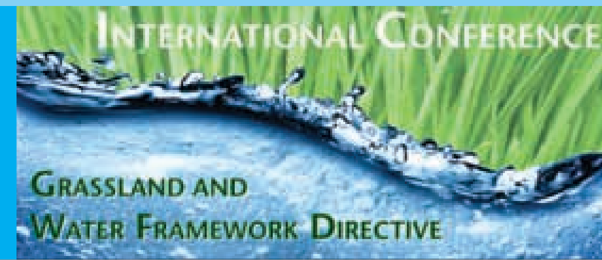
TEAGASC GRASSLAND & EU WATER FRAMEWORK CONFERENCE 2008

ABSTRACTS



Sustainable grassland systems in Europe and the EU Water Framework Directive

Teagasc, Johnstown Castle Research Centre, Wexford, Ireland

12th – 14th November 2008

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NDP
National Development Plan 2007 - 2013
Transforming Ireland

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Edited by H Tunney and O Fenton

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Conference programme

Day 0: 12/11/08	
Meeting of members of COST 869 (Mitigation options for nutrient reduction in surface water and groundwaters, 9:30-17:00 Teagasc, Johnstown Castle)	
Conference Opening	
19:00-20:00	Welcome reception (with finger food) in Wexford (Whites Hotel, Wexford) and Registration
20:00-20:10	Welcome by Dr Seamus Crosse, Director, Agricultural Research, Teagasc
20:10-20:30	**Opening address by Minister of State for Agriculture, Trevor Sargent**
20:30-21:00	Opening presentation: The Emerging EU Agri-environmental Issues Michael Hamell, EU DG Environment

Day 1: 13/11/08	
8:30 – 9:00	Registration at Johnstown Castle
09:00-11:00	**Session 1: Economic and environmental drivers for intensive grassland in the EU and beyond.**
	Chair: Hubert Tunney, Teagasc, Johnstown Castle
09:00	Opening address: Hubert Tunney
09:10	The link between agriculture and nutrient water quality across Europe – an EEA perspective Robert Collins
09:40	The impact of the Water Framework Directive on the economics of Irish farming: A strategy for future research Cathal O'Donoghue
10:10	Challenges from EU and international environmental policy and legislation to animal production from temperate grassland Pat Dillon
10:40	Discussion
11:00	Tea/Coffee
	Chair: Catherine Watson, AFBINI, Belfast

Conference programme – contd.

11:20	Grassland farming and water quality in New Zealand J.M. Quinn
11:45	Capacities and limits of two French grassland systems (intensive and extensive) to comply with the WFD - developing tools between science and policy to improve grassland management F Vertes
12:10	Characterisation of water bodies in Ireland in relation to agricultural pressures Martin McGarrigle
12:35	General Discussion
13:00	Lunch
14:00	POSTER SESSION and Field visit
15:00-17:15	**Session 2: Water quality standards and risks under WFD**
	Chair: Brian Kronvang, NERI Denmark
15:00	The development of nutrient criteria for U.S. Estuaries: State of the science P.M. Gillbert
15:30	Environmental objectives and water quality standards for the classification and management of surface waters in Ireland Colin Byrne
16:00	Sailing uncharted waters: Science and the integration of grassland and water management in England and Wales N. Watson
16:30	Overview of potential European measures for agriculture under WFD, collected within COST Action 869: Mitigation options for nutrient reduction in surface water and groundwaters W. J. Chardon
16:50	Discussion
17:15	End of Day
19:30	Conference Dinner: Whites Hotel, Wexford

Conference programme – contd.

Day 2: 14/11/08	
09:00-13:15	**Session 3: Implementation of measures and associated water quality responses**
	Chair: Frank O'Mara, Assist Director Agric Research, Teagasc
09:00	Implementation and monitoring measures to reduce agricultural impacts on water quality: US experience C. J. Dell
09:30	Water quality requirements limit the use of manure in Dutch dairy farming systems J. J. Schroder
09:50	Lough Melvin – a participatory approach to protecting a unique habitat:a case study for agri-environmental partnership Rogier Schulte
10:10	Grasslands and the Water Framework Directive – the view from the River BasinDistricts to measures Paddy Kavanagh
10:30	Economic aspects of preparing river basin management plans under the Water Framework Directive J Finnegan
10:50	Tea/Coffee
	Chair: Prof. Gerry Boyle, Director Teagasc
11:10	Water quality response to changes in agricultural measures and practices B Kronvang
11:30	Measures and responses in Swiss and Austrian (alpine) grassland - comparison of two contrasting case studies (Mondesee (A) and Sempachersee (CH)) C Stamm
11:50	Influence of catchment hydrology on water quality response O Fenton
12:10	Sustainable options for grassland agriculture in the northwest of Europe J Humphreys

Conference programme – contd.

12:30	Good water status: the integration of sustainable grassland production and water quality in Ireland Karl Richards
12:50	Discussion
13:00	Conference summary and close "Sustainable grassland production in the context of the Water Framework Directive" Hubert Tunney
13:15	Lunch and Depart If required a visit to the laboratories at Teagasc Johnstown Castle can be arranged for Friday afternoon.

Table of Contents

Page

POSTER ABSTRACTS

SECTION 1 NITROGEN

Page

SECTION 2 PHOSPHORUS

Page

Page

SECTION 3 OTHER TOPICS

Foreword

Sustainable grassland systems in Europe and the EU Water Framework Directive

Agricultural production is facing many challenges including the need to comply with new national, EU and international policies and legislation. For example, the EU Nitrates Directive was transposed into Irish law in 2006 (Statutory Instrument 378 of 2006). For the first time this now sets legal limits on the amounts of nitrogen and phosphorus in fertilisers and manures that can be spread on farms and prescribes times when they can not be spread. There are also international commitments to gaseous emissions that can affect agricultural production.

The EU Water Framework Directive is now in place and limits are being set for good water quality and all sectors (including agriculture) may have to take measures to achieve standards.

Most grassland in the EU is devoted to meat (cattle and sheep) production where profitability is low and farmers often rely on EU single farm payments to survive. Thus, grassland farming can face considerable challenges in implementing new environmental measures without financial supports.

In organising this International Conference on "Sustainable grassland systems in Europe and the EU Water Framework Directive", Teagasc wishes to ensure that the impact on agricultural production is minimised and that any extra compliance measures that may be required do not impose additional and unjustifiable burdens on farmers, not only in Ireland but in other EU member states.

Farmers are still striving to come to terms with the considerable restrictions in the Nitrates Directive. By learning from that experience we can help minimise difficulties for the future.

I extend a very warm welcome to all the participants in this Conference and particularly to people who have travelled from other countries. It is evident from the programme that there is a good team of international scientist presenting papers and posters and we are pleased to be able to avail of their expertise and insights during the Conference.

I wish you well in your presentations and discussions and we all look forward to the outcome of this timely Conference.

Professor Gerry Boyle, Director of Teagasc; November 2008

PAPER 1

Emerging EU Agri-environmental issues

Michael Hamell
EU, DG ENV, Brussels, Belgium.

The major influences on the ongoing reform of the CAP over the past 25 years have been budgetary and opportunity cost and the EU's relationship with the rest of the world through GATT, WTO and regional trade considerations. These, together with a strong desire for simplification, remain extremely important and the debate on the post 2013 budgetary shape of the EU will again spotlight the CAP. The environment's relationship with the CAP has been one of catch up over the past decade or so following a difficult earlier period. Environmental legislation, notably with respect to water and biodiversity protection was put in place (and subsequently implemented) really only long after problems had clearly emerged with the result that their resolution was and is a great deal more burdensome both politically and financially than had they been addressed earlier.

Today, following years of painstaking work on integration, agricultural policy contains very strong environmental elements as befits the relationship between two major policy areas of EU competence. Cross-compliance, optional to but largely unused by Member States since 1992, has been obligatory since 2005 and now defines the relationship between farm and the environment, public and animal health and welfare. Agri-environment and related measures for NATURA 2000 areas and eventually aspects of the implementation of the Water Framework directive, as well as several similar forest related measures all within the rural development context, provide the incentives for improved environmental performance beyond the baseline established through cross-compliance. So the frame of the policy relationship between agriculture and environmental is firmly in place, even if there remain issues regarding the extent of cross-compliance and the real funding commitments to rural development and, within it, to the environment.

Climate change will dominate the environmental debate for coming decades but there are many other issues, part related, which also need to be addressed. Clearly, the post Kyoto agreement together with reduction in GHG emissions to be achieved will require that each MS takes the most appropriate measures and these will have repercussions for agriculture. But adaptation now needs to loom larger. Several MS are working on adaptation strategies with land, water and biodiversity crucial to this work. The Commission intends to publish a white paper in the near future and possibly, subsequently, more focused sectoral communications, including on agriculture. There is a need, based on best information available, to ensure that farming on the ground can reduce its GHG emissions, increase sequestration and adapt to inevitable change, not the least an increasingly unpredictable and volatile hydrological regime. That task will need strong scientific underpinning. New approaches to water management and flood control increasingly call for the retention of high waters on floodplains and in the soil, rather than quickly channelling them away. Among agricultural ecosystems, grasslands are the most compatible with such systems.

There is now a wider dimension to the environment's relationship with agriculture than ever before. Issues of natural resource depletion are on the horizon with phosphorous being a striking example but the same applies to several other farm inputs. On the other side of the coin, inefficient resource use leads to significant outputs with increasingly obvious detrimental effects on water bodies and related ecosystems downstream. Approaches to better resource use and recycling will inevitably move up the political agenda. Likewise there is debate on energy supply including on the role of agriculture in its provision. The debate on the Commission renewable target proposals is not yet complete but there is very strong emphasis placed by Member States and European Parliament alike regarding the inclusion of very strong sustainability criteria. Much is expected from 2nd generation bio-fuels and the role of grassland will certainly be debated.

The Commission brought forward proposals for soil protection in 2006 on the basis of very strong support by Council and EP. These proposals have been broadly supported by the EP but at present there is limited progress at Council. Soil degradation will not stop simply because of the reluctance of a few Member Sates to act and the importance of this topic will certainly grow in Europe and worldwide in coming years.

All these topics relate directly or indirectly to the subject of this conference. The benefits of grassland in terms of soil and water protection including carbon sequestration are known but often understated. Pressure to convert permanent pasture to arable will increase to respond to growing world demand and may be hard to resist if these benefits are not more widely known. The importance of grassland in the context of climate change adaptation and particularly for contributing to green infrastructure may well be crucial to supporting terrestrial and sub-terrestrial biodiversity. This is particularly true for extensive grassland now in danger of abandonment and serves to underline the need in Europe to use the land management incentives provided by rural development. The management of manure associated with livestock has been the subject of intense debate and the implementation of the action programmes under the nitrates directives as well as rising inorganic fertiliser prices has led to a huge increase in interest in manure processing not just to ensure better nutrient use but also for energy purposes- a remarkable change in attitude!..

Finally with respect to the water framework directive, those Member states which have vigorously pursued the implementation of the nitrates and urban waste water directives will find their tasks greatly eased as the deadline for the preparation of river basin management plans and for their implementation from 2010 fast approaches.

PAPER 2

The link between agriculture and nutrient water quality across Europe – an EEA perspective

Robert Collins
Water and Agriculture Group, EEA, Copenhagen, Denmark

The European Environment Agency (EEA) undertakes 'state of the environment' assessment of waterbodies across Europe, underpinned by an annual reporting of data by member countries. This information is held on WISE (Water Information System for Europe) and currently includes water quality data, including nutrients (N and P) from more than 6000 river stations, 2200 lake stations and 1100 groundwater bodies. This data is summarised in policy relevant indicator fact-sheets that provide an analysis of the spatial and temporal trends in water quality across Europe. The lowest river nitrate concentrations are currently found in the Nordic countries, the Baltic States, the Alps and western Balkans, whilst the greatest proportion of rivers with high nitrate levels is found in western and central Europe, corresponding with the most intensive areas of agriculture. Nitrate concentrations in rivers across Europe have generally decreased by about 10% since the late 1990's, with a 15% decrease observed for lakes. Some countries show a more substantial decline in river nitrate levels, for example, Germany. These overall decreases are attributed to the implementation of agri-environmental measures whether through national initiatives or the implementation of European water-agriculture related policy and legislation. Groundwater nitrate has remained broadly constant over recent years, whilst there has been no overall reduction in nitrate and chlorophyll-a in coastal and marine waters. A clear reduction in phosphorus levels is apparent in rivers, attributed to the implementation of the Urban Wastewater Treatment Directive.

Quantifying and apportioning the sources of nutrients in Europe's waterbodies remains challenging, although a recent EEA study has shown that agriculture typically contributes 50-80% of the nitrate load across Europe. For phosphorus the contribution is lower, around 50%, reflecting the greater importance of point sources for P compared to N. Nitrogen balances show a general decrease in the level of surplus on agricultural land over recent years. In particular, substantial decreases are observed for the Netherlands, Denmark, Belgium and Germany, although understanding of when and to what degree these declines will impact upon nutrient water quality remains incomplete.

A number of factors are likely to influence the impact of agriculture upon water quality over the coming decades including the growing demand for food and biofuels, and climate change. In addition, the implementation of policy and legislation will play a major role, including not only the WFD, but the Nitrates and Habitats Directives and the degree of uptake of agri-environmental schemes under the Common Agricultural Policy. A major challenge exists, therefore, to be able to monitor and quantify the impacts of these various drivers upon water quality across Europe.

PAPER 3

The impact of the Water Framework Directive on the economics of Irish farming:A strategy for future research

Cathal O'Donoghue
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The Water Framework Directive is a major regulatory reform of water resources management within the European Union. Integrated catchment management plans must be prepared for all river basins, in order to achieve "good ecological status" in all EU waters. However, the benefits of reduced nitrate concentrations in rivers and lakes will come at some cost to farms. In this paper we examine a number of methods of assessing the impact of the WFD on Irish farming. Firstly, we review the literature in relation to existing research on the interaction of water quality and agricultural activity and examine the relevance of previous methodologies used to model the associations between water quality values, agricultural activity and catchment attributes. Secondly, we assess a number of measures proposed to reduce nitrate concentrations in rivers. These include reduced inorganic fertiliser application and reduced livestock stocking rates. For each measure, changes in farm gross margins are estimated using a panel dataset of farms from the National Farm Survey. Thirdly, by combining simulated farm population microdata with spatially referenced ecological status information and urban settlement information within a GIS framework we review catchment urbanisation and agricultural intensity across space. Finally we outline future plans to link the RERC Spatial Microsimulation Model of the Irish Local Economy (SMILE model) and the NCYCLE environmental model (calculates the annual nitrogen transformations, fluxes and losses for cut and grazed grassland at the field scale) developed for Irish conditions in Teagasc, Johnstown Castle. This linkage will facilitate the study of the potential impact of the Water Framework Directive on the the characteristics of the natural resource base, the impact on the environment and the impacts on the economic return of the farm operator.

PAPER 4

Challenges from EU and international environmental policy and legislation to animal production from temperate grassland

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At present the EU faces two fundamental challenges- to produce enough food for the growing number of, on average, better-off and longer living people, and the same time to preserve natural resources and the environment. The two challenges are closely interrelated, and each is heightened by climate change. The objective of Government Policy arising from the Water Framework Directive is to have all waters in the State in a 'good condition' by 2015. It is acknowledged that this target may not be met, but if a reduction in eutrophication levels is not evident by then, more drastic legislative steps may be taken to reduce the risk of losses of nutrients to water bodies. These could reduce farm productivity or at least add to production costs in some circumstances. With the gradual removal of milk quotas there is a unique opportunity in Ireland to significantly increase milk production. The challenge for Teagasc, INRA and European Agriculture Research is to develop systems through science, innovation and development methodologies that allow farmers dairy farmers to expand milk production without compromising water quality. Until recently, many farmers have been unaware of the environmental and financial costs associated with water pollution and have often not recognised the environmental and socio-economic benefits they could provide to the wider society by implementing best management practices. Implementation and adoption of these measures and practices have mostly been hampered by the relativity low price of easily available N and P fertilisers, which often made it more cost effective to apply fertilisers in excess than implement best management practices. This situation has changed dramatically in recent times with large increase in fossil fuel prices which has contributed to corresponding large increase in the cost of fertiliser. The Water Framework Directive is concerned with different aspects of water quality including nutrient enrichment of water bodies, in particular from P and N, the causes of eutrophication. The sustainability of grass-based systems can be improved through increasing the efficiency of conversion of inputs to products, increasing the use efficiency of organic manures and the selection of the optimal cow for the specific system. The presence of grassland will be more favourable to biodiversity and the conservation of soils and carbon storage than cropping systems. Climate change may further enhance grass-based systems in areas with oceanic climate and increase the use of legumes in roughage production. If we are going to be successful in meeting the objectives of the Water Framework Directive it is imperative that there is continual and open dialogue between the science community and those that work in policy and manage land. Farmers are unlikely to be able to implement changes on their own: There is little point identifying environmentally damaging agricultural practices unless related agricultural research provides feasible and economic viable alternatives that farmers can implement. Without the active involvement of all participants in the entire process, from problem identification through to solution, there will not be any long term resolution.

PAPER 5

Grassland farming and water quality in New Zealand

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Pastoral agriculture is the dominant land use in New Zealand, covering 38% of the country, and plays a key role in the economy, with dairy and meat products accounting for 34% of export earnings in 2007. Dairying has intensified and expanded in the last 20 years, at the expense of sheep and beef farming. Dairying now covers c. 23% of the grassland area, but accounted for 21% of the country's merchantable exports in 2007. Deer farming has increased four-fold since 1994, but only comprises 2% of grassland area.

Water quality is relatively good in New Zealand but many lowland agricultural streams and rivers do not meet guideline values for contact recreation. Pastoral land cover has also been associated with river and lake degradation.

The main pressures on water quality from grassland agricultural impacts are exerted through riparian vegetation change, increased input of microbial pathogens, sediment and nutrients, and altered flow regimes associated with land use change, pasture drainage and irrigation. These pressures and their impacts vary widely across New Zealand with farm systems and practices, natural factors that control contaminant delivery pathways (climate, landform, soils and geology), and receiving water characteristics/sensitivities. Conflicts over agricultural effects on water quality have been greatest where dairying occurs or was expanding in catchments with nutrient sensitive lakes or spring-fed streams. In the case of the iconic Lake Taupo catchment, this has recently resulted in a cap on nitrogen load from pastoral farming.

Legislative management of the environmental impacts of agriculture on water quality has been largely devolved to Unitary Authorities who can develop rules in Regional Plans and issue consents for certain activities through the Resource Management Act 1991. The dairy industry has been proactive in promoting improved environmental practice on farms. For example, the main dairy company, Fonterra, has committed its farmers to the Dairying and Clean Streams Accord, which requires several core practice improvements (involving nutrient management, effluent management, exclusion of cows from streams, provision of bridges/culverts at regularly used stream crossings) by 2012.

Agricultural and water researchers are working with industry to develop a toolbox of mitigation measures to control agricultural impacts on water values. This includes riparian management; matching land use to land capability; dairy shed effluent treatment; effluent storage and improved land application methods; artificial wallows for deer, nutrient budgeting; use of nitrification inhibitors; livestock winter grazing strategies; and use of drainage treatment wetlands. The application of these tools to catchments with sheep and beef, deer or dairy farms has shown water quality benefits.

PAPER 6

Capacities and limits of two French grassland systems (intensive and extensive) to comply with the WFD - developing tools between science and policy to improve grassland management

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In France about 45% of the agricultural area is devoted to forage production for herbivores, of which about 70% are permanent grasslands (mountains and lowlands) and 12% are temporary grasslands, generally associated with maize silage in dairy farms. Large changes in land use and grassland management have occurred due to intensification of dairy farming in recent decades, in portions of the western lowlands (e.g., Brittany), where maize area has increased fourfold in 30 years and grassland has decreased by 27%. In such regions, characterized by high stocking rates and small or diminishing grassland areas, water quality and water ecosystems are strongly affected by eutrophication problems (nitrate and/or phosphorus fluxes) or contamination (e.g., with pesticides, ammonia, bacteria, veterinary products), driven by infiltration and/or run-off and functioning of the rhizosphere.

Environmentalists often consider grasslands as beneficial for water quality. This perceived characteristic is linked to their i) permanent soil cover and well-developed rhizosphere that provide a buffer for water quality; ii) frequently riparian location within a catchment and their border vegetation (e.g., hedgerows); and iii) usual management with moderate levels of nutrient input and no pesticides, enabling them to dilute and regulate diffuse pollution. The real situation, however, is more diverse and complex: intensively grazed grasslands can generate diffuse pollution, and poor management of wetlands, riparian zones and watercourses can occur in all types of cattle farms and affect ecosystem health and biodiversity.

Our analysis of the relationships between aquatic-ecosystem quality and grassland management will be based on two contrasting French grassland systems (intensive in Brittany and extensive in an alpine region) 1) to evaluate the need for a specific set of best management practices and 2) to discuss the placement and management of grasslands for more sustainable dairy production. The low effectiveness and acceptability of some scientific and policy tools that aim to maintain grassland areas and protect water resources (e.g., by applying the same standards to all cases) will be discussed to determine how to increase the ability of livestock systems to comply with the WFD.

Some tools already are available to aid decision-makers:

1. Models, such as those predicting N-fate at field (STICS), farm (Mélodie) and watershed (TNT2) scales as a function of agricultural practices and watershed structure; these models can improve quantitative assessment and evaluate the effects of decisions by regional and national authorities who follow outcome-based policies (e.g., the WFD).
2. Decision-support tools, based on diagnostics of landscape and agricultural practices, to improve understanding of local systems and to identify potential solutions for land and watershed managers, farmers, and technical organizations.

PAPER 7

Characterisation of water bodies in Ireland in relation to agricultural pressures

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This paper outlines the approach taken to relating agricultural pressures to water quality in Irish rivers on a national scale for the purposes of the Water Framework Directive (WFD). The Article 5 Report required under the directive required inter alia "a review of the impact of human activity on the status of surface waters and on groundwater". This entailed the identification of pressures and the assessment of impacts on surface waters arising from these pressures. A wide range of pressures was assessed: urban wastewater treatment plants, storm overflows, major industrial point sources and diffuse pressures such as road and rail networks, hydromorphological pressures as well as diffuse agricultural pressures, which are obviously important in an Irish context where most large cities are coastal and inland land use is predominantly agricultural. Ireland has over 4000 river water bodies defined for the purposes of the WFD Article 5 report. Less than half of these have monitoring data (albeit with the monitored water bodies tending in general to be the larger and more important water bodies). The river water bodies for which water quality data were available were used to develop a model that could provide a risk assessment for the unmonitored water bodies. Over 3000 river monitoring points were analysed in relation to their upstream land use patterns. Land cover was based on CORINE 2000 land cover maps and biological quality elements and their supporting physico-chemical elements were used to represent the ecological status of the water bodies. Subsets of almost 800 individual catchments were chosen to be hydrologically independent (i.e. not nested physically) in a semi-random manner and their water quality compared with the catchment land use. A stepwise logistic regression analysis was used to derive 'thresholds' for land use intensity that gave a 75% high probability of having Good ecological status in a river as it flows out of a catchment. This analysis suggested that for rivers in catchments with less than 38% of their area under pasture had a 75% or greater probability of being of Good ecological status sensu WFD. Similar thresholds were 1.3% for tillage or ploughed land and a much smaller 0.03% for urban area. In all cases quite wide confidence limits applied to the estimates. The empirically observed relationships were used to predict the pressures and risk of failing to meet the objectives of Good status required by the WFD. The results informed the design of the monitoring programme for the WFD. Some further characterisation was undertaken to help confirm some of the more uncertain risk assessments with local authority staff and River Basin Districts undertaking some 2000 risk assessments on small streams.

PAPER 8

The development of nutrient criteria for U.S. Estuaries: State of the science

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The U.S. is in the process of developing nutrient criteria for lakes, wetlands and estuaries under the authority of the U.S. Clean Water Act. These criteria provide scientifically defensible limits for States and authorized Tribes to reduce anthropogenic nutrient enrichment of the waterbodies under their jurisdiction. The natural ambient background, or reference condition, is an important element in setting nutrient criteria. It is the historical status against which current conditions can be compared. The challenge in developing nutrient criteria is to describe, and ultimately set quantitative values for water quality parameters below which attainable conditions of biotic integrity or a suite of designated uses for that waterbody can be maintained.

Estuaries are complicated bodies of water, and the task of setting nutrient criteria for them is complex; in fact, far more complex than for lakes or wetlands. Estuarine nutrient complexity arises from the influence of multiple chemical, physical, and biological factors interacting in the delivery of nutrients and their transformations. There are multiple sources of nutrients to estuaries, from land-based point and non-point sources, to atmospheric and groundwater inputs. Each source may vary in the amount of specific nutrients (nitrogen or phosphorus) as well as their proportional ratio to other nutrients in that source. Different sources may also vary in the chemical form of these nutrients. Each of these different forms can affect the biology of the system differently. Systems also vary in their uses, which can alter nutrient processes, for example, the amount of shellfish aquaculture. Estuarine nutrients are also dependent on the physics of the estuary, as residence time determines the amount of time nutrients stay in the system and are available for biological processes. Moreover, ecosystem response to eutrophication is a continual process rather than a static one, and different systems fall on different points along the estuarine continuum making their response to nutrients variable.

One way to establish relationships is to examine variables that are representative of nutrient loading (causal variables) and those that are representative of a biological response (response variables). Causal variables may include nutrient concentrations, nutrient loads, or a proxy for nutrient loads, such as land use. Relationships between causal and response variables will vary depending on the time and space scale under consideration. Another useful approach is to characterize relationships based on estuarine typology, a framework that groups estuaries based on physical characterizations.

Response variables may consider a single measure, such as the amount of chlorophyll a, but more integrated assessments of the biological community may provide an improved understanding of the responses to nutrients. Such integrated assessment, or biocriteria, may include species, populations, or communities of organisms that integrate the aquatic condition and provide information on ecosystem condition, such as algal species composition, or submerged aquatic vegetation. In practice, the establishment of estuarine criteria for each estuary will depend on the availability of current and historical data, the capability for monitoring and the types of parameters that can be assessed, and no single approach can be applied uniformly to all estuaries.

PAPER 9

Environmental objectives and water quality standards for the classification and management of surface waters in Ireland

Colin Byrne
Department of Environment, Heritage and Local Government

In 2000 the European Parliament and Council adopted Directive 2000/60/EC (the Water Framework Directive). The Directive establishes the legal framework for the protection, improvement and sustainable management of inland surface waters, transitional waters, coastal waters and groundwater.

The Water Framework Directive has introduced some major changes to water management across the European Union. An ecological objectives approach, designed to protect and where necessary restore the structure and functioning of aquatic ecosystems, is to be adopted. The Water Framework Directive also introduces a river basin management planning approach, which will be the key mechanism for ensuring the integrated management of the water resource.

Ireland along with other Member States of the European Union is moving towards River Basin Management Planning in accordance with the requirements of the Water Framework Directive. The Directive aims to provide a new, strengthened system for the protection and improvement of water resources and water-dependent ecosystems. It aims at preventing the deterioration in the existing status of waters, including the maintenance of "high status" where it exists, and at ensuring that all waters, with some limited exceptions, achieve at least "good status" by 2015.

Regulations are about to be made which will give legal status to the criteria and standards to be used for classifying surface waters in accordance with the ecological objectives approach of the Water Framework Directive. The classification of waters is a key step in the river basin management planning process and is central to the setting of objectives and the development of programmes of measures. Waters classified as 'high' or 'good' must not be allowed deteriorate. Waters classified as less than good must be restored to at least good status within a prescribed timeframe. The environmental targets or goals and the programmes of measures to be included in river basin management plans must therefore reflect these requirements.

The EPA will be responsible for classifying the status of surface water bodies using new classification tools developed for this purpose.

The environmental quality standards proposed will in addition provide a more coherent and comprehensive system of quality objectives for Irish surface waters than has existed to-date. The standards will apply to all surface waters i.e. to rivers, lakes, transitional, coastal and artificial water bodies. The EPA, local authorities and other agencies involved in authorising discharges to water need environmental quality standards to determine the amount and concentration of a substance that may be allowed in the discharge without causing damage to aquatic biological communities or failure of the environmental objectives of the Directive.

PAPER 10

Sailing uncharted waters: Science and the integration of grassland and water management in England and Wales

Watson, N, Haygarth, P and Heathwaite, L
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Integrated management of grassland and water is a major challenge for both science and policy. To use an analogy, it is not unlike attempting to sail across an unfamiliar sea without the benefit of accurate charts and other navigation devices. Science has made significant advances in our understanding of land-water interactions in the last few years, but the Water Framework Directive (WFD) has raised the bar both in terms of water quality objectives and the sophistication of management required to achieve them. Fulfilling the needs of the WFD entails a great deal of complexity and uncertainty, which presents a major dilemma. On the one hand, action is overdue and policy interventions must be made quickly if the timetable and objectives of the WFD are to be achieved. On the other hand, it will take more time than is available to produce the evidence that we would ideally like in order to develop effective approaches to integrated land and water management.

This paper is therefore concerned with the relationship between science and policy and how they should be conducted in order to deal with uncertainty and achieve the objectives of the WFD. Drawing on experience in England and Wales, the paper examines what we already know about the integration of grassland and water management after more than twenty years of applied research. In the natural sciences, work has concentrated on understanding the key biological, physical and chemical interactions that determine nutrient release from agricultural land. Research on nitrate, phosphorous, pathogens and sediment led to the generation of cost curves for the application of different mitigation measures. In addition, a diffuse pollution inventory and user manual has been created that enables different mitigation packages to be established for model farm systems. In the social sciences, work has focussed on institutional arrangements, policy making and governance regimes for integrated land and water management. This has included evaluations of catchment management initiatives and the design of collaborative governance systems for land and water.

While we know how different mitigation measures and management approaches may perform under controlled conditions and in specific circumstances, we cannot confidently say how they will work in real world situations because of the complexity of soil-water interactions and diversity of catchment systems. In other words, it is simply not possible for science to provide all of the information and answers that policy makers would like at the time when they need it. Consequently, the integration of land and water management is essentially about 'learning to live with uncertainty and complexity'. The paper concludes by outlining a proposal for an adaptive and iterative form of integrated management, whereby science informs the development of policy interventions even in the absence of complete evidence. In this alternative model, policy interventions are treated as 'live' experiments. Although the outcomes of each experiment cannot be guaranteed, the successes and failures provide opportunities for learning and policy adaptation.

PAPER 11

Overview of potential European measures for agriculture under WFD, collected within COST Action 869: Mitigation options for nutrient reduction in surface water and groundwaters

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COST 869 (European COoperation in the field of Scientific and Technical Research) focuses on the steps that need to be taken within the EU Water Framework Directive in order to effectively reduce the nutrient losses from point and diffuse sources to surface waters and groundwater. The Action is undertaken in the context of balancing measures to reduce phosphorus (P) losses with those neces¬sary to reduce other nutrient losses such as nitrogen (N). Such measures are often conflicting and need to be considered as part of an integrated program of measures.

The outcomes of the discussions within the COST Action will be reported to the new board of the WFD dealing with the interaction between agriculture and water quality.

In August 2008 the following 28 countries participated in the Action: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzer¬land, and United Kingdom.Within COST 869, four working groups (WG) are active. Their goals are, respect¬ively, to:

WG1: develop methodologies to localize critical source areas and transport routes in catchments,

WG2: study the influence of nutrients on ecological processes in surface waters,

WG3: evaluate different types of mitigation options,

WG4: evaluate projects in example areas.

A main activity of WG3 is to develop a database with fact sheets about mitigation options. This will be an important tool to share knowledge among participants in the Action. Each fact sheet will contain the following information about the option:

- Description, incl. if effect is aimed at nitrogen (N) or phosphorus (P)
- Rationale, mechanism of action
- Relevance, applicability & potential for targeting
- Effectiveness, including uncertainty
- Time frame
- Environmental side-effects / pollution swapping, e.g.
- Administrative handling, control
- Costs
- References

At present (August 2008) a total of 70+ fact sheets have been written in draft and are in the process of reviewing. They are available via the website of the Action: www.COST869.alterra.nl under “List of options and fact sheets”.

During the presentation more information will be given about COST Action 869 and about the fact sheets of mitigation options themselves, e.g. how they are categorized.

PAPER 12

Implementation and monitoring measures to reduce agricultural impacts on water quality: US experience

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As European nations move toward compliance with the EU Water Framework Directive, national efforts to manage and regulate agricultural impacts on water quality in the US can provide useful guidance. Concentration of livestock and poultry production in the US has changed the distribution of nutrients and negatively impacted water quality in many major watersheds. While nitrogen losses from agricultural lands have long been a concern, the relatively recent increases in phosphorous (P) losses have accelerated eutrophication of surface waters. The US Environmental Protection Agency (EPA) and cooperating agencies of individual state governments have responded by establishing requirements for nutrient management plans for large animal production operations (>200 animal units). Compliance by smaller farms is normally voluntary, but federal and state governments provide incentives for many best management practices (BMPs) to reduce nutrient and sediment pollution through grants and cost-share programs.

Numerous individual and cooperative research programs have provided the basis for nutrient management guidelines. One example is the National P Project, in which federal and university researchers from across the US established common protocols to monitor and assess P loss potentials under varying land management scenarios. Another cooperative research and implementation program that may be of particular interest to Europe is the Watershed Agriculture Project (WAP) in New York. This project was developed to mitigate excess nutrient and pathogen levels entering agricultural watersheds in the Catskill region that provide drinking water for New York City. As an alternative to spending billions of dollars on additional water filtration facilities, WAP has supported site-specific research and has worked with individual farmers to develop farm-by-farm management plans to control nutrient, sediment, and pathogen export to the watersheds. These comprehensive management plans maintain both environmental protection and farm production by considering factors such as animal feeding strategies, manure management, cover cropping, and stream bank fencing.

To determine if recommended conservation practices are having the intended effect, the US Department of Agriculture (USDA) initiated the Conservation Effects Assessment Project (CEAP) in 2003. The project utilizes past and ongoing monitoring and experimental data to validate prediction models that are, in turn, used to evaluate the impact of adoption of BMPs at the watershed scale. One CEAP activity was the evaluation of conservation measures adopted under WAP guidance in the Cannonsville, NY watershed. Modeling showed a 32% reduction in stream deposition of fecal P from the construction of stream back fencing. Additionally, more accurate feeding of P to dairy herds reduced P losses at the watershed outlet by 10%.

Several challenges remain as the US fully implements agricultural water quality programs including: identifying and addressing pollutant sources within multi-farm watersheds; differentiating agricultural sources from other non-point sources; identifying new technologies to reduce nutrient losses (such as manure injection); and, assessing nutrient losses from grazed lands.

PAPER 13

Water quality requirements limit the use of manure in Dutch dairy farming systems

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EU member states define permitted manure application rates in Action Programs (AP's). These AP's are scrutinized by the EU Commission and hence need an underpinning. Numerous factors among which weather, soil type, manure composition and management, crop type, harvest regime, and environmental targets, determine which combinations of manure and mineral fertilizer are justifiable. The model that we developed to handle this complexity is based on field experiments and data collected on commercial farms. It includes the relationship between N and P inputs and surpluses and between the N surplus and the N concentration in upper groundwater (sandy and loam soils) or neighboring surface water (clay and peat soils).

When targeting at a N concentration of at most 11.3 mg N per liter and a P surplus of 0 kg per ha, model runs show that permissible annual manure rates (including dung and urine excreted during grazing) range from 300 kg manure-N (48 kg P) per ha (good growing conditions, clay soil, cut grass only) to 190 kg manure-N (30 kg P) per ha (suboptimal growing conditions, dry sandy soil, 70% grassland with mixed use of cutting and grazing and 30% silage maize). Judicious supplements of either mineral fertilizer N or biologically fixed N are needed to exploit the manure P, thus avoiding P accumulation, whilst limiting risks of N leaching. The simulated mineral fertilizer rates corresponding to the above manure rates and conditions, are 270 and 110 kg N per ha, respectively.

The permitted manure rates stipulated in the current Dutch AP, 42-44 kg P and 250 kg N per ha for most dairy farms, have strongly reduced the room for manure application on these farms. Hence, intensive dairy farms in particular are confronted with costs to export manure and to purchase additional mineral fertilizer N to compensate for this export. This stimulates further measures to reduce the excretion of N and P per unit milk (e.g. via low protein diets, or by limiting the number of followers), to increase the amount of available N per unit applied manure P (by limiting N losses from storage, land spreading and soil), or to decrease the amount of P per unit manure N. The latter can be achieved by slurry separation. The solid fraction, rich in P, is less bulky and can be exported at lower costs to arable farmers. The widened N (largely ammonia-N) to P ratio of the remaining liquid fraction matches better with the requirements of forage crops. Mineral fertilizer N could thus be partly or largely substituted with treated manure, depending on the quality of the separation process.

EU Directives are as yet unclear about the extent to which the compliance with environmental targets may be evaluated after averaging in space and time or not. For individual farms it makes a difference in terms of permissible rates, however, whether compliance is needed in every year under each field or whether a multi year regional compliance suffices.

In summary, our calculations show that the inputs of manure and fertilizers must be regulated. There is little justification, however, for uniform rules that ignore the many factors determining water quality, unless one does not mind that regulations are too mild in one situation and unnecessarily strict in another situation.

PAPER 14

Lough Melvin – a participatory approach to protecting a unique habitat: a case study for agri-environmental partnership

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Lough Melvin is a cross-border lake on the Leitrim-Fermanagh border, with catchment area of 26,500 ha. The lake is ecologically unique as it hosts artic char, salmon and three subspecies of trout, and has not (yet) been invaded by the zebra mussel. As a result, angling and tourism are central to the local economy. In recent years, concerns have arisen re the ecological stability of the lake ecosystem: with phosphorus (P) levels at 0.036 mg l^{-1} in 2001, the lake is now classified as mesotrophic – potentially eutrophic. Potential sources of P include domestic sources, agriculture and forestry operations.

The Lough Melvin Nutrient Reduction Programme is a cross-border, multi-institute project (funded by INTERREG IIIa) with the objective to develop and cost a cross-sectorial catchment management plan (CMP), specifically for the Lough Melvin Catchment. Within this project, our aim was to develop a suite of targeted and cost-effective agri-environmental measures to minimise P-loss to water, that would be practical and acceptable to the farming community.

Fifty farms were selected for risk assessment of P-loss, which included farmer interviews, farm management services, application of the P-ranking scheme, and soil sampling in excess of 400 fields. The risk assessment showed that agriculture in the Lough Melvin catchment mainly involves suckler cows and sheep enterprises, with a low average stocking rate of 0.5 LU's ha^{-1}. However, three key risks were identified: 1. Lack of support structures for the implementation of nutrient advice / nutrient management plans, resulting in locally excessive soil test P (STP) levels (Index 4) and total P inputs; 2. very high physical connectivity between agricultural nutrient applications and water quality; 3. limited availability of suitable spreadlands and spreading windows, resulting in repeated applications of slurry on the same fields. As a result, 31% of the agricultural area was identified as high risk, 30% as medium risk, and 39% as low risk.

Following the identification of the key risks, potential measures were developed from the literature and farmer interviews. These potential measures were then evaluated for cost-effectiveness, total costs, total impact and popularity, again by farmer interviews, stakeholder workshops, and economic analyses. The five measures that were most cost-effective and popular included 1. feeding of low-P concentrates; 2. withholding a P on Index 4 silage areas; 3. implementing support structures for nutrient management planning; 4. provision of compensation for reductions in sheep numbers and 5. Installing sediment traps in drainage ditches. Together, these five measures were estimated to account for 50% of potential P-reduction, at 5% of maximum costs.

Based on these results, we recommend that the CMP for Lough Melvin includes 1. long-term measures such as support structures for nutrient management planning and soil testing; 2. short-term measures aimed at reducing P-transport, e.g. sediment barriers in drainage ditches and 3. a review of regulatory loopholes.

In conclusion, the Lough Melvin project successfully identified measures that are cost-effective, high impact, and targeted at risk areas. Most importantly, the participatory approach ensured that the measures selected would, in addition, be practical and acceptable to the farming community, hence increasing the likelihood and success of implementation.

PAPER 15

Grasslands and the Water Framework Directive – the view from the River Basin Districts to measures

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Agriculture has been identified under the Article 5, National Summary Characterisation report as one of the key significant pressures with the potential to impact on water quality status. This was also highlighted in the Significant Water Matters Issues Report for each River Basin District in the country. Farms cover approximately 66% of the total land area of the country, 90% of which is grassland and 10% as tillage. Grassland related agriculture is therefore a significant land use pressure with the potential to cause enrichment of waters with nutrients (phosphorous and nitrogen) and organic pollution from animal slurries and manures. Critical to the understanding of the potential threat from this source is the use of the Pressure – Pathway –Receptor concept of the WFD. Better understanding has been achieved through much improved data availability, use and management particularly in relation to the pathway and the use of Geographic Information Systems. This has allowed conceptual models to be developed which are essential in underpinning the effectiveness of measures proposed. However, there are still gaps in the information available which if filled would potentially lead to more effective implementation of measures. The development and sharing of further information by all relevant bodies is seen as a basic requirement of good governance.

PAPER 16

Economic aspects of preparing river basin management plans under the Water Framework Directive

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The Water Framework Directive ("WFD") came into effect on 22 December 2000 and sets a framework for the comprehensive management of water resources in the European Community. Member States are required to adhere to a schedule which incorporates a number of milestones such as the establishment of River Basin Districts, the characterisation of these districts, and identification of significant water management issues. A major and significant milestone is the preparation and publication of draft River Basin Management Plans ("RBMPs") in 2008, with final Plans to be put in place in 2009.

A key element of RBMPs is a programme of measures aimed at reducing negative environmental impacts and achieving good status for water bodies by 2015. Goodbody Economic Consultants has developed guidance on the economic aspects of preparing RBMPs. This guidance covers:

- Selecting the most cost effective set of measures to achieve good status in water bodies; and,
- Determining whether these measures would be disproportionately expensive.

These issues are similar those that arise in the appraisal of public capital projects. Goodbody Economic Consultants have drawn on the techniques and tools used in the appraisal of capital projects in developing this guidance. In particular, a number of techniques used in cost benefit analysis and multi-criteria analysis have been adapted for use in this context.

Issues that arose in devising this guidance included:

- Identifying relevant measures;
- Information requirements;
- The need to keep the task manageable given the number of water bodies and pressures involved; and,
- The relationship between measures that can be taken at a river basin level, and national measures.

The tasks carried out included:

- Consultations with a wide range of stakeholders;
- A review of the approaches to the WFD in other Member States;
- Assessing the cost effectiveness of measures identified by the "programmes of measures and standards" exercise currently being carried out by the River Basin Districts;
- A review of academic and public studies of the value of good water status;
- Developing two manuals for River Basin Districts covering Cost Effectiveness Analysis and Disproportionate Cost Analysis; and
- Delivering training on these methods to River Basin Districts and Local Authorities.

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The approach developed to Cost Effectiveness Analysis produces an index of cost effectiveness for each proposed measure or set of measures that is a function of costs, time to implement, durability of the measure and incremental improvement in water quality. A programme of supplementary measure can then be selected based on these index numbers.

The approach developed to Disproportionate Cost Analysis is pragmatic, and recognises the difficulty in placing monetary values on the benefits of improving water status. In the majority of cases a disproportionate cost finding will be based on cost effectiveness analysis already performed. It should only be necessary to quantify the order of magnitude of the benefits of increasing water status in a minority of cases.

PAPER 17

Water quality response to changes in agricultural measures and practices

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Since 1985, seven national Action Plans (AP) have been implemented in Denmark to reduce nutrient losses from point sources (sewage treatment plants, fish farms, industrial plants and scattered dwellings) and diffuse sources. The instruments used to reduce nutrient losses from Danish agriculture include a list of nutrient related measures as e.g. mandatory fertilizer plans, livestock densities, mandatory storage capacity for liquid manure, improved utilization of nitrogen in manure, reduced nitrogen (N) norms to crops, tax on fertilizer and fodder, etc. and area-related measures as e.g. reestablishment of wetlands, buffer strips and buffer zones and afforestation programmes. A national monitoring programme was launched in 1988 to monitor regional and national trends in water quality in groundwater, streams, lakes and estuaries as a response to the AP's adopted. Moreover, a Land Monitoring Programme was launched which included a thorough monitoring of five agricultural catchments in groundwater, soil waters, tile drainage water and stream water including an annual interview on farming practices at field scale.

Four national indicators were defined to follow trends in diffuse nutrients losses from agriculture areas: nutrient surplus in agriculture, nutrient leaching from agricultural land and nutrient concentrations and loads in surface waters. Since 1985, the introduction of mitigation programmes has reduced the discharges of BOD5, total nitrogen and total phosphorus from point sources by 96%, 81% and 81%, respectively. The use of nitrogen and phosphorus in chemical fertilizer has been reduced by 50% and 65%, nitrogen and phosphorus in animal manure by 3% and 6% and the surplus of nitrogen and phosphorus by 31% and 48%, respectively during the period 1989-2003. The model calculated nitrogen leaching from the root zone has on average been reduced by 33% during the period 1989–2002. Trend analysis of total nitrogen concentrations and loads in 86 streams draining smaller agricultural catchments shows an average reduction of 29 and 32% (1989–2004). No general trends in diffuse phosphorus losses can be observed in the Danish streams draining agricultural catchments during the same period. The reason for this might be due to a combination of effects as: i) an ongoing positive P-surplus in Danish agriculture giving rise to increases in soil P and thus increases in erosional P-losses and P-leaching; ii) unintended side effects of some of the adopted measures for nitrogen giving rise to increases in P losses as restoration of wetlands; iii) climate change showing increases in precipitation and runoff during the last 80 years in Denmark. The instruments and measures adopted in Denmark to regulate nutrient losses from different pressures have, therefore, proven successful for nitrogen from point sources and diffuse sources and for phosphorus from point sources, whereas we still need to tighten regulations of phosphorus losses from diffuse sources.

PAPER 18

Measures and responses in Swiss and Austrian (alpine) grassland - comparison of two contrasting case studies (Mondesee (A) and Sempachersee (CH))

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This presentation compares the Mondsee (A) and the Lake Sempach (CH) and their catchments in the Austrian pre-alps and in the Swiss Plateau, respectively. Both lakes are of similar size (about 10 - 15 km^2), and the catchments have comparable soil and climatic conditions. As a consequence the agriculture in both watersheds is grassland-dominated. Despite these similarities, the intensities of animal production differ substantially with a low stocking density in the Mondsee catchment (1.4 LSU/ha) and fairly high values in the Lake Sempach catchment (up to 2.4 LSU/ha in critical subcatchments). The reason for the differences is the intensive pig production that has been developed in the region of Lake Sempach since the 1970s. Due to import of feedstuff the P cycle got out of balance. This is clearly reflected in vastly differing soil P status in the two areas. While the soils in the Mondsee catchment are predominantly very low in available P a large proportion of the Sempach area has a P excess.

The intensity in agriculture is clearly reflected in the water quality of the two lakes. While the Mondsee never experienced P total concentration > 35 mg m^{-3}, the values in Lake Sempach peaked at 170 mg m^{-3} in the mid 1980s being partially due to sewage input as well. To recover an acceptable status of water quality for lake Mondsee, it was - at least until present sufficient to massively reduce point pollution sources. In contrast higher concentrations caused severe negative eutrophication effects in Lake Sempach, including massive fish kills that called for action. Apart from finishing sewage treatments plants, internal lake measures as well as measures concerning agriculture have been implemented. In critical subcatchments for example, the P surplus could be converted into a negative P balance due to subsidizing P-reduced pig feed. Overall, mitigation was rather successful and P concentrations have dropped since 2004 below the water quality threshold of 30 mg P total m^{-3} that has been derived for Lake Sempach in the 1980s. Despite this steady decline of P concentrations over two decades internal lake measures are still in place due to the critical role of lake sediments that continue to release P into the water column. The developments of Lake Sempach and its neighbouring Lake Baldegg demonstrate that mitigation of lakes requires an integrated understanding and management not only of the catchments but also of the complex processes within the lakes themselves.

PAPER 19

Influence of catchment hydrology on water quality response

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Diffuse N sources have generally long and complex pathways between soil, groundwater and rivers. Differences in subsoil and aquifer saturated hydraulic conductivity (K_{sat}) result in different water quality response times. Therefore the lag time between introducing protection measures and first improvements in water quality will occur at different rates in different catchments and should be considered by policy makers and catchment managers. Such NO_3-N pathways from source to potential receptors in four Teagasc research centres (two NO_3-N vulnerable and two non-vulnerable sites) are investigated and compared: 1) Free draining sandy soils (< 3 m, > 60% sand), overlying a gravel aquifer (K_{sat} = 5-10^2 m day^{-1}) with clay lenses (K_{sat} = 0.02 - 0.5 m day^{-1}) underlain by carboniferous limestone, Oak Park, Co. Carlow. 2) Free draining sandy soils (< 4 m, sand ~40%) (K_{sat} = 0.03 - 0.5 m day^{-1}) overlying a Waulsortian karstified limestone aquifer (K_{sat} = 0.004-27 m day^{-1}), Curtin's Farm, Co. Cork. 3) Poorly drained till (<10 m, ~20% sand) with lenses of more permeable material such as gravel or sand and gravel overlying a Devonvian sandstone and mudstone poorly productive aquifer (K_{sat} = 0.01-0.2 m day^{-1}), Solohead, Co. Cork. 4) Shallow soils with fine loam texture (1-10 m, 40-90% sand, K_{sat} = 0.0001-0.01 m day^{-1}) overlying green grey shale of Cambrian age, Johnstown Castle, Co. Wexford. Results show potential travel times and corresponding response times in the range of days to years.

PAPER 20

Sustainable options for grassland agriculture in the northwest of Europe

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Grassland represents approximately 50% of the agricultural area of the main dairying regions of northwest of Europe; particularly in regions with high rainfall, heavy soils and mountainous areas. Risks for water quality associated with grassland depend on soil and climatic conditions. Long-term grassland on heavy mineral soils under high rainfall causes the accumulation of soil organic matter (SOM) up to 200 g kg^{-1}. Cultivation of these soils causes the mineralization of C and N tied up in the SOM; release of 4 t ha^{-1} of N over the 20 years after cultivation has been recorded leading to high losses of nitrate-N to water. Coarse-textured free-draining soils in areas with dry summers are not suited to long-term grassland because swards often do not persist for longer than 5 or 10 years. Under such circumstances temporary grasslands are grown in rotation with forage maize. The SOM content of these soils is generally low (< 20 g kg^{-1}) and, the risks associated with cultivation and mineralization of SOM are also low. Maize produces higher yields of forage with lower inputs of fertilizers than grassland on these drought-prone soils. Balanced fertilization of forage maize, taking into account net mineralization of N from the soil after cultivation of grassland along with N from manures and fertilizers can avoid unacceptable nitrate-N losses from these soils. Ploughing the grassland in spring and following forage maize with a winter catch crop will further lower losses. On these farms there is an increasing trend for cows to be kept indoors and for the time spent grazing to be restricted. This trend is driven by declining dairy farm numbers and increasing intensification on remaining dairy farms. Less grazing is associated with lower nitrate-N losses to water on these soils; there is high risk of nitrate-N leaching losses from urine patches deposited by grazing dairy cows. The localized deposition of dung and urine by grazing cows causes N to be recycled with low efficiency (0-15%) for grass growth. Where cows are kept indoors the dung and urine is collected as slurry, which can be recycled using low emission equipment and techniques with relatively high efficiency (up to 60%) for grass and forage crop production. Not all grasslands are vulnerable to unacceptable nitrate-N losses. Under permanent grassland wet anaerobic soil conditions combined with a readily available carbon (energy source) from SOM fuels denitrification of nitrate in the soil. Grazing under such circumstances does not result in high losses of nitrate-N to water because much of available nitrate-N in the soil is lost to the atmosphere as environmentally benign N2 gas. Loss of P by surface runoff is a greater risk on these soils, particularly on steeper slopes and close to watercourses. Avoiding high soil P concentrations is the key to avoiding losses. This can be achieved by bringing soil P concentrations to environmentally and agronomically acceptable levels and by keeping farm-gate P balances (inputs in fertilizers, feed etc. minus outputs in products via the farm gate) in balance.

PAPER 21

Good water status: the integration of sustainable grassland production and water quality in Ireland

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The challenge for sustainable grassland production is to integrate economically profitable farming systems with environmental protection. The Water Framework Directive aims to achieve good status for all waters by 2015, to be achieved through the introduction of measures across all sectors of society. Within Ireland, the measures introduced under the Nitrates Directive will contribute to the achievement of good status for all Irish waters. The effect of grassland agriculture has historically investigated water quality issues and more recently it has been highlighted that water quality and other environmental impacts such as greenhouse gas emissions must be considered in an integrated manner. Integration is particularly important when the effect of agriculturally derived nitrogen is considered as nitrate leaching to groundwater has regional effects and gaseous emissions of ammonia and nitrous oxide have global transboundary impacts. The source-pathway-receptor model has been used to investigate the impact of agricultural activities on water quality. Much of the focus in Ireland over the past decade has been on the quantification of nutrient loss from different agricultural systems to surface water and groundwater. This research has highlighted factors that contribute to the source of elevated nutrients lost to water such as elevated soil test P and low nitrogen efficiency related to low recovery of nitrogen from organic nitrogen sources. Mitigation measures have been developed through the understanding of the source of nutrient loss to water and in Rep of. Ireland these measures were implemented nationally through the Good Agricultural Practice for Protection of Waters Regulations 2006 (SI 378-2006). Generic mitigation strategies applied nationally or regionally take no account of the inherent differences that occur during nutrient migration within the source, pathway model i.e. in poorly drained soils the main hydrological pathway is via overland flow and where present, land drainage. Areas of poorly drained soils are at higher risk of phosphorus, sediment and pathogen loss to surface waters and thus measures to reduce nitrate leaching on these soils may not be appropriate. Targeting mitigation measures based on the inherent risk of contaminant transport to water recognises both the contaminant source and its transport vector which is likely to improve the cost:benefit ratio for a particular measure. To achieve good status for all waters, measures should recognise inherent regional differences both in terms of nutrient migration as affected by soil type/properties, slope, distance to receptor and hydrogeology coupled with the driving meteorological factors such as rainfall, evapotranspiration and drainage quantities. Spatial and temporal variation in rainfall and associated drainage volumes greatly influence the transport of agriculturally derived contaminants and directly influence the typology of the receiving waters. Predicting the impact of agricultural practices on the quality of receiving waters requires an understanding of biogeochemical processes that occur along the pathway phase and a process such as denitrification should be considered. These processes must also be considered when setting achievable water quality objectives and standards and their downscaling for assessment of the impact of agricultural practices. The political agenda of having cheap readily available food and energy for society must be rationalised with the provision and protection of good water quality.

POSTER 1

Sources and variations of nitrate levels in groundwater collected from a piezometer network on a dairy farm in the south-east of Ireland

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There is little information on variations in nitrate (NO_3-N) concentrations in shallow ground water on farms. The aim of this work, therefore, is to elucidate the possible sources and variations in NO_3-N concentration in 27 piezometers installed on the dairy farm at Teagasc, Johnstown Castle, Wexford where the perched watertable is generally <5 m deep. The soils are mainly fine loam up to 40 cm deep, underlain by a loam to clay-loam subsurface, derived from Irish Sea glacial drift deposits. The pH and organic matter content of surface soils are around 6 and 11% respectively and sandy lenses are interspersed with pockets of heavy clay soils. A primary drainage system connects the beef farm to the north with the dairy farm, with herring bone drainage alleviating poorly drained soils. To the south west the Johnstown Castle artificial lake system causes some dilution to groundwater. The 63 ha dairy farm now has 27 piezometers as well as 3 deeper, nested boreholes (each at 3 depths) and a deep borehole at a depth of 37 m. Water samples are collected on a monthly basis. Samples were analysed for chloride (Cl), phosphorus (P), ammonium-N (NH_4^+-N), nitrite (NO_2^-N) and total oxidised nitrogen (TON). As nitrite-N levels are extremely low, TON can be taken as nitrate-N for practical purposes. Analysis of data from December 2005 to March 2008 for a number of these piezometers (1-8) together with additional data from July 2007 for the remaining piezometers (9-27) indicates high nitrate-N concentrations in several piezometers, above maximum allowable concentrations (MAC) of 11.3 mg L^{-1} nitrate-N. Piezometers 1, 4, 11 and 15 are shown to have been consistently above MAC and numbers 26 and 27 were above it 50% of the time. Maximum mean nitrate-N concentration from monthly measurements of piezometers 1 to 27 (between July 2007 and March 2008) was 15.6 mg l^{-1} (piezometer 15) while the minimum was 0 mg L^{-1} (piezometer 24). The mean nitrate-N concentration for the 27 piezometers was 5.3 mg L^{-1}. Water samples with high nitrate-N tended to remain high between July and March and vice versa. Results for wells 1, 4, 11, 15 and 27 appear to confirm the hypothesis that two historic treatments, rather than the present nitrogen application rate, are producing the high nitrate-N concentrations. A further hypothesis links the varying nitrate-N concentrations to soil properties, particularly where sandy soils have been irrigated by dirty water. Soil properties at a lower depth are likely to control hydraulic-conductivity and might have a greater effect on the enrichment of groundwater nitrate concentrations than soil in the top 40 cm. It is also assumed that where hydraulic-conductivity is low, long residence times of water in poorly drained anaerobic soils may lead to high levels of denitrification and thereby low nitrate concentrations in receiving groundwater. By contrast, where hydraulic-conductivity is high, nitrate leaching may occur faster through aerobic soils, enriching groundwater nitrate levels. Work is underway to attempt to identify the source(s) of nitrate-N in the piezometers, using a natural abundance multi-isotope approach.

POSTER 2

Analysing the unexplored terrain of subsurface microbiology in Irish soils and groundwater systems

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Denitrification is one of the foremost pathways balancing the global nitrogen cycle, involving the microbial conversion of nitrate (NO_3^-) or nitrite (NO_2^-) in wet and poorly drained soils into nitrous oxide (N_2O) and di-nitrogen gas (N_2). Understanding the microbial denitrification process and elucidating the microbes responsible for this within subsoil/groundwater will lead to the identification of management options for reducing both N_2O emissions and NO_3^- leaching, and for improving the utilization of agricultural nitrogen (N). This study focused on the largely unexplored process of sub-soil denitrification. The movement and transformation of nitrate to nitrous oxide and di-nitrogen gas from below the rooting-zone in well/poorly drained soils; and underlying groundwater; in Irish agricultural systems was measured. The occurrence and activity of denitrifiers was then compared with denitrification rates measured in subsoil and groundwater within Irish agroecosystems. Several DNA extraction methods were evaluated on selected core profiles, from a range of soil types, to ascertain the method producing reproducible, robust and high yields of DNA, in terms of quantity and quality. DNA recovery was then quantified in relation to soil depth. The structure of the denitrifying microbial community in soil and groundwater was investigated by determining the presence or absence of functional genes responsible for the nitric oxide reductases (Nor: qnorB/cnorB) and nitrite reductases (Nir: nirK/nirS). Initial results revealed that the UltraClean™ Soil DNA extraction kit (MoBio) produced the highest DNA yield from all soil types. DNA recovery decreased with soil depth, as did the potential for denitrification. Fluorescent in situ hybridization (FISH), Denaturing Gradient Gel Electrophoresis (DGGE) and denitrification assays were carried out on the diverse Irish soil types; and revealed that the denitrifying community structure and activity profile was depth dependent.

POSTER 3

Nitrogen leaching from a grass-dominated catchment simulated with the daisy model

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The Water Framework Directive requires all water bodies to achieve a 'good ecological status' before 2015. Models are fundamental tools for quantifying the effects of regulations imposed on agriculture in order to reduce nutrient losses. In this study we demonstrate how the 1-D mechanistic soil-vegetation-atmosphere model Daisy can be used for calculating root zone losses of nitrate at the field scale in a 7.6 km^2 grass-dominated catchment in Denmark. The model is calibrated on root zone nitrate concentration, nitrogen yield and groundwater depth measured at eight fields within the catchment. The fields are instrumented with suction cups below the root zone, and piezometers. A total of 329 relevant spatial combinations of soil type, crop rotation, and ground water level were defined and simulated with Daisy. Simulated grass yields are on average 222 kg N ha^{-1} yr^{-1} compared to 211 kg N ha^{-1} yr^{-1} as reported by farmers in the catchment in a questionnaire survey. Similarly good results are obtained by comparing modelled net precipitation with stream water discharge. The simulated root zone nitrate losses are higher than the measured nitrate transport in the stream. This was expected due to a high nitrate reduction capacity in groundwater. The study demonstrates that the model concept is a tool well suited for analysing and predicting the effect of agriculture on water quality.

POSTER 4

Measuring denitrification enzyme activity in soils under pasture using membrane inlet mass spectrometer

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Denitrification is mainly the biological process of transforming nitrate (NO_3^-) to end products N_2O and N_2, which have large implications on global nitrogen (N) cycle in terrestrial and aquatic systems. Size and potential activity of the denitrifying organisms in association with relevant environmental factors regulate the rates of denitrification in the ecosystems. Denitrification enzyme activity (DEA) is measured under non-limiting substrates and under anaerobic/saturated conditions for a few hours to several days so as to attain denitrification potential at the time of soil/water sampling. Due to high background of atmospheric di-nitrogen (N_2), denitrification measurement is generally performed using acetylene block or stable isotope techniques. We hypothesized that Membrane Inlet Mass Spectrometer (MIMS), measuring N_2, argon (Ar), oxygen (O_2) and other noble gases by auto-degassing water samples, may also be used to assay DEA in soil slurry/sediments, comparable to anaerobic/saturated conditions. Experiments were conducted with soils of A, B and C horizons collected from two different land uses under pasture to obtain optimal NO_3^- and available carbon (C) rates to initiate DEA. For this, 30 g soil (d/w) followed by deionized water (helium purged) was taken in 160 ml glass bottle and sealed with a rubber stopper without any air entrapments. N as potassium nitrate (0 to 120 mg kg^{-1} soil) and readily available C as glucose (0 to 240 mg C) plus 30 mg NO_3^--N kg^{-1} soil each were added. Incubation was carried out under water in dark conditions at 21°C for six hours. Water for each treatment was sampled in an exetainer and kept it under water in a cold room at 4°C before analysis using MIMS. Peaks for N_2/Ar ratio, representing denitrification, varied between soils under two land uses and also between soil depths/horizons within the land use, being higher in surface over subsurface soils. Soils under grass-clover required generally a small amount of NO_3^--N (15 mg kg^{-1} soil) as well as glucose-C (60 mg kg^{-1} soil) for the short-term DEA assay. By contrast, the amount of N and C for the DEA assay varied largely within horizons under ryegrass, ranging from 30 to 120 mg NO_3^--N, and 60 to 120 mg glucose-C, kg^{-1} soil. The DEA under two ecosystems demonstrated that the soil having high mineralization potential might require less substrate to activate existing denitrifiers activity and vice versa. A follow-up experiment was carried out to see the denitrification capacity/potential of subsoil (C horizon) under ryegrass with simulated unsaturated and saturated conditions plus groundwater and those were treated with the selected, optimal substrate rates (30 mg NO_3^--N, and coupled with 60 mg glucose-C, kg^{-1} dry soil). During the 5 days incubation at 12°C, presumably higher pre-oxidative state of unsaturated subsoil showed a lower denitrification activity over the saturated one. Maximum DEA attained by day 3 was smaller with NO_3^--N, relating again to higher oxidative state and probably the C was limiting, than the unamended control. The application of N and C together depicted relatively a higher denitrification potential over time than the two treatments, achieving peak fluxes within a short period. This signifies that the DEA was mainly limited by substrates and that available C as an energy source could override the temporary oxidative state occurring due to addition of NO_3^--N. Results imply that MIMS could be highly useful in measuring denitrification capacity/potential of subsoils/sediments at coupled substrate rates of 30 mg NO_3^--N and 60 mg glucose-C, kg^{-1} soil.

POSTER 5

Nitrogen fertilizer replacement value of slurry: effect of application method and timing

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Regulations in operation in Ireland to contribute to meeting the requirements of the Nitrates and Water Framework Directives require that a nitrogen fertilizer replacement value (NFRV) of 40% must be assumed for applications of cattle slurry to grassland from 2010 onwards. Up to now, lower NFRV levels of 5% (summer application) and 25% (spring application) have been assumed. The regulatory requirement to increase the NFRV, combined with increasing fertilizer prices, will require that slurry management is adapted to maximise the NFRV of cattle slurry, and reduce the requirements for complementary chemical fertilizers and the associated potential for farm N surpluses to threaten to water quality. Poor NFRV levels are associated with high losses on nitrogen as ammonia gas following slurry application. Application in cool and humid weather conditions, normally more prevalent in spring than summer, and with low emission slurry application methods, such as the trailing shoe, have been shown to reduce ammonia losses. Field trials were conducted at three sites; in Cork (well-drained,) Wexford (moderately-drained), and Clare (poorly-drained). The effect of application timing (April vs. June), and the application method on the NFRV of cattle slurry applied for grass silage crops were being examined. Grass yield was harvested six to seven weeks after slurry or fertilizer application. Nitrogen fertilizer was applied to separate plots to establish the grass DM yield response to N fertilizer. The mean DM yield obtained form the slurry-treated plots were then compared to the fertilizer N response curve to calculate the NFRV of the slurry applications. The mean NFRV of slurry applied with splashplate was 29% in April, and 10% in June. This corresponds with assumed NFRV levels in previous advice. The mean NFRV with trailing shoe application was 39% in April, and 21% in June. Application in April rather than June gave the highest increase in NFRV, increasing the NFRV by 19 percentage points with splashplate and 18 percentage points with trailing shoe. Application using trailing shoe increased the NFRV by 10 percentage points in April and 11 percentage points in June.

The results show that switching application timing from June to April will give the highest increase in NFRV, irrespective of application method. Switching application timing without switching application method will not affect the application cost. Adoption of the more expensive trailing shoe technology will also increase the NFRV, but the increase is lower compared to switching application timing, and the economic benefit will be marginal due to the high cost of the trailing shoe equipment.

Reducing farm N surplus through improved slurry management will contribute to meeting Water Framework Directive targets. The results show that while the NFRV target of 40% is achievable, it will come at a high cost to the farmer by way of trailing shoe adoption, and the marginal benefit of high-cost trailing shoe adoption will be lower than that of switching application timing.

POSTER 6

MANNER version 5: A decision support system to assist in making better use of manure nitrogen

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MANNER (MANure Nitrogen Evaluation Routine) version 3.0 has proved to be a valuable tool enabling farmers and advisors to quantify manure crop available nitrogen (N) supply, and to assess how changing the timing and method of manure applications can affect N losses via ammonia volatilisation or nitrate leaching. More than 10,000 copies have been distributed to users following the launch of version 3.0 in 2000. The development of MANNER version 5 involved the incorporation of more recent research information where significant advances had been made in our understanding of N transformations and losses following manure application to land.

In MANNER version 5, ammonia loss algorithms for the different manure types (which define the maximum potential ammonia loss and the loss rate) were refined based on newly available experimental data. Moreover, the ammonia loss algorithms were modified to account for a number of additional factors that were not included in version 3.0 i.e. slurry application technique and soil incorporation method, land use, application timing and environmental conditions at the time of spreading (i.e. windspeed, rainfall and soil moisture content), which had all been shown in field experiments to influence ammonia emissions. The nitrate leaching module was enhanced to improve predictions of losses from sandy soils (where leaching losses largely occur via matrix flow) and to better represent leaching losses from clay soils where water movement (and hence nitrate leaching losses) largely occurs via by-pass (crack) flow. In addition, a nitrification delay was included to more realistically estimate when manure ammonium-N (following nitrification) was likely to be at risk from loss via nitrate leaching. Also, a more sophisticated approach to estimating organic N mineralisation was developed based on soil temperature (i.e. thermal time), which recognised N mineralisation differences between rapid (i.e. pig slurry and poultry manures) and slow (i.e. straw-based farmyard manure and cattle slurry) organic N release manure types.

A new module was added in to MANNER version 5 to estimate N losses via denitrification, as nitrous oxide (N_2O) and di-nitrogen. Although these losses are generally small in agronomic terms in comparison with ammonia volatilisation and nitrate leaching losses, N_2O is a powerful greenhouse gas. Also, a module was included to accommodate autumn crop N uptake, which will decrease the amount of N at risk from over-winter nitrate leaching, especially where manure applications are made to grassland or before oilseed rape. Finally, the software was enhanced to estimate N available to the following crop (i.e. in crop year 2) through the mineralisation of manure organic N.

Validation of MANNER version 5 crop available N predictions was undertaken by comparing predicted manure fertiliser N replacement values with independently collected field experimental measurements (>200 site/years of data). For cattle, pig and poultry manures there was good agreement ($p<0.001$) between the predicted and measured values.

POSTER 7

Comparison of methods to composite samples for measuring nitrate leaching using ceramic cups in a large scale field experiment

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Porous ceramic cups are widely used to obtain in situ pore water samples from soil and are used by many in nitrate leaching experiments. Usually soil water samples from each ceramic cup are analysed individually and results are frequently presented as the mean concentration for the treatment (i.e. mean of all cups in each treatment). However, in large field scale experiments the high cost of laboratory analytical procedures may require the compositing of samples to reduce analytical costs. The objective of this experiment was to compare two different compositing methods of samples obtained from ceramic suction cups to measure nitrate leaching.

Two independent experiments are currently being undertaken on a free draining soil type. This experiment was undertaken within these two experiments. Both experiments are located adjacent to each other. Within each experiment there are 20 paddocks, each containing 16 ceramic cups vertically installed to a depth of 1 m in a grid type arrangement. Samples were collected bi-weekly from each experiment. To obtain a soil water sample from the ceramic cups 40 k Pa vacuum was applied the day before sampling commenced. Sampling was undertaken on the two consecutive days after vacuum was applied. Two compositing methods were used to bulk samples from each paddock. Method 1 involved removing an equal quantity (10 ml) of soil water from each cup and mixing this for the 16 cups in each paddock from which a sub sample was removed for chemical analysis. Method 2 involved mixing the total soil water sample (minus the 10 ml) from each cup in each paddock and taking a sub sample for chemical analysis. Samples were analysed for TON and NO_2-N using the Aquakem 600 auto-analyser. The nitrate N (NO_3-N) content was calculated by subtracting NO_2-N from TON. Nitrate-N (mg L^{-1}) concentrations were calculated from six sampling occasions per experiment between February and May and used to compare the two compositing methods. Due to the loss of some samples there were 117 observations in Experiment 1 and 110 observations in Experiment 2. Means were compared using the two tailed paired two sample mean test in SPSS.

The average NO3-N content (mg L^{-1}) in Experiment 1 measured using both methods of compositing were 18.1 mg NO_3-N L^{-1}. There was no significant difference between the two methods (P = 0.94). In Experiment 2 the mean NO_3-N content (mg L^{-1}) measured using Method 1 was 20.2 mg NO3-N L^{-1} and 19.7 mg NO_3-N L^{-1} when Method 2 was used. Similar to Experiment 1, the difference between the two methods was not significant (P = 0.44).

There was no significant difference between the two compositing methods in either experiment 1 or experiment 2. This indicates that both methods of compositing would be suitable and method 1 is being used for all ongoing and future sampling due to the ease and speed of compositing.

POSTER 8

The use of tracer experiments to estimate unsaturated and saturated zone travel times for nitrate leaching on a very free draining site

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The EU Water Framework Directive (WFD) (2000/60/EC) requires achievement of a "good quality" water status by 2015. In order to achieve this goal the increased protection of groundwater and development of sustainable agricultural practices are essential. Especially important is the protection of waters against pollution caused by nitrates from agricultural sources. Estimation of unsaturated and saturated travel times, depending on the amount of effective rainfall, is very important for evaluation of leaching losses of water soluble nutrients such as nitrate. Travel times are related primarily to the quantity of total effective rainfall or drainage that is necessary to transport the tracer from the soil surface through the unsaturated zone to the saturated zones. Travel times integrate soil and subsoil factors such as hydraulic conductivity and depth to the water table. This paper presents a case study which is part of a broad on-going project investigating the effect of over winter green cover mitigation strategies for reducing nitrate leaching from cereal crop production systems on very free draining soils. The study site is situated in Oak Park, Carlow, Ireland, near the River Barrow. In 2004 a bromide tracer travel time study was performed c. 300 m south-east of the current experimental site. The KBr tracer was applied in February 2004 (349.5 kgBr/ha and 0.5 mm irrigation). Tracer travel times to 0.9 m depth were 27 - 42 days after its application (13 mm effective rainfall). First detection of tracer in the groundwater occurred in October 2004 (227 days) just after the first effective rainfall of the autumn in 2004. Peak groundwater Br concentration was observed in February 2005 (almost one year later), after 297 mm of effective rainfall. In the second bromide tracer experiment, KBr (300kg Br/ha and 0.5mm irrigation) was applied on 21st November 2007 just before the main autumn recharge commenced on the site. Tracer travel time to 0.9 m and 1.5 m depth was 14 days after its application (51mm effective rainfall). Peak groundwater Br concentration in the second experiment was observed in late April 2008 (after 150 days, 176mm effective rainfall). This paper will compare the travel time results of the two tracer experiments on the site to investigate the difference between solute transport in early spring and in autumn. The paper will further investigate the amount of effective rainfall/drainage necessary for vertical transport of tracer from the soil surface. Knowledge of solute travel times through the unsaturated zone is necessary to interpret the effect of mitigation measures in improving groundwater chemical quality. This study indicates that soil surface activities on this very free draining site could potentially affect groundwater quality within one year or less. This suggests that the effect of mitigation measures on groundwater quality at this site could be detected within one to two years of implementation.

POSTER 9

Nitrogen and phosphorus losses in drainage waters follow contrasting slurry application timings on clay soils

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An estimated 47 million tonnes of cattle/pig slurry supplying c.210,000 tonnes of nitrogen (N) and c.50,000 tonnes of phosphorus (P) are applied to agricultural land in the UK each year. On drained land (which covers c.6.4 million ha in England and Wales) the rapid transfer of water from the soil surface to field drains, via soil macropores, can lead to high nutrient concentrations and losses in drainage waters following slurry application.

An experiment was undertaken on a clay (54%) textured soil of the Denchworth Association, at the Brimstone Farm experimental site in Oxfordshire (England). The site consists of 18 hydrologically isolated plots (40 m by 48 m), of which 9 are in arable production and 9 are grassland production (following arable reversion). Cattle slurry was applied to the arable and grassland plots in autumn (August-October), winter (November-January) and spring (February-March) in 2003/04, 2004/05 and 2005/06, with 3 replicates of each timing. The cattle slurry was applied at a rate of c.45 m^3/ha, supplying 120 kg/ha total N (60 kg/ha ammonium-N) and 20 kg/ha total P (of which c.20% was water soluble). Drainflow volumes were measured continuously and drainage water samples were collected on a flow proportional basis, using automatic water samplers, and analysed for ammonium-N (NH_4-N), nitrate-N (NO_3-N), molybdate reactive P (MRP) total dissolved P (TDP) and total P (TP).

The autumn slurry applications, which were applied before the soil reached field capacity (i.e. before the soil began to drain in the autumn/winter), had little or no effect on NH4-N or TDP concentrations in drainage waters at the start of drainflow. However, on both the arable and grassland plots, drainage water NH_4-N and TDP concentrations were elevated following slurry applications in winter and spring, where the slurry was applied to 'wet' soils and rainfall (typically > 10 mm) fell within 10 days of slurry application and caused drainflow. Concentrations of up to 6 mg/l NH_4-N and up to 7 mg/l of TDP were measured, indicating that slurry N and P had moved rapidly from the soil surface to field drains, via cracks/mole channels, with little interaction with the soil matrix.

In general, NH_4-N and TDP concentrations were higher from the grassland than from arable plots, which most probably reflected greater connectivity on the grass plots between the soil surface and field drains, as a result of 'by-pass' flow in cracks/mole channels, than on the cultivated arable plots. Overall, slurry phosphorus losses accounted for 64% and 43% of total P losses following winter applications to grassland and arable land, respectively

POSTER 10

A review of remediation and control systems for the treatment of agricultural wastewater in Ireland to satisfy the requirements of the Water Framework Directive

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In Ireland, agricultural activities have been identified as major sources of nutrient input to receiving waters and it has been estimated that these activities contribute 75.3% of the nitrogen (N) and 33.4% of the phosphorus (P) in these waters. Strategy at European level focuses on the prevention of nutrient loss by improved farm management. However, it does not focus on nutrient remediation or incidental nutrient loss of farmyard manures to surface and groundwater. This review describes the impact of agriculture on the environment in Ireland and examines emerging technologies such as permeable reactive barriers, dirty water or slurry amendment for agricultural wastewater treatment. An integrated approach at pre-treatment and field stages for nitrate (NO_3) remediation and P control is recommended.

POSTER 11

Prediction of contributing areas for P losses from grassland – assessing P losses with sprinkling experiments

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Diffuse Phosphorus (P) losses from agricultural land are a major cause for eutrophication of surface waters. Different studies indicate that most P losses originate from small regions of a catchment only. Lazzarotto (2005) developed a semi-distributed model to predict such critical risk areas in the Lake Sempach region (Switzerland). In general, the model results were promising but several questions arose regarding the role of incidental P losses (IPL). To investigate those questions sprinkling experiments were carried out in summer 2008. They were performed on two different sites, on one site with low and on one site with high concentrations of P in the topsoil, in order to compare the effects of soil P status and IPL. On each site 8 plots were installed and manure was applied on half of the plots. Artificial rainfall was applied 1 day and 8 days after manure application to investigate the dependence of IPL on the time of manure application. In addition, these experiments will be used to improve the database regarding the relationship between the Water Soluble P (WSP_{soil}) in soils and Dissolved Orthophosphate in runoff (DP_{runoff}). First analyses of the data demonstrate that manure effects P concentrations on low and on high-P soils. However, the manure P cannot override the effects of different soil P status. These are preliminary results. Runoff patterns and other factors were not taken into account yet. Further analyses will bring more clarity and lead to more precise statements.

POSTER 12

Soil, plant and environmental indicators to minimize phosphate inputs in permanent grasslands

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Phosphate (P) losses to surface waters remain a major problem in many European agro-ecosystems supporting a high livestock density. Phosphorus losses from over-fertilized grasslands are particularly difficult to control because of high soil P stocks and because in these conditions, fertilization with farmyard manure to cover the nitrogen needs provokes too large an input of P. Decreasing soil available P contents has been suggested as a measure to decrease P losses. However, because of the complexity of a permanent grassland ecosystem it is difficult to foresee how changes in P inputs will affect grassland productivity and soil P availability. The aim of an ongoing project is therefore to develop a set of soil, plant and environmental indicators to assess the effect of different P inputs on soil P availability, herbage production and on the fate of P in the environment.

We investigated six permanent grasslands at three locations in Switzerland (Baldegg, Watt and Les Verriéres), which differ mainly in cutting intensity, soil properties and local climate. In four on farm trials at Baldegg the grasslands are intensively managed, i.e. five to six cuts per year and fertilized after each cut. The other two grassland sites are long term fertilizer experiments with lower cutting frequency and various rates of N, P or K fertilization. Soil samples were taken in 0-5, 5-10, 10-20 and 20-40 cm depth. Plant samples were cut on an area basis and separated in the three botanical fractions grasses, legumes and forbs. Plant available P was estimated by resin P extractions and correlated to plant parameters such as biodiversity and phosphorus nutrition index (PNI), and to soil parameters like degree of phosphorus saturation (DPS) as a measure for the risk of P losses to the environment.

First results show a decrease of available P (from 65-3, 10-1 and 37-1 mg P kg^{-1} soil in Baldegg, Watt and Les Verriéres, respectively) with soil depth and P availability increased with higher use intensity (and fertilization). PNI as a plant indicator reflected the plant nutritional status and soil P status, but the botanical composition needs to be considered because legumes have lower and forbs higher P concentrations in above ground plant tissue than grasses. In addition fertilization and cutting intensity affected forage quality and botanical composition. The DPS increased with higher P fertilization, especially on soil with high accumulated P, and therefore indicated higher risk of P losses from those grasslands.

In conclusion we saw that even in little intensive managed grasslands relatively high yields were obtained, but lower forage quality was produced, which resulted mainly from the late first cut. With management intensification the forage quality rises but also the risk of P losses to the environment. The investigated indicators can be used potentially in a field specific risk or fertilizer evaluation to improve the grassland management and thus reduce P losses. In future studies we will investigate the mineralization of P from organic soil pools, the retention and re-supply of available P by the soil and colloidal P fractions which can be a tremendous part of P lost from grasslands.

POSTER 13

The impact of grazing animals on sediment and phosphorus mobilisation and delivery to surface waters from improved grasslands

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There is a need to improve our understanding of the link between degradation of vegetation and soil through the impacts of grazing animals and the rate of soil erosion, sediment and nutrient delivery to surface waters. This NERC PhD project aims to further our knowledge of the link between land management and soil degradation within the South West (SW) of England, UK. We will observe fluxes of water, sediment and nutrients from nested scales within headwater catchments, of similar slope gradients and areas, but on contrasting soil types. Analysis of the dominant soil series of the SW and their associated hydrological characteristics enabled the selection of three model soil series representative of grassland systems in the SW of England, and of the UK as a whole. Three representative sites were chosen for monitoring and sampling. In-stream samples will be taken alongside data on the amount, location, spatial distribution and connectivity of bare or degraded areas, of improved grassland catchments and how these areas change through the grazing season and throughout the hydrological year. Monitoring at the catchment outlet scale will commence in the winter and continue until the start of the next hydrological year. Bounded plots, constructed at different scales, will then be used with a rainfall simulator in order to assess the risk of mobilisation and transport of sediment, organic matter and phosphorus (P), in areas representative of different degrees of degradation. The data collected will be in the context of farm stocking rates and downstream datasets describing the larger sub-catchment which are currently monitored by the University of Exeter, North Wyke Research and the Environment Agency. The spatially explicit profiling of mobilisation will help identify the field areas which pose the greatest threat to water quality, while monitoring of delivery and degradation allows this data to be placed in a temporal context. This paper sets out our conceptual and proposed experimental approach. It is designed to encourage dialogue between researchers and other key stakeholders in order to advance our understanding of the temporal and spatial impacts of livestock grazing on the mobilisation and delivery of sediment and P to surface waters.

POSTER 14

Phosphorus in manure impacted runoff from grass and maize stubble

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Research in the United States (US) has shown how reducing phosphorus (P) in the diet of dairy cows to close to the absolute P requirements of cows substantially lowers the P content of manures. Surface application of dairy manure from a reduced P diet to maize stubble in the US lowered P concentrations in runoff particularly in the dissolved reactive P (DRP) fraction which was lowered by 90% in comparison compared to manure from a high P diet (Ebeling et al., 2002. Soil Sci. Soc. Amer. J. 66:284-291). Runoff studies on permanent grassland at Hillsborough, Northern Ireland (NI) show that reducing the P content in a manure of 6% dry matter (DM) from 13.3 to 4.9 g P kg^{-1} DM lowers P in runoff but that the reductions in TP of 47% and DRP of 66% in runoff were less than observed by Ebeling et al,. 2002. Concentrations of DRP in manure impacted runoff from grass were up to 9 mg P L^{-1} compared to < 1 mg P L^{-1} for DRP in runoff from maize in the US. These high concentrations observed from grassland could reflect fundamental differences in the composition of manure from dairy cows in NI which were fed grass silage and concentrates as opposed to concentrates and maize silage in the US and/or could reflect differences related to land cover as maize stubble consists of mostly bare soil. To test the latter, a runoff experiment was carried out on maize stubble at Hillsborough, three months post-harvest and compared with P measured in runoff following a winter application of the same manure to grassland. The manure was a high P manure (13.3g P kg^{-1} DM) at 6% DM which was applied at 50 m^3 ha^{-1} to five replicate 0.5 m^2 plots with five control plots receiving no P amendment. Two days after manure application rainfall simulations of 20 mm hr^{-1} were applied for 30 minutes. DRP (50%) dominated TP in runoff from the maize manured plots with particulate P (PP) contributing 41%. By comparison PP accounted for 78% of TP from the maize control plots. The fractionation of P in manure impacted runoff from maize was almost identical to that observed from the grassland experiment. The mean TP concentration in runoff from maize stubble of 14 mg P L^{-1} was less than TP of 33 mg P L^{-1} from grassland. Slurry applications raised the TP concentration in runoff from maize by 9.8 mg L^{-1} above TP concentrations in the control treatment compared to a TP increase of 30.2 mg L^{-1} in manure impacted runoff from grassland. Runoff from the maize plots of 3.1 mm was slightly larger than from grassland (2.5 mm). Therefore the large difference in TP concentrations in runoff from grass was responsible for a higher P loading from manure applied to grass, which was equivalent to 0.9 kg P ha^{-1} compared to 0.5 kg P ha^{-1} in runoff from maize stubble following application of the same manure.

POSTER 15

Phosphorus concentrations in overland flow water from grassland field plots

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Grassland is a large proportion of farmland in many countries and in Ireland grassland accounts for 80% of farmland. This study compared phosphorus (P) in overland flow from grassland subjected to cutting and grazing. Flows and P in runoff sampled on a flow proportional basis were measured over two years from three sets of ca.1 ha paired cut and grazed grassland plots. Plots were paired according to Morgan's soil test P (STP) status which, between plots, ranged from 3.5 to17.9 mg L^{-1} soil. Dissolved reactive P (DRP) was the largest P fraction in runoff and total P (TP) concentrations were strongly correlated with total dissolved P (R^2 =0.86) and DRP (R^2 =0.77). DRP in overland flow ranged from <0.010 mg L^{-1} to 3 mg L^{-1} with mean annual DRP concentrations varying more than ten fold between plots with the lowest and highest STP (0.047 vs. 0.585 mg L^{-1} P in 2002 and 0.029 vs. 0.723 mg L^{-1} P in 2003). Annual mean DRP concentrations were positively correlated with log STP but no consistent significant effect of grazing or cutting was detected. Loads of DRP in overland flow from the plots ranged from 0.2 to 1.7 kg ha^{-1} yr^{-1}. At the end of summer, a wash out effect of DRP in overland flow was consistently observed. As this autumn period combined high flows with high P concentrations, TP and DRP loads were also high. Conclusions from the study are: 1) DRP was the dominant form of P exported from grassland, especially where STP was high; 2) the marked autumn P wash-out effect led to high P annual losses from high STP grassland; 3) exports of P were more influenced by variation in STP rather than any effects cutting or grazing management regimes. Although no significant difference in P losses from cutting and grazing regimes was observed, no assessment was made of P losses that could occur when manure P, generated when the conserved forage was fed to livestock, was returned to grassland.

POSTER 16

Agriculture as a phosphorus source for eutrophication in the north-west European countries, Norway, Sweden, United Kingdom and Ireland

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The relative importance of agriculture compared to other phosphorus (P) sources for loss to water show considerable variation in NW Europe. Despite the geographical proximity and climate similarities (Atlantic influence), variability in local situations is very high.

Most P loss from agriculture is generally considered to be as particulate P, but dissolved P can nonetheless make up 9 – 93%. High levels of agricultural soluble phosphorus can result from desorption from particles following storm flow events or snow melt, loss from fertiliser or manure applications, or from decomposing vegetation. The proportion of dissolved P will also be higher if particulate P losses are lower, because of permanent pastures or soil "sieving" which retain particles, or if erosion prevention measures are taken.

Subsurface drainage can contribute 12 – 60% of agricultural total P losses and surface erosion 40 – 88%. Total P export for small agricultural stream catchments for the four countries considered vary from 0.3 to 6 kg P ha^{-1} year. Phosphorus loss is particularly high in Norway where historic landscape modifications result in a high risk of soil erosion.

Use of mineral fertilisers has decreased in recent years. In addition, all four countries are currently developing measures to reduce agricultural P losses, in response to the EU Water Framework Directive obligations to achieve "Good Quality" status in surface waters. Average P concentrations in South Swedish streams have shown reductions of 2% per year since 1993, following measures to reduce soil erosion. However, climate change may increase P losses (more frequent freezing-thawing of the soil, more heavy precipitation events and enhanced water runoff) leading to soil erosion and this will be a challenge for each of these countries.

POSTER 17

Phosphorus and nitrogen losses from a grassland site on a heavy clay soil in a fluvial plain in the Netherlands

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Transport of dissolved nutrients by water through the soil matrix to groundwater and drains is assumed to be the dominant pathway for nutrient losses to ground- and surface water in level areas like the Netherlands. In 2003 a study was started to investigate nutrient losses from a grassland site on a heavy clay soil in a fluvial plain in the Netherlands. The site was drained by drains and trenches. Annual N and P surpluses (input minus uptake) were on average 115 kg N ha^{-1} yr^{-1} en 11 kg P ha^{-1} yr^{-1}. The topsoil (10-40 cm) was non-calcareous, with an organic matter content of 5%, a clay content of 57% and a low degree of phosphate saturation (7%). The $CaCO_3$ content increased with depth to 7% at 1 m depth. Amount and composition of the discharge from the drains, trenches and ditches were monitored for five years.

Monitoring results showed that rapid discharge by means of the trenches was the dominant pathway (60-90%) for water and nutrients. Discharge to the groundwater was negligible. The contribution of the drains to the discharge of the plot depended on the existence of shrinkage cracks in the clay soil. At the end of a dry summer (2002), cracks were abundant and discharge was equally divided to drains and trenches. After prolonged wet periods, cracks were absent and discharge by drains was almost negligible.

Average N losses to surface water by trenches was 13.1 kg N ha^{-1} yr^{-1}, with an average concentration of 6 mg/l. Average N losses by drains was 3.5 kg N ha^{-1} yr^{-1} (5 mg/l). Average P losses to surface waters were 2.6 and 0.7 kg P ha^{-1} yr^{-1} for respectively the trenches and drains with average concentrations of 1.2 mg/l and 0.7 mg/l respectively. These concentrations are remarkable high considering the low degree of phosphate saturation and low concentrations in the soil solution. Results of the first three measurement years showed that only a small part of the N and P losses were in dissolved inorganic form (25-50%), accordingly a large part of the annual losses are due to the loss of organic, colloidal or particulate N and P. From autumn 2006 to spring 2008 the discharge was analysed for the presence of dissolved organic, colloidal and particulate N and P. Despite the fact that colloidal P was abundant in water extracts of soil samples (Koopmans et al., 2005), colloidal N and P were not detected in the discharge. Particulate N and P forms were abundant and contributed to 41% of the total N and 72% of the total P discharge. Dissolved organic forms contributed to 42% of N and 9% of the P losses.

It may be concluded that rapid discharge of water by trenches is the dominant pathway for nutrient losses on this heavy clay soil, leading to discharge concentrations which are far above environmental standards for surface water. However, large part of the N and P losses are in organic and particulate form, part of these fractions may not by bioavailable.

Koopmans, G.F., W.J. Chardon, and C.v.d. Salm. 2005. Disturbance of water-extractable phosphorus determination by colloidal particles in a heavy clay soil from the Netherlands. Journal of Environmental Quality 34:1446-1450.

POSTER 18

High losses of P to land drainage water from grassland swards despite a zero P surplus

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Phosphorus (P) inputs (wet deposition and fertilizer P) and outputs (animal product and drainflow) were studied on reseeded grazed grassland swards receiving different nitrogen (N) inputs (100 to 500 kg N ha^{-1} $year^{-1}$) for ten years at an experimental site in Northern Ireland. All plots received the same maintenance application of P fertilizer (8.5 kg P ha^{-1} $year^{-1}$) to meet grass requirements, to minimize the P surplus and to quantify the impact on P losses to land drainage water.

The annual flow weighted mean total P concentrations in drainflow ranged from 187 to 273*g P $litre^{-1}$ and were well above the concentrations believed to trigger eutrophication. Annual total P lost to drainage water ranged from 0.28 to 1.73 kg P ha^{-1}, but was unaffected by N input. As the average annual P balance was zero, there was no significant change in total P in the top 15 cm soil. However, there was a highly significant redistribution of P to the soil surface from the 10-15 cm depth, possibly as a result of root acquisition and earthworm activity. Total P in the top five cm of soil increased from 0.85 g kg^{-1} to 1.04 g kg^{-1}, over the ten years of the study, despite there being no net P input. This P accumulation in the top few cm soil is likely to exacerbate P losses in overland flow and make improvements in water quality difficult to achieve.

POSTER 19

Assessing the vulnerability of Irish aquifers to contamination by key pathogens

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Biological contamination of Irish drinking water supplies is a serious problem and a continual threat to public health. Of the 200,000 private drinking water supplies currently estimated in Ireland, 35.8% are frequently contaminated with faecal microorganisms from human and animal sources (EPA, 2007). The rapid infiltration of microbial contaminants through thin, free draining overlying soils and bedrock into aquifers is a major contributing factor to groundwater contamination, with infiltration further amplified following heavy rainfall. However, the biological monitoring of groundwater systems is challenging, since relatively few environmental pathogens can be cultivated; while tracing water flow and assessing the vulnerability of groundwater sources to contamination is difficult. To address this, a groundwater susceptibility matrix was developed and applied to identify all geological and hydrogeological factors influencing groundwater sources and rank aquifer vulnerability to microbial contamination while also incorporating pressure magnitudes and pathway characteristics. Protocols were also designed for nucleic acids-based detection of verotoxigenic E. coli (VT1 & VT2), Adenovirus (Ad41), Enterovirus (EV71) and Norovirus (G11.4) as well as Microbial Source Tracking (MST) primers to determine the source of contamination. Untreated groundwater samples were collected from vulnerable supplies bi-monthly over 24hr following intense rainfall events. Samples were subjected firstly to culture tests for the detection of total coliforms and E. coli (FIO). Two-phase tangential flow filtration was then employed to large (20-50 l) samples of water to concentrate bacterial and viral cells, with viral cells undergoing an additional adsorption-elution step. All concentrates underwent extraction of total bacterial and viral nucleic acids coupled to PCR and RT-PCR assays. Assay sensitivity and validity were determined using serial dilutions of nucleic acid extracts from targeted pathogens and applied to extracted groundwater nucleic acids. These were then assayed with primer sets targeting (i) VTEC Shiga like toxin I and II genes (stxI and stxII) (ii) host-specific primer sets targeting universal, human-associated and bovine-associated faecal Bacteroidales 16S rRNA genes (iii) degenerative primers for adenovirus, Enterovirus and Norovirus. This study observed rapid and short lived breakthrough of FIO following heavy rainfall events with counts always higher in Summer than Autumn. No VTEC were detected in groundwater supplies but assay sensitivity ranged from 1/50 dilution (stxII) to 1/400 (stxI) respectively. Universal MST primers (BacUni) detected Bacteroidales in all samples whereas human-specific primers (BacHum) and bovine-specific primers (BacCow and BoBac) detected Bacteroidales of human and bovine origin but with some cross reaction detecting sheep and horse samples. Assays sensitivity ranged from 1/100 dilution to 1/400 dilution. Although assay sensitivity for each viral assay showed high sensitivity, no viruses were detected in Irish groundwater supplies. The results from this study demonstrated that (i) specific seasonal and meterological factors influence groundwater contamination in a predictable manner (ii) MST can be applied to groundwater and (iii) although viruses and VTEC were not detected, the rapid response to aquifers to rainfall highlights their vulnerability to contamination.

POSTER 20

Grassland system management: role in the protection of underlying groundwater from health-related microbial pathogens

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Ecological and health concerns regarding water quality have provided the impetus for the development of legislative frameworks, such as WFD, for the protection of groundwater. The identification of agriculturally related diffuse pollution sources and transport pathways has become crucial in the development of management systems, and mitigation strategies, to enable Ireland to meet standards set out in regulations derived from water quality related directives. The landspreading of agricultural slurries and manures on grassland is widely used by the agricultural sector as a means of essential nutrient recycling and manure reuse. The management of landspreading practices on grassland systems can however have important implications for the quality of groundwater, as it is believed to be a significant source of diffuse pollution. In addition to nutrients, landspread agricultural faecal materials can contain a large array of microbial agents pathogenic to both humans and animals. Some of the pathogenic microorganisms applied to soil have been observed to leach through soil into groundwater, affecting drinking water quality, and posing a risk to public health. The EPA has reported that 57% of Irish groundwater sources tested in the 2004-2006 period were found to be contaminated with faecal coliforms. A range of sources of contamination have been implicated, but international evidence suggests that the landspreading of animal slurries and manures is a major contributor. This study aimed to investigate the impact of landspreading practices on the fate and transport of microbial pathogens through soil. In particular the effects of spreading time, soil type and rainfall intensities were considered. A lysimeter trial was established for this purpose, with nine replicate lysimeters for each of four soil types, representative of major drainage patterns and soil parent materials. Three lysimeters for each soil type received an application of cattle slurry at a rate of 33 tonnes per ha in summer 2006, while a further three received a similar application in spring 2007. The remaining three lysimeters per soil type were maintained as controls throughout the experimental period. The experiment was run under natural rainfall conditions. Leachate was analysed for E.coli using the Idexx Colisure MPN method. Leaching of the bacterium was observed predominantly from the poorly drained gley soil type, with low levels of bacterial contamination observed frequently in the drainage water throughout the experimental period. This indicates that soil type may be important factor in the survival of landspread pathogens. Rainfall intensity was also found to be important in the microbial quality of the leachate. Data received from this work will provide framework on which farmers can be advised on management practises to reduce diffuse pollution impacts on groundwater.

POSTER 21

The feasibility of auctions as a method for delivery of agri-environmental measures in the Lough Melvin catchment

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This research reports on the feasibility of auctions as a more cost effective policy approach than agri-environment schemes in creating incentives for farmers to conduct environmentally sensitive land management practice. Whilst agri-environment schemes are well established in agricultural policy, some research has suggested that effectiveness can be limited (Latacz-Lohmann & Schilizzi, 2005).

Lough Melvin is a cross border lake situated within the counties of Leitrim (ROI) and Fermanagh (NI). As a mesotrophic lake, the Lough and its catchment support unique fish species under threat from increasing nutrient levels (Girvan and Foy, 2006).

Given the threats to Lough Melvin and the potential problems facing standard agri-environment schemes, there is strong justification for investigating the possibility of adopting auctions to engage landholders in a program to reduce nutrient levels in Lough Melvin by modifying land use practice in the catchment.

Auctions have been successfully adopted as a voluntary land management programme in the USA since 1986 (Conservation Reserve Program) and more recently piloted at various locations in Australia. Typically, farmers submit 'bids' to a regulator outlining compensation required for implementation of approved agri-environmental measures. Those bids which offer most environmental benefit for least cost are awarded short term contracts. Through this competitive bidding process, true costs of participation are revealed resulting in a more cost efficient allocation of land management funding.

A review of relevant literature and case study schemes confirms that specific conditions in Lough Melvin appear to accommodate application of such an auction process. In order to devise a forward strategy for the implementation of auctions in the context of Lough Melvin, a number of recommendations are proposed:

1. Conduct economic experiments as the next step to test auction design, to remove uncertainty about costs and to train prospective participants.
2. Compile information to facilitate calculation of an Environmental Benefits Index that can be used to assess bids. This information would include the effectiveness of best management agricultural measures, in terms of average phosphorus reduction for each measure (Byrne et al, 2008).
3. Coordinate commitment of government departments and agencies to oversee the implementation of an auction system through devising necessary regulation and set up a Catchment Management Board to run the auctions at a local level.
4. Conduct trials to further test the auction process as whole.

Achieving this would yield Lough Melvin as an example of best practice which can be replicated across Ireland and act as a model for inclusion in catchment management in the future.

POSTER 22

A participatory approach to the development of agri-environmental measures

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In recent years stakeholder participation has increasingly become accepted as a necessary component of effective environmental policy as it helps to build consensus and ease the implementation of policy. This has been highlighted by the promotion of stakeholder participation in Article 14 of the Water Framework Directive. The implementation of agri-environmental policy has often been characterized by conflict and uncertainty due to difficulty in reaching consensus and synergy between the requirements of agricultural and environmental stakeholders. The aim of this paper is to describe the contextual and theoretical framework of the participatory approach adopted during the Lough Melvin Nutrient Reduction Programme to integrate farmers into the development of catchment specific agri-environmental measures that were developed to reduce phosphorus (P) loss to water. Farmers participated during three stages of the development of the agri-environmental measures; (1) during the development of the survey methods, (2) during the implementation of the survey, and (3) during the evaluation of the agri-environmental measures arising from the survey. This innovative participatory approach combined the objectivity of scientific research with the innate knowledge and opinions of farmers resulting in the development of agri-environmental measures that are scientifically robust while incorporating human and social factors. The participatory process also facilitated a regional approach to the development of catchment specific agri-environmental measures. The Lough Melvin project highlighted the benefits and difficulties associated with implementing such processes. There is a need to develop 'communities of practice' so that farmers can be successfully integrated into regionally specific agri-environmental research and the subsequent development of policy. 'Communities of practice' are where stakeholders engage in a process of collective learning to achieve a common goal. This requires all stakeholders, including policy makers, scientists and farmers to adopt an approach that places their role in the full socio-economic-environmental context and to acknowledge the need for synergy between protecting farmer's incomes and maintaining the good ecological status of waterbodies as required by the Water Framework Directive. The successful integration of stakeholders into the development of agri-environmental policy will facilitate a broader acceptance of such policy in the future.

POSTER 23

Spatial and temporal variation in soil water repellency in Northern Ireland grassland soils

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Soil water repellency (SWR) is a phenomenon which reduces the affinity of soils to water such that they resist wetting for periods ranging from a few seconds to weeks. Historically SWR has been associated with dry arid regions such as Australia, Spain and parts of the USA. However, more recent studies in the United Kingdom and the Netherlands have demonstrated that SWR is also of concern in more humid temperate climates such as Ireland. Climate change is predicted to have a significant impact on precipitation and soil moisture in Northern Ireland. While intense summer storms will increase, it is predicted there will be a decrease in summer precipitation of up to 50% by 2080, resulting in significant decreases in soil moisture content during the summer and autumn. It has been demonstrated that there is an inverse relationship between soil moisture and the occurrence of SWR in soils. In addition, the high organic carbon content of many grassland soils in Ireland further increases the risk of SWR occurring during periods of high soil moisture deficit. The predicted impact of climate change on SWR in grassland soils is of agronomic and environmental interested due to its potential impact on overland flow and preferential flow and hence on the vulnerability of grassland soils to nutrient losses. The aim of this research is to investigate the temporal and spatial variation in SWR in Northern Ireland grassland soils. Soil samples were collected from twenty of the major grassland soils in Northern Ireland and weekly soil samples were taken from five hydrologically isolated plots in Hillsborough. Soil Water Repellency was measured using the Water Droplet Penetration test (WDPT) and the Molarity of Ethanol Droplet (MED) test. This analysis was conducted on all samples for potential water repellency (air dried conditions) and on temporal samples for actual water repellency (field moist conditions). Analysis of the spatial data demonstrated potential SWR in half of the soils sampled, accounting for over 25% of land cover within Northern Ireland. Analysis of the temporal variation in SWR at the Hillsborough site demonstrated that it was present in the field moist samples following a prolonged dry period, however it was not present in subsequent samples following persistent rainfall over the summer months. In addition, tests for potential SWR on air dried Hillsborough soil samples indicated that SWR was present at soil moisture values below 25% soil moisture content but was not present above this value. These results demonstrate the occurrence of SWR in Northern Irish grassland soils. With the potential impact of SWR on the vulnerability of grassland soils to nutrient losses, further research is required to elucidate the impact of SWR on hydrological processes in Irish soils.

POSTER 24

Approaches for water quality prediction and management in southern Australia

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Water scarcity and impaired water quality are both significant barriers to sustainable agriculture in Australia. In Victoria, in southern Australia, a range of tools and models have been developed to assess and predict nutrient loss from farms to catchment waterways. Two examples are presented here, along with an approach that informs natural resource management policy choice in Australia.

A Nutrient Loss Index for Australian grazing industries has been incorporated into prototype web-based spatial farm management software called eFarmer. eFarmer allows assessment of the annual average risk of phosphorus or nitrogen loss from fields based on the farmer's knowledge of land characteristics, water, stock and nutrient management practices. Risk rankings for each field are presented using a 'traffic lights' map of the property. The three factors contributing most to nutrient loss are reported for each field that has a high risk of loss to help identify the most appropriate mitigation options on a field-by-field basis. Dairy farmers completed farm nutrient budgets and used eFarmer to assess nutrient loss risk in a trial natural resource management program that was led by the largest milk-co-operative in Australia. Feedback from 12 farmers identified that the maps were useful fertiliser and runoff management aids and ten of the respondents planned to improve their nutrient and waterway management practices as a result of participating in the program.

To better understand how farm management practices affect downstream water quality, a participatory modelling approach is being developed in a 3200 km^2 mixed grazing and cropping catchment in North Central Victoria. Field-scale predictions of runoff and percolation of hydrologic units were calculated with a 1-dimensional farming system model (Howleaky?) that captured changes in soil water balance and surface erosion due to land management. Predicted field-scale outputs of surplus water, soil and phosphorus loss were scaled to subcatchment level using historical stream discharge data and will be integrated with assessments of subcatchment gully erosion and point source nutrient contributions using the CatchMODS model. CatchMODS allows for routing and attenuation of soil and nutrients to the catchment outlet. The modelling methodology will applied to a beef and dairy grassland catchment in 2009. Outcomes of the eFarmer trial and farm to catchment modelling research will be used to advise and influence the way private industry, as well as government and natural resource management agencies, invest in the management of water quality in Victoria.

INFFER is a framework designed to make the most cost-effective decisions about where best to invest for environmental outcomes using available science and local knowledge (see www.inffer.org). It starts with identifying the most important publicly valued environmental assets (e.g. rivers, wetlands, biodiversity), followed by assessing threats, feasibility of intervention, and then cost-effectiveness. INFFER is underpinned by an elegantly simple public: private benefits framework which underpins the choice of policy mechanism (e.g. incentives, extension, regulation, R&D, informed inaction) when deciding whether to invest in a particular investment. INFFER is now being implemented across ten catchment regions in four states in Australia and is influencing both state and national environmental investment.

POSTER 25

The application of a dynamic catchment model to a grassland catchment in Ireland – a potentially valuable water quality management tool

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The EU Water Framework Directive (WFD) requires the achievement of 'good water quality' for all water bodies by 2015. Achieving this goal is of particular concern for agricultural grassland catchments in Ireland. Grasslands in Ireland, which provide over 90% of all agricultural land, have been identified as areas at high risk of nutrient losses to water and are the main diffuse source of phosphorous loss to surface waters. Dynamic catchment models, such as the Generalised Watershed Loading Function (GWLF), provide valuable tools for exploring nutrient dynamics in grassland catchments and for predicting nutrient losses from grasslands to water. Such models can provide long-term high resolution water quality data that are of immense importance as historical water quality monitoring datasets are usually limited or absent. Such datasets are crucial for addressing issues key to successful implementation of the WFD, including the establishment of baseline conditions for restoration of water bodies and the determination of relevant limits for pollutant loads from land to water.

This study used GWLF to simulate past nutrient and sediment loads from a west of Ireland agricultural grassland catchment (Robe, Co. Mayo) for the past c. 100 years, using a range of current and historical catchment data (climate, population, soil and landuse). The Robe catchment, the largest inflow to Lough Mask, Co.Mayo, provides the main source of nutrient inputs to the lake and has experienced significant changes in catchment pressures over the last century, including changes in human and animal population, agricultural activity and landuse. GWLF-simulated nutrient and sediment loads were validated by comparison with available measured data. Modelled and measured loads were found to compare well, thus facilitating the use of GWLF for further hindcast modelling of historical nutrient and sediment loads.

This study highlights the potential of catchment modelling, together with a range of catchment data, for application to water quality management in grassland catchments. For example, in the provision of otherwise unavailable long-term high resolution data required for the establishment of baseline water quality conditions and for setting appropriate pollutant load limits. The results indicate the value of catchment modelling to the successful implementation of the WFD. One way of ensuring this is through the incorporation of catchment modelling into River Basin District Management Plans. Catchment modelling also potentially provides a means of testing the likely effectiveness of particular programmes of measures aimed at reducing pollution impacts prior to their, often costly, implementation.

POSTER 26

Soiled water/dilute slurry on Irish dairy farms: towards economic and environmental sustainability

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Soiled water and dilute slurry are produced on Irish dairy farms through the washing-down of milking parlours and holding areas. These effluents contain nutrients that are potentially available to grass, but also pose a potential threat to water quality if not managed correctly. The EU Water Framework Directive sets targets for water quality but current management of slurries and soiled water in Ireland is regulated primarily by the Nitrate Regulations. These regulations do not distinguish between dilute slurry and more concentrated slurries. They also provide no closed periods for spreading of soiled water and no guidance for nutrient management. There is evidence to suggest that N availability from dilute slurry and soiled water may be greater than from more concentrated slurries. However, very little is known of the quantity and composition of soiled water/dilute slurry produced on Irish dairy farms. To assess this and the best management options available to farmers, a research project was initiated involving a farm survey and investigations of management options. The farm survey involves 60 dairy farms across Ireland, recording management systems and other farm characteristics and volumes and nutrient content of soiled water/dilute slurry on a monthly basis. The two management options being investigated are: 1. treatment with a wood-chip filter followed by re-use of water and land application of wood chips and 2. application to grassland. Timing, rate and concentration of effluent application are being investigated for their effect on grass growth and N uptake. Risk of nutrient loss to the environment is being investigated using soil lysimeters with two soils of contrasting drainage. Losses of N and P to water will be assessed in leachate. Gaseous losses of N and immobilisation in soil will also be assessed. The final stage of the project will involve an agronomic assessment of management options for soiled water/dilute slurry. Initial results indicate that soiled water/dilute slurry offers a potentially significant source of nutrients for grass production, particularly given the constraints in fertiliser use under the Nitrate Regulations. Initial results also suggest that wood-chip filters have potential to remove significant quantities of N through uptake in biofilms.

POSTER 27

Sediment and nutrient loss from five Irish tillage soils at a 30 mm hr^{-1} rainfall intensity

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In erosion events, nutrients can be transported from soils in surface runoff or on soil particles that are detached during erosion. Laboratory flume studies on soil slabs using a rainfall simulator provide excellent controlled conditions in which nutrient and sediment releases from soils can be examined and quantified. In this study, the nutrient and sediment releases from 5 tilled soils from Clonmel, Co. Tipperary, Letterkenny, Co. Donegal, Tullow, Co. Carlow, Bunclody, Co. Wexford, and Fermoy, Co. Cork were examined at two slopes, 10 and 15 degrees, and under a rainfall intensity of 30 mm hr^{-1}. Each rainfall simulation comprised 3 successive 1-hr rainfall events at time intervals of 1 hr and 24 hrs to determine the effects of the interval between rainfall events on the transport of soluble phosphorus (P) in runoff. Suspended sediment (SS) and nutrients in runoff water from each soil tended to decrease with consecutive simulated rainfall events. The SS and dissolved reactive phosphorus (DRP) releases were highest from the Clonmel and Tullow soils, respectively, during the first 1-hr rainfall event. Relationships between the mean weighted nutrient concentrations in the surface runoff and soil properties were investigated. These relationships could help in predicting the runoff of SS, particulate phosphorus (PP), and DRP from Irish tillage soils.

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