Enteric Fermentation Flagship

GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

31 July 2017

Overview

Enteric methane (CH_4) is the biggest source of global GHG emissions from livestock. Emissions per animal vary widely depending on the species, feed and productivity and this presents a significant challenge for measurement and estimation of greenhouse gas emissions from herd to national scales. However, this variability also presents an opportunity to mitigate emissions by improving the selection and breeding of animals, improving and changing feeds, manipulating the rumen microbiome, improving animal health status, and increasing the productivity of animals and farm systems.

The Enteric Fermentation Flagship is focused on developing a suite of collaborative projects that will assist GRA member countries account for and reduce their enteric methane emissions within the context of sustainable development and food security goals. The programme of work has three main components:

i. Development of solutions for reducing enteric methane emissions
ii. Improved quantification of livestock emissions at national to farm scales
iii. Identification, testing and implementation of appropriate mitigation solutions in diverse situations

The purpose is to develop a suite of key projects that can attract resources from GRA Member countries, GRA Partners and external organisations and improve cooperation between members of the GRA. Our vision is that these projects will better harness the collective expertise of the GRA and achieve beneficial outcomes beyond those achievable by individual countries/organisations operating independently.

This document puts forward three initial projects for consideration by Council at its meeting in Tsukuba, Japan in August 2017.

Initial priority projects for Council discussion

Over 50 project ideas were submitted for possible inclusion in the Enteric Fermentation Flagship. These came from participants in the flagship's taskforce, as well as ideas put forward during the Livestock Research Group meeting in April 2017. Please note that the vast majority of these were simple one-line ideas that require further discussion and development over time.

Of the project ideas that were more detailed, three have emerged as initial priorities for discussion with the Council:

1. **Adaptation in ruminants for increased productivity and lowered environmental impact**
2. **Improved quantification of the effects of feed and nutrition on enteric methane emissions from cattle managed under a wide range of production conditions and environments**
3. **Relating ruminant diet, methane output and animal production to the rumen microbiome**

Appendix 1 outlines the process that led to these three projects being prioritised. Importantly, they all extend existing activities that will benefit multiple countries, they have project champions or leaders to take them forwards, and they already have a core funding base that can be easily built upon.

A number of the remaining 40+ high-level project ideas have already been flagged as having the potential to become a flagship project in the future (see Appendix 2). However, it will be critical for countries to step forwards and take the lead in transforming an idea into a concrete project proposal that can be considered by Council.

Project 1: Adaptation in ruminants for increased productivity and lowered environmental impact

Leader: S.J. Rowe, New Zealand

Countries involved: Initially New Zealand, Denmark, Australia, Brazil, African countries, and Uruguay - potentially all GRA countries

Why is this a priority GRA activity? Enteric methane is almost entirely produced by microbial fermentation in the rumen. There is increasing evidence that ruminants have evolved to control this fermentation and therefore adapt to different environments. These control mechanisms are important for mitigation of methane in intensive and extensive livestock production systems and for selection of livestock that can adapt to challenges from global warming (via alterations in grass species and forage quality and availability) whilst maintaining productivity.

Brief description: A method is under development for rapid low cost profiling rumen microbiomes in sheep in New Zealand and Australia. Our evidence suggests that these profiles are predictors or methane emissions and potentially feed efficiency and are to some extent also under host genetic control. This rapid low cost method will be made available to other GRA countries and for other ruminants such as cattle, goats and deer. Rumen methane emissions and microbial profiling including volatile fatty acid measurements will be undertaken in dairy and beef systems for native breeds including *Bos indicus* in Australia, Brazil and Africa as well as breeds associated with intensive global production such as Angus and Holstein Friesian. A LEARN post-doctoral fellowship will be aligned to the project.

Outcomes: Determination of how the rumen adapts to different production systems, and what the effect of this adaptation is on rumen outputs and how this affects livestock production. A method that does not require expensive infrastructure and can be used in live animals at any stage of production. Use of this method for the identification and selection of animals that emit lower methane, are better adapted to sustain periods of feed restriction and low quality forage.

Resourcing needs: The project will build upon existing activities being funded by the GPLER4 fund to develop efficient methods to characterise the microbiome in sheep. Rumen samples from other ruminants in other production systems measured for methane and for feed intake will be required. Funding for initial sequencing will be required for comparison of cattle with the sheep resource and with existing microbial databases. New resources will include additional funds for the project leader to lead the project, supporting supervision and training of a LEARN post-doctoral fellowship. Resources for co-ordination of samples, and for disseminating information to the wider global network. Total additional costs will depend upon the number of countries involved and the number of additional samples for which sequencing and VFA profiling will be required. Range $0.2-0.5m p.a.

Resourcing mechanisms:

In-kind contribution of 280 rumen samples from New Zealand dairy cattle measured for methane and feed intake to validate that the transfer of methods developed in sheep is appropriate.

In-kind contribution from individual countries of samples and phenotypes from further ruminant systems and cash contributions towards sequencing of samples and VFA profiling.

In-kind contribution from individual countries to cover staff time involved in helping analyse data and contribute to writing reports and papers.

Use of existing scholarship programme e.g. LEARN post-doctoral fellowships to provide additional regional resources

New GRA funding mechanisms to provide cash for supervision of LEARN post-doc to analyse data and for initial sequencing of cattle samples.

Key partners and existing resources/projects:

- NZAGRC-PGgRc
- DairyNZ
- GPLER project – granted 3 year funding from September 2017
- ASGGN network
- ILRI, University of Aarhus, Embrapa, University of Queensland

Project 2: Improved quantification of the effects of feed and nutrition on enteric methane emissions from cattle managed under a wide range of production conditions and environments

Leader: LRG Feed & Nutrition Network coordinator (A. Hristov, USA); ERAGAS CEDERS project leader (A. Bannink, Netherlands)

Countries involved: Potentially All GRA countries

Why is this a priority GRA activity? Manipulating feed type and supply is one of the principle methods of manipulating enteric methane production because the organisms responsible for producing methane are influenced by the specific characteristics of different feeds. Enteric methane:feed type/characteristic relationships are complex and the analysis of large quantities of data is a very powerful method for discovering these relationships. The GRA has a unique ability to bring together these data and thus add value to its members at relatively low cost. This project will add value to all GRA member countries from both an inventory and mitigation perspective and provides an opportunity for mass participation without large scale additional investment.

Brief description: Further populate and analyse existing feed/methane relationship databases to obtain better quantitative information on feed characteristic:methane relationships. The unique opportunity here is to have data provided from collaborators throughout the globe, representing various production systems and environments. Methane yield (Y_m)values that are more specific for local feeds and production circumstances will be developed. These factors can be used by participating countries and partners in the compilation of improved enteric methane inventories. Of particular importance will be obtaining information on diets fed in tropical livestock systems and those systems relying heavily on by-products which are currently under-represented. The identification of the modes-of-action and the creation of increased understanding of how feed and feed additives influence enteric methane emissions will be a core component of the programme. The proposed programme offers the opportunity for all countries to be involved via the submission of locally obtained information on methane emissions as related to animal type, production system, and feed and total diet characteristics.

Outcomes: Improved methane prediction algorithms and improved national methane and greenhouse gas inventories based on comprehensive data obtained from a wide range of production systems; from poor to high quality diets, temperate to tropical regions, extensive to intensive production systems. Well quantified feed mitigation options will be developed, suitable for a wide range of systems based on comprehensive data.

Resourcing needs: The project will build upon existing activities being undertaken by the LRG's Feed and Nutrition Network. New resources will include additional funds for the coordinator (and assisting coordinators if applicable) to lead the project, undertake further database development, and post-doctoral support for data analysis and maintenance of the expanded database. Resources for country contact points to submit data, and co-author papers. If funds are available, consideration should also be given to the appointment of regional coordinators to assist the central coordinator in compiling, analysing and publishing data. Total cost approximately $0.5-1m p.a.

Resourcing mechanisms:

In-kind contribution from individual countries for staff time to cover from those countries able to assemble and submit local data to central coordinator.

In-kind contribution from individual countries to cover staff time involved in helping analyse data and contribute to writing reports and papers.

New GRA funding mechanisms to provide cash for recruitment of additional personnel to compile, analyse and maintain the feeds database.

Use of existing scholarship programme e.g. LEARN post-doctoral fellowships to provide additional regional resources

Key partners and existing resources/projects:

- FNN, feed databases and contribution partners
- FACCE-JPI Global Network
- ERAGAS-CEDERS project – granted 3 year funding from September 2017
- CGIAR, FAO, FACCE-JPI
- Local governments and funding agencies

Project 3: Relating ruminant diet, methane output and animal production to the rumen microbiome

Leader: Sharon Huws, Rumen Microbial Genomics Network (RMG)

Countries involved: Potentially All GRA countries

Why is this a priority GRA activity? Enteric methane emissions are produced by microbes present in the fore-stomach of ruminants and manipulating these microbes is potentially a highly effective mitigation route. It has also been shown that reducing methane output can re-divert energy for animal production. Our understanding of the make-up and function of these microbial communities is advancing rapidly thanks in part to collaborative GRA projects such as the Hungate 1000 and the Global Rumen Census. The need to have access to material obtained under a wide range of conditions means that the GRA is uniquely placed to undertake this project and thus add value to its members at relatively low cost.

Brief description: Exploit existing data on rumen function and the rumen microbiome, and understand how changes in the rumen microbiome alter rumen function.

Outcomes:

1. Use published data to develop a database which links animal genetics, diet, and rumen microbiome to environmental outputs. This database will enable modelling

approaches to be undertaken to predict environmental output and enable better implementation of mitigation strategies.

2. To build upon available data as published data do not report upon animal genetics, diet, and rumen microbiome to environmental outputs in their entirety. Therefore, in order to build a robust database for modelling, further experimentation which assess each parameter is required
3. Be able to forecast environmental output of the animals and to suggest which mitigation strategies may be best implemented in certain geographical areas or upon feeding particular diets.

Resourcing needs: The project will build upon existing activities funded under the ERAGAS proposal (1.592.000 €) and the Hungate 1000 and Global Rumen Census. New resources will include additional funds for the coordinator (and assisting coordinators if applicable) to lead the project, undertake further database development, and post-doctoral support for analysis of the expanded database. Resources for country contact points to submit data, and co-author papers. Total cost approximately $0.2-0.5m p.a.

Resourcing mechanisms:

In-kind contribution from individual countries for staff time to cover from those countries able to assemble and submit local data to central coordinator.

In-kind contribution from individual countries to cover staff time involved in helping analyse data and contribute to writing reports and papers.

New GRA funding mechanisms to provide cash for recruitment of additional personnel to compile, analyse and maintain the feeds database.

Use of existing scholarship programme e.g. LEARN post-doctoral fellowships to provide additional regional resources

Key partners and existing resources/projects:

- RMG and FNN,
- ERAGAS-RumenPredict project – granted 3 year funding from October 2017
- FACCE-JPI Rumen Stability project-2014-2017

Appendix 1: Developing and prioritising project ideas

Fundamental principles underlying the Enteric Fermentation Flagship

- Unique GRA added value – utilise knowledge & expertise of 47 member countries and partners
- Inclusive – must give opportunities for all members to be engaged in some way, availability of funds should not be a barrier to participation
- Relevant – all Members need to have benefit from some or all of the Flagship, i.e. something in it for everyone
- Solution focussed – clear link to the development and implementation of mitigation practices/technologies
- Multifaceted – address greenhouse gas mitigation and/or soil carbon sequestration along with co-benefits and synergies for livelihoods & adaptation; supportive of policy needs
- Increase capacity/capability of member countries
- Supplement and support existing efforts by Member countries and Partners

Developing project ideas

The flagship will only be as strong and attractive as the specific projects and activities it promotes, and to the extent that those projects offer real value to GRA member countries and attract interest from partners and potential external funders.

The immediate goal was to develop a 'long-list' of project ideas under each component with a prioritised 'short-list' for immediate action, i.e. projects that can be presented to the GRA Council in August 2017 and commence in the 2017 calendar year. The taskforce was asked to take the following into account in developing specific project proposals:

- **Be realistic** – prioritise projects that can deliver tangible benefits in the short & medium term. Small solutions are more attractive than unsolved big problems, even if a solution to the big problem ultimately would have a bigger impact.
- **Build on existing projects** – projects already exist in all of the priority areas; how can we extend these to add value to GRA Members and Partners?
- **Better use of existing data** – no individual country may have enough data but collectively we may make progress where individual countries can't.
- **Build on existing databases and/or develop databases** – collate and examine existing and new data to determine how they could be made more accessible.
- Projects need to **demonstrate concrete products/outcomes** that are beneficial to multiple GRA members.
- **Leadership is critical** – prioritised projects need to have committed leader(s) who is resourced to do the job.
- **Development of resourcing mechanisms** – we need to ensure that mechanisms are in place that facilitate collaboration in practice for each project. Any project on the 'short list' needs to have a resourcing plan.

Prioritising project ideas

The concept of GRA flagships is new and ideas as to what constitutes an effective flagship proposal will inevitably evolve over time. The taskforce received a large number of project ideas (see Appendix 2) but it was necessary to identify and get underway a small number of projects that can quickly demonstrate the value of the concept to the GRA. Priority projects for 2017 were identified using the following criteria.

- Directly addresses one of the three identified work areas and has the potential to make a major contribution to reducing enteric CH4 emissions across the GRA member countries
- Involves or has the potential to involve multiple GRA countries and these countries are representative of the interests of its broad membership
- Involves GRA Partners or provides an opportunity for them to be involved
- Builds on and expands an existing piece of work that is already resourced and underway
- Opportunities for involvement are not restricted to those able to provide cash support; alignment and in-kind contributions provide a route for involvement
- A leader and lead organisation are in place and resourced to take responsibility for developing the flagship proposal into an implementable project
- Builds on and/or supports the efforts of existing LRG research networks

Appendix 2: Long list of project ideas for the Enteric Fermentation Flagship

The following project ideas were generated within the flagship taskforce and at the April 2017 LRG meeting. Further work is needed before many of them can be taken forwards into detailed project concepts.

Submitted flagship idea	How this is being addressed
Ideas that are or can be addressed within the initial three prioritised flagship proposals	
Characterizing the rumen microbiome - host interactions for reduced CH4 emissions and improved production efficiency using single methodologies	Flagship proposal 'Relating ruminant diet, methane output and animal production to the rumen microbiome'
Introduce logicalities on microbial metabolism, and well-established laws and mode-of-actions, in quantifications of enteric methane (i.e. place biology next to CH4 empiricism; for all regions)	Flagship proposal 'Relating ruminant diet, methane output and animal production to the rumen microbiome'
Expanding the predictive ability of CH4 emissions for a wider range of feeds and farm/production systems and region-specific combinations, e.g. build on FNN database, CATIE, IICA and SAMPLES	Flagship proposal 'Improved quantification of the effects of feed on enteric methane emissions from cattle managed under a wide range of production conditions and environments'
Use of industrial feed by-products (e.g. copra, peanut meal, palm kernel cake) to reduce CH4	Flagship proposal 'Improved quantification of the effects of feed on enteric methane emissions from cattle managed under a wide range of production conditions and environments'
Rumen fate of soluble carbohydrates in forages / roughages with a high soluble content and consequences of harvesting method on enteric methane	Flagship proposal 'Improved quantification of the effects of feed on enteric methane emissions from cattle managed under a wide range of production conditions and environments'
New tools for use in the selection of low CH4 emitters Use of proxies for implementing enteric methane selection in practice	Flagship proposal 'Adaptation in ruminants for increased productivity and lowered environmental impact'
Studies of the botanical composition of the diet of small ruminant on extensive systems and its impact to emissions of greenhouse gases Oleo seeds inclusion as supplements for dairy Algae inclusion as supplements for dairy Introduction of balanced concentrates to locally adopted cross dairy cattle breeds in semi-arid areas	Flagship proposal 'Improved quantification of the effects of feed on enteric methane emissions from cattle managed under a wide range of production conditions and environments'
Pulling together different databases (e.g. nutrition, measurements) into one centralised resource	This is already being done to some extent (eg LRG Feed & Nutrition Network feeds database incorporates methane emissions and feed characterisation).
Plant bioactives and their influence on enteric emissions, production efficiency and ability to replace antibiotics	Future flagship proposal 'Optimising efficacy of antimicrobial feed additives'
Potential of alternating strategies for additives with demonstrated non-persistent effect on enteric methane (e.g. with using plant metabolites	Future flagship proposal 'Optimising efficacy of antimicrobial feed additives'
Ideas that need further development before being submitted as flagship projects	
Validation of SF6 tracer technique modified for longer collection period for grazing animals on extensive management.	Potentially a valuable GRA flagship project as it could facilitate the development of a measurement approach for animals that are not handled frequently. Currently only involves a single country. First step is perhaps to ascertain interest from other countries and then develop a multi-country collaborative project. Could perhaps become a broader project on measurement techniques (see also proposed project on Developing guidance on measurement techniques) as alternatives to SF6 are available.
Creating / inflating hydrogen sinks to increase efficacy of methane mitigating measures	Develop a programme of work that can encompass a range of GRA member countries and demonstrate unique GRA added value
Persistency of established rumen microbiomes and methanogenesis through nutrition during early life	Develop a programme of work that can encompass a range of GRA member countries and demonstrate unique GRA added value

Efficacy of combinations of mitigation strategies (exploiting combinations of additives, plant metabolites, alternative hydrogen sinks, feeding strategies	Develop a programme of work that can encompass a range of GRA member countries and demonstrate unique GRA added value
Developing guidance on measurement techniques and protocols, including a decision-tree and minimum data needs	Need to assess to what extent this information is already available to researchers. Could be developed into a flagship proposal if it is felt that currently available information is insufficient.
Developing proxies for feed intake, production, emissions etc. to fill activity data gaps	The flagship proposal 'Improved quantification of the effects of feed on enteric methane emissions from cattle managed under a wide range of production conditions and environments' may address some of this but there is a need to develop a programme of work that can encompass a range of GRA member countries
Study of extensive livestock systems management and their effects on the emission of greenhouse gases	As written only applies to a single country but the approach could be perhaps developed into a flagship proposal via the development of a database characterising system impacts on GHG emissions. Information from other enteric methane flagships (e.g. Feed effects on emissions) would assist in the quantification of emissions from different systems.
Identification of implementation of BMP (best management practices?) to reduce enteric methane emissions Identification of series of management practices, corresponding to different livestock production systems, that can reduce intensity of Ch4 per unit of production and increase production per hectare/animal – objective parameters Retrospective analysis of how GHG have reduced in livestock systems over past decades to try and identify most important practices that led to biggest reductions Identify best practices in regions, in relation to improved production, how much is related to feed, health, breeding. Identify farms that are clear examples of improved economy and reduced emissions intensity Global characterisation of livestock production systems (i.e. by agroecological context, current management) and identification of mitigation options, especially in terms of opportunities to reduce emissions intensity by improving productivity Understanding CH4 mitigation within the farm system, e.g. simplifying and improving GLEAM Modelling GHG emissions at farm level considering analysis of alternative management Monitor/evaluate long term effects of management options on GHG intensity Validation and scaling up of options (has to be easily implemented; linkages to financing schemes/tools)	A common theme. Need perhaps to develop a single programme of work that encompasses a range of ideas put by different people/groups.
Validation and scaling up feeding systems with lower GHG emissions intensity. Builds upon research conducted in 12 countries of Latin America and the Caribbean Validating and scaling up sustainable and intensive livestock systems Builds upon FONTAGRO experience in 12 countries	Need to work with FONTAGRO and the countries involved to develop a concrete proposal as soon as possible. Clarify existing funding base and currently funded activities. How would this link to large number of other suggestions around modelling, identifying and characterising low emitting systems.
Calculating economic values for breeding indices for methane emissions Measuring large scale across breed, species etc Handling G + E Simulation models to estimate economic value Setting up scenarios for the future	Exceedingly resource intensive, needs sophisticated measurement methods, IP considerations, economic values will depend on local policies to some extent (eg GHG pricing), potentially very expensive. Perhaps need to develop a programme of work that brings together existing efforts so that better use made of existing data.
Lead the way on generating the/an evidence base for green financing Business models and business cases for emission-reducing practices	At the LRG annual meeting strong interest expressed by some in looking at policy & financial aspects of effective GHG mitigation – the enabling environment. Potential widespread benefit to

Validation and scaling up of options (has to be easily implemented; linkages to financing schemes/tools)	GRA members. Need to work with Partner organisations with strong expertise in the area to develop a flagship project that accords with the needs of GRA members.
Ideas that may be difficult to develop into flagship projects	
New approaches to developing low methane forages through gene editing (Crispr-CAS)	An exciting technology but contentious in some countries. Intellectual property issues may make it difficult to develop a collaborative GRA programme of work.
Evaluation of methane mitigation strategies at animal level	This proposal describes a series of experiments conducted in a single country. To become a flagship proposal it needs to be much broader in scope and involve collaborators from the broader GRA community. The information gathered could contribute to flagships looking more broadly at nutritional, microbial and feed additives.
Delivery of rumen bioactive compounds in a range of extensive systems	Not clear what this really means' Is it via slow release devices? Identification of plant species containing bioactives that are suitable for use in extensive systems? More clarity needed.
Intensification of livestock systems on farms to avoid deforestation – link intensification and preservation of the forest. Agreement with the farmer: the project will improve on area of the farm (silvopastoral system) with the commitment of possessing a mature forest in the farm and reforesting an area	As suggested more of an approach than a project. Perhaps a component of the evaluation and characterisation of farm system approaches to mitigation?
Use of simple methodologies at farmers' level in the measurement of emissions Proxy indicators for feed efficiency (broad applicability)	More detail needed. Is this about measurement or estimation? More detail needed
Standardised full LCA accounting tools to allow comparison across countries	Isn't this already being addressed by other initiatives e.g. LEAP. What is the GRA added value?
Build capacity of farmers to adopt good practices for pasture/grassland management Build capacity	The research groups already have elements of capacity building in their work programmes. Specifically building capacity of farmers may be difficult to achieve under a flagship umbrella as needs will be localised.
Ideas that need to be integrated with Inventory flagship proposals	
Guidelines and/or tools for improving activity data (including productivity), working in partnership with CCAFS, e.g. minimum data requirements for Tier 2, characterising uncertainties etc.	
Remote sensing of activity data, pasture quality, production, seasonality	
Consistency of emissions estimates across scales	
Bridging the gap from grey literature to IPCC database	
Sensitivity testing to address uncertainties in methane yield and activity data	Methane yield sensitivities addressed by the flagship proposal 'Improved quantification of the effects of feed on enteric methane emissions from cattle managed under a wide range of production conditions and environments'. Uncertainties in activity data a broader inventory issue.