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

# Research Stimulus Fund

## Final Report

**'Defining optimal pasture composition and its relationship with management factors in order to maximise dairy and beef productivity, whilst minimising nitrous oxide emissions (urine N output), methane emissions and product quality'**

**DAFM Project Reference No:** 11/S/105

**Start date:** 01/01/2013

**End Date**: 28/02/2018

**Principal Coordinator and Institution:** Dr. Aidan Moloney, Teagasc
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**Collaborating Research Institutions and Researchers:**
Teagasc: Dr. Aidan Moloney, Dr. Padraig O'Kiely, Dr. Mark McGee, Dr. Paul Cormican, Dr. Richard Dewhurst

University College Dublin: Dr. Bridget Lynch, Dr. Tommy Boland

Agri-Food and Biosciences Institute, Northern Ireland: Dr. Tianhai Yan

Queens University, Belfast: Dr Niamh O'Connell

**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 | 4X | 5 | 6 | 7 |
|---|---|---|---|---|---|---|

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

| **Priority Area (s)** | I Sustainable Food Production and Processing |
|---|---|

**Key words:** *Grass, nitrogen, beef, dairy*

## 1. Rationale for Undertaking the Research

The efficiency of converting herbage protein into milk and meat protein is central to efficient and sustainable milk and beef production systems. This requires new understanding of the effects of grassland management on herbage composition and subsequently, on nitrogen (N) losses to the environment and greenhouse gas (GHG) emissions. This information could be incorporated into farm practice, as well as into models of GHG emissions used for Ireland's GHG inventory. The challenge for Ireland is to intensify production in pasture-based systems, exploiting a major competitive advantage, while minimizing environmental impacts. The major problem with this 'intensification' will be increased herbage N content: associated with improvements in grazing management, increased N fertiliser use, and the use of legumes to increase productivity. The combination of increased stocking rates and herbage N concentration results in a large increase in urine N excretion per hectare, leading to increased nitrate leaching potential and nitrous oxide emissions. It is important therefore to identify grassland management strategies that maximise herbage intake and animal productivity, without increasing urine N. The main objectives of this project were to:

- Identify and test animal, diet and other management factors that affect N partitioning, urine N output and urine N concentration in dairy and beef cattle.
- Model the effect of management changes designed to reduce urine N output and urine N concentration in dairy cows using data from full lactations.
- Incorporate findings from the project into whole-farm models of GHG emissions.

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## 2. Research Approach

- Datasets from previous studies were assembled and interrogated to understand influences on herbage composition (*what other feed components change when herbage N alters? how are these relationships affected by management?*) and herbage intake (*how does herbage N affect feed intake?*).
- Datasets were also assembled and interrogated on N partitioning data from animal studies with conserved grass/concentrates to identify *what factors affect the quantity and concentration of N in urine?*.
- The outcome of these desk-based studies guided experiments undertaken with lactating cows (Hillsborough) and beef cattle (Grange) offered grazed grass. Approaches included variations in grassland management, concentrate supplementation, N balance and methane production *in vivo* (Hillsborough) and *in vitro* (Grange) measurement.
- Equations were derived to allow prediction of urinary N losses in dairy cows based on milk urea N concentrations. These equations were applied to three different studies in which the data were available for a full lactation.
- Data from the project were incorporated into a modified model of GHG emissions.

In the course of the project and in consultation with the project team, the following modification was approved: Rather than on-farm studies to collect urine and predict N losses, refined equations were developed based on published literature and "in-house" datasets. These models were used to predict urine N excretion of dairy cows using 3 full lactation datasets of dairy cows obtained from the Agri-Food and Biosciences Institute and Teagasc.

## 3. Research Achievements/Results

The main grassland management factors that influenced herbage digestibility and crude protein concentration were:

- cutting regime
- harvest season
- length of regrowth and
- fertiliser N application rate

Fertiliser N application rate and length of regrowth are more practical tools for altering herbage composition. The requirement to balance herbage yield and 'quality' restricts the extent to which stage of growth can realistically be utilised to manipulate grass composition in practice.

Regression equations were derived to relate grass nutritional composition and intake with urine volume, urinary N concentration and urinary N output. N intake was the principal factor in predicting daily urinary N excretion.

*In vivo* (animal) experiments examining the effects of fertiliser N application rate to pasture on N metabolism in zero-grazed beef cattle for autumn, spring and summer pasture and the effects of carbohydrate supplementation on N excretion in zero-grazed beef cattle showed that reducing fertiliser N application rate to temperate grass and supplementing grass with a low-protein, high-energy feed are strategies to reduce total and urinary N excretion. These findings are supported by *in vitro* studies using rumen simulation fermenters.

Reducing N concentration of the supplementary concentrate may be a successful method of reducing urinary N excretion of lactating dairy cattle on pasture-based systems.

A zero-grazing experiment investigated the effect of white clover (WC) inclusion on performance, nutrient digestibility and N utilization of lactating dairy cows fed fresh perennial ryegrass *ad libitum* and low crude protein concentrates. The data indicate inclusion of WC at 200g/kg of dry matter intake may sustain milk production with no adverse effect on N utilization efficiency of lactating dairy cows when offered in combination with low CP concentrates and good quality fresh perennial ryegrass.

Equations have been developed to predict urine N excretion using milk urea N as sole predictor or in combination with dietary N content. Modelling of urinary N loss in full lactation studies using these equations showed: little effect of breed or multiparous cows; inclusion of white clover in grass pasture can reduce urine N per kg energy corrected milk yield; increasing stocking rate and concentrate input can increase urine N per kg energy corrected milk yield.

## 4. Impact of the Research

A wide range of strategies, combining compilation and synthesis of existing data and the generation of new data, to decrease N losses to the environment and increase N use efficiency in dairy and beef cattle were examined in this project. The main implications are: Intensification of pasture-based production of milk and meat may increase urine nitrogen (N) loss leading to increased nitrate leaching potential and nitrous oxide emissions.

- Equations have been developed to allow prediction of N losses from cattle in pasture-based production systems.
- Decreasing N consumption seems to be the most effective strategy for deceasing N losses to the environment.

The main stakeholders/end users of the information from this project are beef farmers, Environmental regulatory agencies, policy makers, Teagasc advisory service, agri-consultants and scientific community.

### 4(a) Summary of Research Outcomes

(i) Collaborative links developed during this research

Excellent collaborative links were formed in the course of the project. This was facilitated by the inclusion of three research performing organisations from two jurisdictions in the project team. Personnel spent time in the various institutions. In addition, further collaboration across research sites in Teagasc and across departments within UCD were developed within the project. Regular meetings across locations facilitated excellent collaboration and co-ordination. Selected publications from the project were collaborative.

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

The project did not set out to develop a new product *per se*. Equations derived from this project can be used to estimate urinary N loss to the environment from grazing cattle. Dietary management strategies to mitigate these losses can be identified and recommended from application of these equations.

(iii) Outcomes with economic potential

The output of the project is exploitable by farmers to ensure environmentally-friendly production of Irish milk and beef. The Irish food sector needs to target high value markets through increased value-added output. Production methods are of increasing concern to consumers but can also be part of "value-added". It is therefore essential that the perception of grass-based production systems as environmentally friendly is underpinned by science. This project has contributed to that objective.

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

The health of the environment *per se* is of increasing concern to citizens. This is influencing national and EU policy on issues such as abatement of GHG emissions from ruminant agriculture production in particular. The information and tools produced within this project expand the relevant knowledge and should assist in future policy formation. The AFBI data were used to update manure N excretion in dairy cows and the outcome has been implemented in the Northern Ireland Nutrient Action Programme 2019-2022.

**4 (b) Summary of Research Outputs**

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

***Acceptable Format:*** ***Walsh, D.R., Murphy, O., Cosgrave, J. (2008). Echinococcosis - an international public health issue. Research in Veterinary Science 774, 891-902.***


1. Stergiadis, S., Allen, M., Chen, X.J., Yan, T. (2015). Prediction of nutrient digestibility and energy concentrations in fresh grass using nutrient composition. Journal of Dairy Science 98, 3257-3273.
2. Stergiadis, S., Chen, X.J., Allen, M., Wills, D., Yan, T. (2015). Evaluating nitrogen utilization efficiency of nonpregnant dry cows offered solely fresh cut grass at maintenance levels. Journal of Animal Science 93, 709-720.
3. Stergiadis, S., Allen, M., Chen, X.J., Yan, T. (2015). Prediction of metabolisable energy concentrations using digestibility data measured with non-pregnant dry cows. British Journal of Nutrition 113, 1571-1584.
4. Hynes, D. N., Stergiadis, S., Gordon, A., Yan, T (2016). Effects of concentrate crude protein contents on nutrient digestibility, energy utilization and methane emissions of lactating dairy cows fed fresh-cut perennial grass. Journal of Dairy Science, 99, 8858–8866.
5. Hynes, D. N., Stergiadis, S., Gordon, A., Yan T. (2016). Effects of nitrogen levels in concentrate supplements on animal performance and nitrogen utilization of lactating dairy cows fed fresh-cut perennial grass. Journal of Dairy Science 99, 8111–8120.
6. Stergiadis, S., Zou, C.X., Chen, X.J., Allen, M., Wills, D., T. Yan, T. (2016). Equations to predict methane emissions from cows fed at maintenance energy level in pasture-based systems. Agriculture, Ecosystems & Environment 220, 8-20.

7. Stergiadis, S., D. N. Hynes, D.H., A. L. Thomson, A.L.., K. E. Kliem, K.E., C. G. B. Berlitz,G.B., M. Günal, M.,Yan, T. (2018). Effect of substituting fresh-cut perennial ryegrass with fresh-cut white clover on bovine milk fatty acid profile. Journal of the Science of Food and Agriculture, 98, 3982-3993.
8. Herron, J., Curran, T., Moloney, A.P., O'Brien, D. (2019). Whole farm modelling the effect of grass silage harvest date and nitrogen fertilizer rate on nitrous oxide emissions from grass-based suckler to beef farming systems. Agricultural Systems, 175, 66-78.
9. O'Connor, A., McGee, M., Moloney, A., Boland, T., O'Kiely, P. (2019). Digestion and N metabolism in beef cattle and *in vitro* rumen fermentation of autumn grass differing in fertilizer N application rate. Grass and Forage Science, 74, 535–547.
10. O'Connor, A., Moloney, A., O'Kiely, P., Boland, T., McGee, M. (2019).Effects of fertiliser nitrogen rate to spring grass on apparent digestibility, nitrogen balance, ruminal fermentation and microbial nitrogen production in beef cattle and *in vitro* rumen fermentation and methane output. Animal Feed Science and Technology, 254, 114198.
11. Hynes, D. N., Stergiadis, S., Gordon, A., Günal, M. Yan, T (2020). Effects of fresh white clover inclusion on animal performance, nutrient digestibility and nitrogen utilization of lactating dairy cows fed fresh perennial ryegrass and concentrates. Animal (Submitted)
12. Herron, J., Hennessy, D., Curran, T., Moloney, A.P., O'Brien, D (2020).The simulated environmental impact of incorporating white clover into grass-based dairy production systems. Journal of Dairy Science (Submitted).

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

1. Hynes, D., Stergiadis, S., Yan, T. (2014). Prediction of dry matter intake by beef steers fed grass silage only diets. In: Book of Abstracts of the 65th Annual Meeting of the European Federation of Animal Science, p427, Wageningen Academic Publishers, Wageningen, The Netherlands.
2. Stergiadis, S.,Yan, T. (2014). Prediction of manure nitrogen output from dry cows fed freshly cut grass. In: Book of Abstracts of the 65th Annual Meeting of the European Federation of Animal Science, p415, Wageningen Academic Publishers, Wageningen, The Netherlands.
3. Yan, T. (2015). Manipulating diet nitrogen content to reduce urine nitrogen excretion in lactating dairy cows. In: Book of Abstracts of the 66th Annual Meeting of the European Federation of Animal Science, p525, Wageningen Academic Publishers, Wageningen, The Netherlands.
4. Stergiadis, S., Allen, M.,Chen, X.J.,Wills, D., Yan, .T (2015). Equations to predict grass metabolisable energy in pasture-based systems. In: Book of Abstracts of the 66th Annual Meeting of the European Federation of Animal Science, p336, Wageningen Academic Publishers, Wageningen, The Netherlands.

5. Hynes, D., Stergiadis, S., Yan, T. (2015). Reducing nitrogen output from zero-grazed lactating cows by using low-protein concentrates. Journal Veterinary Science and Technology, 6: 5 http://dx.doi.org/10.4172/2157-7579.C1.010.
6. Hynes, D., Stergiadis, S., O'Connell, N.E., Yan, T. (2015). Prediction of methane emissions from lactating dairy cows fed fresh cut grass and concentrates. In: The proceedings of the Annual Meeting of British Society of Animal Science, p145, Chester, UK.
7. Stergiadis, S., Allen, M.M., Chen, X.J., Yan, T. (2015). Predicting grass digestible and metabolisable energy contents from chemical composition. In: The proceedings of the Annual Meeting of British Society of Animal Science, p111, Chester, UK.
8. Stergiadis, S., Zou, C., Chen, X., Allen, M., Wills, D., Yan T. (2016). Equations to predict methane emissions in pasture-based systems. In: Book of Abstracts of the 67th Annual Meeting of the European Federation of Animal Science, p328, Wageningen Academic Publishers, Wageningen, The Netherlands.
9. Hynes, D., Stergiadis, S., O'Connell, N.E., Yan, T. (2016). Effects of concentrate nitrogen levels on production performance and nutrient digestibility of lactating dairy cows fed fresh grass and concentrate diets. In: The proceedings of the Annual Meeting of British Society of Animal Science, p116, Chester, UK.
10. Yan, T. (2016). Life cycle assessment models for prediction of dairy farm GHG emissions using Tiers 2 and 3 methods. In: Book of Abstracts of the 67th Annual Meeting of the European Federation of Animal Science, p239, Wageningen Academic Publishers, Wageningen, The Netherlands.
11. O'Connor, A., Moloney, A. P., O'Kiely, P. Nolan, P., T. Boland,T., McGee, M. (2016). In vitro rumen fermentation and methane output of autumn grass fertilised at two rates of nitrogen In: Book of Abstracts of the 67th Annual Meeting of the European Federation of Animal Science, p468, Wageningen Academic Publishers, Wageningen, The Netherlands.
12. Stergiadis, S., Hynes, D.N., Thomson, A.L., Kliem, K.E. Berlitz, C.G.B Yan, T. (2017). Fatty acid profile of milk from cows fed diets based on fresh-cut white clover. In: Book of Abstracts of the 68th Annual Meeting of the European Federation of Animal Science, p441, Wageningen Academic Publishers, Wageningen, The Netherlands.
13. O'Connor, A., Moloney, A.P., O'Kiely, P., Boland, T., McGee, M. (2017). Digestibility and nitrogen balance in beef cattle offered autumn grass herbage differing in fertiliser nitrogen application rate. Proceeding of British Society of Animal Science Annual Conference, Chester, UK. p124.
14. Herron, J., Moloney, A.P., Curran, T.P. (2017). Whole farm modelling of management factors affecting nitrous oxide emissions from livestock production systems In: Proceedings of Environ 2017, Athlone, 10th-12th April.
15. Herron, J., Curran, T.P., Moloney, A.P., O'Brien, D. (2017). Whole farm modelling of management factors affecting nitrous oxide emissions from livestock production systems. In: Proceedings of Ramiran "Sustainable Utilisations of Manures and Residue resources in agriculture. Wexford, 4th- 6th September, p161.

16. O'Connor, A., Moloney, A.P., O'Kiely, P., Boland, T., McGee, M. (2018). Intake, digestion and nitrogen balance in beef cattle offered grass herbage supplemented with citrus pulp. Proceedings of American Society of Animal Science.
17. O'Connor, A., Moloney, A.P., O'Kiely, P., Boland, T., McGee, M. (2018). Nitrogen balance in beef cattle offered mid-season grass herbage fertilised with two rates of nitrogen. Proceedings of American Society of Animal Science.
18. O'Connor, A., Moloney, A.P., O'Kiely, P., Boland, T., McGee, M. (2018). Effects of nitrogen fertiliser application rate to spring grass on intake, digestion and nitrogen balance in beef cattle Proceedings of British Society of Animal Science, Chester, UK, p106.
19. Herron, J., Curran, T.P., Moloney, A.P., O'Brien, D. (2018). Effect of silage harvest date and fertilizer rate on modelled N2O and total greenhouse gas emissions from pasture based suckler beef systems Proceedings 27th European Grassland Federation meeting, Cork, 17-21June.

(iii) National Report

Moloney, A.P. (2019). Technology update, Teagasc

(iv) Workshops/seminars at which results were presented

1. Yan, T. Staff update - Stimulus funding project. AFBI Hillsborough Scientific Seminar.22/03/2013.
2. Stergiadis, S. Basic ruminant nutrition and environmental issues facing livestock production. Agri-Food and Biosciences Institute Open Day for Portadown College students.11/04/2014.
3. Hynes, D., Stergiadis, S., Yan, T. Improvement of efficiencies of nitrogen utilisation to reduce greenhouse gas emissions in dairy production. International Global Food Security Symposium. 28/05/2014.
4. Stergiadis, S. Ruminant basic nutrition and production in Northern Ireland: environmental issues and current research in AFBI Hillsborough Agri-Food and Biosciences Institute Open Day for Greenmount College students 28/11/2014
5. Stergiadis, S. Prediction of manure nitrogen output from dry cows fed freshly cut grass Agriculture Branch Seminar Day 05/12/2014.
6. Hynes, D., Stergiadis, S., N O'Connell, N., Yan, T. PhD project: The improvement of nitrogen utilisation efficiencies to reduce greenhouse gas emissions in lactating dairy cattle. R Workshop, in Poland 2015.
7. Stergiadis, S., Allen M., Yan, T.AFBI Research provides new insights on the feeding value of grass. United News. 01/05/2015.
8. Hynes, D. The improvement of nitrogen utilisation efficiencies to reduce greenhouse gas emissions in lactating dairy cattle. EU COST Project -METHAGENE workshop, Poland, 01/09/2015.

9. O'Connor, A, Moloney, A.P., McGee, M. ExcessN project outline. Grange Beef Open Day.05/072016
10. Zhao, Y.G., Hynes D., Yan, T. Reducing the environmental impact of dairy cattle, AFBI On-farm dairy events, 12-14/09/ 2017.
11. Herron, J. Whole farm modelling the effect of grass silage harvest date and nitrogen fertilizer rate on nitrous oxide emissions from grass-based suckler to beef farming systems. School of Biosystems and Food Engineering research day, UCD. 20/03/2018.

(v) Intellectual Property applications/licences/patents

No intellectual property has arisen from the project.

(vi) Other

N/A

## 5. Scientists trained by Project

Total Number of PhD theses: 2

- Deborah Nicola Hynes (Queens University, Belfast). "Effects of dietary protein level and source on milk production, nitrogen and energy utilisation and methane emissions of zero-grazed dairy cows" (Submitted 2016)

- Alan O'Connor (UCD). "Reducing urinary nitrogen excretion by grass-fed beef cattle" (Submitted 2018).

Total Number of Masters theses: 1(1)

- Denise Williams (UCD.) "Optimising herbage composition to maximise production of milk and meat output relative to urine nitrogen output" (Submitted 2016)

- Jonathan Herron (UCD). "Whole farm modelling of management factors affecting nitrous oxide emissions from livestock systems" Transferred to PhD programme funded by Teagasc (see Section 10).

## 6. Permanent Researchers

| Institution Name | Number of Permanent staff contributing to project | Total Time contribution (person years) |
|---|---|---|
| Teagasc | 8 | 1.79 |
| UCD | 2 | 0.30 |
| AFBI | 4 | 2.80 |
| **Total** | **14** | **4.89** |

## 7. Researchers Funded by DAFM

| Type of Researcher | Number | Total Time contribution (person years) |
|---|---|---|
| Post Doctorates/Contract Researchers | 2 | 3.22 |
| PhD students | 2 | 6.58 |
| Masters students | 2 | 3.09 |
| Temporary researchers | | |
| Other | | |
| **Total** | **6** | **12.89** |

## 8. Involvement in Agri Food Graduate Development Programme

| Name of Postgraduate / contract researcher | Names and Dates of modules attended |
|---|---|
| Alan O'Connor | "Science writing for the Agri-food sector", June 2015 |
| Alan O'Connor | "Management skills for the food sector", June 2016 |

## 9. Project Expenditure

| | |
|---|---|
| Total expenditure of the project: | €554,149 |
| Total Award by DAFM: | €610,165 |
| Other sources of funding including benefit in kind and/or cash contribution(specify): | N/A |

Breakdown of Total Expenditure

| Category | Institution 1 Teagasc | Institution 2 UCD | Institution 3 AFBI | Institution 4 QUB | Total |
|---|---|---|---|---|---|
| Contract staff | | | | | |
| Temporary staff | | | | | |
| Post doctorates | | | 153735.03 | | 153,735.03 |
| Post graduates | 144583.31 | | 64817.14 | | 209400.45 |
| Consumables | 19635.75 | | 25341.90 | | 44977.65 |
| Travel and subsistence | 8127.02 | 179.94 | 8436.37 | 1412.00 | 18155.33 |
| Sub total | 172346.08 | 179.94 | 252330.44 | 1412.20 | 426268.46 |
| Durable equipment | | | | | |
| Other | | | | | |
| Overheads | 51703.82 | 53.98 | 75,699.13 | 423.60 | 127880.54 |
| **Total** | **224049.90** | **233.92** | **328,029.57** | **1835.60** | **554149.00** |

## 10. Leveraging

A Teagasc Walsh Fellowship was awarded to allow the conversion of the Master's degree scale of research by Jonathan Herron to a PhD programme, subsequent to, but related to the overall theme of the project. Metagenomic analysis is being carried out on rumen samples collected from the Teagasc tasks within the project. This analysis is being funded by Teagasc and will add value to the project.

## 11. Future Strategies

The results of the research have been disseminated through AFBI and Teagasc Open Days, publications in the popular press, conference presentations and peer reviewed publications as outlined in section 4b. Further work should focus on the application of the empirical models developed within the project at an animal level. Information from the project is being used to refine current "whole-farm" greenhouse gas models to facilitate life-cycle analysis that is more appropriate to Irish milk and beef production conditions.

## 12. Consent to Publish Final Report on the DAFM Website and/or Through Other Dissemination channels

I consent to this report being made available to the public, through the Department's website and other dissemination channels.

Yes □X No □

## 13. Declaration

I declare that the information contained in this final report is complete and true to the best of my knowledge and belief.

Signed:  Project Coordinator

Date: June 12, 2020