FLAGSHIP PROJECT IDEA

GLOBAL RESEARCH ALLIANCE
ON AGRICULTURAL GREENHOUSE GASES

Title of project idea
GHG mitigation in cattle farming - how much is possible where and what are the economic implications on-farm?
Project leader
Thünen Institute
Countries involved
Argentina, Australia, Bangladesh, Belgium, Canada, Germany, Ghana, Peru, Portugal and South Africa. Further countries can be included depending on project partner interest and availability. **Council Champions:** Argentina, Germany, South Africa, Bangladesh (tbc), Belgium (tbc), Peru (tbc), Canada (tbc), Australia (tbc)
Brief description of idea

Background

The economic perspective on GHG mitigation strategies remains a challenge in global climate research. Especially, the costs of implementation and realization of GHG mitigation strategies at the farm level are not yet well-known, the data needed for economic assessment of GHG mitigation options at farm level is often not available or not comparable. This is of importance, as mitigation potentials, production costs as thus mitigation costs vary between production systems, but also within the same production systems. Countries need cost data to implement their NDCs and decide on how to allocate financial resources to support climate mitigation measures.

Project aim

The project aims to fill the cost data gap. It will investigate the feasibility and cost-effectiveness of GHG mitigation strategies on farm-level. It aims to identify the most cost-effective management and technology options in different global production systems and regions and to provide evidence-based policy recommendations on GHG mitigation strategies at the farm level.

Project description

In the beginning, the project will focus on beef cattle (cow-calf, backgrounding and finishing) as well as dairy farming systems. Production systems in beef and dairy farming differ worldwide, in some cases significantly, in terms of factor input and costs (labour, land, capital), other costs, animal performance and productivity, and GHG emission profile. The production environment also shows some significant differences, e.g. with regard to the availability of resources and infrastructure, climatic conditions or the cultural significance of animal husbandry. Based on the diversity of production conditions, mitigation strategies must be adapted to regional circumstances. The basic hypothesis for this research project is that, given the above, there are significant differences in mitigation potentials and abatement costs.

Climate protection and GHG mitigation are a global challenge. For an effective climate protection policy, analyses based on comparable data sets are necessary. Within the framework of the project, a concept for the harmonised evaluation of GHG mitigation

strategies will be developed, which allows comparisons to be made with regard to costs and potentials across production systems and countries.

The selected partner countries represent globally relevant beef cattle and dairy farming production systems and climatic zones. Data sets are specified to represent locally prevailing production. Locally adapted mitigation strategies are identified, specified and their effects quantified within the framework of calculations for typical farms. This allows us to upscale the farm-level results to the regional level in a second step. The results are analysed with regard to their GHG mitigation potential and costs using a marginal abatement cost curve approach. In addition, possible adoption barriers will be identified. The reduction scenarios are examined for their acceptance by farmers and probability of implementation. The results of the GHG reduction strategies will also be discussed with regard to possible side effects (e.g. rebound or leakage effects). Finally, the results will help to identify the most cost-effective managerial and technological GHG mitigation options per region to provide evidence-based policy advice.

The basis for the comparative analysis of typical production systems is the Standard Operating Procedure[1] used in the *agri benchmark* Network Beef and Sheep.

In focus groups with producers, consultants and local production economists, we collect data on production systems (animal numbers, categories, performance data, feed rations, etc.) and on prices and costs of typical cattle farming systems. For this baseline the economic viability and GHG emissions are calculated.

Some of the partners are already members of the *agri benchmark* Network. Further, the situation in terms of data availability (farm level and emissions) differs. As a consequence, the following option for the next steps are available:
Option a) Add existing GHG emission data to existing typical farm dataset
Option b) Add new GHG emission data to existing typical farm dataset
Option c) Add new typical farm dataset to existing GHG emission data
Option d) New data collection covering economic and emission data
Option e) Compare existing GHG and economic data sets and harmonize

The calculation of production-related GHG emissions is based on internationally recognised methods (IPCC, 2019). The reduction strategies are determined on the basis of local research results and focus groups. For this purpose, the individual production and accounting model TIPI-CAL is applied. The economic analysis is extended by questioning beef cattle and dairy farmers about their willingness to implement reduction measures.

Depending on the interest and involvement of partners in the field of natural science, the analysis can be expanded to further environmental indicators (nutrients, water, biodiversity) as well as animal welfare aspects.

Planned next steps

- Q1/22: Concept paper with flagship project milestones planned for 2022 will be sent out to flagship partners for comments
- Q1/22: Meeting with all flagship project partners to discuss concept paper and final details

[1] Chibanda C, Agethen K, Deblitz C, Zimmer Y, Almadani I, Garming H, Rohlmann C, Schütte J, Thobe P, Verhaagh M, Behrendt L, Tudela Staub DF, Lasner T (2020) The typical farm approach and its application by the Agri Benchmark network. Agriculture 10(12):646, DOI:10.3390/agriculture10120646

- Q2/22: Working paper preparation to be presented at the *agri benchmark* beef and sheep conference, 17th – 22nd June 2022
- Q3+4/22: Develop a publication for peer-reviewed journal

Expected Outcomes

The analysis aims at contributing to the following questions:

- What are the greenhouse gas profiles of typical beef cattle and dairy production systems in different production regions?
- Which greenhouse gas reduction strategies can be applied in the different production systems and regions and what are the associated reduction potential and costs / what are the most cost-effective managerial and technological GHG mitigation options?
- What are the barriers to the implementation of reduction strategies and how high is the probability of adoption in this context?
- What are the potential trade-offs and co-benefits of mitigation strategies?

Based on the calculations on mitigation extent and related costs, we aim to identify the least cost abatement measures for various farming situations.
The developed methodology could be transferred to other sectors, such as sheep farming, pig farming, arable farming or horticulture.

How will you encourage participation by a wide range of members, including low-income countries?

The partners from the *agri benchmark* Network would be available at relatively short notice. Furthermore, participation of members of the GRA Farm to Regional Scale Integration Network is expected. For all research partners involved funding is required for data collection, local travel, regional workshops and presentation of results to local stakeholders. Low income countries in South America, Sub-Sahara Africa and Asia would be addressed with high priority to link them to international research activities and provide capacity building, where required. The involvement of local producers and other experts as well as the dissemination of results is an integral part of the research. The project aims to especially involve young researchers from low-income countries through e.g. CLIFF-GRADS Fellowships or DAAD climapAfrica scholarships.

Benefits to the GRA

- Global scope: several GRA member countries have indicated their willingness and capacity to collaborate on the project. The participation signalled to date covers globally relevant beef cattle and dairy farming production systems and climatic zones.
- Global cost-benefit analysis of GHG mitigation strategies at farm-level in beef cattle and dairy sector: only possible through GRA-wide collaboration.
- Fill the existing research gap on identifying cost-effective managerial and technological GHG mitigation options across regions and complement existing GRA research work with socioeconomic analysis.
- Synergies with GRA work: multiple connecting points, e.g. the mitigation database of the GRA Feed and Nutrition Network, the MELS (Mitigating greenhouse gas emissions from livestock systems) project of the GRA Manure Management Network are suitable for an economic evaluation of the developed technical options.

- Development of harmonized approach to analyze costs and benefits of GHG mitigation strategies to make results comparable between regions and provide evidence-based policy advice on cost-effective managerial and technological GHG mitigation options.
- The methodology is globally applicable, and especially suitable in countries with limited official statistical data availability, as it integrates experts and producer knowledge in the data collection phase.
- Build database for farm-level assessment of GHG mitigation strategies related to costs and benefits

Intended start date and project length

Anytime, 3-5 years depending on number of countries and case studies.

Key partners and existing resources

Depending on the countries selected. Existing partners from the *agri benchmark* countries and GRA Farm to Regional Scale Integration Network can form a basis (see table below). In other countries new partners must be found.

Country	Partner name	Type of resource	Possible length of support
Germany	Thünen Institute	Human resources: • Dr. Claus Deblitz • Katrin Agethen • Nina Grassnick	• Full flagship project length • Full flagship project length • Until April 2024
		Project resources: • International research collaboration on mitigating climate change in agriculture • GHG mitigation in cattle farming - how much is possible where? • Implementing sustainable agricultural and livestock systems for simultaneous targeting of forest conservation for climate change mitigation (REDD+) and peace-building in Colombia (CIAT Project C-073-19)	• Until April 2024 • Full flagship project length • Until December 2022

South Africa	Agricultural Research Council	**Human resources:** • Prof. Michiel Scholtz • N Thuli Chabalala • Motshabi Chadyiwa • N Olivia Mapholi • Dr Marsia Grobler • Gilbert Pule • Francuois Muller • L Letsoalo • M Kidson • Dr Mokhele E Moeletsi • Idani A Gundula	• March 2025 • September 2022 • March 2025 • June 2023
		Project resources (see appendix): • The farm gate carbon footprint of diverse beef cattle genotypes in South Africa and its environmental impact • Carbon footprint of natural grazed rangeland in relation to extensive beef cattle production • Estimating greenhouse gasses from three livestock production systems in Gauteng	• Until September 2022 • Until March 2025 • Until June 2023
Bangladesh	Bangladesh Livestock Research Institute	**Human resources:** • Nani Gopal Das • Dr. Nasrin Sultana	• Until June 2022 • tbc
		Project resources: • A Gate-to-Gate Analysis of Beef Cattle Carbon Footprint at South-West Region of Bangladesh during Eid ul-Adha	• Until June 2022

Australia	Charles Sturt University	**Human resources:** • Dr. Karl Behrendt (tbc) • Dr. Sosheel Godfrey (tbc)	• ... • ...
		Project resources: • ...	• ...
Peru	Universidad Nacional Agraria La Molina	**Human resources:** • Prof. Dr. Carlos Gomez (tbc) • Dr. Eduardo Fuentes Navarro (tbc)	• ... • ...
		Project resources: • Improving sustainability and resilience of Peruvian Amazon systems through silvopastoralism • Collaborative research project with CIAT and CIFOR/ICRAF on silvopastoral cattle in the Amazonian region	• Until April 2023 • ...
Argentina	Universidad Nacional de Córdoba	**Human resources:** • Florencia Garcia	• Full flagship project length
		Project resources: • Local-adapted GHG mitigation strategies for pastoral livestock systems of the semiarid region of the center of Argentina (see appendix)	
	Instituto Nacional de Tecnología Agropecuaria (INTA)	**Human resources:** • Dr. María Paz Tieri • Jorge Martínez Ferrer • Dr. Patricia Ricci	
		Project resources: • INTEGRITY – Integrated crop-ruminant livestock	• Until February 2025

		systems as a strategy to increase nutrient circularity and promote sustainability in the context of climate change	
Belgium	Flanders Research Institute for Agriculture, Fisheries and Food (ILVO)	**Human resources:** • Dr. Nico Peiren • Dr. Veerle Van Linden • Dr. Karen Goossens	• Full flagship project length • Full flagship project length • Full flagship project length
		Project resources: • Climate actions with economic potential on farm - Klimrek support (https://www.klim-rekproject.be/) • KlimGras • BovINE WP6 (Climate and environmental sustainability)	• Until August 2023 • Until November 2024 • Until December 2022
	Walloon Agricultural Research Centre CRA-W (tbc)	**Human resources:** • tbc	
Ghana	Council for Scientific and Industrial Research	**Human resources:** • Dr. John K. Nyameasem	• Full flagship project length
		Project resources: • Evaluation of greenhouse gas emissions from grazing ruminants on coastal grasslands of Ghana	• Until September 2023
	Kwame Nkrumah University of Science & Technology	**Human resources:** • Dr. Christopher Antwi (tbc)	• ...
		Project resources: • ...	• ...

Canada	Canfax Research Services	**Human resources:** • Brenna Grant	• ...
		Project resources: • Canadian Cow-calf Cost of Production Network	• ...
Portugal	Algarve University	**Human resources:** • Prof. Maria de Belem • Prof. Miguel Sottomayor (tbc)	• Full flagship project length • Full flagship project length

Further resourcing needs (financial and personnel)

- Financial needs:
  - Participation of Nani Gopal Das in the project after June 2022
  - South Africa will have to commit more finances to the project beyond the finances that are currently committed to ensure participation for the full duration of the project. If South Africa is to align the existing projects fully to the flagship project, more financial sources will be needed
- Personnel needs:
  - Portugal needs researcher to support data collection (e.g. Cliff-GRADS student)
  - Argentina needs additional personnel support to align existing projects to flagship project (e.g. Cliff-GRADS student)
  - South Africa will have to commit human resources for the full period of the project

Resourcing mechanisms

As indicated above, the key partners will provide personnel and project resources. Further financial resources have to be found as indicated above.

Linkages

Flagship project activities will be aligned with planned activities of the GRA Farm to Regional Scale Integration Network and ongoing projects of its members.
Collaboration with the MELS project, BovINE project and MACSUR SciPol might also be possible.

Appendix

Local-adapted GHG mitigation strategies for pastoral livestock systems of the semiarid region of the center of Argentina

Introduction

Due to the contribution of GHGs emissions associated with ruminants, several recent reports on diets and food systems have generated much debate on the role of animal-based foods in the human diet. A large portion of consumers have internalized this problem, and this has influenced their meat consumption behavior. The demand of consumers regarding the quality of products and the way in which food is produced are increasing, and imply an important challenge for animal production: how to sustainably supply the growing demand for food of animal origin while addressing consumers' demands.

The Sustainable Development Goals (SDGs) provide a new perspective to consider climate action within the various dimensions of sustainability. In this sense, it has been identified that nine of the seventeen SDGs have direct and significant links with the livestock sector (SDG: 1, 2, 3, 5, 8, 12, 13, 15 and 17). In summary, livestock production plays an important role in various dimensions related to food security and territorial development. Moreover, ruminants have the unique ability to convert fibrous feed that cannot be directly exploited by humans, such as forage, into food products of high nutritional value.

There is global consensus that livestock accounts for an important portion of the GHG emissions. On the other hand, grazing lands have a great potential to sequester carbon dioxide and it has been proposed that they can even change the equation in terms of carbon balance. However, the information of the potential of pastoral systems for carbon sequestration at a regional level is rather scarce. There is a need to consider the system's net global carbon balance, and efforts should be center on reducing emissions while enhancing capture.

The project seeks to provide information on the environmental impact that livestock production has locally, while identifying which strategies would improve the environmental performance of the livestock system in the Semiarid region of the center of Argentina. It is postulated as a hypothesis of this project that, due to the potential of the plants to fix carbon, pastoral-based livestock and with the presence of trees and shrubs, as in the northwest of the province of Córdoba (Semiarid region), could constitute a solution to the problem of GHG accumulation.

Methods

There are several alternatives to reduce GHG emissions from livestock reported in the literature, the question that arises is: which of the existing GHG mitigation strategies would be applicable to livestock systems in the northwest region of Córdoba?

The first step of this project is to identify applicable GHG mitigation strategies. An exhaustive bibliographic search will be carried out to compile all the strategies proposed so far. The strategies will be classified and analyzed taking into account the scale of application (animal or system), the type (nutritional, pasture management, etc.), the mitigation potential, as well as technical and economic aspects. To define the feasibility of implementation, local farmers will be consulted. The identification of the mitigation strategies applicable to the livestock systems of the northwest of Córdoba will be carried out by contrasting the characteristics analyzed in the first instance with the characteristics of the livestock systems. The second step will be to calculate the carbon balance, following the suggestions of the IPCC guidelines (2006).

Results

This project started in middle 2019; it is in early stages and no results are available so far.

Conclusions

There is a need for changing the perspective of analyses when analyzing the contribution of animal-food production to climate change. Not only livestock plays an important role in various dimensions related to food security and territorial development, but also pastoral production

systems could potentially be a part of the solution if we focus in the carbon balance rather only in the emission.

Policy/practice relevance

There is an urgent need to investigate the potential of pastoral livestock systems in our region to answer the question of whether livestock is a source of a problem or an alternative solution to climate change. This project proposes to address this complex question, while identifying which strategies would improve the environmental performance of the livestock system. If the hypothesis that pastoral livestock systems are part of the solution to global warming is confirmed, this information will have high strategic value for our region.

As a final product, it is expected to obtain and provide concrete information to recommend public policy guidelines, plans / programs for extension and training, etc. intended for sustainable livestock development. Findings will allow policy makers to make educated decisions when formulating funding opportunities and policies aimed to accelerate the transition towards low carbon livestock production systems and increase the production and access of high-quality protein.

Possible collaboration of South Africa in the GRA Flagship project "GHG mitigation in cattle farming"

Initially South Africa only submitted one possible proposal, but it has since been extended to three project ideas. They are summarized below.

1. **The farm gate carbon footprint of diverse beef cattle genotypes in South Africa and its environmental impact**" can be considered as part of the project.

Research staff: N.T. Chabalala, M.C Chadyiwa, M.M. Scholtz & N.O. Mapholi
Aims and objectives
To estimate the current farm-gate carbon footprint of the major beef breeds in South Africa that is representative of the different breed types e.g. Sanga (Indigenous), Sanga derived, Zebu, Zebu derived, British and European breeds.
Anticipated outcome
The quantification of the carbon footprint of the major South African beef breeds and its environmental impact can supply information to develop an emissions baseline for the Agriculture, Forestry and Other Land Use (AFOLU) sectors.
The information can be used to develop a model that can estimate the farm-gate methane emission intensity for different breed types, production levels and production systems. Information on South African production systems, production levels and breed types will be available for the estimation of country specific carbon footprints of beef production.
Funder
Department of Agriculture, Land Reform and Rural Development (DALRRD)
Duration
Until September 2022

2. Carbon footprint of beef cattle production in relation to natural grazed rangeland

Research staff: S M Grobler, M M Scholtz, G Pule, F Muller L Letsoalo & M Kidson
Aims and objectives
To determine the carbon and water footprint of extensive beef cattle grazing natural rangeland in the Sourish Mixed Bushveld.
To relate cattle methane production, measured with a Laser Methane Detector, to the water use efficiency and rangeland condition over different seasons and years.
(With additional funding soil microbial population and rangeland carbon balance can be investigated to quantify soil carbon sequestration within grazed rangeland)
Anticipated outcome
Results obtained will make it possible to calculate the carbon footprint of beef cattle grazing natural rangeland. Obtaining local results will prove useful in future modelling activities.
Relating enteric methane production with rangeland water use efficiency and rangeland condition over different seasons and years will shed light on the dynamics of rangeland condition and cattle's greenhouse gas emissions.
Funders
Red Meat Research and Development South Africa (RMRD SA)
Agricultural Research Council (ARC)
Duration
Until March 2025

3. Estimating greenhouse gasses from three livestock production systems in Gauteng

Research Staff: M Moeletsi & I A Gundula
Aims and objectives
The study aims to estimate the amount of GHG's emitted from three beef cattle production systems, mainly focusing on inputs, on-farm operations, and outputs. In addition, a sensitivity analysis will be carried out to assess the sensitivity of the calculations to estimations of input parameters and to assess possible mitigation options.

Anticipated outcome

There is a need for more detailed information on GHGs emissions, mainly from beef cattle production, since research suggests that cattle production emits more GHGs than other agricultural activities. Most analyses to estimate GHG emission factors are based on literature and default values.

Funder

Agricultural Research Council (ARC)

Duration

Until June 2023

FLAGSHIP PROJECT IDEA

GLOBAL RESEARCH ALLIANCE
ON AGRICULTURAL GREENHOUSE GASES

Title: MAC-B: Mitigation and Adaptation Co-Benefits

Leader: AgMIP/GRA Partnership, Cynthia Rosenzweig and Erik Mencos (NASA GISS/Columbia University)

GRA Council Champions: *list the names of at least 5 GRA Members and Partners (including at least 3 Member countries)*

1. *USA (TBC)*
2. *Canada (TBC)*
3. *France (TBC)*
4. *Australia (TBC)*
5. *Bangladesh (TBC)*

The activity is led by the Agricultural Model Intercomparison and Improvement Project (AgMIP), a partner of the GRA.

Countries involved:
Currently: Bangladesh, USA, Australia
Intended: Additional GRA country members. We already have expressed interest from colleagues in Vietnam, Zimbabwe, and Peru.

Start date and project length:
Ongoing pilot study in Bangladesh started September 2021 and will end December 2022. Building on the Bangladesh pilot study, we anticipate expanding MAC-B to other GRA countries with full 3-year projects beginning in 2022 and extending to 2025.

Brief description of project:
Based on the activities of the GRA Integrative Research Group, the MAC-B Flagship Project will build a community of experts within the GRA Membership to develop and apply new protocol-based methods for providing national decision-makers evidence-based knowledge about the benefits and trade-offs of mitigation and adaptation interventions.

The AgMIP/GRA Partnership will develop a globally-applicable 'Mitigation and Adaptation Co-Benefits' (MAC-B) assessment methodology, adapted from the Agricultural Model Intercomparison and Improvement Project (AgMIP) Regional Integrated Assessment (RIA) approach that has been implemented across Sub-Saharan Africa and South Asia (published protocols available at www.agmip.org). The protocols link agricultural models used to simulate greenhouse gas (GHG) emissions and mitigation interventions and models used to simulate climate change impacts and adaptation. The methods utilize climate, crop/livestock, and socioeconomic data, models and tools in order to assess the impacts of agricultural mitigation and adaptation interventions, climate change, and food security.

Dedicated stakeholder engagement is embedded throughout the project to ensure that the data, models, and tools developed contribute to climate change decision-making at national levels.

We will hold an annual MAC-B forum for all GRA countries to share lessons learned from the project.

Key partners and existing resources:
We have received 250,000 AUD from the Australian Centre for International Agricultural Research to conduct an initial pilot study in Bangladesh.

Key partners include:

In-country: Bangladesh Rice Research Institute, Bangladesh Agriculture Research Institute, Bangladesh Met Department, and Rural Development Academy, CIMMYT Bangladesh

Support team: Columbia University, Oregon State University, New York University, DNDC-ART

The intended goal is to develop long-lasting partnerships with local researchers, stakeholders, and institutions in each country where we apply the MAC-B methodology.

Benefits and outcome from Flagship project:

This project will apply a modeling approach for quickly and efficiently determining the likely best options for changing agricultural practices in ways that deliver both mitigation and adaptation benefits. The intended long-term outcome is to be able to accelerate the process of identifying the most promising options, and thus progress to trialing and scaling more quickly than has been done to date. The project will generate new knowledge with high scientific impact.

All countries will benefit from GRA-wide collaboration on MAC-B through learning about the effectiveness of mitigation and adaptation interventions in a wide range of agricultural and development contexts.

Further Resourcing needs:

We are creating a three-tiered approach to activities and funding, so as to ensure the widest possible engagement among GRA countries.

Tier 1 ($250K/country): Pilot Study with data and model calibration and validation; MAC-B results from one intervention package; Stakeholder engagement (1 year)

Tier 2 ($500K/country): Data and model calibration and validation; MAC-B results from 2 intervention packages; Extended stakeholder engagement, including Researcher/Stakeholder Training (2 years)

Tier 3 ($750K/country): Data and model calibration and validation; national/within country region data platform; Full MAC-B Assessment for multiple interventions (3 years)

We are currently performing a fast-track pilot study in Bangladesh. Our ultimate goal is to complete a full MAC-B regional integrated assessment in Bangladesh, as well as conduct studies in other countries. We anticipate a need of 750K USD per country for a full 3-year MAC-B assessment. As an initial phase, we will complete the full project in Bangladesh and conduct MAC-B assessments in an additional 3 countries from 2022-2025 for a total of $3 million. At the same time, we will be developing MAC-B projects in as many GRA member countries as interest is manifested.

Resourcing mechanisms:

Following the current funding model, we will seek funding from GRA country members interested in MAC-B to fund assessments in their own region or other countries of interest.

Linkages:

The project is being led by the Agricultural Model Intercomparison and Improvement Project (AgMIP), a GRA Partner.

We will link to other key climate change programs including at the CGIAR and bilateral programs.

FLAGSHIP PROJECT IDEA

GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

Title: Hungate Collection: Second Coming

Leader: Professor Sharon Huws, School of Biological Sciences/Institute for Global Food Security, Queen's University Belfast, UK.

GRA Council Champions: *list the names of at least 5 GRA Members and Partners (including at least 3 Member countries)*

1. *Dr Hugo Jiminez, Agrosavia, Columbia*
2. *Professor Itzik Mizrahi, Ben-Gurion University, Israel*
3. *Professor Wei-Yun and Professor Yanfen Cheng, Nanjing Agricultural College, China*
4. *Dr. Shengguo Zhao, Chinese Academy for Agriculture, China*
5. *Professor Sinead Waters, Teagasc, Ireland*
6. *Professor Richard Dewhurst, SRUC, UK*
7. *Dr David Ruiz Yanez, CSIC, Spain*
8. *Dr Diego Morgavi, INRAE, France*
9. *Dr Rodolpho Prado, Universidade de Maringa, Brazil*
10. *Dr Rob Gruninger, D Renee Petri and Dr Tim McAllister, AAFC Canada*
11. *Professor Leluo Guan, University of Alberta, Canada*
12. *Dr Matthias Hess, UcDavis, California, USA.*
13. *Dr Garrett Suen and Dr Hilario Montovani, Madison University, USA.*
14. *Professor Hauke Smidt, Wageningen University and Research, Netherlands*
15. *Dr Graeme Attwood and Nik Palevich, AgResearch, New Zealand*

Countries involved:
As hubs and co-hubs of culturomics:
Brazil
Canada
China
Columbia
France
Ireland
Israel
Netherlands
New Zealand
Spain
UK
USA

As partners sending samples to the nearest hub:
Open to all and hope that LMIC countries without infrastructure to become hubs can participate through sending samples and being named as a co-author on a publication.

Start date and project length:
01/06/21 for 2 years with some flexibility

Brief description of project:
The rumen is a complex, dynamic ecosystem composed of mainly anaerobic bacteria, protozoa, anaerobic fungi, methanogenic archaea and phages. These microbes interact with each other and have a symbiotic relationship with the host, providing energy from the breakdown of plant cell wall carbohydrates that are largely inedible by human. The rumen bacteria far outnumber the other microbial groups (approx. 10^{10}-10^{11} cells/mL), with rumen protozoa, fungi and archaea being reasonably similar in densities (10^3-10^5 cells/mL), but the number and diversity of the rumen viruses remains largely unknown. Our understanding of most microbiomes, including the rumen, has been hindered by poor culture collections and a lack of effort placed on culturing in an era that has seen an explosion in metataxonomic and metagenomic sequencing. This has led to an assumption that many microbes are unculturable, when it is well recognised that with some effort they could be cultured. Nonetheless, the emphasis on culture, termed culturomics when combined with genome sequencing, is returning as these culture collections are hugely valuable to our fundamental understanding of microbiomes, use as probiotics/direct-fed microbials and a source of bioactive compounds for biotechnological applications.

In terms of the rumen microbiome, the seminal work of Robert Hungate in the 1960s resulted in many of the culture technologies for anaerobic bacteria, that are still widely used throughout the world. The recent Hungate collection Joint Genome Initiative (previous GRA flagship) represents a major step change in our understanding by providing 501 rumen bacterial and archaeal genomes, resulting largely from the pioneering work of Robert Hungate, which allowed culture of these microbes in the laboratory. This is an immense achievement, which has greatly enhanced our ability to understand the rumen microbiome and resulted in much scientific impact in terms of follow on publications. Nonetheless, the project has now ended, due to funding rather than reaching the end of the rumen microbial cultures available. As such, many genomes for rumen microbes remain unavailable. The Hungate collection is also underrepresented by the Phylum Bacteroidetes and family Bacteroidales compared with their representation within the global rumen census dataset (previous GRA flagship project) and genomes from so called unulturable rumen bacteria are also hugely underrepresented. Some genomes from so called unculturable rumen bacteria have recently been assembled from metagenomics sequences (called metagenomically assembled genomes (MAGs)), nonetheless, there is a need to get these microbes in culture to test key hypothesis arising from the genomic information in the laboratory are somewhat hindered. Undoubtedly, there is a crucial need to develop methods for isolation and culture of 'missing' rumen microbes and subsequently obtain 'omic level information. Likewise, many cultures remain in our culture collections, which were not sequenced as part of the initial Hungate collection; the phenotypes and genomes of which are crucial to drive further innovation in sustainable livestock production.

In terms of advances in rumen culturomics, our ability to culture rumen bacteria has notably improved in recent years, through the development of new culture media and use of dilution to extinction. For example, development of the enhanced rumen bacterial media RMO2, and use of the dilution to extinction technique allowed the isolation of 54 novel bacteria. Indeed, partners in QUB and Ben-Gurion university have also recently placed substantial emphasis on rumen bacterial culturomics, with over 100 novel isolates (according to 16S rDNA) being in pure culture (as yet unpublished), including those which are most closely related to so-called unculturable bacteria, illustrating the potential power of such applications. Whilst such efforts will undoubtedly form the basis of further understanding and biotechnological exploitation of rumen microbiome, the potential to use some of these bacteria as direct-fed microbials in the diets of ruminants in order to re-direct hydrogen away from the methane biochemical pathways are immense. In particular in combination with additives, which reduce methane emissions, these potential direct-fed microbials could not only further reduce methane output but provide a production enhancement in a sustainable manner. Consequently, given the impetus, the aims of this GRA flagship are to isolate, phenotype and genotype novel rumen bacteria (or the latter 2 only if novel cultures are already available) from cultures or samples sent from as many GRA member countries to QUB, which will form the flagship hub (with the option given to other partners with resources available to also be a hub of activity for the flagship, whilst utilising aligned protocols), in order to drive future innovations for enhanced sustainability of livestock production. We will

instruct member countries appropriately as to how to send DNA, cultures or samples and protocols involving minimal input from countries with limited resources have already been developed. We also recognise the governmental challenges that sometimes can be associated with member countries sending samples and we will work closely with the Northern Ireland government to overcome obstacles and also we will aim via the CLIFF-GRAD program to train staff/students from a variety of countries, particularly those who experience difficulties in sending samples, such that they can get involved and that they will be trained to carry out the research in their own country and get maximal benefit from the flagship. In essence, every attempt will be made to ensure this flagship is open to all member countries, ensuring it's global impact in enhancing sustainable livestock production.

Key partners and existing resources:
See above list of partners and country of residence. Partners who will act as the hub and co-hubs have substantial infrastructure for anaerobic microbiology. Most of these partners are also partners in the following substantial projects:

EU Horizon 2020 (Acronym: MASTER) https://www.master-h2020.eu/
FACCE ERA-Net Gas (Acronym: RumenPredict) https://www.eragas.eu/en/eragas/research-projects/rumenpredict.htm
FACCE ERA-Net Gas (Acronym: SeaSolutions) https://seasolutions.ie/
FACCE ERA-Net Gas (Acronym: INTEGRITY) https://www.eragas.eu/en/eragas/Research-projects/INTEGRITY.htm
DAFM/DAERA (Acronym: MethAbatehttps://www.agriland.ie/farming-news/cross-border-research-project-to-cut-methane-emissions-on-the-cards/
EU Horizon 2020 (Acronym: Holoruminant) https://cordis.europa.eu/project/id/101000213

Our aim is to add value to the existing infrastructure and funding and providing facilities allowing partners from countries lacking infrastructure to become involved and shape the flagship. Involvement of LMIC countries is particularly required as the samples will no doubt represent unique biodiversity given the differences in diet.

Benefits and outcome from Flagship project:
Without the need to culture from samples received globally, we already have over 200 pure cultures available within QUB, Ben-Gurion University, AAFC Canada and many others partners. Therefore at a minimum, we will phenotype these 200 using the Omnilog system and classical Gram staining etc. Following 16S rDNA sequencing we will choose those which are of most interest to genome sequence alongside partners and in line with funding availability for the sequencing effort. This GRA flagship will undoubtedly lead to a very impactful publication, involving all partners which have participated in some way. It will also help to assemble and annotate metagenomic and metatranscriptomic sequences, leading to a deeper understanding of the rumen microbiome. The follow on publications utilising these datasets are expected to be large, as are those resulting from the Hungate collection, therefore ensuring major legacy and impact. These sequences will also be used to further enhance the CowPI 16S rDNA based functional inference tool, thus enhancing the understanding within studies that have been unable to find funding to go beyond metataxonomy as is the case for many of the studies coming from LMIC countries. As well as providing resources for biotechnological exploitation of novel bioactives, the most crucial expected outcome of this flagship is to provide biological resources to investigate the possibility of using some of these microbes as direct-fed microbials to re-direct hydrogen within the rumen for further reducing methane emissions and enhancing productivity in a sustainable manner. These cultures will be kept within -80 and -20°C freezers within each hub, ensuring that each culture is at least duplicated. We expect many follow on projects will ensue as a consequence of this flagship and the intention is to ensure that the isolates are available to all either through the hubs or through deposition in cheap and accessible culture collections, such as DSMZ (subject to IP discussions).

The benefits to the GRA from this flagship are immense. We will be utilising the skill sets of the most knowledgeable anaerobic microbiologists globally to form the most comprehensive culture collection, alongside phenotype and genotypic biological and bioinformatic resources. The impact of this project will be immense in terms of 1. Global visibility and engagement with the GRA, 2. Brining global GRA partners together and maximising country value from being members of the GRA, 3.Publication impact, 3. Potential for global novel innovations from the project. Prof Huws has led the Rumen Microbial Genomics network for 8 years and within this time has been an advocate of the GRA, organised global workshops and communicated to all members from developed and non-developed countries with respect to opportunities etc. and will continue to do so whilst marketing the potential to become involved in this project and disseminating outcomes.

Further Resourcing needs:
We require a post-doctoral scientist for a period of 2 years (at a minimum) at a cost of approximately £170,000 and would value the appointment of a scientist from a low or middle income country supported by CLIFF-Grad scholarships to increase the impact of the flagship and the training opportunity in rumen microbiology for all GRA partner countries. This person will communicate to all partners to coordinate sample delivery from GRA members, intellectual property discussions (alongside internal experts within QUB with consultancy with New Zealand partners who conducted the Hungate collection research using similar governance) and lead the culturing and storage aspects of the project. In return we will use existing funds for an affordable level of consumables and will apply for appropriate funding to enhance capabilities, whilst also asking those with resources to become co-hubs. Resourcing mechanisms We will use a small proportion of budgets within existing projects (EU FACCE JPI RumenPredict, EU Horizon 2020 MASTER and EU Horizon 2020 Holoruminant) to purchase consumables to culture and phenotype bacterial isolates and sequence a proportion of those which are of interest, initially using 16S rDNA sequencing for identification and thereafter a further refined list for genome sequencing (£250/bacterium via MicrobesNG including illumina Hi-seq and oxford nanopore sequencing, assembly and annotation of closed genomes). We will also seek further funding to increase our capacity to phenotype and genotype isolates, from funders such as the EU (Cost Action possibly), UKRI and especially the JGI CSP calls.

Resourcing mechanisms:
Thirty % funding will be covered from funding within the projects named above.

Linkages: As noted we will also use resources within EU FACCE JPI RumenPredict and Horizon 2020 projects MASTER and Holoruminant. Between ourselves, Ben-Gurion University and AAFC Canada we have over 200 isolates to work with already and intent from the other countries noted that they will be involved get involved in various capacities (sending DNA, pure cultures or samples or through exchange/training). The partners are world leaders in this area and have extensive networks of stakeholders, including academics, industry, farmers, policy makers, which will be used to disseminate data and maximise potential impact from this project beyond academic resources and publications.