained most of the difference between observed input choices and profit maximizing choices. I would like to improve the method by: disentangling risk preferences from other management characteristics; better approximating producers’ behaviour (with non-expected utility theory insight); including in the production function the input risks; and by adding in the econometric specification geographical data. With respect to the analysis of risk exposure, I would like to use the tools developed in the literature on the sources of inequality (distribution of wealth) to quantify the different components of risk (a probability distribution).

Reduced tillage and cover cropping increase leaching losses of dissolved carbon

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Abstract

Cover cropping and reduced tillage are two potential methods of increasing carbon (C) sequestration. However, an increase in dissolved C losses could potentially offset any benefits associated with such management systems. We therefore assessed the effect of non-inversion tillage and cover cropping on both dissolved organic carbon (DOC) and dissolved inorganic carbon (DIC) leaching from an Irish arable soil under spring barley over a two and a half year period. Soil solution was sampled using glass suction cups and fluxes calculated by multiplying concentrations with drainage volumes, estimated using a soil water capacity model. Biogenic and lithogenic contributions to DIC were estimated by means of its $\delta^{13}C$ signature.

Leaching losses of DOC plus biogenic DIC were of the same order of magnitude as the net biome productivity estimates. Losses from the non-inversion tillage plus cover cropping treatment were almost twice those of the conventionally tilled plot (35.5. ± 2.2 versus 17.9 ± 4.0 g C m^{-2} yr^{-1}), which equates to 8–16% of C removed in harvest. Biogenic DIC was consistently the major component of the total dissolved C concentrations (77–96%) and therefore comprised 85–91% of total dissolved C losses, highlighting the need to include DIC leaching losses in field scale, flux-based C sequestration estimates. Considering the high uncertainty attached to such net biome productivity estimates and the large difference in annual dissolved C losses between management treatments (17.6 g C m^{-2} yr^{-1}), the beneficial effect of the management practices designed to increase C-storage may indeed be reduced when such losses are incorporated and therefore requires further quantification.

The effect of forage source and supplementary methionine on nitrogen balance and in-vitro ammonia emissions in dairy cows offered low crude protein diets

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Abstract

The inefficiency with which the dairy cow utilises feed nitrogen (N) is of environmental concern. Excreted N has the potential to be lost to the environment as ammonia (NH_3). Dietary manipulation is an important strategy for the reduction of N gasses. The purpose of this experiment was to investigate the effect of forage source and supplementary methionine on N balance in dairy cows. Additionally, the effect of forage source on in-vitro NH_3 emissions was investigated. Holstein Friesian cows (n=2) were offered 1 of 4 dietary treatments in a 2*2 factorial, latin square design. The diets contained either predominantly grass (GS) or maze (MS) silage with (M+) or without (M-) rumen protected methionine. Diets were iso-nitrogenous (135g kg DM^{-1}) and iso energetic (0.97UFL Kg DM^{-1}). Animals were housed and milked in metabolic stalls to facilitate collection, weighing and sampling of milk, feed and excreta. Data was analysed using PROC mixed of SAS. Feed N (0.42 and 0.46± 0.013 kg day^{-1} for GS and MS respectively) was higher for maize based diets ($P < 0.05$) however, there was no dietary effect of either forage or methionine supplementation on N output in the faeces, urine or milk ($P > 0.05$). There was no effect ($P > 0.05$) of forage source on in vitro NH_3 emissions (115 and 128±6 mg kg $slurry^{-1}$ day^{-1} for GS and MS respectively). The results of this experiment indicate that neither forage source or methionine supplementation effects N balance or in-vitro NH_3 production with low crude protein diets. However, there is a requirement for further studies to evaluate these dietary treatments in field scale experiments.

Effect of pre-grazing herbage mass on methane production, dry matter intake and milk production of grazing dairy cows during the mid-lactation period

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Abstract

Increasing milk production from pasture, while increasing grass dry matter intake (GDMI) and lowering methane (CH_4) emissions, are key objectives of low cost dairy production systems. It was hypothesized that offering swards of low herbage mass (HM) with increased digestibility would lead to increased milk output with a concurrent reduction in CH_4 emissions.

A grazing experiment was undertaken to investigate the effects of varying levels of HM on CH_4 emissions, GDMI and milk production of grazing dairy cows during the mid-season grazing period. Prior to the experiment 46 Holstein-Friesian dairy cows were randomly assigned to one of two treatments in a randomised block design. The treatments consisted of two target pre-grazing HM: 1000 kg DM ha^{-1} – Low or 2200 kg DM ha^{-1} – High. The experimental period lasted two months from 1 June until 31 July. Within the experimental period, there were two measurement periods, Measurement 1 (M1) and Measurement 2 (M2), where CH_4 emissions, GDMI and milk production were measured.

Mean HM throughout the measurement periods was 1075 kg DM ha^{-1} and 1993 kg DM ha^{-1} for the Low and High treatments respectively. Grass quality in terms of organic matter digestibility was significantly higher for the Low treatment in M2 (+12 g kg^{-1} DM, $P < 0.05$). In M1 the effect of HM on grass quality was approaching significance (+10 g kg^{-1} DM, $P < 0.1$) in favour of the Low treatment. Herbage mass did not significantly affect milk production during the measurement periods. Cows grazing the Low swards had increased GDMI in M1 (+1.5 kg DM, $P < 0.05$) compared to cows grazing the High swards. No difference in GDMI was observed in M2. Grazing High HM swards increased CH_4 production per cow per day (+42 g, $P < 0.01$), per kg milk yield (+3.5 g kg^{-1} milk, $P < 0.01$), per kg milk solids (+47 g/kg milk solids, $P < 0.01$) and per kg GDMI (+3.1 g kg^{-1} GDMI, $P < 0.05$) in M2. Cows grazing the High HM swards lost a greater proportion ($P < 0.05$) of their gross energy intake as CH_4 during both measurement periods (+0.9% and +1% for M1 and M2 respectively).

It was concluded that grazing Low HM swards will reduce CH_4 emissions from grazing dairy cows due to increased grass quality in terms of organic matter digestibility.

NOTES

NDP
National Development Plan 2007 - 2013

Teagasc
Agriculture and Food Development Authority

Dublin
Convention Bureau