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

Research Stimulus Fund

Final Report

'Increased environmental efficiency of ruminant production systems through the incorporation of a Life Cycle Assessment into a quality assurance scheme (ERUMINANT)'

DAFM Project Reference No: 11 S 143

Start date: 01/12/2012
End Date: 30/11/2016

Principal Coordinator and Institution: Laurence Shalloo
Animal and Grassland Research and Innovation Department, Teagasc, Moorepark, Fermoy, Co Cork
Email: Laurence.Shalloo@Teagasc.ie

Collaborating Research Institutions and Researchers:
Environment Research Dept., Johnstown Castle Wexford - John Finn
Bord Bia - Michael Houlihan
School of Agriculture and Food Science, University College Dublin - Helen Sheridan
School of Biosystems Engineering, University College Dublin - Nick Holden
Irish Cattle Breeding Federation (ICBF) - Mike Lynch

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

Key words: Biodiversity, Carbon, Water, Energy

1. Rationale for Undertaking the Research

A central requirement within the Food Harvest 2020 Report and the Food Wise Report targets was that output is increased in a sustainable manner. The Food Harvest 2020 Report called for the development of a sustainability audit system that will benchmark the overall sustainability of Irish farms that can also be used as a benchmark system for comparing greenhouse gas (GHG) emissions, using an internationally standardised methodology. Another key focus was the development of mitigation strategies which link practices at farm level with national emissions accounted for in the national inventory using life cycle assessment (LCA) based approaches. To realise the Food Harvest 2020 vision this project developed the internationally standardised modelling methods and metrics necessary to verify Ireland's "green" credentials and help promote "Brand Ireland". A number of whole farm and LCA models have been developed by Teagasc (Lovett et al., 2006; 2008; O 'Brien et al., 2010; 2012; Foley et al., 2011) which are compliant with present national accounting procedures and LCA procedures (ISO, 2006; Duffy et al., 2011). This project further developed these models for dairy and beef systems and developed a similar model for sheep production systems. In addition, the wider environmental affects of ruminant production systems: biodiversity, water and energy consumption, trans-boundary and eutrophic emissions was evaluated. The development of a decision support tool that identifies specific environmental impact mitigation strategies at farm level was developed and integrated into the audit system as well as a stand alone system. Appropriate components of the models were generated in a way that they could be integrated within the National inventories and a subsequent project with the EPA allowed the national inventory methane models to be updated.

2. Research Approach

The LCA method estimates environmental impacts using models and does not directly measure impacts in most cases. However, the parameters and algorithms used to develop and operate LCA models are based on the outcomes of research studies. The parameters and algorithms needed to develop LCA models in this project were obtained from field work carried out measuring biodiversity, water consumption and non-renewable energy use and from Irish research studies that have assessed GHG emissions and nutrient enrichment of waterways. Following the development of the LCA models, they were applied to measure the sustainability of Irish dairy, beef and sheep production. Some of the models have been implemented as part of the Bord Bia Quality Assurance Scheme and provide scientific integrity around the sustainability audits. The LCA models can identify the main causes of environmental impacts on-farm and can be used as a basis to develop strategies to improve the environmental sustainability of ruminant production systems. A checklist system was calibrated to ensure the data capture process is possible at farm level as part of the implementation plan around the quality assurance scheme. Bord Bia in conjunction with Teagasc developed a sustainability assurance scheme that includes data capture, model development, data storage and report formation. All models were developed to an international standard and published in internationally peer reviewed Journals.

3. Research Achievements/Results

- Embedding the certified LCA model in the national farm survey showed the average carbon footprint of Irish dairy farms in 2012 was 1.11 kg of CO2-equivalent/kg milk with the 95% confidence interval ranging from 0.67 to 1.56 CO2-eq/kg milk.
- When the carbon footprint of dairy farms was related to profitability, there was a strong relationship found. The carbon footprint of milk for the top one-third of farms ranked in terms of net margin/ha was 7% lower than the middle third (profitability) and 14% lower than the bottom third (profitability).
- Increases in productivity after the removal of milk quota in 2015, on the dairy farms within the project, led to the average annual carbon footprint of milk declining from 1.15 kg to 0.99 kg of CO2-equivalent/kg of milk. For the same period, there was little change in the projects beef and sheep footprints, which averaged 13.1 and 8.3 kg of CO2-equivalent per kg of live weight, respectively.
- Of the 80 farms within this project, seventy five percent of the E-Ruminant farms could be classified as improved grassland or semi improved grassland across dairy, beef and sheep farms.

4. Impact of the Research

This research has greatly enhanced the sustainability metrics within the Irish dairy industry. When fully published it will have resulted in over 10 scientific papers published in Internationally recognised high ranking scientific journals. The models developed within this project either have been deployed or will be deployed within either the national farm survey or the Sustainable Dairy Assurance Scheme (SDAS) database allowing Irish sustainability metrics to be expressed Internationally as well as over time. There is also now significant data sharing happening across different aspects of the dairy industry as a result of this project (e.g. ICBF & Bord Bia).

4(a) Summary of Research Outcomes

(i) Collaborative links developed during this research

There was strong links developed among the project team during this project. In particular the project team developed strong collaborative links with Bord Bia and Irish Cattle Breeding Federation (ICBF).

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

New models were developed in this project which are published and embedded within the Bord Bia SDAS system as well as within the NFS.

(iii) Outcomes with economic potential

The models developed allow the quantification of Irelands sustainability credentials. These scientifically robust numbers can be used to verify Irelands green credentials.

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

The models developed in this project are now being used within the SDAS program and are being used to underpin origin green. The GHG emissions models embedded with the

National Farm Survey (NFS) allows Ireland to evaluate change over time in an extremely robust fashion

4 (b) Summary of Research Outputs

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

Murphy, E., I. J. M. de Boer, C. E. van Middelaar, N. M. Holden, L. Shalloo, T. P. Curran, and J. Upton. 2017. Water footprinting of dairy farming in Ireland. J. Clean Prod. 140, Part 2:547-555.

O'Brien, D., Geoghegan, A., McNamara, K., Shalloo, L., 2016b. How can grass-based dairy farmers reduce carbon footprint of milk. Animal Production Science, 56, 495-500.

O'Brien, D., Bohan, A., McHugh, N., Shalloo, L., 2016a. A life cycle assessment of the effect of intensification on the environmental impacts and resource use of grass-based sheep farming. Agricultural systems, 148, 95-104.

O'Brien, D.; Hennessy, T.; Moran, B.; Shalloo, L., 2015. Relating the carbon footprint of milk from Irish dairy farms to economic performance. Journal of Dairy Science 98 10 7394-7407

Rice P., O'Brien D., Shalloo L., Holden N. (2017). Evaluation of allocation methods for calculation of carbon footprint of grass based dairy production. Journal of Environmental Management 202 1 311-319

Rice, P., O'Brien, D., Shalloo, L., Holden, N.M., 2018. Defining a functional unit for dairy production LCA that reflects the transaction between the farmer and the dairy processor. The International Journal of Life Cycle Assessment. In press, https://doi.org/10.1007/s11367-018-1486-0

Upton, J., M. Murphy, L. Shalloo, P. W. G. Groot Koerkamp, and I. J. M. De Boer. 2015. Assessing the impact of changes in the electricity price structure on dairy farm energy costs. Applied Energy 137(0):1-8.

Upton, J., M. Murphy, P. W. G. Groot Koerkamp, I. J. M. D. Boer, L. Shalloo. 2014. Investment Appraisal of Technology Innovations on Dairy Farm Electricity Consumption. J Dairy Sci. 2015 Feb;98(2):898-909.

Upton, J., M. Murphy, L. Shalloo, P. W. G. Groot Koerkamp and I. J. M. D. Boer. 2014. A mechanistic model for electricity consumption on dairy farms: Definition, validation and demonstration. Journal of Dairy Science, 97(8):4973-4984.

Upton J., Murphy, E. Shalloo, L. ; Murphy, M. Boer, I. J. M. de Koerkamp, P. W. G. G.(2017).Improved energy and water management to minimize the environmental impact of

dairy farming. Achieving sustainable production of milk. Volume 2: Safety, quality and sustainability 211-226

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

Murphy, E., Curran, T., Holden, N.M. and Upton, J. (2015). Water use on Irish dairy farms. TResearch 10 (2) 10-11 ISSN 1649-8917 33891

O'Brien, D., McNamara, K., Upton, J., Humphreys, J., Ruane, E., Shalloo, L., Murphy, E., 2016e. Sustainable dairy farming: The Carbery Experience. Teagasc Milk Quality Farm Walk, O'Sullivans family farm, Dunmanus, Goleen, Co. Cork, p24-26.

O'Brien, D., McNamara, K., 2014. Proving Irish beef production's "green credentials". Beef 2014 - The business of cattle. Teagasc, Grange, Dunsany, Co. Meath, June 18th, p116-117.

McNamara, K., O'Brien, D., Geoghegan, A., Shalloo, L., 2015. E-Ruminant – improving environmental efficiency of ruminant production systems. Irish Dairying – Sustainable expansion. Moorepark '15 Open Day, July 1rd. Teagasc IE p164-166.

(iii) National Report

O'Brien, D., O'Donoghue, C., O'Kiely, P., O'Mara, F., O'Shea, R., Richards, K., Ryan M., Shalloo, L., Schulte, R., 2015. Interim report on greenhouse gas emissions from Irish agriculture: Teagasc submission made in response to the discussion document on the potential for greenhouse gas (GHG) mitigation within the agriculture and forestry sector. Teagasc, Oak Park, Carlow. Accessed March 25, 2015 from http://www.teagasc.ie/publications/view_publication.aspx?publicationID=3534

(iv) Workshops/seminars at which results were presented

Breen M., Murphy M., and Upton J. 2015. Development and validation of photovoltaic and wind turbine models to assess the impacts of renewable generation on dairy farm electricity consumption in Proc. ASABE Annual International Meeting. ASABE, New Orleans, LA, USA.

Eory, V., Philippe, F., O'Brien, D., 2015. Economic assessment of greenhouse gas mitigation on livestock farms. In: Climate smart agriculture: Global science conference, 16th-18th March, 2015, Le Corum, Montpellier, France, p 65.

Murphy, E., Curran T., Holden N., and Upton J.(2015) Water required for grass growth on Irish dairy farms., In: Agricultural Research Forum 2015, Tullamore, Co. Offaly,10 March 2014, P136-137.

Murphy, E., Curran T., Holden N., and Upton J.(2014) Research Update: Understand water use on Irish dairy farms., In: Teagasc National Agri-Environment Conference 2014, Tullamore, Co. Offaly, 13 November 2014, P24-25.

Murphy E, Upton J, Holden J and Curran T.(2014) Direct water use of Irish dairy farms., In: Biosystems Engineering Research Review 19, University College Dublin, March 2014, P146-148.

Murphy, E., Curran T., Humphreys J., and Upton J.(2014) Direct water use of Irish dairy farms., In: Agricultural Research Forum 2014, Tullamore, Co. Offaly,10 March 2014, P46-47

Murphy M., O'Mahony and Upton J. 2015. Analysis of an Optimized Milk Cooling Controller for Dynamic Electricity Pricing Tariffs in Proc. ASABE Annual International Meeting. ASABE, New Orleans, LA, USA.

O'Brien, D., Brennan, P., Ruane, E., Humphreys, J., Shalloo, L., 2014. Auditing the carbon footprint of milk from commercial Irish grass-based dairy farms. In: Livestock, climate change and food security conference, Madrid, 19th–20th May, 2014, p 102.

O'Brien, D., Capper, J.L., Garnsworthy, P.C., Grainger, C., Shalloo, L., 2014. A life cycle assessment case study of the carbon footprint of high performance Irish, UK and USA dairy farms. In: Farming systems facing global challenges: Capacities and strategies. The 11th European International farming systems association symposium, 1st-4th June, 2014, p 84.

O'Brien, D., Geoghegan, A., McNamara, K., Shalloo, L., 2016d. How can grass-based dairy farmers reduce carbon footprint of milk. In: Proceedings of the 6th Greenhouse Gases and Animal Agriculture Conference, 14th-18th February, 2016, Pullman Albert Park, Melbourne, Australia, p 19.

O'Brien, D., McNamara, K., Shalloo, L., McHugh, N., Creighton, P., Geoghegan, A., Bohan, A., 2016b. Life cycle assessment of the environmental impact of extension supported commercial grass-based sheep farms. In: 10th International Conference on Life Cycle Assessment of Food, 2016: Putting LCA into Practice, 19th-21 October 2016, University College Dublin, Ireland, p 474-481.

Rice, P., Holden, N.M., Shalloo, L., Crosson, P., O'Brien, D., 2015. The effect of allocation method on the carbon footprint of milk and dairy derived beef. In: Proceedings of the Agricultural Research Forum, Tullamore, March 9th-10th, 2015, p52.

Rice, P., O'Brien, D., Shalloo, L., Holden, NM., 2016. Evaluation based on data quality of allocation methods for calculation of carbon footprint of grass-based dairy production. In: 10th International Conference on Life Cycle Assessment of Food, 2016: Putting LCA into Practice, 19th-21 October 2016, University College Dublin, Ireland, p 87-98.

Shine, P., Scully, T., Murphy, M., Upton, J., Shalloo, L. (2015) Analysis of water and electrical power consumption for grassland dairy production in Proc. International Manufacturing Engineering Conference, IMC. Belfast, Ireland.

Stienezen, M., O'Brien, D., Cutullic, E., Faverdin, P., Fiorelli, J.L., Holshof, G., Hutchings, N.J., Olesen, J.E., Perdok, H., Shalloo, L., Topp, C.F.E., 2014. Mitigation options in perspectives of greenhouse gas emissions and production on European dairy farms. In: Livestock, climate change and food security conference, Madrid, 19th–20th May, 2014, p 107.

Topp, C.F.E., O'Brien, D., Philippe, F., Stienezen, Wreford, A., M.W.J., Olesen, J.E., 2015. Synergies and trade-offs of adaptation and mitigation on dairy farms. In: Climate smart agriculture: Global science conference, 16th-18th March, 2015, Le Corum, Montpellier, France, p 226.

Upton, J., M. Murphy, L. Shalloo, P. W. G. Groot Koerkamp, and I. J. M. De Boer. 2014. Strategies to reduce electricity consumption on dairy farms. Proceedings of the ASABE annual meeting. Montreal, Canada. P.1-7

Upton, J., M. Murphy, L. Shalloo, P. W. G. Groot Koerkamp, and I. J. M. De Boer. 2014. Effect of electricity tariffs and cooling technologies on dairy farm electricity consumption, related costs and greenhouse gas emissions. Proceedings of AgEng 2014. Zurich, Switzerland. P. 1-10

Upton, J., J. Humphreys, P. W. G. Groot Koerkamp, P. French, P. Dillon, and I. J. M. D. Boer. 2013. Life cycle assessment of energy use on Irish dairy farms. 2014. Agricultural Research Forum. Teagasc, Tullamore, Ireland. P. 47

(v) Intellectual Property applications/licences/patents

None

(vi) Other

LEAP, 2015. Environmental performance of large ruminant supply chains: Guidelines for quantification. Livestock environmental assessment and performance (LEAP) partnership. FAO, Rome, Italy.

5. Scientists trained by Project

Total Number of PhD theses: 2

Murphy, E. 2017. Water footprinting of dairy, beef and sheep farms in Ireland. University College Dublin, Dublin, Ireland. Submission March 2017, Publication June 2017.

Rice P. Evaluation of methodologies used to estimate the environmental impact of dairy production. Submission June 2018.

Total Number of Masters theses: 0

6. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (person years)
Teagasc Moorepark	4	1.12
Teagasc J.C.	1	0.335
UCD	2	0.2
Total	**7**	**1.655**

7. Researchers Funded by DAFM

Type of Researcher	Number	Total Time contribution (person years)
Post Doctorates/Contract Researchers	3	6.498
PhD students	4	7.825
Masters students		
Temporary researchers		
Other		
Total	**7**	**14.323**

8. Involvement in Agri Food Graduate Development Programme

Name of Postgraduate / contract researcher	Names and Dates of modules attended
None	

9. Project Expenditure

Total expenditure of the project: €757,780.49

Total Award by DAFM: €784,554.00

Other sources of funding including benefit in kind and/or cash contribution(specify): €

Breakdown of Total Expenditure

Category	Teagasc	UCD	ICBF	Bord Bia	Total
Contract staff	102,988.33	0	207,65.63	0	123,753.96
Temporary staff		0	0	0	0
Post doctorates	137,327.33	0	0	0	137,327.33
Post graduates	148,249.99	7,400.00	0	0	155,649.99
Consumables	24,674.68	1,501.83		0	26,176.51
Travel and subsistence	34,826.68	3,504.88		0	38,331.56
Sub total	448,067.01	12,406.71	207,65.63	0	481,239.35
Durable equipment	92,174.21			0	92,174.21
Other	23,983.01 10,956.42 4,018.80	1,036.89		0	39,995.12
Overheads	134,420.11	3,722.01	6229.69	0	144371.81
Total	**713,619.56**	**17,165.61**	**26,995.32**	**0**	**757,780.49**

10. Leveraging

As a result of this work, there has been funding secured from Carbery in order to continue work in this area with Carbery farms. The models developed in this project will be used within the recently funded SFI Centre called VistaMilk.

11. Future Strategies

The models developed within this research are now being deployed across the industry (e.g. NFS and SDAS) to generate carbon footprints. These models are generating approximately 10,000 carbon footprints per year across the dairy industry. The energy and water models are being deployed on a pilot basis with the Carbery greener dairy farms. Models are currently been deployed with the SDAS system to generate energy and water footprints for a greater number of farms and without the detailed monitoring which occurred in E-Ruminant. This will place Ireland at the forefront of sustainability assessment globally through the integration of scientifically robust models with the SDAS infrastructure.