Project number: 5783
Funding source: RSF07-516
Date: September 2012
Project dates: Dec 2007 – Feb 2012

Quantification of the potential of white clover to lower GHG emissions from Irish grassland-based dairy production

Key external stakeholders:

Policy makers, milk processors, such as Carbery group, and the research community. This project was closely linked to international collaborative projects: Interreg IVB Dairyman and FP7 Legume Futures and FP7 Cantogether. The project entitled 'Carbery Greener Dairy Farms' funded by Carbery group was also initiated as a consequence of the present project.

Practical implications for stakeholders:

The inclusion of white clover in grassland can maintain high productivity and profitability while substantially lowering greenhouse gas emissions from pasture-based dairy production

Main results:

- N_2O emissions due to biological N fixation (BNF) in permanent ryegrass/white clover grassland were negligible indicating that BNF is not an important source of N_2O. These results support the exclusion of BNF as a direct source of N_2O from the IPCC methodology.
- Annual N_2O emissions from the two clover based systems were much lower (20 to 23%) than from the fertilized N system.
- The process-based DNDC model simulated N_2O fluxes reasonably well when compared with the measured values.
- The results of the LCA of systems at Solohead Research Farm showed that the white clover-based systems (WC) had 11 to 26% lower carbon footprint (CF) compared with the fertilizer N-based systems (FN) (average CF was 0.86 to 0.89 and 1.00 to 1.16 kg CO_2 eq/kg Energy Corrected Milk (ECM).
- In the study of 18 commercial dairy farms, large variation was found in farm attributes and management tactics. The overall CF of the milk production from the 18 dairy farms was 1.23 ± 0.16 kg CO_2 eq/kg ECM. Effective sward management of clover within a few farms lowered the CF.

Opportunity / Benefit:

- The inclusion of white clover in grassland can maintain high productivity and profitability while substantially lowering greenhouse gas emissions from pasture-based dairy production. Both the measured and simulated results supported that there was a clear reduction of greenhouse gas emissions when fertilizer N was replaced by biological N fixation.

Collaborating Institutions:

University College Dublin

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Teagasc project team: Dr. James Humphreys (PL)
Dr. Gary Lanigan
External collaborators: Dr. Dejun Li, University College Dublin and The University of Oklahoma
Dr. Mingjia Yan, University College Dublin
Professor Nick Holden, University College Dublin

- **Project background:**

- Agriculture is the single largest contributor to greenhouse gas (GHG) emissions in Ireland accounting for nearly 27% of national emissions. Emissions are primarily determined by livestock numbers and mineral fertilizer N (FN) use on farms. Ireland, as a member of the European Union (EU), is committed to a 20% reduction in emissions by 2020 relative to 1990 and achieving this target poses a substantial challenge.
- Rhizobia bacteria in association with white clover have the capacity to produce plant-available N in the soil via biological N fixation (BNF), which can replace FN in grassland resulting in lower direct and indirect emissions of nitrous oxide from grassland and thus GHG emissions from pasture-based dairy production. However, there is uncertainty about the potential reduction of soil N_2O emission when FN is partially or completely replaced by BNF in temperate grassland. Furthermore, there is uncertainty about the impact of replacement of FN by BNF on overall GHG emissions from pasture-based dairy production, both on farm and pre-farm (associated with the manufacture of fertilizer N, for example).

1. Questions addressed by the project:

- Quantify changes in N_2O emissions when BNF is used to replace FN in permanent grassland and evaluate the applicability of the process-based model DNDC to simulate N_2O emissions from Irish grasslands.
- To determine, using LCA, the difference in GHG emissions between BNF and FN-based systems of dairy production on the clay loam soil at Solohead
- To determine, using LCA, the change in GHG associated converting from FN-based to white clover-BNF-based grassland on commercial dairy farms in Ireland.

3. The experimental studies:

- The experiment to quantify changes in N_2O emissions when BNF is used to replace FN in permanent grassland was a randomized block design with five treatments and three replicates. The treatments were: 1) grazed perennial ryegrass (*Lolium perenne*) paddocks receiving 226 kg FN ha^{-1} yr^{-1} (GG+FN), 2) grazed ryegrass/white clover (*Trifolium repens*) paddocks receiving 58 kg FN ha^{-1} yr^{-1} (GWC+FN), 3) grazed ryegrass/white clover paddocks receiving no FN (GWC-FN), 4) perennial ryegrass plots (G-B) and 5) ryegrass/white clover plots (WC-B). G-B and WC-B were not grazed and did not receive slurry or FN and herbage was harvested by mowing. The area of these paddocks ranged from 0.32 to 1.63 ha. The dimension of each plot was 10m × 10m. Paddocks were rotationally grazed by dairy cows with stocking densities of 2.1 cows ha^{-1} for GG+FN and GWC+FN, and 1.6 cows ha^{-1} for GWC-FN. N_2O fluxes were measured weekly using the static chamber method between October 2009 and September 2010. In addition to measurements, the DNDC model was used to simulate N_2O emissions (DNDC 9.3).
- Life-Cycle Assessment (LCA) was used to determine the difference in GHG emissions between BNF and FN-based systems of dairy production on the clay loam soil at Solohead Research Farm. Data were sourced from two system-scale studies conducted at Solohead Research Farm in Ireland between 2001 and 2006. Ten FN stocked between 2.0 and 2.5 livestock units (LU) ha^{-1} with fertilizer N input between 173 and 353 kg ha^{-1} were compared with six WC stocked between 1.75 and 2.2 LU ha^{-1} with fertilizer N input between 79 and 105 kg ha^{-1}.
- Life-Cycle Assessment (LCA) was used to determine the contribution of white clover-BNF and other tactical management on 18 commercial dairy farms in Ireland to GHG emissions. This study was based on foreground data from a twelve month survey capturing management tactics and background data from literature.

4. Main results:

- N_2O emissions due to biological N fixation (BNF) in permanent ryegrass/white clover grassland were

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negligible indicating that BNF is not an important source of N_2O. These results support the exclusion of BNF as a direct source of N_2O from the IPCC methodology.

- Annual N_2O emissions from the two clover based systems were much lower (20 to 23%) than from the fertilized N system.
- The process-based DNDC model simulated N_2O fluxes reasonably well when compared with the measured values.
- The results of the LCA of systems at Solohead Research Farm showed that the white clover-based systems (WC) had 11 to 26% lower carbon footprint (CF) compared with the fertilizer N-based systems (FN) (average CF was 0.86 to 0.89 and 1.00 to 1.16 kg CO_2 eq/kg Energy Corrected Milk (ECM).
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5. Opportunity/Benefit:

- The inclusion of white clover in grassland can maintain high productivity and profitability while substantially lowering greenhouse gas emissions from pasture-based dairy production. Both the measured and simulated results supported that there was a clear reduction of greenhouse gas emissions when fertilizer N was replaced by biological N fixation.

6. Dissemination:

International conferences

Li DJ, Lanigan G, Humphreys J, (2011) Use of white clover to lower soil N_2O emissions from temperate moist grassland, Oral presentation at the 'Nitrogen & Global Change' conference, Edinburgh, UK, April 11-14, 2011.

Yan, M.-J, Humphreys, J. and Holden, N.M.(2012) Carbon footprint of Irish milk production. 8th International Conference on LCA in the Agri-Food Sector, Rennes, France, 2-4 October 2012 (in press).

Yan, M-J., Humphreys, J. and Holden, M.N. (2010) Life cycle comparisons of greenhouse gas emissions from pasture-based dairy production of Ireland. Proceedings of VII International conference on Life Cycle Assessment in the agri-food sector Bari, September 2010, 22-24.

Yan M., Humphreys J., Holden N.M. (2009) LCA studies: how comparable are they? Examples of milk production in Europe, New Zealand and Canada. Oral presentation at the 2nd Chinese Conference on Life Cycle Management, Nov 15-16, 2009. Beijing, China.

Yan M.-J., Humphreys J., Holden N. M. (2009) Life cycle comparisons of greenhouse gas emissions from pasture-based dairy production in Ireland. *Irish Journal of Agricultural and Food Research*, 48, 275.

International workshops and seminars

Yan, M-J., Humphreys, J. and Holden, N.M. (2012) Carbon footprint of Irish milk production. In: Proceedings from 17th international Nitrogen Workshop, 26-29 June 2012, pages 404-405. (Oral presentation).

Yan, M-J., Humphreys, J. and Holden, N.M. (2012) Carbon footprint of Irish milk production: can white clover make a difference? In: Proceedings from 17th international Nitrogen Workshop, 26-29 June 2012, pages 409-410.

Yan, M-J., Humphreys, J. and Holden, N.M (2012) Carbon footprint of Irish milk production. Oral presentation at the annual meeting of American Society of Agricultural and Biological Engineers (ASABE), Jul 29 - Aug 1st 2012, Texas, USA

Yan M., Humphreys J., Holden N.M. (2010) Methods and results of research on GHG emissions from dairy farms in Ireland. Invited speech at EGF (European Grassland Federation) pre-conference workshop 'Green effects of dairy farming', August 29, 2010, Kiel, Germany.

National Conferences and seminars

Humphreys, J., Li D, Yan M, Lalor, S., Hyde, B., Lanigan, Gary, Holden, N. and Watson, C. (2010). The role of N-efficiency in lowering nitrous oxide emissions from agriculture in Ireland. In: Proc. 'A Climate for Change' - Opportunities for carbon efficient farming, Mansion House, Dublin, 24-Jun-2010, p23-24.

Li, D., Lanigan G. and Humphreys J. (2011) Use of white clover to lower soil N_2O emissions from temperate moist grassland. *Agricultural Research Forum*, page 68. The Tullamore Court Hotel, 14-Mar-2011.

Yan, M-J., Humphreys, J. and Holden, N.M. (2012) Life Cycle Assessment of Irish milk production. Oral presentation at 2012 Sino-European Symposium on Environment and Health (SESEH), Page 54. August 20 - 25, 2012, Galway, Ireland.

Yan M.-J., Humphreys J., Holden N. M. (2011) Life cycle comparisons of greenhouse gas emissions from pasture-based milk production of Ireland. Agriculture Research Forum. 14th-15th March 2011. *Agricultural*

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Research Forum, page 65. The Tullamore Court Hotel, 14-Mar-2011.
Yan M., Humphreys J., Holden N.M. (2009) Reducing the carbon footprint of Irish dairy farming. Poster presented at AgMet Group 25th Anniversary meeting, Dec 7, 2009, Dublin, Ireland.

Open Days

There were presentations about tasks 1 and 2 of this project at the international conference entitled 'Forage Legumes in Temperate Pasture-based systems' conference visit to Solohead farm on 16 October 2009.
There was a presentation about this project at the Teagasc Agri-environment Conference 2010 which took place on 7 September in Ballykisteen Hotel, Tipperary with a visit to Solohead Research Farm in the afternoon.
Three presentations about this project were made at the Fourth General Meeting of the Dairyman project which visited Solohead Research Farm and two of the dairy farms involved in this project on 19 April 2011

Farmer discussion groups

Presentation of the results of this project was made to the dairy farmers involved in this project at Moorepark Research and Innovation Centre on 12 April 2011 and on 24 July 2012.
Many farmer discussion group visits to Solohead Research Farm during this experiment.

Main publications:

Li DJ, Lanigan G, Humphreys J, 2011, Measured and simulated nitrous oxide emissions from ryegrass- and ryegrass/white clover-based grasslands in a moist temperate climate. *Plos One*, doi: 10.1371/journal.pone.0026176.
Yan M-J., Humphreys J. and Holden N.M. (2011) An evaluation of life cycle assessment of European milk production. *Journal of Environmental Management*, Volume **92**, Issue 3, 372-379.
Yan, M.-J., Humphreys, J., Holden, M.N. The carbon footprint of pasture based milk production: can white clover make a difference? Submitted to Journal of Dairy Science
Yan, M.-J., Humphreys, J., Holden, M.N. LCA of milk production from commercial dairy farms: the influence of management tactics. Submitted to Journal of Dairy Science.

7. Compiled by: Dr James Humphreys

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