An Roinn Talmhaíochta,
Bia agus Mara
Department of Agriculture,
Food and the Marine

Research Stimulus Fund

Final Report

'Improving the productivity of heavy wet grassland for delivery of Food Harvest 2020. Soggyland'

DAFM Project Reference No: 11/S/152

Start date: 01/03/2013

End Date: 28/02/2018

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Collaborating Research Institutions and Researchers:
University College Dublin: Prof. Nicholas Holden, Dr. Pooja Sharma
Trinity College Dublin: Prof. Michael Williams
Teagasc, Johnstown Castle: Prof. Owen Fenton, Prof. Gary Lanigan, Dr. Tristan Ibrahim, Dr. William Burchill
Teagasc, Moorepark: Dr. Patrick Tuohy, Ms Nuria Valbuena

Please place *one* "x" below in the appropriate area on the research continuum where you feel this project fits

Basic/Fundamental →			Applied →			Pre Commercial
1	2	3	4	5	6 x	7

Please specify priority area(s) of research this project relates to from the National Prioritisation Research Exercise* (NRPE) report;

Priority Area (s)	Sustainable Food Production and Processing Systems

Key words:
Agricultural drainage, water quality, gaseous losses, land use

1. Rationale for Undertaking the Research

Producing milk from grazed grass is an important part of the Irish Economy. However, grazing on heavy wet soils can be problematical and farms with heavy wet soil have limited productivity and higher costs of production. Historically, Ireland has a low level of artificial drainage compared with other European countries. Approximately 20% of the utilizable agricultural area in Ireland has undergone artificial drainage compared with 65% in England and 74% in the Netherlands. Since the abolition of the milk quota much of the increase in milk production has come from existing dairy farms, many of which are on heavy soils in traditional dairying areas in higher rainfall parts of the country. Achieving higher productivity from farms on heavy wet soils while minimising environmental impact can make an important contribution to realising the targets set out in Food Harvest 2020.

2. Research Approach

This study used a combination of field measurements at Solohead Research Farm (plot-scale and systems-scale experiments) and modelling, including the DNDC Ecosystem Process Model, Dairy System Simulation Model (Dairy-Sim) and Life Cycle Assessment to examine the impact of artificial drainage of grassland on productivity and on environmental impact in the context of improving drainage to facilitate expansion of dairy production on poorly-drained soils.

Questions addressed by the project were:

- The role of artificial drainage in increasing the productivity and profitability of farms on heavy wet soils.
- The risk that facilitating the discharge of water from soils by artificial drainage could increase nutrient losses to aquatic systems.
- The potential of a zeolite interceptor to lower nutrient concentrations in drainage water.
- The risk that drainage could increase greenhouse gases emissions from the soil.
- The national and global implications of improving land drainage to expand dairy production in Ireland.

3. Research Achievements/Results

Improved drainage increased herbage production by up to 13%, livestock carrying capacity, the length of the grazing season and milk solids production. It shortened the housing period and costs of production. Artificial drainage lowered total annual P loss to water (by 114 g/ha) by improving infiltration of surface water, which facilitated the capture (sorption) of P in the soil. On the other hand, improved drainage increased loss of nitrate-N; increasing concentrations to 0.99 mg/L, which is very low relative to the 11.3 mg/L threshold for drinking water. Drainage also increased ammonium-N losses with concentrations of 0.64 mg/L. The installation of a zeolite interceptor has potential to lower the latter concentrations by up to 90% and to below the maximum admissible concentration for surface waters. Artificial drainage *per se* had no impact of Greenhouse

Gas (GHG) emissions from the soil and soil C storage. Modelling using the DNDC Ecosystem Process Model indicated that, in the long term, artificial drainage can significantly lower nitrous oxide emissions (an important GHG) from the soil mainly due to drier soil conditions being conducive to lower rates of denitrification. On the other hand, the expansion of milk production onto this land is increasing national GHG emissions (associated with dairy herd expansion rather than artificial drainage *per se*). From the perspective of global emissions expansion of dairy production on artificially drained soils in Ireland can have net global environmental benefits due to displacement of less efficient dairy production in other regions of the world.

4. Impact of the Research

Drainage can increase herbage production and carrying capacity of dairy cows and, hence, facilitate the expansion of dairy production on heavy wet land. Drainage has the potential to improve water quality by lowering P loss to water although it also increases the risk of nitrate losses to water from heavy soils. In general P loss to water from heavy soils is a far bigger problem than nitrate losses from such soils and the nitrate levels recorded were very low in this study. Furthermore, artificial drainage can significantly lower nitrous oxide emissions (an important GHG) from the soil in the long term. On the other hand, the expansion of milk production onto this land is increasing national GHG emissions. Expansion of dairy production would need to coincide with expansion of forestry and supplanting other agricultural land uses to maintain or lower GHG emissions from land use in Ireland. From the perspective of global emissions expansion of dairy production on poorly drained soils in Ireland can have net global environmental benefits due to displacement of less efficient dairy production in other regions of the world. It is concluded that there are many benefits associated with artificial drainage to increase national dairy output in line with Food Harvest 2020 with little or no impact of artificial drainage *per se* on GHG emissions and nutrient losses to water. Mitigating emissions associated with expansion *per se* of the national dairy herd is a challenge for policy makers.

4(a) Summary of Research Outcomes

(i) Collaborative links developed during this research

There was good collaboration between staff at Teagasc, Moorepark and Johnstown Castle, UCD and TCD during the project that has continued after the end of the project, for example, team members from Teagasc and TCD continue to work together on the Horizon 2020 True project. During the Soggyland project collaborative links were developed with Dr. Magdalena Necpalova at Department of Sustainable Agroecosystems, ETH Zurich and Tim Grant, adjunct professor at the University of Melbourne (see below).

(ii) Outcomes where new products, technologies and processes were developed and/or adopted

(iii) Outcomes with economic potential

- Artificial land drainage and appropriate grassland management can improve the profitability of dairy farms on heavy wet soils.

(iv) Outcomes with national/ policy/social/environmental potential

- Artificial drainage can increase herbage production and carrying capacity of dairy cows and, hence, facilitate the expansion of dairy production on heavy wet land and to increase national dairy output with minimal environmental impact in line with Food Harvest 2020.
- Artificial drainage has the potential to improve water quality by lowering P loss to water although it also increases the risk of nitrate losses to water from heavy soils. In general P loss to water from heavy soils is a far bigger problem in Ireland than nitrate losses from such soils and the nitrate levels recorded were very low in this study.
- Artificial drainage can significantly lower nitrous oxide emissions (an important GHG) from the soil in the long term.

4 (b) Summary of Research Outputs

(i) Peer-reviewed publications, International Journal/Book chapters.

Valbuena-Parralejo N., Fenton O., Tuohy P., Williams M., Lanigan G.J., Burchill W. and Humphreys J. (2019) Greenhouse gas emissions from temperate permanent grassland on clay-loam soil following the installation of artificial drainage. Agriculture, Ecosystems and Environment, 269, 39-50.

Valbuena-Parralejo N., Fenton O., Tuohy P., Williams M., Lanigan G.J. and Humphreys J. (2019) Phosphorus and nitrogen losses from temperate permanent grassland on clay-loam soil after the installation of artificial mole and gravel mole drainage. Science of the Total Environment, https://doi.org/10.1016/j.scitotenv.2018.12.173.

Sharma P., Humphreys J. and Holden N.M. (2018) The effect of local climate and soil drainage on the environmental impact of grass-based milk production. International Journal of Life Cycle Assessment, 23, 26-40. DOI 10.1007/s11367-017-1302-2.

Sharma P, Humphreys J, Holden N.M. (2018) Environmental impacts of alternative agricultural uses of poorly drained farm land in Ireland. Science of the Total Environment, 637–638, 120–131.

Sharma P, Humphreys J, Holden N.M. (2018) The environmental impact of dairy production on poorly drained soils under future climate scenarios for Ireland. Journal of Environmental Management, 223, 625-632.

Ibrahim, T.G., Goutelle, A., Healy, M.G., Brennan, R., Tuohy, P., Humphreys, J., Lanigan, Gary, Brechignac, J. and Fenton, O. (2015). Mixed agricultural pollutant mitigation using woodchip/pea gravel and woodchip/zeolite permeable reactive interceptors. Water Air Soil Pollution 226:51 ISSN 1573-2932 33423.

Sharma P, Humphreys J, Holden N.M. (2019) The influence of field drainage on the productivity and environmental impact of grass-based, rotational-grazing dairy production. Environmental Management (under review).

(ii) Popular non-scientific publications and abstracts including those presented at conferences

Humphreys J. and Barrett D. (2017) How much poaching is acceptable? Todays Farm, Jan-Feb, 56-58.

Humphreys J. and Barrett D. (2017) Restricting dairy cow access to pasture and milk production on a heavy wet soil. Mooepark Openday 2017; Irish Dairying – Resilient Technologies, 105-106.

Humphreys J., Phelan P., Tuohy P. and Barrett D. (2013) Farming on wet ground at Solohead, Moorepark 2013 - Irish Dairying - Harvesting the Potential, 119-121.

(iii) National Report

(iv) Workshops/seminars at which results were presented

Sharma, P., Humphreys, J., Holden, N.M. (2017). The effect of field drainage on productivity and environmental impact of grass based dairy production systems. Paper presentation in the 10th International Conference on Life Cycle Assessment in the Agri-Food Sector (LCA Food 2016), 19th to 21st October 2016, Dublin, Ireland.

Sharma, P., Humphreys, J., Holden, N.M (2017). The effect of future climate scenario on carbon footprint of milk produced in Ireland. Oral presentation in the European Meteorological Society (EMS) Annual Meeting, 4th to 8th September 2017, Dublin, Ireland.

Sharma, P., Humphreys, J., Holden, N.M. (2017). Intensification or Extensification? Environmental impacts of Irish dairy farms. Biosystems and Food Engineering Research Review 22, 2017.

Valbuena-Parralejo N., Tuohy P., Fenton O., Williams M., Lanigan G.J., Burchill W. and Humphreys J. (2016) Environmental impact of land drainage. Seminar was given to the Dairy Advisors for the Sustainable Dairy Course. Teagasc, AGRIC, Moorepark, Fermoy, Co. Cork on the 14th June 2016.

Valbuena-Parralejo N., Tuohy P., Fenton O., Williams M., Lanigan G.J., Burchill W. and Humphreys J. (2016) Environmental impact of agriculture subsurface artificial drainage. Presentation at the Moorepark Walsh Fellow student's seminar. Teagasc, AGRIC, Moorepark, Fermoy, Co. Cork on the 20th February 2016.

Sharma, P., Humphreys, J., Holden, N.M. (2016). System simulation and environmental impact assessment to define sustainable management practices for dairy farms on poorly drained land. Poster presented in Greenhouse Gas and Animal Agriculture Conference (GGAA, 2016), Melbourne, Australia.

Sharma, P., Humphreys, J., Holden, N.M. (2016). Sensitivity analysis of eutrophication impact of a typical Irish farm. Biosystems and Food Engineering Research Review 21, 2016.

Sharma, P., Humphreys, J., Holden, N.M. (2016). The effect of field drainage on productivity and environmental impact of grass based dairy production system. Paper presented in the 10th International Conference on Life Cycle Assessment in the Agri-Food Sector (LCA Food 2016), 19 – 21st October 2016, Dublin, Ireland. UCD, Dublin, Ireland.

Valbuena-Parralejo N., Fenton O., Tuohy P., Williams M., Lanigan G.J., Burchill W. and Humphreys J. (2015) The effect of mole drainage on N2O emissions from a clay-loam soil under grassland. Wageningen International Soils Conference 2015, in Wageningen, The Netherlands on the 27th August 2015.

Valbuena-Parralejo N., Fenton O., Tuohy P., Williams M., Lanigan G.J., Burchill W. and Humphreys J. (2015) The effect of mole drainage on background N2O emissions from an unfertilised clay-loam soil'. The Agriculture Research Forum 2015, in Tullamore, Co. Offaly, Ireland. The 9th March 2015.

Sharma, P., Humphreys, J., Holden, N.M. (2015). The influence of regional climate and soil drainage on global warming potential of Irish dairy farms. (Biosystems and Food Engineering Research Review 20, 2015).

Valbuena-Parralejo N., Tuohy P., Fenton O., Williams M., Lanigan G.J., Burchill W. and Humphreys J. (2014) Environmental impact of agriculture subsurface artificial drainage – materials and methods. Postgraduate symposium of the Botany Department at Trinity Collage Dublin, on the 20th February 2014.

(v) Intellectual Property applications/licences/patents

(vi) Other

Dissemination was through publication in peer-reviewed scientific journals, conference presentations and proceedings (see above). There were also presentations at in-service training for advisors, technical seminars, technical articles and the farming press. Dissemination was also via Moorepark Opendays and approximately 50 farm walks held at Solohead Research farm since the beginning of the project.

In May 2015, Nuria Valbuena was awarded a Teagasc Overseas Training Award. This consisted of one month training on DNDC and Century biochemical models at ETH Zurich, Department of Sustainable Agroecosystems. Hosted by Prof. Dr. Johan Six and Dr. Magdalena Necpalova.

In 2016 Pooja Sharma attended a course entitled "Environmental Impact Assessment of Livestock Systems" at Wagenignen University.

Between January and March 2017, Pooja Sharma spent 2.5 months working with Tim Grant, who is an adjunct professor at the University of Melbourne and director of a company called Lifecycles in Melbourne, http://www.lifecycles.com.au. He is also the President of Australian Life Cycle Assessment Society http://www.alcas.asn.au/contact-us.

Pooja Sharma was awarded 'The Austin Bourke Bronze Medal' for or a recent significant contribution to Irish agrometeorology, applied environmental meteorology, biometeorology or a related discipline. She was presented with the award at the Inaugural Tom Keane AGMET Lecture, on 5th Sep 2017 at the National Botanic Gardens (http://agmet.ie/bronze-medal-winner/)

5. Scientists trained by Project

Total Number of PhD theses: 2

Pooja Sharma, UCD School of Biosystems and Food Engineering. Thesis title: System Modelling and Life Cycle Assessment of Dairy Production on Poorly Drained Soils in Ireland. Pooja Sharma has been awarded a PhD degree

Nuria Valbuena, TCD. Thesis title: The impact artificial sub-surface drainage on greenhouse gas emissions, change in soil carbon storage and nutrient losses from grassland. Nuria Valbuena passed her viva 7 June 2019 and will be awarded a PhD degree in due course.

Total Number of Masters theses: 0

Please include authors, institutions and titles of theses and submission dates. If not submitted please give the anticipated submission date

6. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (person years)
Teagasc Moorepark	6	6.663
Teagasc Johnstown	4	0.543
UCD	1	0.695
TCD	1	0.300
Total		

7. Researchers Funded by DAFM

Type of Researcher	Number	Total Time contribution (person years)
Post Doctorates/Contract Researchers	0	0
PhD students	4	10.417
Masters students	0	0
Temporary researchers	0	0
Other	0	0
Total		

8. Involvement in Agri Food Graduate Development Programme

N.A

9. Project Expenditure

Total expenditure of the project:	€449,031.36
Total Award by DAFM:	€519,925.00
Other sources of funding including benefit in kind and/or cash contribution(specify):	€0

Breakdown of Total Expenditure

Category	Teagasc Moorepark	Teagasc Johnstown Castle	UCD	TCD	Total
Contract staff	0.00	0.00	0.00	0.00	0.00
Temporary staff	0.00	0.00	0.00	0.00	0.00
Post doctorates	0.00	0.00	0.00	0.00	0.00
Post graduates	68,227.65	74,925.56	86,599.97	0.00	229,753.18
Consumables	20,213.59	5,109.32	3,008.92	331.00	28,662.83
Travel and subsistence	1,539.43	4,171.33	5,422.03	0.00	11,132.79
Sub total	89,980.67	84,206.21	95,030.92	331.00	269,548.80
Durable equipment	0.00	0.00	1,474.77	0.00	1,474.77
Other	69,438.15	27,205.00	500.00	0.00	97,143.15
Overheads	26,994.20	25,261.86	28,509.28	99.30	80,864.64
Total	**186,413.02**	**136,673.07**	**125,514.97**	**430.30**	**449,031.36**

10. Leveraging

N.A

11. Future Strategies

Results from this project have been included in the Teagasc MACC report (https://www.teagasc.ie/media/website/publications/2018/An-Analysis-of-Abatement-Potential-of-Greenhouse-Gas-Emissions-in-Irish-Agriculture-2021-2030.pdf; page 29) and in Teagasc land drainage theory and design training courses for farmers, contractors and advisors (https://www.teagasc.ie/about/our-organisation/connected/professional-education/agricultural-land-drainage/). Since the completion of the Soggyland project (11/S/152) we have been working on developing systems of dairy production with very low GHG emissions, with a target of 50% of the national average litre of milk. Land drainage is a component of the system in that increase herbage production and significantly lower nitrous oxide emissions. The methods used in task 5 of Soggyland project are being refined and improved for use in future similar research projects.