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1 Acknowledgments

This Small Research Activity (SRA) ‘Defining GHG Inventory System Priorities for Agriculture’ was designed as a bridging solution between Phase 1 and Phase 2 of a larger project ‘Agriculture based emission-reduction options to support NDCs in Vietnam and Fiji’. Phase 1 of the project was funded by ACIAR from 2018 to 2020. The SRA has refined the outputs of this project to inform the development of Phase 2 with a focus on ‘Supporting greenhouse gas inventories and targeted mitigation options in Vietnam and Fiji’. The financial support of ACIAR and the guidance and support from Dr Veronica Doerr are gratefully acknowledged. We are most grateful for the support and guidance of our in-country colleagues: Jeanette Mani (Ministry of Economy, Fiji), Avinesh Dayal (Ministry of Agriculture, Fiji), Ms Le Hoang Anh (Ministry of Agriculture and Rural Development, Vietnam), Professor Mai Van Trinh (institute of Agricultural Environment, Vietnam) and Dr Tran Van The (Institute of Agricultural Environment, Vietnam). The administrative support from Ms Florence Rahiria and Ms An Nguyen (ACIAR Regional Managers) and Mrs Annabelle Ramsay (QUT) is also gratefully acknowledged.

2 Acronyms

AFOLU	Agriculture, Forestry and other Land Use
ALU	Agriculture and Land Use
AWD	Alternate Wetting and Drying
BUR	Biannual Update Report
CCAFS	Climate Change, Agriculture and Food Security
CCICD	Climate Change and International Cooperation Division
DOSTE	Department of Science, Technology and Environment
EF	Emission Factor
GHG	Greenhouse gas
GRA	Alliance on Agricultural Greenhouse Gases
IAE	Institute of Agriculture and Environment
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
MARD	Ministry of Agriculture and Rural Development
MoE	Ministry of Economy
MONRE	Ministry of Natural Resources and Environment
MRV	Monitoring, Reporting and Verification
NDC	Nationally Determined Contribution
NZ MPI	New Zealand Ministry of Primary Industry
NZAGRC	Agricultural Greenhouse Gas Research Centre
RAID	Agriculture for International Development
SDG	Sustainable Development Goals
SRA	Small Research Activity
SRI	System of Rice Intensification
ToC	Theory of Change
USEPA	United States Environment Protection Agency

3 Executive summary

Numerous climate change mitigation measures with co-benefits to agriculture have been identified in both Fiji and Vietnam (LWR/2017/029). However, the effective implementation of these actions at a national level requires robust supporting greenhouse gas inventory systems to capture and account for greenhouse gas (GHG) mitigation as part of NDC commitments.

Estimates of GHG emissions can be captured, at the most basic level, as a Tier 1 inventory using IPCC default emission factors. However, if we are to advance the capability of inventories to accurately assess GHG emissions and the impact of mitigation strategies, this requires country specific Tier 2 data. For example, improving the feed quality for livestock requires a Tier 2 methodology that utilises local science and activity data to underpin calculations because the emissions calculations using default Tier 1 IPCC are not sensitive enough to detect mitigation, beyond the removal of animals. Similarly in cropping systems, Tier 2 inventories are required to predict the impact of different mitigation actions across diverse agroecological zones.

This Small Research Activity (SRA) acknowledged that generating inventory systems is a large and complex task that not only involves advancing data collection, but also requires the development of governance structures that will support inventory compilation and improvement over time. Therefore, the aim of the SRA was to assess the state of the current inventory and identify the most strategic gaps to fill in the next phase of the project, given the time and resources available.

The most strategic gaps to address in the Vietnamese inventory were determined to be the development of a Tier 1 agricultural inventory in the cropping sub-sector and a Tier 2 inventory in rice (using locally developed emission factors and modelling). In addition, there will be a strong focus on the development of institutional and governance arrangements to support the GHG inventory as the responsibility is transferred from MONRE to MARD. In Fiji, the priority is to advance the livestock inventory to Tier 2 so that mitigation action can be accounted for, beyond the removal of animals. These research priorities were used to inform the development of the Full Project Proposals for CLIM/2019/150 and CLIM/2021/160.

4 Background

Adaptation of agricultural systems to climate change will be necessary in efforts to eradicate poverty and hunger and contribute to numerous sustainable development goals (SDGs) – in particular, SDG #2 (zero hunger) and SDG #12 (action for climate). Without adaption, it is estimated that climate change could decrease global crop yields by 5-30 % by 2050 (Porter *et al.* 2015) threatening food security and increasing the incidence of poverty (Kesar 2011). At the same time, the agriculture sector accounts for more than 13% of global emissions, rising to nearly a quarter of emissions when accounting for land use change (IPCC 2019). Emissions from agriculture will continue to rise, driven by global demand for resource-intensive foods like meat and dairy, and through the increased use of synthetic fertilizer (Searchinger *et al.* 2019). Mitigation is therefore an essential component of global efforts to limit global temperature rise to 1.5℃ to avoid the most severe climate impacts that will affect global poverty and food security.

Advancing the climate mitigation agenda presents numerous opportunities to bring together climate change (mitigation and adaptation) and SDGs such as ending hunger, supporting sustainable livelihoods, and reducing poverty. For example, the practice of alternate wetting and drying in rice systems can increase yields and water use efficiency, while reducing CH_4 emissions (Basak 2016; Allen and Sander 2018; Wang *et al.* 2020). Systems of rice intensification can increase yields and water use efficiency, while improving crop resistance to droughts, storms and flooding (Thakur *et al.* 2021). In livestock, many developing countries have systems with relatively high emissions intensity that could be reduced with, for example, better quality feed (Henderson *et al.* 2017). A diet that is balanced in energy and protein, and that includes improved forages (e.g. incorporation of legumes), leads to greater animal production and improved fertility (GRA 2015). This in turn will strengthen the assets of rural households helping to generate income, improve food security and achieve their livelihood needs.

While numerous mitigation measures with co-benefits have been identified, the effective implementation of these actions at a national level requires robust supporting greenhouse gas (GHG) inventory systems to capture and account for GHG mitigation. This can be captured, in its simplest form, as a Tier 1 inventory using Intergovernmental Panel on Climate Change (IPCC) default emission factors. However, if we are to advance the capability of inventories to also capture GHG reductions as a result of mitigation action, this requires Tier 2 data. For example, improving the feed quality for livestock requires a Tier 2 methodology that utilises local science and activity data to underpin calculations because the emissions calculations using default Tier 1 IPCC are not sensitive enough to detect mitigation, beyond the removal of animals. Similarly in cropping systems, Tier 2 inventories are required to determine the impact of different mitigation actions across diverse agroecological zones.

Generating inventory systems is a large and complex task that not only involves advancing activity and emissions data, but also requires the development of governance structures that will support inventory compilation and improvement over time. Countries that have gone through the process of establishing and improving national inventory systems, and integrating mitigation action into these systems, can facilitate and co-design the development of inventory procedures.

Australia is a world leader in GHG mitigation research and the development of sustainable food production systems that increase productivity and strengthen the resilience of agricultural systems to climate change. Previous Australian investments have occurred through the national Climate Change Research Program, the Carbon Farming Futures Program, and current research is led by the national agricultural research and development corporations. Australian scientists can guide in-country partners and work together to build national institutional capacity that promotes equitable opportunities at all levels of decision making.

The development of inventory systems that promote sustainable mitigation options and good Monitoring Reporting and Verification (MRV) practice, will support emission reduction efforts, whilst meeting multiple SDGs. Although this project focuses on Fiji and Vietnam, the outputs will be widely applicable to other developing countries requiring support in establishing inventory systems to enhance their mitigation efforts.

The purpose of this SRA was to clarify the strategic gaps to fill in inventory systems in each country and how best to fill them in order to plan for what is expected to be a next stage of more significant investment. This project, including the initial selection of partner countries, was developed in consultation with representatives of the 'Inventories and Nationally Determined Contribution (NDC) Network' of the Global Research Alliance on Agricultural Greenhouse Gases (GRA) to ensure complementarity and not duplication of global research efforts. A concurrent, complementary project was led by the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC). NZAGRC focused on working with Indonesia and Kenya, but the two project teams shared insights and methods.

5 Objectives

Overall aim

Long-term: This project aimed to assist in the development of robust and sustainable agricultural GHG inventory systems that underpin effective mitigation policy and action while safeguarding food security and the livelihoods of smallholder farmers in Fiji and Vietnam.

For this SRA: Assess inventory systems in Fiji and Vietnam and determine the most strategic gaps to fill – and the activities required to fill those gaps – in ways that support long-term capacity-building in both countries involved as well as effective south-south collaboration and learning.

SRA Objectives

1. Support partners in Fiji and Vietnam to conduct reviews of their national agricultural GHG inventory with an emphasis on cropping and livestock sectors (including information gathering, data analysis, governance arrangements, external partnerships, and capacity building),
2. Support partners in Fiji and Vietnam to identify the most critical gaps in development of robust national agricultural GHG inventory systems in the crop and livestock sectors, taking into account country specific goals, existing external support and internal investments, and how best to leverage Australian expertise. Improvements will lead to the greatest near-term benefits both in terms of mitigation and enabling co-benefits to producers,
3. Collaborate with NZAGRC and other international partners to target improved reporting in the cropping and livestock sectors of national agricultural GHG inventory systems and facilitate greater south-south collaboration and cooperation in developing accurate and defensible country specific agricultural GHG inventories, and
4. Work with all partners to construct detailed project plans for a larger investment to fill research gaps in the development of the national agricultural GHG inventory systems for the cropping and livestock sectors in Fiji and Vietnam.

6 Methodology

The project followed a collaborative approach with in-country partners supported by Australia (and links to the New Zealand-led parallel project) to complete reviews of their national agricultural inventory systems.

The Australian team led the collaboration with Vietnam and Fiji, while the New Zealand team focused on Indonesia and Kenya, with both teams sharing outputs. The project team (Australia, New Zealand, Fiji, and Vietnam) were committed to equity among co-researchers and created space for common thinking, mutual learning, and joint action between diverse research partners in order to create knowledge, understanding and ultimately to induce change.

Project Operational Leaders (Elaine Mitchell, Vietnam; Natalie Doran-Browne, Fiji) held regular (at least fortnightly) meetings via Zoom/email with in-country partners to provide continuous opportunities for engagement and response. Meetings between Australian and NZ project teams were also conducted regularly to share resources and ideas - in particular the outputs of inventory development work by NZ (via the NZAGRC) in Kenya and Indonesia.

The SRA commenced with a desk-based review and synthesis of existing inventory support documentation including:

- The ACIAR Governance Checklist (developed in LWR/2017/029)
- CGIAR (2017) Research Program on Climate Change, Agriculture and Food Security (CCAFS) and the Global Research Alliance on Agriculture Greenhouse Gases (GRA) “A Framework for Identifying Country-Specific MRV Improvement Needs in the Livestock Sector: Lessons from Kenya, Ethiopia and Nigeria.”
- IPCC (2017) Handbook for the Review of National GHG Inventories
- EPA Toolkit for Building National GHG Inventory Systems

This review culminated in a simple, transparent, and consistent methodology for reviewing agricultural inventory systems (see Appendix). The agricultural inventory review consisted of three main phases: (i) a review of the agricultural GHG inventory systems (activity data, emissions factors, sources of data, methods of data collection, data storage and maintenance, uncertainty assessment, quality control, reporting systems, and governance arrangements), (ii) identification of gaps and options for improvements in the current agricultural GHG inventory systems, and (iii) prioritisation and identification of options for improving agricultural inventory systems that will generate the greatest impact and why. This included a consideration of in-country partner goals, other sources of external support, internal initiatives, leveraging Australian and NZ expertise, and which improvements will lead to the greatest benefits both in terms of mitigation and co-benefits. This methodology was consolidated through the use of a Theory of Change (ToC) log frame, which generated a narrative on how filling priority gaps in the next phase will deliver the intended outcomes and what assumptions this is based on. The ToC has informed the activities included in the Full Proposal for the next phase of work that will be submitted to ACIAR to consider as part of a larger investment plan.

The outcomes of the inventory assessment were discussed in one virtual workshop across Australia, Fiji, and Vietnam to focus on ‘south-south’ shared learning with a focus on the challenges and priorities for agricultural inventory development. At this workshop, Fiji and Vietnam participants were invited to reflect on 1) What are the main difficulties that you have encountered in trying to progress your agricultural inventory system? 2) What process did you use to identify priority activities for the ACIAR project? 3) What networks and collaborations have you found helpful in agricultural inventory system improvement? 4) What are some positive developments in your country that will help support agricultural inventory policy and action? 5) What agricultural system inventory issues will require long-term support and continued collaboration to address? A summary of the meeting outcomes can be found in the Appendix.

A collaborative approach to project design for the next phase has ensured that the needs and priorities of the different countries are reflected in the Full Project Proposal and that greater ownership of the project will likely ensue. The project will fill strategic gaps in the inventory system in each country to ensure that inventory systems are robust and sustainable and can support policies that contribute to mitigation, while also benefiting small-scale producers.

7 Achievements against activities and outputs/milestones

Objective 1: To support partners in Fiji and Vietnam in conducting reviews of their national agricultural GHG inventory systems with an emphasis on cropping and livestock sectors

no.	activity	outputs/ milestones	completion date	comments
1.1	Compile and synthesise existing inventory review methods and checklists (including the governance checklist developed in LWR/2017/029) to arrive at a simple, transparent, and consistent method for reviewing inventory systems.	Completed inventory review checklist (see Appendix).	29/03/21	It was initially anticipated that the review would update the current governance checklist. However, it became apparent that a methodology for review was required, rather than a checklist. Therefore, a new document was written built on previous work of reviewing inventory systems by CCAFS and IPCC (see Appendix).
1.2	Review and evaluate the current national agricultural GHG inventory systems with respect to cropping and livestock sectors for Fiji and Vietnam including Monitoring, Reporting and Verification (MRV) and governance. Work closely with in-country collaborators and stakeholders to draw on their expertise as well as prior project results.	A complete review of Vietnamese and Fijian agricultural inventory systems.	15/05/21	A comprehensive review of the Vietnamese and Fijian agricultural GHG inventory systems was conducted. These results are not presented separately but instead were used as inputs in the subsequent activities.
1.3	Identify gaps and areas of desired improvement including capacity building based on each country's goals, confirmed through close collaboration in-country.	Full list of country-specific gaps or desired improvements in their current inventory systems based on the review and country goals.	24/06/21	These results are not presented separately but instead were used as inputs in the subsequent activities.

PC = partner country, A = Australia

Objective 2: To support partners in Fiji and Vietnam to identify the most critical gaps in the development of robust and sustainable national agricultural GHG inventory systems in the crop and livestock sectors

no.	activity	outputs/ milestones	completion date	comments
2.1	Engage widely to identify others who are working to improve each country's inventory systems (including efforts in-country as well as internationally). Map existing efforts against the full list of identified gaps to see which gaps are not being addressed at the moment.	Overviews of agencies engaged in inventory improvement for Vietnam and Fiji have been generated. See Appendix.	23/07/21	Results presented in Appendix to inform and guide ongoing relationships in the next phase of work. Results also used as inputs in the subsequent activities.
2.2	Map Australian and New Zealand applied research expertise to the full list of identified gaps.	Full list of country specific gaps or desired improvements in their current inventory systems mapped against Australia/NZ expertise.	1/07/21	These results are not presented separately but are included in the Appendix, which shows the complementary expertise of the Australian support in relation to the types of support provided by others.
2.3	Develop a theory of change with in-country collaborators and stakeholders in each country and use this process to identify gaps that will have the greatest impact.	Theory of Change plan developed for each country with narrative about which gaps or improvements will create the greatest impacts and why.	24/06/21	Theory of Change document (see Appendix)
2.4	Work closely with collaborators and stakeholders in-country to prioritise gaps to be filled based on the outputs of Objective 1, gaps not currently being addressed by others, gaps that will have greater impact, and gaps that can leverage Australian and New Zealand expertise.	List of priority gaps to address, approved by each country, based on the above outputs and the volume of resources available for a larger project.	15/07/21	This activity was the final synthesis of the above steps, clarifying the key issues to address in the next phase of work. These results are presented in Section 7, where each key result is a priority gap to address.

PC = partner country, A = Australia

Objective 3: Collaborate with NZAGRC to similarly target improved reporting in the cropping and livestock sectors of national agricultural GHG inventory systems of Indonesia and Kenya and facilitate greater south-south collaboration and cooperation in developing accurate and defensible country specific agricultural GHG inventories

no.	activity	outputs/ milestones	completion date	comments
3.1	Share methods and outputs for Vietnam and Fiji with NZAGRC team.		On-going	A close collaboration was developed with NZAGRC. Moving forward, the ACIAR project will work with NZAGRC in Vietnam to deliver inventory improvements in the cropping (ACIAR) and livestock (NZAGRC) sectors. Joint capacity building will be required to prevent duplication.
3.2	Participate in NZAGRC review of the inventory systems of Kenya and Indonesia.		1/05/21	Outputs of NZAGRC review of inventory systems of Kenya and Indonesia have been shared and discussed among the project team.
3.3	Co-host regular meetings between Australian and NZ project teams, ACIAR and NZ Ministry of Primary Industry to discuss progress and sharing of resources.		On-going	Fortnightly meetings between NZAGRC and ACIAR have taken place.
3.4	Co-host one virtual workshop across all six countries (Australia, NZ, Fiji, Vietnam, Indonesia and Kenya) to focus on south-south shared learning about past successes, challenges, and priorities.	Report on 1) how resources and insights were shared among countries and 2) lessons learned and insight gained from south-south collaboration virtual workshop.	2/09/21	This activity was simplified. One virtual workshop across Australia, NZ, Fiji and Vietnam was hosted to focus on south-south learning. Notes from this workshop are available in the Appendix.

PC = partner country, A = Australia

Objective 4: Work with all partners to construct detailed project plans for a larger investment to fill research gaps in the development of the national agricultural GHG inventory systems for the cropping and livestock sectors in Fiji and Vietnam.

no.	activity	outputs/ milestones	completion date	Comments
4.1	Work with in-country collaborators and NZAGRC, to develop a detailed proposal for addressing priority gaps in inventory systems identified in Objective 2 for Fiji and Vietnam including the specific activities, methods, outputs, and staff roles and responsibilities in a larger project.	Revised Full Project Proposal (FRP)	25/07/21	Revised Full Project Proposal submitted separately to ACIAR. QUT and NZAGRC have collaboratively ensured that proposed work in Vietnam on cropping (QUT) and livestock (NZAGRC) will be aligned in the next phase of the project.
4.2	Work with NZAGRC collaborators to develop a detailed proposal for addressing priority gaps in inventory systems of Indonesia and Kenya.	Revised Full Project Proposal (FRP)	25/07/21	NZAGRC is progressing work in Indonesia and Kenya and the Australian project team has been available for consultation as requested.

PC = partner country, A = Australia

8 Key results and discussion

Vietnam

Key result 1: *The institutional and organisational arrangements for the agricultural GHG inventory are in a state of flux and require significant support as responsibility is transferred from MONRE to MARD.*

Currently, the following organisations are involved in the Agriculture Forestry and other Land use (AFOLU) GHG Inventory.

- Ozone Layer Protection and Economy Low Carbon Development Center (CCOZONE), Department of Climate Change (DCC)
- Ministry of Natural Resources and Environment (MONRE): responsible for compiling the GHG-Inventory to date.
- Institute for Agricultural Environment (IAE): providing agricultural data, conducting research, also working on sub-national strategies.
- Ministry of Agriculture and Rural Development (MARD): so far involved in generating the agriculture and forestry data sets.
- Forest Inventory and Planning Institute (FIPI): responsible for conducting the national forest inventory, producing forest cover change maps under REDD+ reporting, preparing and updating the Forest Reference Emission levels.
- National Remote Sensing Centre, under MONRE: responsible for providing all land cover data for GHG-reporting (SilvaCarbon is currently working with FIPI and NRSD to harmonize the land cover mapping methodologies).

However, the governance of the agricultural inventory is going to change under the Environmental Protection Law (which will take effect from Jan 1st 2022). Relevant government ministries will implement the GHG inventory of their own sector and submit their GHG inventory report (every 2 years) to MONRE for synthesis and compilation. MARD will take responsibility for compiling the agricultural GHG Inventory. The shift in responsibilities from MONRE to MARD will result in large gaps in general inventory capacities in addition to sub-sector specific issues.

The Vietnamese project team is currently in the process of providing comments on the draft of the Government's Decree to propose a structure for the new institutional arrangements. The team have proposed that the Department of Science, Technology and Environment (DOSTE) will assign the departments responsible for different parts of the agricultural inventory e.g. Department of Crop Production, Department of Livestock Production, R&D institutes etc. and how this will be coordinated at MARD level. DOSTE will need to determine, for example, if the rice and crop sector emissions will be compiled by the same institution (or even the same group within that institution) or will be done by different institutions and then integrated at the MARD level.

There is considerable work required to ensure that there are the necessary governance arrangements in place and to facilitate collaborations and linkages among various departments, R&D institutes, and universities for compiling the inventory. IAE will be tasked with the development phase of the inventory (i.e. in the timeframe of this project) with eventual responsibility being with MARD.

We have engaged widely in stakeholder discussions (e.g. in-country partners, NZAGRC, US-EPA) to determine how we can effectively support the transition of responsibility from MONRE to MARD in the next phase of the project. This will start with the creation of a workplan that details the necessary steps required for the effective transfer of roles and responsibilities for the agricultural GHG inventory to MARD.

Key result 2: *MARD require training in how to develop and maintain an inventory tool for the cropping sub-sector*

The core project team, who will be responsible for the development of the agricultural GHG inventory (IAE and MARD), have requested the development of an Excel based inventory tool for the cropping sub-sector. This will be developed in collaboration with NZAGRC who are responsible for inventory development in the livestock sub-sector. This project recognises the need to move away from current problems with GHG inventory development where many countries have relied on input from external consultants. A reliance on external consultants often means that skills are not retained beyond the timeframe of the project. This will be an iterative process combined with training that will likely be more time-consuming in the short-term, but will generate a greater connection, ownership and understanding of the tool and inventory systems in the long-term. It is expected that this data will eventually be compiled into the Agriculture and Land Use (ALU) software for the AFOLU sector as a whole, but only when the project team are comfortable with using the Excel version.

Key result 3: *Rice is the most important sub-sector for mitigation, but there are numerous important data gaps that need to be filled to account for rice in the agricultural inventory and advance the rice GHG mitigation agenda.*

Rice production is a significant source of GHG emissions in the national budget of Vietnam contributing to more than 50% of total emissions from the agricultural sector and approximately 15% of total national GHG emissions, exceeding GHGs emitted from land transport (Wassmann 2019).

Besides the general scarcity of rice management data (activity data), the calculation of national GHG emissions from rice production systems is also constrained by the limited availability of GHG measurements to determine country-specific emission factors. Reliable emissions data are not only needed for computing baseline emissions but also for quantifying GHG mitigation potentials. This requires the disaggregation of emission factors (EFs) for, (i) rice management regimes, (ii) agroecological zones and, (iii) seasonal variations. This spatio-temporal resolution is required for elevating Vietnam's GHG inventories to a more substantiated Tier 2 approach.

The development of country-specific EFs to fill important inventory data gaps, with accompanying guidelines, will ensure a more accurate inventory, while training on experimental set up and measurement will enable future experimentation when data gaps are identified. Local EFs will be incorporated into modelling that will allow the quantification of emission reductions under different soil, climate and management conditions. Training in the DayCent simulation model (which underpins the US Tier 3 GHG inventory) will ensure that these skills are retained within the country and can be used to progress the rice inventory to Tier 3 at a later date. Training on the use of simulation models for exploring GHG mitigation strategies in rice will also allow in-country partners to provide a more robust evidence base for the uptake of selected mitigation options and highlight where these measures are likely to be the most effective.

Key result 4: *Mitigation options have been identified in the updated NDC (2020)*

The updated NDC for Vietnam identified priority mitigation opportunities in rice as: alternate wetting and drying (AWD), system of rice intensification (SRI), mid-season drainage (MSD), and shifting double rice or triple rice to rice shrimp. These priorities are planned to be implemented by an unconditional NDC contribution (potential GHG reduction of 6.88 MtCO2e, 6.13% by 2030). Therefore, no further work on prioritizing mitigation options is planned for the next phase of the project in Vietnam. Instead, work will focus on accounting for rice mitigation options that have already been identified.

Fiji

Key result 1: *As Fiji moves toward Tier 2 reporting which draws on a variety of data sources, it needs new institutional arrangements to verify the integrity of these data and to maintain consistency with Tier 1 processes that are currently being used and further developed.*

The development of the National Inventory and associated systems is coordinated by Fiji's Climate Change and International Cooperation Division (CCICD), which is part of the Ministry of Economy (MoE). There is strong capacity for collaborative action amongst international organisations while working with CCICD. A complete list of collaborators who are contributing to the development of national inventory systems in Fiji can be seen in the Appendix. These organisations complement each other's project work on Inventory Systems by contributing a range of different skillsets and expertise.

Fiji's National Inventory and Biennial Update Report (BUR) is compiled from a variety of data sources. Although basic activity data exists, the systems are not in place to verify the integrity of this data. Therefore, MRV systems, including quality assurance and quality control of data, need to be developed for available data.

Relationships built during this project with US EPA and GHGMI resulted in the development of a formal Gaps Analysis tool (led by GHGMI) across all sectors, with this SRA providing input and collaboration on the agriculture sector. Moving forward, MoE recognises the need to move away from a reliance on external consultants to calculate the National Inventory and instead to develop this capacity within Fiji. This would mean that capacity would be built around inventory calculation, enabling these important skills to be retained beyond the life of the project. This will generate a greater connection, ownership and understanding of the inventory system in the long-term. It is expected that through collaboration with US EPA and GHGMI, the data will be compiled into the ALU software and the process extended by this project to incorporate Tier 2 systems for the agriculture sector that are compatible and extend on the work to build Tier 1 systems. Additionally, Australian researchers have expertise in the mitigation of agricultural emissions, which will complement the capabilities of researchers from other organisations in the area of inventory development.

Key result 2: *Fiji will need to ensure new Tier 2 EFs will be accepted by the IPCC and that the process for this to occur through the IPCC is clarified.*

When countries update from Tier 1 to Tier 2 methods, the local EF values and calculations must be justified to the IPCC in person and should always be based on peer-reviewed data. The processes for upgrading to a Tier 2 method and integrating EFs into the national inventory system, as stipulated by the IPCC, requires clarification within the Fijian research context. The importance of including Fijian research institutions such as Fiji National University and University of the South Pacific was identified to facilitate the formal publication of local research data into peer-reviewed scientific journals to underpin material changes to their inventory. At this stage it is not clear that the key research scientists are aware of this requirement.

Key result 3: *Fiji aspires to develop a Tier 2 inventory for livestock to facilitate mitigation actions. This requires local EFs to be developed quickly and efficiently.*

There is a need for more certainty around livestock data and livestock emissions. The production of CH_4 versus dry matter intake in pasture and rangeland cattle in Australia has demonstrated a linear relationship, where CH_4 production increases as intake increases, regardless of cattle breed (Charley *et al*. 2016). Measuring CH_4 output from Fijian cattle will confirm whether the relationship between CH_4 and intake is consistent with cattle in other parts of the world, as some preliminary data from ILRI would suggest that under-fed cattle may produce more methane per unit intake, justifying an adjustment to a universal equation for enteric CH_4 EFs.

The default IPCC Tier 1 EFs are not able to reflect emission reductions from mitigation options, other than the reduction of livestock numbers. Therefore, the development of livestock mitigation options requires a Tier 2 approach in the national inventory. The development of local Fijian EFs has far-reaching consequences as there is the potential to extrapolate these data to other Pacific Island Countries (PICs) and develop other national inventory systems more broadly in other LMICs.

Key result 4: *Promising livestock mitigation options for Fiji focus on feed management. Implementing options requires experimental verification as well as research on implementation approaches, including understanding the different roles of men and women in mitigation to deliver co-benefits in a gender equitable way.*

Fiji's Third National Communication (Government of Fiji, 2020) has identified agriculture as a high-priority area to address Fiji's development objectives. Agriculture is responsible for 22% of Fiji's national emissions and livestock contributes 97% of those agricultural emissions. Therefore, livestock must be a significant focus to reduce Fiji's agricultural GHG emissions.

Mitigation options suitable to reduce CH_4 in Fiji were explored in LRW/2017/029. The most promising options are those that deliver co-benefits and where the barriers to implementation can be overcome. The best options determined for Fiji were improving feed quality and digestibility, the use of tannins, saponins or dietary supplements to supress CH_4 production, and a range of animal health and breeding options. Feed options are relatively easy to implement but further research is required into which specific feeds, particularly identifying by-products of other agricultural practices that may be high in oil or phenolic compounds (e.g. sugar cane or sweet potato) have the most potential to be developed for farmers to use in Fiji. Further research will also be required into Fiji's agricultural extension processes for engaging women and for ensuring that women gain access to new technologies such as improved feed options.

Shared Learning

The virtual workshop across Australia, Fiji, and Vietnam on 'south-south' shared learning about the challenges and priorities for agricultural inventory development revealed that both Fiji and Vietnam were valuing support from multiple partners and thus the coordinated approach the ACIAR project had taken. Both recognised the technical as well as governance challenges and the fact that inventory management and improvement will be an ongoing process, emphasising the importance of in-country capacity building.

9 Impacts

9.1 Scientific impacts – now and in 5 years

- This SRA has promoted the collaboration of international scientists who have shared insights and resources on inventory development. In Vietnam, Australian scientists have forged a strong partnership with NZAGRC who will work on the livestock inventory, whilst Australian scientists will focus on the cropping inventory. Furthermore, we have collaborated in the formulation of the next project phase with US-EPA, the Greenhouse Gas Management Institute (GHGMI) and others (see Appendix for a matrix of the likely roles and responsibilities of each organisation), creating a stronger global consortium working to improve inventories in developing countries. We are committed to ensuring that these scientific collaborations continue beyond the lifetime of the project.
- The SRA has allowed us to develop a simple and transparent review process document that can be applied to any country going through a similar agricultural GHG inventory review (see Appendix).
- It is expected that the data generated from project activities in this SRA will already inform policy and decision making. For example, the review process revealed that even though rice-rice to rice-shrimp is currently prioritised in Vietnam's NDC, anecdotal reports suggest that this system might actually increase GHG emissions. There is now a priority placed on demonstrating whether this is the case, and if so, considering ways to reduce GHG emissions from these systems or prioritise different mitigation actions.
- The next phase of work will build explicitly on the gaps identified here to result in better understanding of country-specific emissions and the emissions reduction potential from tangible mitigation options in each country.
- Modelling emission reduction scenarios in future work (highlighted as an important gap in this SRA) will also inform decision making, allowing users to determine mitigation scenarios under multiple management strategies or leverage work done in similar systems elsewhere in the world through the extrapolation of experimental data. This, in turn, supports realistic recommendations for site-specific mitigation actions that would yield the largest emission reductions, such as AWD for rice production in Vietnam, or improved feed quality to reduce GHG emissions from livestock systems in Fiji.

9.2 Capacity impacts – now and in 5 years

- We have developed a matrix of all the key international players operating in the inventory space in both countries to ensure that we do not overlap in terms of our future efforts (see Appendix).
- The process of reviewing inventories and identifying priority gaps has increased the understanding among all project participants of both the technical and governance elements required for building and sustaining GHG inventories that can effectively inform policy and action and support Nationally Determined Contributions and associated reporting.
- The project has connections with the GRA's networks, such as the I&NDC network, and will continue to collaborate and present research through these channels. Researchers in Agriculture for International Development (RAID) network will continue to be used to network with other researchers and present research outcomes to local research institutions, to engage more effectively with international research networks under the auspices of the GRA and the CGIAR and to build a wider range of international and national expertise and continue to develop capacity.

- As a result of the next phase of work planned in this SRA, in-country partners, especially those in the technical teams will have the knowledge, skills and experience to continue to develop their GHG inventory systems, MRV systems and governance arrangements beyond the lifetime of the project. This includes an in depth understanding of how inventories are compiled with a focus on Tier 2 approaches; the collection and management/governance of local Tier 2 data; the knowledge of how to develop local EFs and design mitigation experiments; and in the case of Vietnam the use of modelling tools under different soil, climate and management conditions to fill data gaps and develop emissions reduction strategies.
- This improved and shared knowledge will empower local scientists to provide policy relevant scientific information to assist decision makers in the development of policy instruments to support mitigation.

9.3 Community impacts – now and in 5 years

9.3.1 Economic impacts

By promoting mitigation actions that also boost productivity, it can be expected that smallholder farmers will be supported in the implementation of mitigation actions that increase their income and improve the resilience of their farming systems.

9.3.2 Social impacts

The SRA was intended to identify priority gaps for the next phase so it did not directly connect with communities. But the next phase of work will aim to elucidate gender significance and awareness of gender roles in mitigation and thus how mitigation action can be an additional vehicle for gender empowerment. The team is committed to enhancing gender balance within all project workshops, training sessions and scholarship opportunities. It is recognised that the meaningful participation of women in project activities will ensure that a diverse set of skills, knowledges and abilities are incorporated which will enhance project impact.

9.3.3 Environmental impacts

Through enabling better systems and processes for agricultural GHG inventory compilation it is expected that Fiji and Vietnam will be able to increase their commitments to GHG mitigation in the agricultural sector. Improved and shared knowledge will enable local scientists to develop and integrate GHG mitigation strategies into productivity, food security, and sustainable agriculture practices more rapidly. It will enable local scientists to provide relevant scientific information to assist policy makers in the development of policy instruments to support mitigation. It will enable local institutions to increase the knowledge of agricultural extension staff to provide advice to farmers on how they can reduce their GHG emissions while boosting productivity and profitability.

9.4 Communication and dissemination activities

The outcomes of the project were communicated with ACIAR, ACIAR in-country representatives, and the wider project team including NZAGRC, US-EPA and IRRI. The outcomes of the project have been used to inform the next phase of investment in Vietnam and Fiji.

10 Conclusions and recommendations

10.1 Conclusions

The most strategic gaps to address in the Vietnamese inventory were determined to be the development of a Tier 1 agricultural inventory in the cropping sub-sector and a Tier 2 inventory in rice (using locally developed emission factors and modelling). In addition, there will be a strong focus on the development of institutional and governance arrangements to support the GHG inventory as the responsibility is transferred from MONRE to MARD. These research priorities were used to inform the development of the Full Project Proposal for CLIM/2019/150.

In Fiji, the priority is to advance the livestock inventory to Tier 2 so that mitigation action can be accounted for, beyond the removal of animals. These research priorities were used to inform the development of the Full Project Proposal for CLIM/2021/160.

10.2 Recommendations

The outcomes and recommendations from this SRA have been used to inform the development of the Full Project Proposals for CLIM/2019/150 and CLIM/2021/160 designed to address the most strategic gaps in inventory development.

11 References

11.1 References cited in report

Allen JM, Sander BO (2018) The Diverse Benefits of Alternate Wetting and Drying (AWD).

Basak R (2016) Benefits and costs of climate change mitigation technologies in paddy rice: focus on Bangladesh and Vietnam. *CCAFS Working Paper* 52-pp. https://cgspace.cgiar.org/rest/bitstreams/79059/retrieve.

GRA S (2015) Reducing greenhouse gas emissions from livestock: Best practice and emerging options. 'Livest. Res. Gr. Glob. Res. Alliance Greenh. Gases Sustain. Agric. Initiat.' (Palmerston North, New Zealand)

Henderson B, Falcucci A, Mottet A, Early L, Werner B, Steinfeld H, Gerber P (2017) Marginal costs of abating greenhouse gases in the global ruminant livestock sector. *Mitigation and Adaptation Strategies for Global Change* **22**, 199–224. doi:10.1007/s11027-015-9673-9.

Kesar AS (2011) 'Shock Waves: managing the Impacts of Climate Change on Poverty.' http://www.journals.cambridge.org/abstract_S0022112081001535.

Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, Lobell DB, Travasso MI, Aggarwal P, Hakala K, Jordan J (2015) Food security and food production systems. *Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects* 485–534. doi:10.1017/CBO9781107415379.012.

Searchinger T, Waite R, Hanson C, Ranganathan J (2019) Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050. *World Resources Report* 558.

Thakur AK, Mandal KG, Mohanty RK, Uphoff N (2021) How agroecological rice intensification can assist in reaching the Sustainable Development Goals. *International Journal of Agricultural Sustainability* **0**, 1–15. doi:10.1080/14735903.2021.1925462.

UNFCCC (2017) Guide for Peer Review of national GHG Inventories. (Bonn, Germany)

US-EPA (2011) Developing a National Greenhouse Gas Inventory System. Template Workbook.

Wang H, Zhang Y, Zhang Y, McDaniel MD, Sun L, Su W, Fan X, Liu S, Xiao X (2020) Water-saving irrigation is a 'win-win' management strategy in rice paddies – With both reduced greenhouse gas emissions and enhanced water use efficiency. *Agricultural Water Management*. doi:10.1016/j.agwat.2019.105889.

Wassmann R (2019) Environmental Footprints of Modernization Trends in Rice Production Systems of Southeast Asia. 'Oxford Res. Encycl. Environ. Sci.'

Wilkes A, Wassie S, Dijkman J (2020) A framework for identifying country-specific MRV improvement needs in the livestock sector: Lessons from Kenya, Ethiopia and Nigeria. CCAFS Working Paper no. 346. (Wageningen)

Charmley E, Williams SRO, Moate PJ, Hegarty RS, Herd RM, Oddy VH, Reyenga P, Staunton KM, Anderson A, Hannah MC (2016) A universal equation to predict methane production of forage-fed cattle in Australia. *Animal Production Science* **56**, 169–180. doi:10.1071/AN15365.

Government of Fiji. (2020). *Republic of Fiji Third National Communication. Report to the United Nations Framework Convention on Climate Change*. (Suva, Fiji).

12 Appendices

Matrix of collaborators in inventory improvement

Table 1: Matrix of collaborators in inventory system improvement in Vietnam

	Country Counterparts	Potential Collaborators	Focus of Technical Assistance					
			Training on ALU	IPCC 2006 Guidelines	Emissions Factors	MRV	Institutional Arrangements	Other
SilvaCarbon	MONRE (previously)	U.S. EPA	Support trainings on 1) practical application of ALU, 2) one-on-one technical support for data compilers, 3) Training of Trainers for technical experts from different departments (US-EPA lead)					
ACIAR	IAE			Development of Tier 1 cropping inventory and Tier 2 inventory for rice, with MRV capabilities. Development of country-specific emission factors.			Support for institutional arrangements as inventory responsibilities are transferred from MONRE to MARD.	
NZAGRC	IAE, MARD, working with scientists		Could coordinate on ALU Tool training	Support for Tier 2 Enteric Fermentation Estimation; working on developing EF and compiling science; also covering MM				

	Dept. of Science and Tech – how they want to see complementarity							
GIZ (Support to Vietnam for the Implementation of the Paris Agreement)	MONRE DCC, MARD, MPI, Others					Outlining MRV system design and quantifying emission potentials from NDC LULUCF measures		Working with MARD on LULUCF, livestock, crop production NDC implementation, developing a NAMA for rice
UNFCCC Secretariat	MONRE, DCC staff			Regional training on IPCC inventory software (June 2021)				
JICA	MONRE	Global Research Alliance		Previously trained MONRE staff on using IPCC worksheets				
U.S. EPA Transparency Accelerator	MONRE, IAE, MARD	SilvaCarbon, Global Research Alliance	Lead on training Support series of trainings on ALU; provide hands-on TA to staff to understand the emissions calculations (linking GRA efforts with SilvaCarbon/EPA)	Conduct trainings on 2006 IPCC Guidelines and software (building off the support provided by the UNFCCC Secretariat); provide sector-specific TA			Support establishing and strengthening institutional arrangements under newly decentralized GHG accounting approach using EPA templates	

Table 2: Matrix of collaborators in Fiji for inventory improvement. Adapted from work developed by ICF, US EPA and GHGMI.

Agency	Fijian Country Counterparts	Potential Collaborators	Focus of Technical Assistance				
			IPCC 2006 Guidelines	Emission Factors	MRV	Institutional Arrangements	Other
US EPA		ACIAR/ NZAGRC GHGMI Silvestrum	Propose to conduct trainings on 2006 IPCC Guidelines and software; provide sector-specific technical assistance for AFOLU.			Propose to support National Inventory System and institutional arrangements, including but not limited to, data collection, QA/QC, and uncertainty systems.	Propose to support series of trainings on practical application of ALU.
ACIAR	Ministry of Agriculture; Ministry of Economy; FNU, USP	US EPA GHGMI	Developing country-specific emission factors through analysis of experimental data for use in national inventories and further assessments, including Tier 3 GHG emissions inventory for agriculture and MRV framework suitable for compliance of NDC.		Facilitating the establishment of national GHG accounting systems to monitor, report, verify, and certify emissions reductions to a Tier 2 inventory approach.		Providing cross-cutting support for the AFOLU sector.
CfRN/ NORAD	Ministry of Economy; Ministry of Agriculture					Designing institutional arrangements and recommendations to harmonize the national reporting system and Fijian national GHG inventory for the agriculture sector.	
Gauss Intl Consulting	Ministry of Economy		Supporting the development of Fiji's GHG inventory, including the development of Fiji's Biennial Update Report.				
GHGMI/ ICAT	UoF; FNU; USP; PIFON; Fiji Crop and Livestock Council	US EPA	Building capacity to calculate emissions from key agricultural emission sources (livestock, including enteric fermentation and manure management, and rice cultivation) using 2006 IPCC methodologies to promote the growth of domestic climate MRV expertise in the sector.				Developing recommendations for agriculture sector policies in Fiji's enhanced NDC.

Agency	Fijian Country Counterparts	Potential Collaborators	Focus of Technical Assistance				
			IPCC 2006 Guidelines	Emission Factors	MRV	Institutional Arrangements	Other
Regional Pacific NDC Hub	Not identified					Potential to provide NDC-related support, including enhancements to MRV systems.	
Silvestrum	Not identified	US EPA					Propose to support estimates of flooded land area for wetlands GHG inventory estimates.
UK IPP Common Sensing Project	Not identified						Supporting data collection using satellite remote sensing capabilities to provide Fiji with improved data, which could support GHG inventory development.
UNEP/ GEF	Ministry of Economy				Expected to support MRV systems to track and transparently report on NDC implementation and resultant GHG emissions, and climate finance received.	Expected to support the development of institutional arrangements to enable regular and transparent reporting on NDC implementation and GHG inventory.	
World Bank	Ministry of Economy; Ministry of Forestry						Supporting a new national forest inventory for Fiji.

ACIAR, Australian Centre for International Agricultural Research; CfRN, Coalition for Rainforest Nations; FNU, Fiji National University; GEF, Global Environment Facility; GHGMI, Greenhouse Gas Management Institute; ICAT, Initiative for Climate Action Transparency; NORAD, Norwegian Agency for Development Cooperation; NZAGRC, New Zealand Agricultural Greenhouse Gas Research Centre; PIFON, Pacific Islands Farmers Organization Network; UNEP, UN Environment Programme; UoF, University of Fiji; USP, University of the South Pacific; US EPA, United States Environmental Protection Agency.

South to South Learning Workshop Output

	Fiji	Vietnam
1. What are the main difficulties that you have encountered in trying to progress your agricultural inventory system?	Data sources and collection process. Lack of institutional arrangements to facilitate collecting and reporting of data Data exists but scattered and lack of national data.	How to identify the gaps. Technical capacities need to be improved. Uncertainty around new institutional arrangements with shift in responsibility from MONRE to MARD.
2. What process did you use to identify priority activities for the ACIAR project?	Ministry of Agriculture had a list of priorities as did Ministry of Economy. The two ministries met and identify common priorities for the project. This was a useful process, and initiatives to strengthen the collaboration between these two ministries would be helpful.	Review process involving three main stages (i) build an overview of current agricultural GHG inventory including governance arrangements, (ii) worked with stakeholders to identify long list of options for improvement, and (iii) discussions with stakeholders to identify priority list of gaps to address.
3. What networks and collaborations have you found helpful in agricultural inventory system improvement?	Inter-Ministerial collaboration. US EPA, GHGMI, ICAT and ACIAR networks. Fiji were very positive about the different external organizations working together and bringing their own area of expertise to the table.	Main collaboration is with NZAGRC who will cover the livestock inventory, whilst ACIAR will cover cropping. US-EPA hope to collaborate later in the project.
4. What are some positive developments in your country that will help support agricultural inventory policy and action?	ICAT project looking at emissions from livestock manure management and rice cultivation. Discussions around what to include in the next INDC submission.	Policy developments such at the Environmental Law and the Decree on GHG Emissions Reduction Management have made the legal framework clear. Next step is implementation of the framework.

5. What agricultural system inventory issues will require long-term support and continued collaboration to address?	Country specific data for livestock and rice. In Fiji – need to start somewhere with getting country data. Modelling and experimentation provide a strong evidence base for policy development.	New land-use practices are constantly evolving e.g. intercropping within rice systems, conversion of rice to upland crops. There is therefore a huge amount of data required. Therefore we need to find a way to streamline the process. We discussed how modelling may help to fill this gap. Trinh made the point that the models must be calibrated using experimental data so these part of the project needs to be more streamlined. We also need to investigate how we can leverage existing global datasets. QUT will follow this up with Trung who will be working on the modelling component. Vietnam raised that they have important reporting requirements to meet in the short term (BUR 2023) that they are hoping we can support.

Agricultural GHG Inventory Review Method

Introduction

This purpose of this document is to outline a method for reviewing the agricultural section of a National Greenhouse Gas (GHG) Inventory, including the associated measurement, reporting and verification (MRV) and governance requirements. A robust national GHG inventory is recognised as the essential foundation for developing appropriate and realistic mitigation options that support the reduction of GHG emissions in agriculture. The outcome of this process will generate a country-specific plan that reflects national priorities and circumstances.

The review process has 3 main phases:

Phase 1: Build an **overview of the current agricultural GHG inventory system**, including MRV and governance arrangements. Assess the current performance of these arrangements.

Phase 2: Work with stakeholders to **identify capacity gaps and options for improvement** in the current agricultural GHG inventory, MRV and governance arrangements. Identify specific constraints affecting progress and performance of the agricultural GHG inventory.

Phase 3: **Prioritise options for improvement of agricultural GHG inventory**. Involve stakeholders in developing a plan for future GHG inventory, MRV and governance improvements.

Phase 1: Overview of current agricultural GHG inventory system

Phase 1 allows stakeholders to build an overview of the current agricultural GHG inventory, MRV and governance arrangements. This involves a review of 3 main areas of the agricultural GHG inventory:

I. Governance, policy and institutional arrangements (section 3.1)
II. Technical aspects e.g. activity data and emission factors (section 3.2)
III. Procedural e.g. quality control and quality assurance, data storage, review and improvement (section 3.3)

Governance, policy and institutional arrangements

An assessment of the current policy context:

- What is the policy context for climate action with mitigation co-benefits? This will include a review of existing reports on national agricultural investment plans; agricultural development or food security policies; climate smart agricultural policies; multilateral and bilateral project design documents; private sectors and industry investment and development strategies.
- Which ministries, government agencies and non-government entities (e.g., industry associations) are key stakeholders in each relevant policy or plan for GHG mitigation in agriculture?
- What are the main agricultural mitigation actions? What is known about their mitigation potential?

An assessment of the current agricultural GHG Inventory:

- Which organisation will manage and coordinate the agricultural GHG inventory? How will this organisation align and communicate with the National Inventory Coordinator?
- Which organisation/ministries/agencies are involved in providing data for the agricultural GHG inventory?
- Describe how different agencies collaborate and cooperate in inventory compilation.
- Describe the human resources (staff, outside experts etc.) available in each agency.
- What measures have been taken to ensure gender representation and meaningful participation of women at all levels of agricultural governance?
- Summarise the performance of these institutional arrangements: what has been going well, what outputs have been produced?
- What (if any) are the shortcomings in institutional arrangements? How could these shortcomings be addressed to improve the performance of inventory compilation?

Technical aspects of the agricultural inventory

An assessment of the technical aspects of the agricultural GHG inventory is required to identify the **methods and data sources** that are used to estimate GHG emissions from agriculture in the national GHG inventory. Existing methods for GHG measurements and accounting must be: transparent, accurate, comparable, complete, and consistent (UNFCCC 2017).

For each agricultural GHG sink or source, countries are required to describe the source of activity data, any methods or assumptions used to process the activity data, and the source (Tier) of the emission factors and other variables used in calculations.

More detail is provided below:

GHG emissions from livestock: enteric fermentation and manure management

Livestock population

- Is the feed intake calculated based on IPCC guidelines?
- Are the same methods (Tier 1, 2 or 3) used to estimate CH_4 from enteric fermentation, and CH_4 and N_2O from manure management?
- If Tier 2 (country-specific) methods used
    - Does the level of intake change according to the feed digestibility and is this reflected in animal growth?
    - Was the emission factor (EF) for enteric fermentation developed using the same livestock characterisation?
- Activity data:
    - Are activity data consistent for enteric fermentation and manure management?
    - Is it desirable to use national statistics data?
    - Are the primary data sources valid, reliable and verifiable?
    - Have annual animal numbers included births and slaughters?
    - Has livestock migration within or between countries resulted in double counting or undercounting of animals?
    - Are all livestock classes covered? Are additional animal classes or categories used than what is listed in the IPCC?
    - Has rapid change in livestock populations occurred due to economic or market restructuring? Is the time series consistent?

Manure management system

- Are country-specific manure management EFs calculated for CH_4 and N_2O? IPCC guidelines provide Tier 2 method for calculating EFs.
- Activity data:
    - Ideally the data on manure management systems will be based on statistics or other reliable and verifiable sources.
    - Is the distribution of manure management systems periodically updated to reflect practice changes?

Other points around manure management

- In countries with multiple agro-climate zones, are CH_4 emissions estimated regionally and applied to the percentage of animals in that region?
- Are direct N_2O emissions estimated from total N excreted without subtracting N lost through leaching or volatilisation?
- Are indirect N_2O emissions considered?

    - Are N_2O emissions included from the volatilisation of NH_3 and NO_x, and from leaching and runoff?
    - Are indirect N_2O emission from agriculture included in the national total?
- Cross-sectoral issues
    - Have direct and indirect emissions from manure on pastures and rangelands been correctly allocated to the agricultural soils category?
    - Has any treatment of manure in anaerobic digesters been subdivided into categories for biogas recovery flaring and storage after digestion?
    - Has the burning of manure with energy recovery been reported in the energy sector?
    - Has the burning of manure without energy recovery been reported in the waste sector?

GHG emissions from cropping systems

Rice cultivation:

- Does the method used account for the various agro-climatic and management conditions of rice cultivation within a country?
- Are the EFs country specific or default IPCC?
- Are country specific EFs based on recent research results within the country?
- Have the following rice production characteristics been considered in developing EFs: regional differences in rice cropping practices, multiple crops, ecosystem type, water management regime, addition of organic amendments, and soil type?
- Activity data: Does the activity data for rice consist of rice production and harvest statistics? Is the activity data broken down by rice ecosystem or water management system type?
- Is the total cultivated area consistent with international data sources such as FAO and the International Rice Research Institute (IRRI)?

N_2O emissions from agricultural soils

N_2O emissions from agricultural soils are divided into direct and indirect emissions. These emissions are further divided into other emission subcategories.

- **Direct emissions**: are all sub-categories estimated? The significant sources of anthropogenic nitrogen inputs resulting in direct N_2O emissions from agricultural soils are: (a) application of synthetic fertilisers, (b) application of animal manure, (c) cultivation of nitrogen fixing crops, (d) incorporation of crop residues into soils, (e) soil nitrogen mineralisation due to cultivation of organic soils, (f) other sources such as organic manures and sewage sludge. Note: N_2O emissions from pasture, rangeland and paddock manure are to be reported in the agricultural soil category.
- Is the fertiliser consumption disaggregated? It is good practice to collect activity data as detailed as possible. This will allow for a more accurate revision of previously constructed inventories once country or crop-specific emission factors become available. Has country specific data on synthetic fertiliser consumption been compared to usage data from the IFS and synthetic fertiliser consumption estimates from the FAO?
- Are the data on crop residues in line with the data reported for field burning of agricultural residues?
- **Indirect emissions**: are all sub-categories estimated? The significant sources of anthropogenic nitrogen inputs result in indirect N_2O emissions from agricultural soils are: (a) volatilisation of NH_3 and NO_x (b) leaching/ runoff. N of gases volatising in manure management must be excluded.

Burning agricultural residue

It is important to use appropriate activity data to estimate CH_4 and N_2O emissions from burning agricultural residue, considering mass balance of residue and avoiding double counting. To achieve a complete mass balance of residue, local and regional practices must reflect the following factors: (1) the fraction of residue burnt in the field, (2) the fraction transported off the field and burned elsewhere, (3) the fraction consumed by animals in the field, (4) the fraction decayed in the field, (5) the fraction used by other sectors.

Liming urea application

For estimating CO_2 emissions from liming, it is important to use appropriate activity data. If there are no actual usage data, estimated usage data based on annual sales data or production data may be alternatively used. Lime is separated to two types, calcic limestone and dolomite. The EFs of these are different – therefore the activity data needs to be separated.

Urea application

CO_2 emissions from urea application. For activity data it is desirable to use the actual usage data, but if this is not available, estimated usage data based on annual sales data may be used. If other carbon-containing fertilisers are used, the party must report CO_2 emissions from applying those fertilisers. And if those fertilisers also contain N, N_2O emissions from applying those fertilisers must also be reported.

Procedural aspects

This section reviews the Quality Assurance and Quality Control (QA/QC) procedures required to develop a robust agricultural GHG inventory. Quality control (QC) and quality assurance (QA) are two distinct type of activities. The IPCC defines them as follows: QC is a system of routine technical activities implemented by inventory compilers to measure and control the quality of the inventory as it is prepared. QA is a planned system of review procedures conducted by personnel not involved in the inventory development process. QA procedures are performed upon a completed inventory following the implementation of QC procedures and preferably by independent third parties. QA and QC are critical components of an inventory management system because when they are implemented efficiently, they drive inventory improvement (US-EPA 2011).

- Who is responsible for QA and QC in the agricultural GHG inventory?
- What procedures are in place for QA and QC of data collection, data input, data handling, data documentation, calculation checks?
- Is there an archiving plan or set of procedures for archiving? Who is responsible for data archiving?

Phase 2: What are the current gaps?

Phase 2 aims to identify the gaps between current agricultural GHG inventory and the desired performance of the inventory - Box 1 outlines some examples. This phase therefore requires close collaboration with in-country partners to answer the following questions:

- Does the current agricultural GHG inventory provide the information that is needed to the quality required and in a timely manner?
- What suggestions do in-country partners have for improvement in the agricultural GHG inventory?
- What institutional, technical, or procedural barriers may prevent these improvements being realised?
- How can we overcome these barriers to deliver a more robust agricultural GHG inventory?

Box 1: Examples of Gaps in the Agricultural GHG Inventory and Associated Systems

- Lack of local data required to calculate GHG emissions e.g. in the measurement of emissions from livestock and development of local emission factors.
- Lack of central data repository to hold all available data (local, regional, national) on GHG emissions.
- Lack of local capacity and expertise in the measurement and development of local emission factors.
- Inadequate communication between relevant ministries, universities, institutes, and other relevant stakeholders in GHG mitigation.
- Uncertainty on the economic benefit of different mitigation options (e.g. lack of cost-benefit analysis for prioritising different migration actions).

Phase 3: What is the plan for improvement?

Phase 2 will likely identify several options for GHG inventory improvements. Phase 3 therefore involves engaging stakeholders in **prioritising inventory improvement needs** and outlining a plan for implementing improvements. This step involves developing a Theory of Change with in-country collaborators and stakeholders in each country to identify gaps that will have the greatest impact if they are filled.

- What options for inventory improvement have been identified?
- What inventory improvements will generate the greatest impact if they are filled?

The output from this phase should be a plan for implementing inventory improvements that stakeholders have prioritised. It is important to facilitate the relevant stakeholders to elaborate this plan so that there is ownership by the stakeholders responsible for its implementation. A plan can be elaborated through one or more participatory workshops. It is likely that there will be a large number of potential inventory improvement options and that not all options can be simultaneously implemented (Wilkes *et al.* 2020). Inventory improvement must be viewed as an iterative process over time: different stakeholders have different priorities, the feasibility of different options will vary, some options may depend on other gaps being filled e.g. by another project, and resource constraints will inevitably imply that not all options can be implemented at once (Wilkes *et al.* 2020). An example of a plan or ‘roadmap’ for agricultural GHG inventory improvement in Ethiopia is shown in Figure 1.

The roadmap was discussed in a stakeholder workshop. Improvement options were identified and allocated into three categories:

Short-term: MRV improvements for which the relevant stakeholders' readiness is already high and few resources are required, or the required resources are readily available;

Medium-term: MRV improvements that, if they proceed, will enable a number of other MRV improvements to be put in place, but the implementation of which may require capacity building and dedicated resources.

Longer-term improvements: Improvements help build the national framework for livestock MRV across multiple areas that need improvement but require other MRV elements to be put in place and require additional resources.

Outline roadmap for livestock GHG inventory improvement in Ethiopia

Objective	A continual improvement process is implemented for the livestock GHG inventory
Short-term (1-6 months)	• Fill missing data for commercial dairy, feedlot and pastoral/agro-pastoral population data • Design and test manure management data collection tools in different production systems • Test methods to fill missing data, consult with stakeholders for missing data on pastoral areas
Medium-term (6-18 months)	• Collect data on manure management systems • Develop institutional arrangements based on the data sources used • Capacity building for data providers and data users
Longer-term (18 months +)	• Collect livestock population data for pastoral areas using aerial survey • Develop automated data management systems

Figure 1: A roadmap for GHG inventory improvement in Ethiopia (Wilkes *et al.* 2020)

References

Allen JM, Sander BO (2018) The Diverse Benefits of Alternate Wetting and Drying (AWD).

Basak R (2016) Benefits and costs of climate change mitigation technologies in paddy rice: focus on Bangladesh and Vietnam. *CCAFS Working Paper* 52-pp. https://cgspace.cgiar.org/rest/bitstreams/79059/retrieve.

GRA S (2015) Reducing greenhouse gas emissions from livestock: Best practice and emerging options. 'Livest. Res. Gr. Glob. Res. Alliance Greenh. Gases Sustain. Agric. Initiat.' (Palmerston North, New Zealand)

Henderson B, Falcucci A, Mottet A, Early L, Werner B, Steinfeld H, Gerber P (2017) Marginal costs of abating greenhouse gases in the global ruminant livestock sector. *Mitigation and Adaptation Strategies for Global Change* **22**, 199–224. doi:10.1007/s11027-015-9673-9.

Kesar AS (2011) 'Shock Waves: managing the Impacts of Climate Change on Poverty.' http://www.journals.cambridge.org/abstract_S0022112081001535.

Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, Lobell DB, Travasso MI, Aggarwal P, Hakala K, Jordan J (2015) Food security and food production systems. *Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects* 485–534. doi:10.1017/CBO9781107415379.012.

Searchinger T, Waite R, Hanson C, Ranganathan J (2019) Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050. *World Resources Report* 558.

Thakur AK, Mandal KG, Mohanty RK, Uphoff N (2021) How agroecological rice intensification can assist in reaching the Sustainable Development Goals. *International Journal of Agricultural Sustainability* **0**, 1–15. doi:10.1080/14735903.2021.1925462.

UNFCCC (2017) Guide for Peer Review of national GHG Inventories. (Bonn, Germany)

US-EPA (2011) Developing a National Greenhouse Gas Inventory System. Template Workbook.

Wang H, Zhang Y, Zhang Y, McDaniel MD, Sun L, Su W, Fan X, Liu S, Xiao X (2020) Water-saving irrigation is a 'win-win' management strategy in rice paddies – With both reduced greenhouse gas emissions and enhanced water use efficiency. *Agricultural Water Management*. doi:10.1016/j.agwat.2019.105889.

Wassmann R (2019) Environmental Footprints of Modernization Trends in Rice Production Systems of Southeast Asia. 'Oxford Res. Encycl. Environ. Sci.'

Wilkes A, Wassie S, Dijkman J (2020) A framework for identifying country-specific MRV improvement needs in the livestock sector: Lessons from Kenya, Ethiopia and Nigeria. CCAFS Working Paper no. 346. (Wageningen)