National Inventory System Guidelines for the Agriculture Sector, Fiji

Initiative for Climate Action Transparency – ICAT

Deliverable title: ***National Inventory System for the Agriculture Sector, Fiji***

DISCLAIMER

PREPARED UNDER

Initiative for Climate Action Transparency (ICAT) project supported by the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, the Children´s Investment Fund Foundation (CIFF), the Italian Ministry for Ecological Transition, and ClimateWorks

The ICAT project is hosted by the United Nations Office for Project Services (UNOPS)

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Introduction

The National Inventory Systems (NIS) for Fijis Agriculture sector provides a comprehensive guidance to inventory compilers on the necessary steps that must be taken to prepare a *transparent, accurate, complete, consistent, and comparable* greenhouse gas inventory for the agriculture sector. This document was prepared with reference to the USEPA Template on developing national greenhouse gas inventory systems and was refined to make the guidance specific to Fijis national circumstances.

This document provides guidance on the various sectoral activities, roles and responsibilities that must be established or used (where available) to compile the GHG inventory for the agriculture sector. The systems considered under the NIS are:

1. Institutional arrangements required inventory compilation as per the inventory cycle.
2. Data collection and approval processes for GHG inventory development.
3. QA/QC plan and procedures for GHG inventory development.
4. Uncertainty estimation.
5. GHG emission estimation for the agriculture sector.
6. Inventory archiving system for Fiji.
7. National Inventory System (NIS) Improvement Plan

1. Institutional Arrangement for Fijis Agriculture Sector

This section will document the proposed institutional arrangements (IA) for greenhouse gas (GHG) inventory management in Fiji for the agriculture (Ag) sector.[1][2] The following Steps were also followed to develop and finalise the proposed IA for the Livestock and Rice Cultivation sectors:

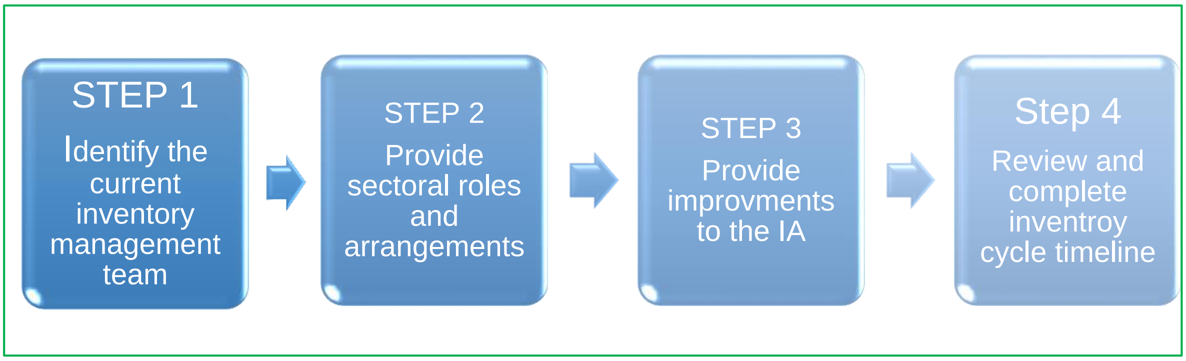


Figure 1: Step-by-Step Instructions for Developing IA

The Guidelines are a live document that needs to be checked prior starting planning for each inventory and updated, if needed.

1.1. STEP 1: Overview of the Proposed Inventory Management Team

The role of the proposed inventory management team is to coordinate the development of the National GHG

[1] The proposed IA for the Livestock and Rice Cultivation sectors have been developed as an outcome of the **ICAT Agriculture Institutional MRV System Development Workshop** which was held at the Pearl Resort, Fiji, on the 19th and 20th of April 2022.

[2] This will be the reference to the Workshop materials

Inventory (NGGI) in conjunction with the designated inventory agency for the country. The following tables give the proposed outline of the designated inventory agency and national inventory management team for Fiji's Ag sector, as in June 2022.

Table 1: Designated Inventory Agency

Designated National GHG Inventory Preparation Agency/Organization	UNFCCC Focal Point (Name) and UNFCCC Focal Point Agency	Describe the arrangements or relationship between Inventory Agency/Organization and UNFCCC Focal Point Agency, if different.
Climate Change Division, MoE	Permanent Secretary, MoE[3]	N/A

Table 2: National Inventory Management Team

Role	Name	Organization	Contact Information	Comments
Agriculture Sector Lead (Livestock & Rice)	Climate Change Team/Livestock + Rice Experts	MoA	TBC	Is planned to be established
Archive (Data and Document) Manager/Coordinator	Economic, Planning & Statistics Division	MoA	Chief Economist, MoA	Using the raw data collected from livestock farms and rice farms, preliminary data processing and centralized archiving system (CBIT Project, SAGE)
QA/QC coordinator	Dr. Francis Mani Ms. Zahra Nizbat Dr Deeksha Krishna	USP[4] USP Consultant	francis.mani@usp.ac.fj zahranizbat@gmail.com dikshakrishna@gmail.com	Research/Academic specialists in the field who have been trained in the Ag Sector inventory as well.
Uncertainty Analysis coordinator	Dr. Francis Mani, Ms. Zahra Nizbat and Dr Deeksha Krishna, in collaboration with Climate Change Team and the Fiji Bureau of Statistics.	USP, consultant, MoA, MoE[5] (FBoS[6])	francis.mani@usp.ac.fj zahranizbat@gmail.com dikshakrishna@gmail.com	Research/Academic specialists in the field who have been trained in the Ag Sector inventory as well.
Other: e.g., GHG Policy Specialist who tracks capacity building efforts and IPCC processes	Climate Change Team Ms. Jeanette Mani	MoA Consultant/Expert	TBC jeanette93.jm@gmail.com	Is planned to be established National expert in climate mitigation and has knowledge of Climate Change Act, government policies and processes for inventory development.

[3] Ministry of Agriculture
[4] The University of the South Pacific
[5] Ministry of Economy
[6] Fiji Bureau of Statistics

The **ICAT Agriculture Institutional MRV System Development Workshop** recommended to a steering committee as part of the Institutional Arrangements for the Agriculture sector GHG inventory development. The steering committee would consist of PS-MoA nominated managerial members from MoA (Director Animal Health and Production (AH&P), Head of Agriculture (R&D), Head of Operations (Agriculture Development), Chief Economist, National Experts for Livestock and Rice Cultivation, Climate Change Team, and representative from the MoE). The structure of the Steering Committee is illustrated in Figure 2 below.

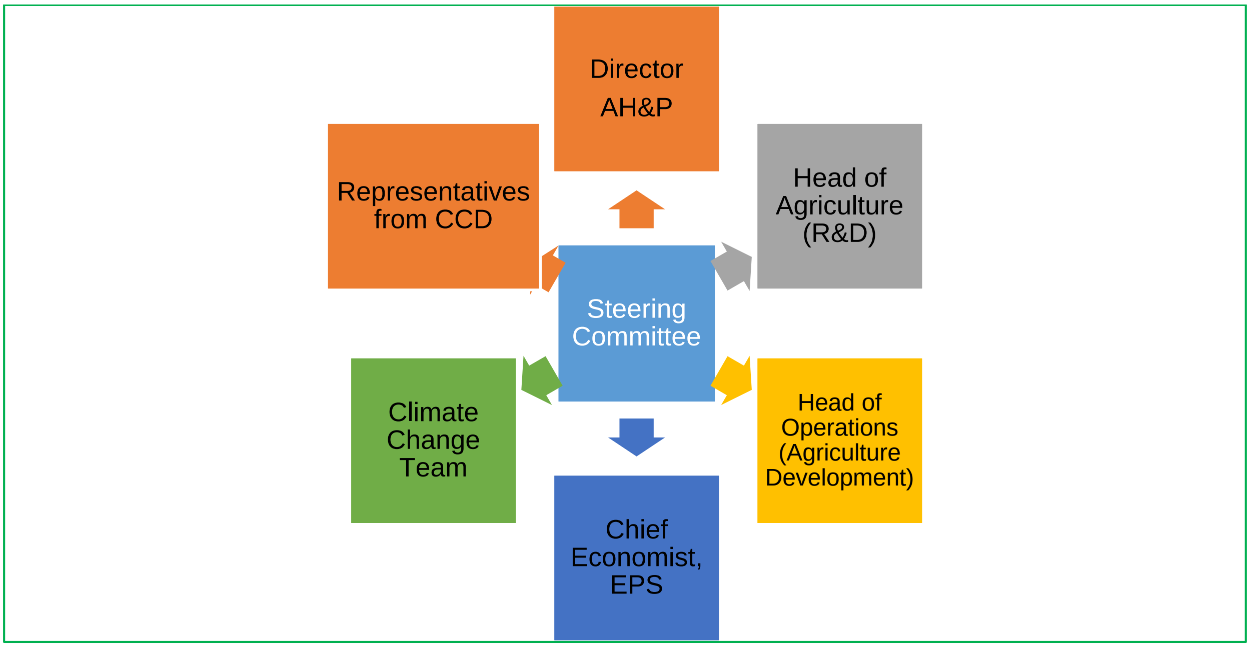


Figure 2: Structure of the Steering Committee for the development of the GHG Inventory for Fiji

The Climate Change Team would consist of selected members from MoA (representing the livestock and rice division) and MoE (mitigation team). However, the establishment of this team has been planned and has been proposed to be included in the project scope for Phase 2 of the ICAT project.

1.2. STEP 2: Identifying Sectoral Roles and Arrangements

Identifying the sectoral roles and responsibilities relates to the documentation of existing (and proposed) arrangements for requesting, compiling, and reviewing inventory data for GHG estimation. The following table lists specific information on the key personnel responsible for the development of the GHG inventory for Fiji's Ag sector and the status of the Institutional Arrangements. This includes the role, organisation, and contact information of the personnel responsible for providing and compiling activity data for GHG inventory estimation for Fiji.

Table 3: The Agriculture Sector Institutional Arrangements - Livestock & Rice Cultivation

Role	Organization	Contact(s) [Name]	Contact Information [E-mail, Phone, etc.]	Participated in meetings on GHG inventory development? [Yes/No]	Comments [See instructions above]
Technical coordinator	Climate Change Team/Livestock + Rice Experts	MoA	TBC	YES	Planned to be established.
National Expert compiling	Climate Change Team/Livestock + Rice Experts	MoA	TBC	YES	Planned to be established.

estimates					
Expert reviewer	Dr. Francis Mani Ms. Zahra Nizbat Dr Deeksha Krishna	USP USP Consultant	Francis.mani@usp.ac.fj zahranizbat@gmail.com dikshakrishna@gmail.com	YES	Research/Academic specialists in the field who have been trained in the Ag Sector inventory as well.
Data provider	Extension Services, LLOs, SAO's, AGO's	MoA	Senior Agriculture Officers (Livestock + Rice Division)	NO	Raw data providers. The current data collection templates need to be updated.
Other	Farmers	N/A	N/A	NO	Raw data providers. Need training on template usage

The proposed IA, encompassing the data vendors, compilers, data and inventory approval processes and data archiving structures are illustrated in the figures below. The proposed IA structures for GHG Inventory estimation for the AG sector was finalised during the **ICAT Agriculture Institutional MRV System Development Workshop** with significant input and validation by the MoA representatives from the livestock and rice divisions.

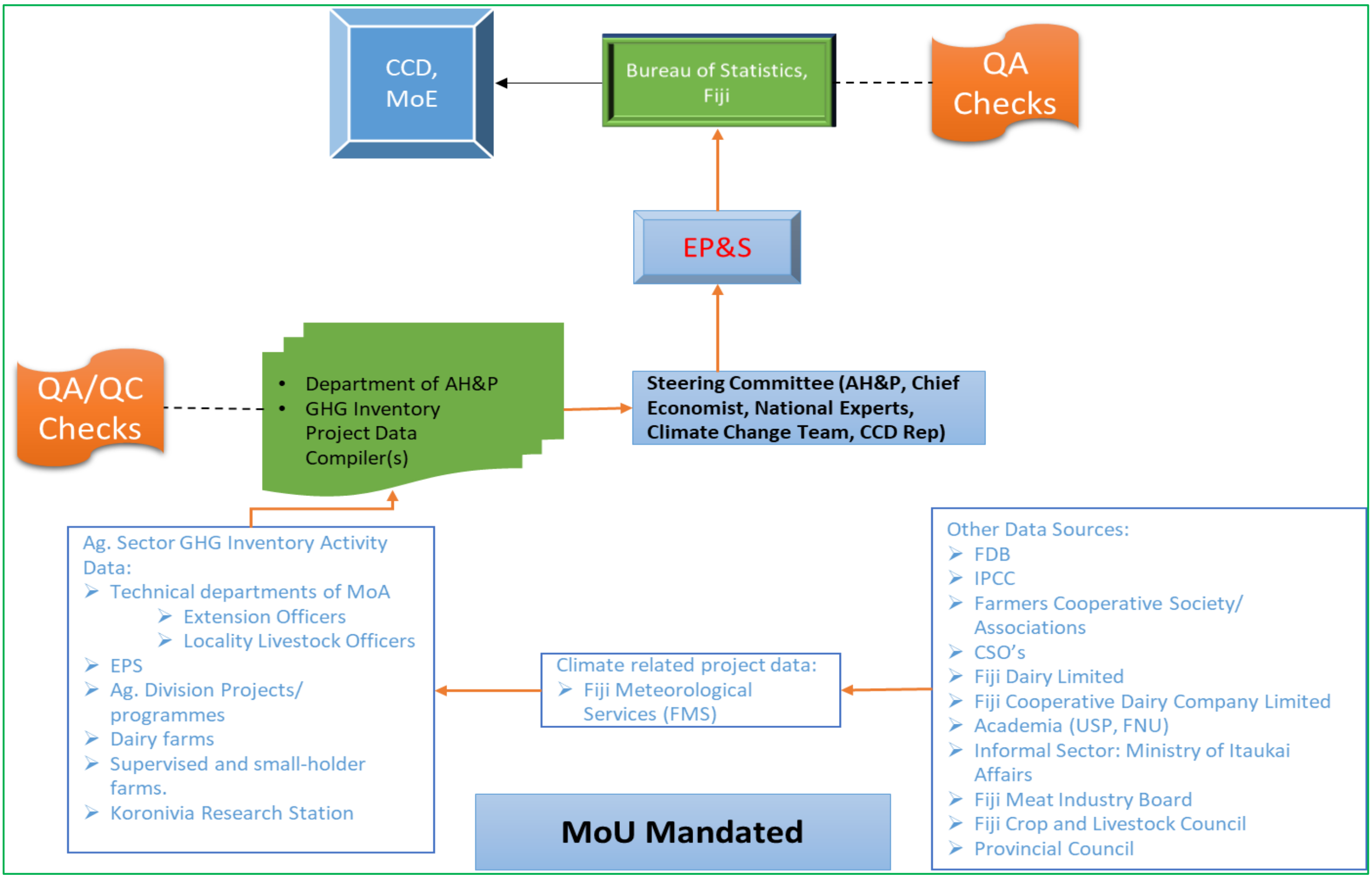


Figure 3: Proposed institutional arrangements for developing the GHG inventory for Livestock

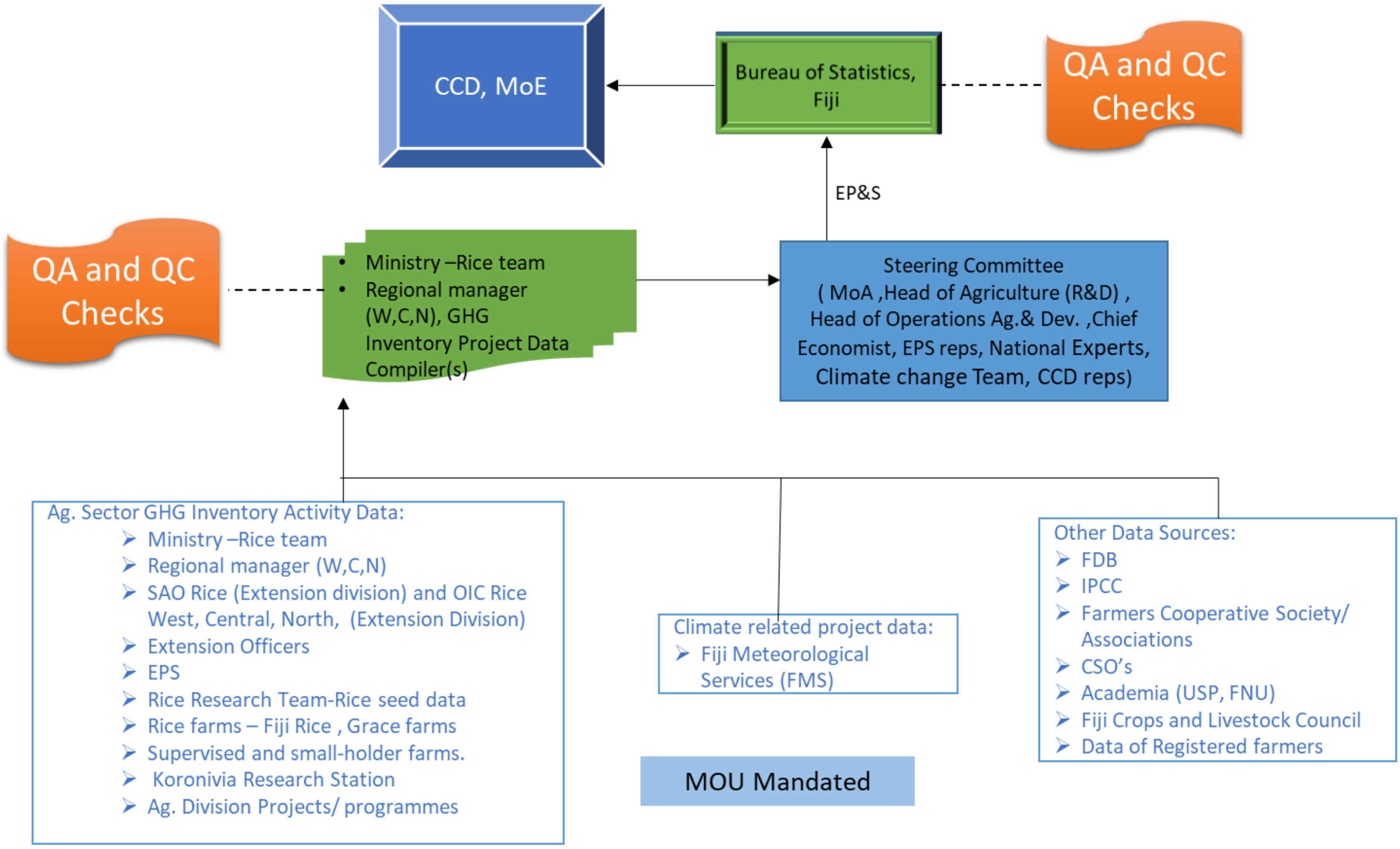


Figure 4: Proposed institutional arrangements for developing the GHG inventory for Rice Cultivation

Additionally, the following steps are also followed for the approval of activity data and inventory estimations for the agriculture sector for Fiji prior to submission to UNFCCC:

- Step 1 – PS for Ministry of Agriculture approves the final Agriculture sector GHG inventory
- Step 2 – PS for Ministry of Economy approves the final National GHG inventory
- Step 3 – The NCCCC approves the National GHG Inventory
- Step 4 – The Cabinet approves the National GHG Inventory

These processes and the institutional arrangements for data approval are also illustrated in Figure 5 below.

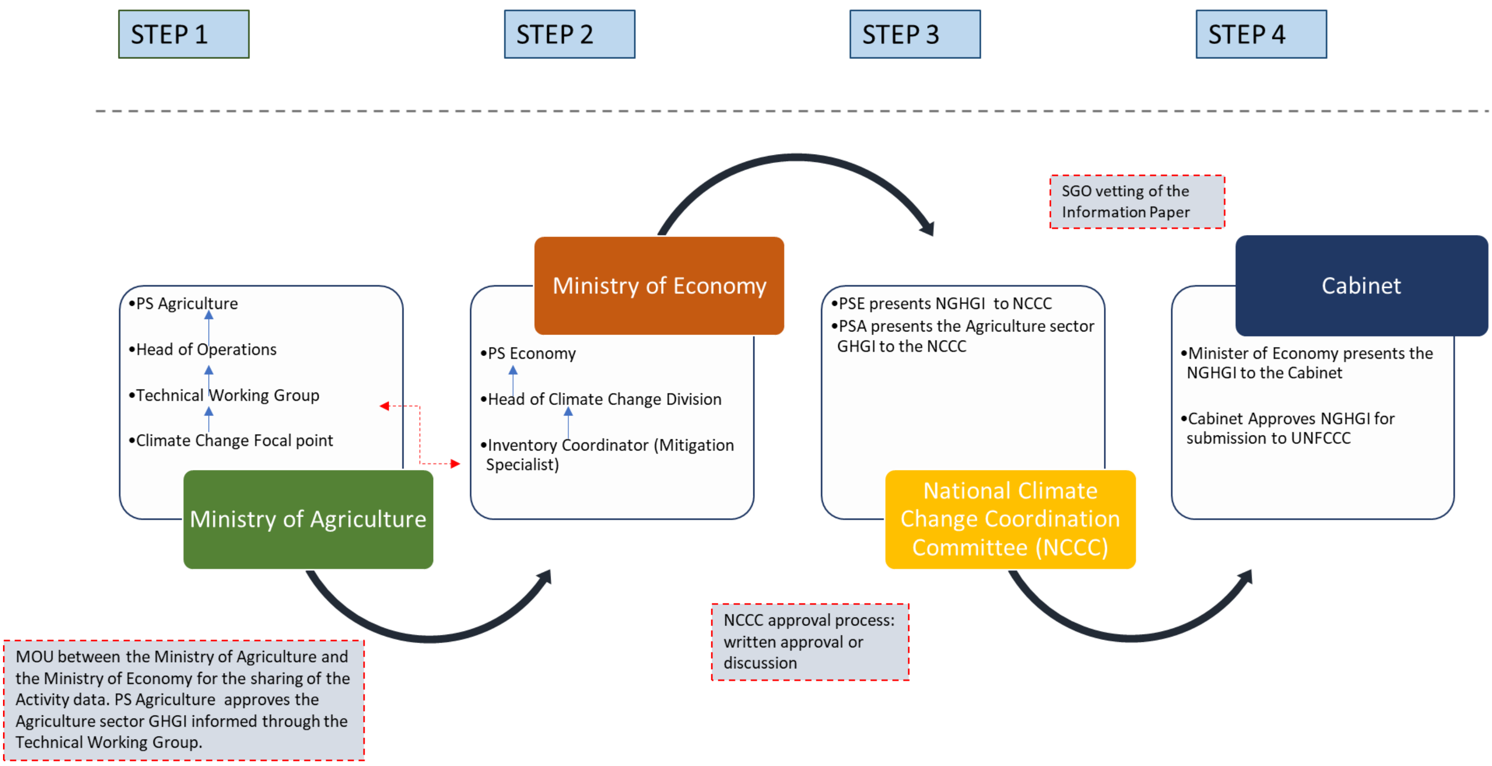


Figure 5: Activity Data and the Agriculture Sector GHG Inventory Approval Process for Fiji

1.3. STEP 3: Potential Improvements in the Management Structure of the National Inventory System

There are numerous strengths in the existing IA which supports the development of the Ag sector inventory for Fiji. This includes existing institutional structures that are well-developed, with adequate data compilation processes and data management. However, despite the strengths in the existing structure, improvements to help enhance the existing institutional arrangements have been identified and proposed. Table 4 provides a detailed summary of the strengths of the existing IA and the proposed improvements to enhance the IA for the Agriculture sector GHG Inventory development.

Table 4: Potential Improvements in Management Structure of Fijis National Inventory System

Sector	Strengths in Management Structure of National Inventory System	Potential Improvements in Management Structure of National Inventory System
Agriculture	• Climate Change Act is endorsed. • Extensions officers are established and have a good connection with primary sources of raw data (farmers). • MoA is willing to establish a new team for climate change reporting. • The data collection system and templates exist, however, need updating. • The CBIT Project incorporated financing for	• Request and receive financial support for NC4 and BTR • Establish the Climate change team at MoA (with the focal point for each of Livestock and Rice Cultivation) dedicated to the GHGI. • The roles and responsibilities for MoA, MoE are clearly established and agreed upon with the relevant formal provisions • The roles and responsibilities of the extension

	development of information system support for NDC tracking (currently for energy, will be extended for the Agriculture and other sectors), and inventory. • The activity data collection systems (e.g., SAGE) is being developed and will be available for preliminary data processing for BTR. • Emission calculations systems exist and are available FOC or for a small annual fee and are available for use. (ALU, IPCC Software, Atmo,) • Data collection templates for Ag exist and are made available through the ICAT project. • Fiji experts received training of the Agriculture methodologies (theoretical and practical for Tier 1) through the ICAT project. • The instruction manuals for Ag emission estimations using Tier 1 from 2006 IPCC GLs have been developed by Fiji Experts through the ICAT project. • The NS GLs are being developed by Fiji Experts. • The institutional arrangements, QA/QC systems and data flows have been discussed with MoA and MoE representatives (19th – 20th April, 2022) – feedback was received and implemented through the ICAT project. • Climate Change Division at MoE is established. • ACAIR project will be supporting development of emission factors for T2 emission estimations for livestock	offices will be clearly defined in accordance to the MoUs (including the timeframes and frequency) established above. • The data governance and data transfer agreements need to be established and signed. • The surveys for data collection for both Livestock and Rice cultivation are designed and piloted, and the relevant funding is secured for implementation (e.g., through ICAT phase 2) • The QA/QC plan is produced and QA, QC & Verification responsibilities are assigned, and the relevant personnel has received the training and template support • The approval mechanism to ensure timely GHGI approvals need to be established and put in place. • Uncertainty training is needed to develop and use country-specific uncertainty values, and relevant templates are required. • The templates for data collection need to be updated to minimize the efforts for data collection. • The information support system needs to be designed and developed; the interfaces between the main repository system, data collection tool and emission calculation tools need to be developed (e.g., through ICAT phase 2 and ACAIR projects). • The personal need to be trained on how to use data collection tool (e.g., SAGE) and emission calculation systems (e.g., IPCC tool, ALU, or Atmo) • Development of country specific EF's and potential shift to Tier 2 is considered where applicable, and relevant training provided (e.g., ACAIR project). • The proposals for financial support to support research for high Tier the Agriculture Sector reporting should be produced and submitted to the relevant funding organizations. • Training for the mandatory elements of GHGI reporting is needed (for example, chapter writing, CRT software use) • The mandatory data reporting systems for UNFCCC and Enhanced Transparency Framework under the Paris Agreement (NC, BUR, BTR) need to be introduced and national experts need to be trained.

1.4. STEP 4: Inventory Cycle

The development of an inventory cycle is dependent on national circumstances and the reporting requirements of a given country. For Fiji, the inventory cycle is representative of a biennial inventory reporting cycle for the Agriculture sector. The 1st year of the inventory cycle will focus on the data collection from data providers and applying QA/QC checks to the activity data collected while simultaneously providing refresher training to inventory compilers on how to estimate GHG emissions from enteric fermentation, manure management systems and rice cultivation. The 2nd year of the inventory cycle will focus on GHG emission estimations, ensuring transparency, completeness, consistency, comparability, and accuracy. The inventory cycle is represented in the figure below.

Figure 6: Inventory cycle for estimating GHG emissions from Fiji's Agriculture Sector.

The inventory cycle represents the deadlines for the respective tasks for inventory development. It acts as a tracking mechanism for responsible stakeholders within the IA and an indicator of the submission schedules to avoid the chances of surpassing deadlines. This will ensure that the inventory reporting is on track with the deadlines and would avoid delays in submission to the UNFCCC.

2. Data Collection and Approval Processes for GHG Inventory Development

Data collection is an integral part of developing and updating a greenhouse gas inventory. Formalized data collection activities should be established, adapted to countries' national circumstances, and reviewed periodically as a part of implementing good practice (Figure 7).

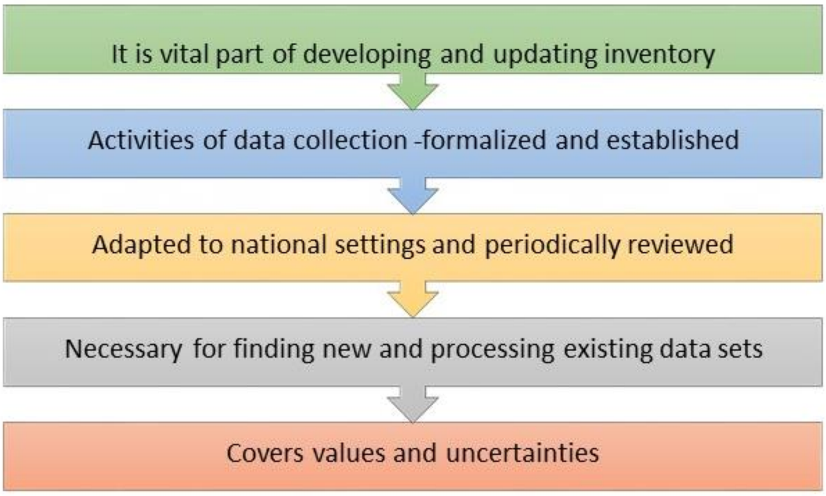


Figure 7: Importance of data collection for the development of GHG inventory.

2.1. Data Collection and Approval Processes for Livestock Category

Activity data required to enable GHG calculation is of paramount importance and such data needs to be collected systematically that is accurate, complete and has a time series consistency. Enteric fermentation from ruminant animals is a key category and therefore requires a methodological approach for data collection for robust emission estimates from this sub-sector. This section will enlighten about the system proposed to collect data from original point of source, QA/QC checks for data collection, approval and archiving data that could be used by GHG inventory compilers.

2.1.1. Activity Data Collection

To date, activity data has been recorded on ad hoc basis and as to when it is required and even then, it is not recorded in the correct format to enable emission estimation effectively and efficiently. It was discussed in the national stakeholder workshop on MRV held at Pearl Resort on 19th and 20th April that a template should be developed for data collection and that should also have in-built QA/QC check features. A USEPA template for data collection and QA/QC checks could be used to collate all the activity data required. The template was revised to suit the national circumstances and would now record correct categorization and sub-categorization of animals and relevant and mandatory activity data that needs to be recorded for both enteric fermentation and manure management (see Table 5). The personnel responsible for data collection such as divisional extension officers, locality livestock officers (LLOs) and livestock farmers need some form of training in the use of these templates so that it could be consistently applied.

Table 5: Modified USEPA Template for Data Recording and Collection of Activity Data for Enteric Fermentation and Manure Management from Livestock in Fiji

Category 1: Enteric Fermentation and manure management
Animal Category (*cattle, swine, chickens, sheep, goats, horses, ducks***):** _______________
Subcategory (dairy/beef, market/breeding swine, broilers/layers chickens): _____________
% use of different MMS for each category or subcategory animal (refer to Table 10.18 in Chapter 10 of the 2006 IPCC Guidelines for the definition of the different MMS):
____

Type of Activity data:	Annual Headcount	Average lifespan (Only for broilers, layers, breeding and market swine, ducks)	Average annual live weight (For all categories)	Annual Milk Production/ dairy cow (For dairy cattle only)
Reporting unit: *This should be the unit in which the data are reported for estimating emissions/removals. Example: metric tons.*	Headcount number	Months	Kilograms	Liters
Appropriateness to national circumstances: *State how these specific activity data were chosen. Example: The National Cement Association compiles production data from all of its members.*	National Animal Survey Report	MoA quarterly reports	MoA quarterly reports	MoA quarterly reports
Time series covered: *Record the years for which the activity data are available. Example: 2001-2013*				
Reference (if applicable): *If the activity data are from a publication, record the full reference. Example:* 2013. National Cement Association Annual Report				
Date of provision *Record the date of receipt of the activity data. Example: August 29, 2016*				
Source of data *Record the source of the activity data, e.g. the institution and department that provided it. Example: National Cement Association*	MoA	MoA	MoA	MoA
Contact details *Record the name, email address, and phone number of the contact person at the entity which provided the data. If applicable, ensure that this information is recorded in Template 2. Institutional Arrangements, or that Template 2 refers to this template. Example: John Smith, john.smith@example.com, +12 3456 7890*	Divisional Extension Officer, Locality Livestock Officer and Livestock farmers.	Divisional Extension Officer, Locality Livestock Officer and Livestock farmers.	Divisional Extension Officer, Locality Livestock Officer and Livestock farmers.	Divisional Extension Officer, Locality Livestock Officer and Livestock farmers.
Basis for data provision: *State the basis upon which data are provided, e.g., voluntary provision, legal requirement, data sharing agreement, or a memorandum of cooperation or understanding. (If you used the Confidential Business Information (CBI) Agreement or Memorandum of Cooperation (MoC) supporting templates from EPA's Toolkit for Building a National GHG Inventory System, cite the final MoC or CBI agreement developed from use of those or other templates here.) Example: Voluntary provision*	MoU	MoU	MoU	MoU
Coverage: *State whether the activity data cover all emissions or removals in the category. Example: The national cement association claims to cover all clinker production at the national level.*	Covers only registered farms	Covers only registered farms	Covers only registered farms	Covers registered farms
Adjustments applied to activity data: *Explain any adjustments applied to the original activity data received from the data source to make*				

it usable for the calculation, e.g., unit conversion or gap-filling. Example: The data were provided in kg and recalculated to t.											
Activity data values (headcounts; milk production rate): *Extend or modify the years as necessary to cover your time series.*											
1990	1991	1992	1993	1994	1995	1996	1997	1998			
1999	2000	2001	2002	2003	2004	2005	2006	2007			
2008	2009	2010	2011	2012	2013	2014	2015	2016			
2017	2018	2019	*[insert as needed]*								
The activity data values in the rows above are derived from the files listed here:	*List all files from which the activity data values above come, and indicate where these files are located, and whom to contact in order to access these files*.										
Quality control measures *Indicate in the following rows what quality control measures you have applied to the activity data indicated above. Add additional rows if you need to describe additional QC activities. Before adding any additional quality control measures, refer to Template 4. QA/QC. For suggestions about quality control activities, see chapter six of volume 1 of the 2006 IPCC Guidelines. In case of data gaps or problems with time series consistency, refer to chapter five of volume 1 of the 2006 IPCC Guidelines.*											
Comparison with trend: *Describe the results of the comparison of the new activity data with the previous trend, e.g., what developments were expected based on projecting the trend of past activity data values, what developments happen in the real activity data? Example: Trend indicated a further increase by 3%. Real development is an increase by 5%.*											

2.1.2. Activity Data verification and Approval Process

The systematic approach in collating data from original data source right to archiving for use by GHG inventory compilers is illustrated in Figure 7 below. The flow chart below describes the various level of data verification process, approvals, and archiving. Once the activity data is gathered by extension officers, locality livestock officers (LLOs) and livestock farmers then the activity data will be verified by the Agriculture Technical Officers (ATO) or the

Agricultural Officers (AO) if any activity data is not recorded or not recorded correctly then it will be reverted to point of source origin. Once the data is verified by ATO then a Senior Agriculture Officer will undertake further verification and internal QC checks before submitting the data to OIC (AH&P). The team at AH&P will verify the data collected with their database of registered farms and will endorse the activity data that will be submitted to EP&S section of MoA for recording and further data inconsistencies and data gaps analysis will be carried out. Once a data series is complete and accurate it would be presented to the Climate Change Steering Committee, whose membership will be approved by the Permanent Secretary for Ministry of Agriculture. The steering committee will approve the datasets only on the basis that the data set has been thorough the rigorous process of data verification. Once the activity time series data is approved by the steering committee then it will be archived by EP&S and could be used in the annual reports, census reports and could be readily accessible to Fiji Bureau of Statistics Department, Climate Change Division, FAO, and any other agencies covered by the data sharing agreement.

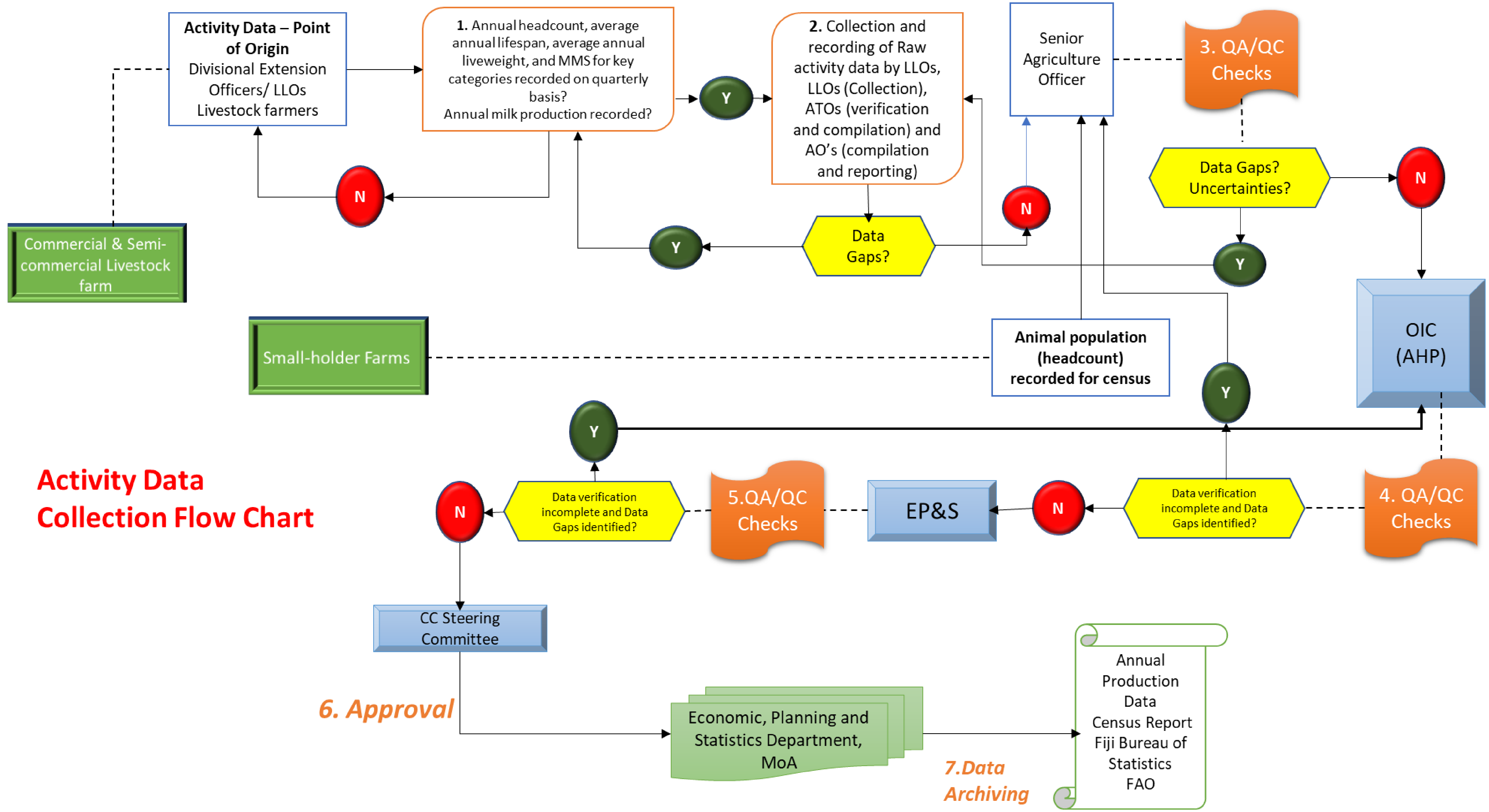


Figure 8: Data collection flow chart for GHG emission estimation from enteric fermentation and MMS

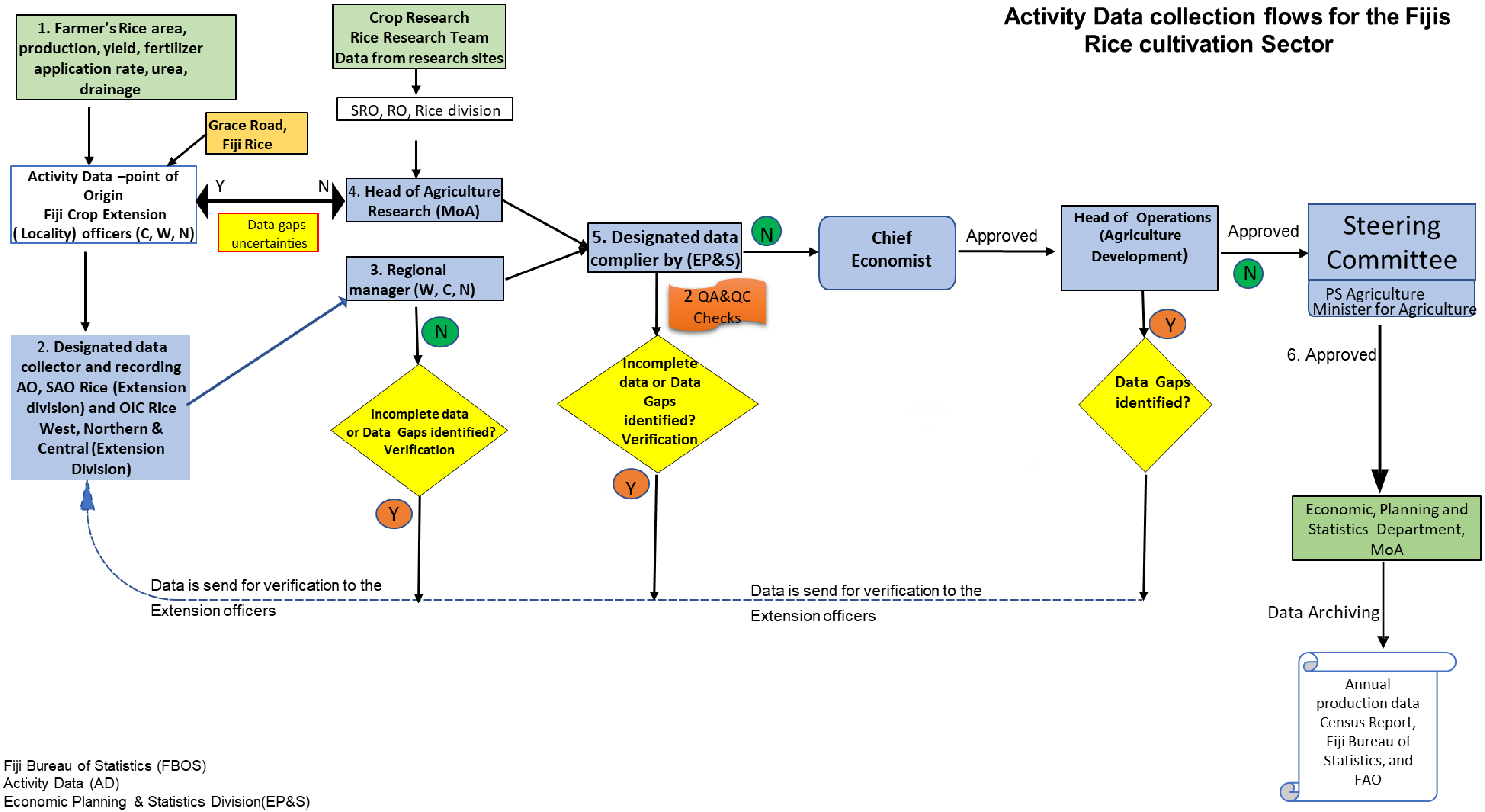
2.2. Data Collection and Approval Processes for Rice Cultivation

The demand for high-quality national greenhouse gas inventories is growing. For Fiji to vouch the credibility of its inventories, the integrity of the methodologies used, the completeness of reporting, and the procedures for compilation of data must meet the highest standard of transparency. The data collection and preparation of QA/QC plan is one of the major steps Fiji will be taking to reform the way the GHG inventory is done. This outlook is designed to provide a step-by-step instruction to guide the inventory team on the planning and implementing QA/QC activities. The plan is simply about structuring the data collection, QA/QC activities in the inventory and communicate who will be responsible for which task at a specific time in the inventory cycle. In addition, this guidance system for MoA to use and follow on how to improve to datasets collections, report on uncertainties and steps that the inventory compilers (national expert consultants) have to commit in the process of shifting to a higher tier uncertainty assessment. The quantity of GHG emissions from rice farming not only depends on the amount and types of farm inputs, but also varies with irrigation systems and water management practices.

Data collection is an integral part of developing and updating a greenhouse gas inventory. Formalized data collection activities should be established, adapted to Fiji' national circumstances, and reviewed periodically as a part of implementing good practice. The data collection in case of GHG emission in rice cultivation focused on key categories. In the present inventory process, Tier 1 approach was used to calculate GHG emissions from rice cultivation due to lack of country specific information (such as emission factors, scaling factors, etc.).

2.2.1. Data collection systems proposed for rice cultivation in Fiji

After the feedback from the project workshop, the activity data collection flow for rice cultivation for GHG inventory was revised and the data flow process (Figure 1) depicts the rice field data is collected from the various rice growing areas and are collected by Extension officers from Northern, Central and Western divisions from Fiji. This activity data will then be collected, complied, and recorded and a copy of this is send to the SAO (Senior Agriculture Officer) and OIC (Officer in Charge) Extension of Northern, Central and Western Divisions and the other set of same datasets is sent to the MoA Rice Research team under Head of Research and Development, Fiji. The activity data from public and private sector (e.g., Fiji Rice, Grace Road Rice farm data) and from other sources are also collected by the extension officers from the same locality and this data sets and information is transferred to MoA, Head of Research Team for compilation. The data from the experimental research trails which the Rice team at MOA conducts, will also be added their research activity data. All this activity data and information is then passed to EP &S section where the data gaps and uncertainties are checked. If there are any data gaps, data is sent back to the extension officers for rechecking, if the data is having no data gaps and is verified then it is passed from EP&S section to Chief Economist for approvals and further to the Head of Operations (Agriculture Development) for approvals. If the data is approved, it goes to the Steering committee and once approved it is handed over for approval from the meeting Chair PS and Minister of Agriculture for archiving. The approved data is then used for Annual data for production, Census, import export data and is also provided to the FAO and other organisation. So, there is one key data, and this will avoid data duplication and errors.



Fiji Bureau of Statistics (FBOS)
Activity Data (AD)
Economic Planning & Statistics Division(EP&S)
Quality assurance and Quality Checks as per T1 IPCC 2006
QA/ QC

Figure 9:Data collection flow chart for GHG emission estimation from rice cultivation

2.2.2. Screening and refining of available Fiji activity data

It was best to start data collection activities with an initial screening of available data sources. This was an iterative process where details of data that are available are built up. This screening process was slow and required questioning until a final judgement was made about the usefulness of a data set for the inventory. Once the national experts (inventory compiler) selected a data set which was published data, and this was simply used in their original form. For the next step it will be good to develop a formal plan for data request procedure. This formalization will enable efficient annual updating (through knowing what to ask for, from whom, and when) while complying with QA/QC requirements for documentation and for future reference.

2.2.3. Recommended and proposed data collection Fiji

As a recommendation for future inventory work, for essential activity data, it is good practice to match data on organic amendments and soil types to the same level of disaggregation as the activity data. It may be necessary to complete a survey of cropping practices to obtain data on the type and the amount of organic amendments applied in the future. The key activity data required and responsibilities to estimate GHG emissions from rice cultivation *(Table 6, 7 and 8)*. The use of locally verified areas was the most valuable when they are correlated with available data for emission factors under differing conditions such as climate, agronomic practices, and soil properties. Therefore, it may be necessary to consult local experts for a survey of agronomic practices relevant to methane emissions (organic amendments, water management, etc.). For Rice GHG inventory data from rice is cultivated in 2 seasons or 3 times in a year based on variety, the data collection will take around a year and GHG inventory would be complied on biennial basis.

Table 6: Key activity data required to estimate GHG emissions from rice cultivation

Check list for Activity data required for collection
Activity Data
✓ **Rice production and yield for each rice ecosystems** ✓ **Harvested area of rice in each ecosystem** **Disaggregated by three baseline water regimes as listed below:** ✓ **Irrigated.** ✓ **Upland** ✓ **Rainfed and Deep Water**
Cultivation period (number of days) of rice for different ecosystems ✓ **Irrigated.** ✓ **Upland** ✓ **Rainfed and Deep water**
Water regime during the cultivation period different water regime (continuously flooded, intermediated single aeration, multiple aeration
✓ **Organic amendments/ crop residues applied – type and amount**
✓ **Type of drainage for each area and ecosystem type**
✓ **Pre-season flooding (time/days)**
✓ **Rice cultivar**
✓ **Fraction of crop residue burnt**
✓ **Soil carbon change (if available)**
✓ **Soil type**
Activity Data for Direct and Indirect N_2O and CO_2 by Urea emission in Managed soils
Data from different ecosystems of rice per area per year in
✓ **Rice crop yield statistics from each ecosystem- irrigated, rainfed, upland** ✓ **Rice crop cultivation period** ✓ **Type of drainage** ✓ **Soil type and cultivar**

✓ **Area of rice ecosystems** ✓ **Rice cultivation period** ✓ **Pre-season flooding** ✓ **Organic amendments/crop residues (type and amount)** ✓ **Nitrogen fertilizer applied (type and amount)** ✓ **Soil C change data**
✓ **Application method (e.g., broadcast, incorporated, etc.)** ✓ **Dates of applications** ✓ **Amount of crop residue returned to soil (including from crop rotations)** ✓ **Amount of synthetic fertilizers, animal manure, compost, sewage sludge, crop residues changes to land use or management added for different ecosystems per area per year**
✓ **Crop residue burning data segregated by:** • **non-N-fixing grain crops (e.g., maize, rice, wheat, barley)** • **N-fixing grains and pulses (e.g., soybean, dry beans, chickpea, lentils)** • **root and tuber crops (e.g., potato, sweet potato, cassava)** • **N-fixing forage crops (alfalfa, clover)** • **other forages including perennial grasses and grass/clover pastures** ✓ **National statistics for carbonate lime to determine amount of lime applied to soils annually** ✓ **Annual sales of carbonate lime** ✓ **Domestic production records and import/export data on urea to obtain an approximate estimate of the amount of urea applied to soils on an annual basis** ✓ **Supplemental data on sales and/or usage of urea** ✓ **Consistent representation of lands by land use type, climate zone/temperature regime** ✓ **Classification of land on ecological zone classes** ✓ **Land use maps are available**
✓ **Climatic conditions in the country**

Table 7: Sectoral roles and responsibilities for activity data collection from rice cultivation.

No.	Key activity Data	Name	Organization
1	Rice field data is collected from the various rice growing areas by Northern, Central and Western divisions by Extension officers	Regional Manager and Head, Rice team, MOA	Rice division Ministry of Agriculture, Koronivia
2	For each ecosystems data Rice area, productivity, yield Extension officers from Northern, Central and Western divisions	Head, Rice team, MOA and EP&S	Rice division Ministry of Agriculture, Koronivia
3	Climate Data	Head, Fiji Met	Fiji Metrological data
4	Rice variety, cultivation period – time in days.	Head, Rice team from Extension officers	Rice division Ministry of Agriculture, Koronivia
5	Pre – season flooding – time in days Organic amendments/ crop residues applied – type and amount Fraction of crop residue burnt; amount of lime applied etc. Soil carbon change (if available) Fertilizer amount and rate of application in each rice ecosystem	Head, Rice team from Extension officers	Rice division Ministry of Agriculture, Koronivia

Table 8: Details for sources of activity data in Fiji

Data Sources	Website
Fiji Bureau of Statistics (FBoS)	**https://www.statsfiji.gov.fj/index.php**
FAO STAT	**http://www.fao.org/faostat/en/#home**
Fiji Data source 2020 Census	

MPI Fiji (Rice Division)

MPI officials	Email Contact
Mr. Amena (Head , Rice team MoA)	amena.banuve@govnet.gov.fj
EP&S (Quality Checks)	
Ms. Sera Bose	sera.bose@govnet.gov.fj
Ms. Helen Mua	helen.mua@govnet.gov.fj

No.	Name of Staff	Designation	Phone Contact	Email Address
Northern Division				
1	Davendra Nath	ATO Rice North	9362000	Davendra_nath_2005@yahoo.com
2	Krishneel Chand	Research Officer Dreketi	9907393	Krishneel1993@gmail.com
3	Arvind Chetty	ATO Savusavu	8449232	chettyarvind@ymail.com
4	Fouziya Nisha	AA Bua	9899057	fouziyanisha7@gmail.com
Central Division				
1	Inosi Sugucolo Vulawalu	SAO Serua/Namosi	9924549	Inosi.vulawalu@govnet.gov.fj; Inosivula8@gmail.com
2	Malti Devi	MIS officer Central	9271512	prasad.malti@yahoo.com
3	Irene Chand	TO Research – Rice	9253538	irenerozika@yahoo.com
4	Nileshni Devi	STA Research – Rice	9655555	devinileshni12@yahoo.com
Western Division				
1	Morien Prasad	OIC Rice West	2181361	prasad.morien@yahoo.com
2	Naveen Chand	Ba Officer	9430653	Nvcsc5@gmail.com

Moreover, the information on activity data that may be required to estimate GHG emissions from rice cultivation the procedure for data collection is simple. Following steps can be applied by MoA while collecting the data, methodological principles of data collection underpin *good practice* from rice cultivation are:

- Choosing procedures that continuously improve the quality of the inventory
- Collecting data/information at a level of detail appropriate to the method used

- Reviewing data collection activities and methodological needs on a regular basis
- Introduce agreements with data suppliers to support consistent and continuing information flows.
- for the completeness of the current data, which is not sufficient due to incomplete records, it is good practice to gather additional data for future inventory reporting, particularly if they are the key source category.
- Time Series Consistency: While it is good practice for the same data protocols and procedures to be used across the entire time series, in some cases this may not be possible, and inventory compilers should determine the influence of changing data sources on the trends.

3. Description of QA/QC Procedures for GHG Inventory Development

3.1. QA/QC Plan for the Agriculture Sector

The quality assurance and quality control (QA/QC) plan is mandatory for accurate reporting under the United Nations Framework Convention on Climate Change (UNFCCC) and future required reporting under the Enhanced Transparency Framework (ETF) for National GHG Inventories. This section discusses setting up a QA/QC plan for Fiji GHG inventory using the tables from Template 4 of the USEPA Templates for creating a National Inventory System Manual. The QA/QC plan builds confidence in national GHG inventories and could also help to identify improvement options to enhance transparency, accuracy, consistency, comparability, completeness in the inventories.

To develop a QA/QC plan the following steps and activities needs to be done by assigned personnel. It is imperative that a country appoints QA/QCV coordinator who will ensure that the following steps and its associated activities are followed stringently.

Table 9: QA/QC Plan for Fijis Agriculture GHG Inventory

Step	Activities
1. Convene a QA/QC Plan launch meeting and identify QA/QC personnel.	• Convene a meeting with all team members to initiate the development of the QA/QC plan. Identify the people that could be involved in the plan. The plan should apply to the whole team (including consultants, universities, etc.) that is involved in the estimation and reporting of the GHG inventory. • Identify the QA/QC coordinator. This is the main person responsible for developing, maintaining, and implementing the QA/QC plan. In this role, the QA/QC coordinator: o Clarifies and communicates QA/QC responsibilities to inventory members. o Develops and periodically reviews and updates the QA/QC checklists appropriate to various inventory team member roles (or ensures that these tasks are accomplished). (See Table A2-3 and Table A2-4 in Annex 2 for examples). o Determines an overall QA/QC timeline and when external reviews will occur and ensures the timely and accurate completion of QA/QC checklists and related activities. o Manages and delivers documentation of QA/QC activities to the NIC and archive coordinator. o Coordinates external reviews of the inventory

	document and ensures that comments are incorporated into the inventory. • Identify key QA/QC personnel and any additional country-specific QA/QC responsibilities. • Complete Table A2-1 (See Annex 2 with the names and contact information of the appropriate staff.
2. Develop a timeline for distributing the QA/QC plan amongst the inventory team and experts.	• *It is essential to communicate the contents of the QA/QC plan to inventory team members and outside experts involved in quality assurance of the GHG inventory so that the procedures can be effectively implemented, evaluated, and improved. The QA/QC coordinator should develop a timeline for taking the following actions:* ○ *Creating or updating the QA/QC plan* ○ *Participating in an inventory inception meeting with all of those working on the inventory (including consultants, universities, etc.), and at the meeting, introducing the plan to all team members required to perform QA/QC, and distributing QC checklists (see National GHG Inventory Inception Memorandum supporting template)* ○ *Checking that members of the inventory team understand the purpose and outcomes of the QA/QC plan, and updating the plan to address any questions* ○ *Periodically reminding team members of their QA/QC responsibilities and the overall QA/QC schedule* • *Use Table A2-2 in Annex 2 to develop a QA/QC plan distribution timeline. Add rows as needed to accommodate additional tasks.*
3. Establish general QC procedures for source/sink category leads to follow.	• To develop the QA/QC plan, gather existing QA/QC procedures. Include QA/QC procedures used by data providers. These procedures can then be strengthened if necessary. • The first part of developing the QA/QC Plan is to establish general QC procedures. These include generic quality checks related to calculations, data processing, completeness, and documentation that are applicable to all inventory source and sink categories and should be implemented each year. A minimum set of QC procedures should be followed each year for all categories to ensure that basic standards of quality are met. These standards generally focus on the processing, handling, documenting, archiving, and reporting procedures common to all categories. • Table A2-3 (Annex 2), lists the QC activities that should be performed at the category or subcategory level by staff compiling these estimates.
4. Establish category specific QC procedures for source category leads to follow	*Category-specific QC focuses on specific types of data used in the methods for individual source or sink categories.* • *Table A2-4 (Annex 2), lists the category-specific QC procedures that should be performed.*
5. Document recommendations received as a result of experts' QA activities.	• *Quality Assurance involves expert reviewers not involved in preparing the inventory, and a basic peer review process. QA activities follow QC activities and complement QC activities.* • *Expert review offers the opportunity to uncover technical issues related to the application of methodologies, selection of activity*

	data, and development and choice of emission factors. The comments of the expert reviewers should be reviewed and addressed, as appropriate, prior to the submission of the Inventory, and documented/archived appropriately to ensure transparency and for reference of future compilation teams. • *Experts should be independent of the inventory agency, and affiliated with other national agencies, research facilities, international organizations, or other organizations with relevant expertise in GHG emission estimation methodologies, activity data, or other parameters. If third party reviewers are unavailable, staff from another part of the inventory agency not involved in the portion of the inventory under review can fulfill this role.* • *Key categories should be given priority for review, as well as source categories where significant changes in methodology or data have been made.* • *Using Table A2-5 (Annex 2), identify the experts who are reviewing the GHG inventory. In the Comment Summary column, summarize experts' recommendations regarding specific improvements that could be made to the GHG inventory because of experts' QA activities. Add major improvements identified by expert reviewers to the GHG inventory improvement plan in Template 7.*
6. Propose GHG inventory improvements as a result of QA/QC activities.	• An important part of QA/QC activities is to use the results of these activities to identify how to improve the quality of the GHG inventory. • In Table A2-6 (Annex 2) describe all such potential improvements to the inventory. • Add as many rows as necessary to accommodate all potential improvements. • Instructions by column follow: • Topic: Describe the topic this improvement relates to (e.g., Institutional Arrangements, Methodology/Data, QA/QC, Communication, and awareness, Other - please specify). • Category Code and Name: If the topic is "Methodology and data," please state the code and name of the category to which this improvement relates. • Issue: Concisely describe why an improvement is needed. • Relevant Inventory Quality Principle: State the relevant inventory quality principle (e.g., transparency, accuracy, completeness, consistency, or comparability). • Improvement Option: Describe the action to be taken, and how it should resolve the issue. • When this table is complete, copy its contents into Template 6, National Inventory Improvement Plan.

7. QA/QC Checklists	• *This section includes three additional checklists that may help the NIC and QA/QC Coordinator track progress of the development of the overall QA/QC plan, and QA/QC activities. The checklists may be modified to suit country-specific circumstances.* • *The checklists are:* o *QA/QC Coordinator Checklist* o *National Inventory Coordinator Checklist: Cross-Cutting Checks for Overall Inventory Quality* o *National Inventory Coordinator Checklist: Detailed Checklist for Inventory Document*

3.2. QA/QC Procedures for the Agriculture Sector

The QA/QC plan would be initiated once the National Inventory coordinator, QA/QC coordinator is appointed or when the climate change team at MoA is established. The following QC activities are implemented during the QA/QC plan:

- Check that assumptions and criteria for the selection of activity data, emission factors, and other estimation parameters are documented.
- Check for transcription errors in data input and references
- Check that emissions/removals are calculated correctly
- Check that parameter and emission/removal units are correctly recorded and that appropriate conversion factors are used
- Check the integrity of database files
- Check for consistency in data between categories
- Check that the movement of inventory data among processing steps is correct
- Check that confidential data are appropriately protected
- Check that uncertainties in emissions and removals are estimated and calculated correctly.
- Review internal documentation and archiving
- Check methodological and data changes resulting in recalculations
- Check time series consistency
- Check completeness
- Trend checks

QA/QC process for the compiled activity data will take place at different levels of autonomy of MoA (See Figure XX below). Once the data is collected from the point of source origin then the Senior Agricultural Officer will undertake the QC procedures such as:

- Check time series consistency and completeness
- Check for transcription errors in data input file
- Check the parameter units are correctly recorded

Once the above QC checks are done then the activity data will be further scrutinized by commodity heads at Animal Health and Production, EP&S and Management Information System (MIS) units. Further verification of data against the registered number of farms and animal headcounts, trend checks with previous data and comparability of data and check for time series consistency and completeness will be carried out. After approval of the activity data by the steering committee then the activity data will be archived and could be readily accessed by the consultant to compile the national GHG inventory report.
The consultant will further undertake QC procedures as such:

- Check for time series consistency and for missing data apply extrapolation or interpolation to fill the data gaps.
- Undertake verification of the emission factors considering the local parameters.
- Comparison with other secondary data sources for completeness.
- Check parameters and emission units are correctly recorded, and appropriate conversion factors are used.
- Emissions are calculated as per 2006 IPCC guidelines

After the compilation of the GHG Inventory then it will be finally reviewed by external experts (those who were not involved in the compilation process). This is the QA process which will ensure that thorough scrutiny of the emission estimate is undertaken. The experts will check if the IPCC methodologies have been applied rigorously and that the uncertainty estimate is undertaken and that the emissions are calculated as accurately as possible.

The QA/QC process for the livestock and rice cultivation are illustrated in the flowcharts below.

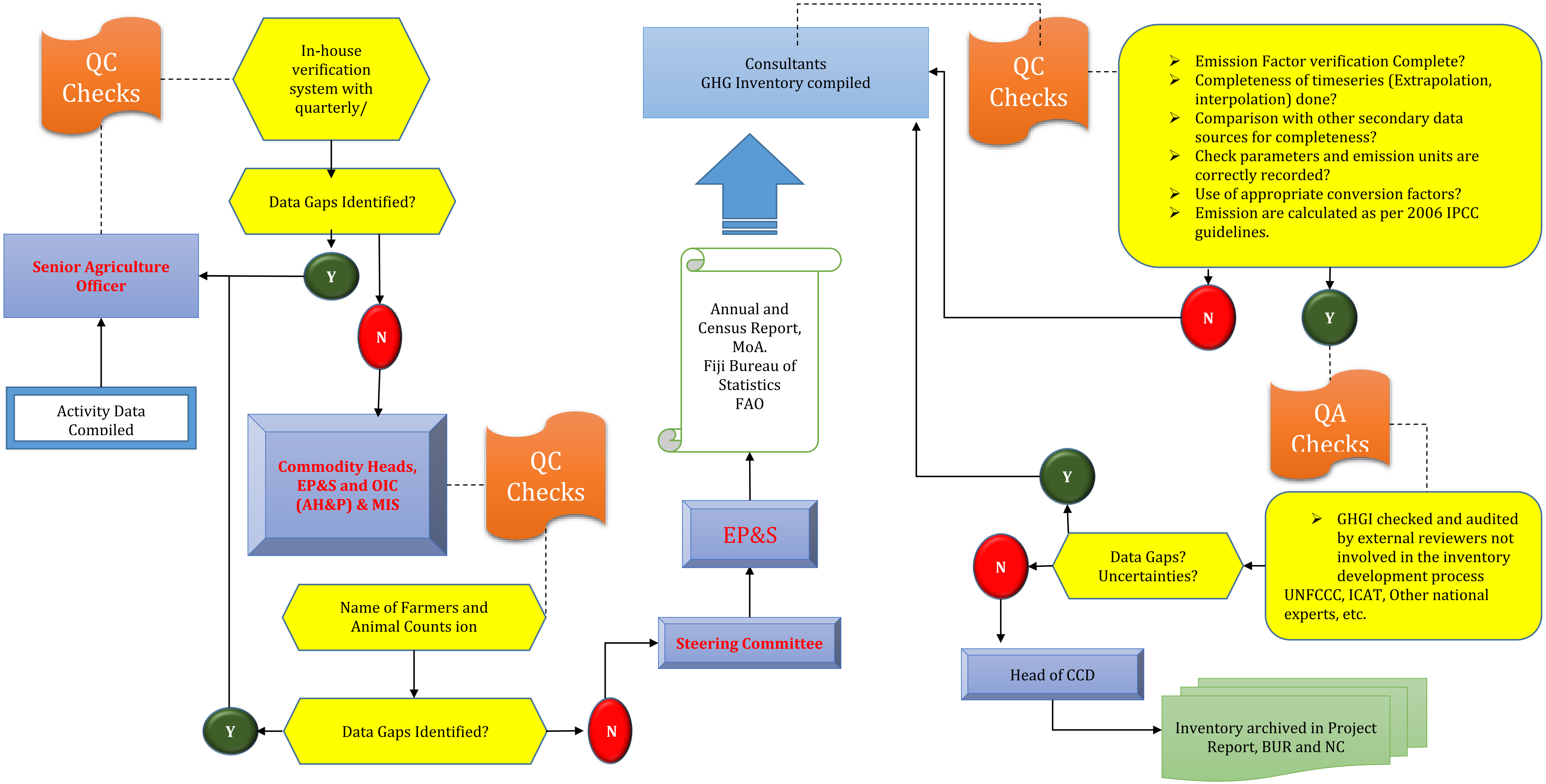


Figure 10: Flowchart for QA/QC Procedure for Livestock GHG Inventory

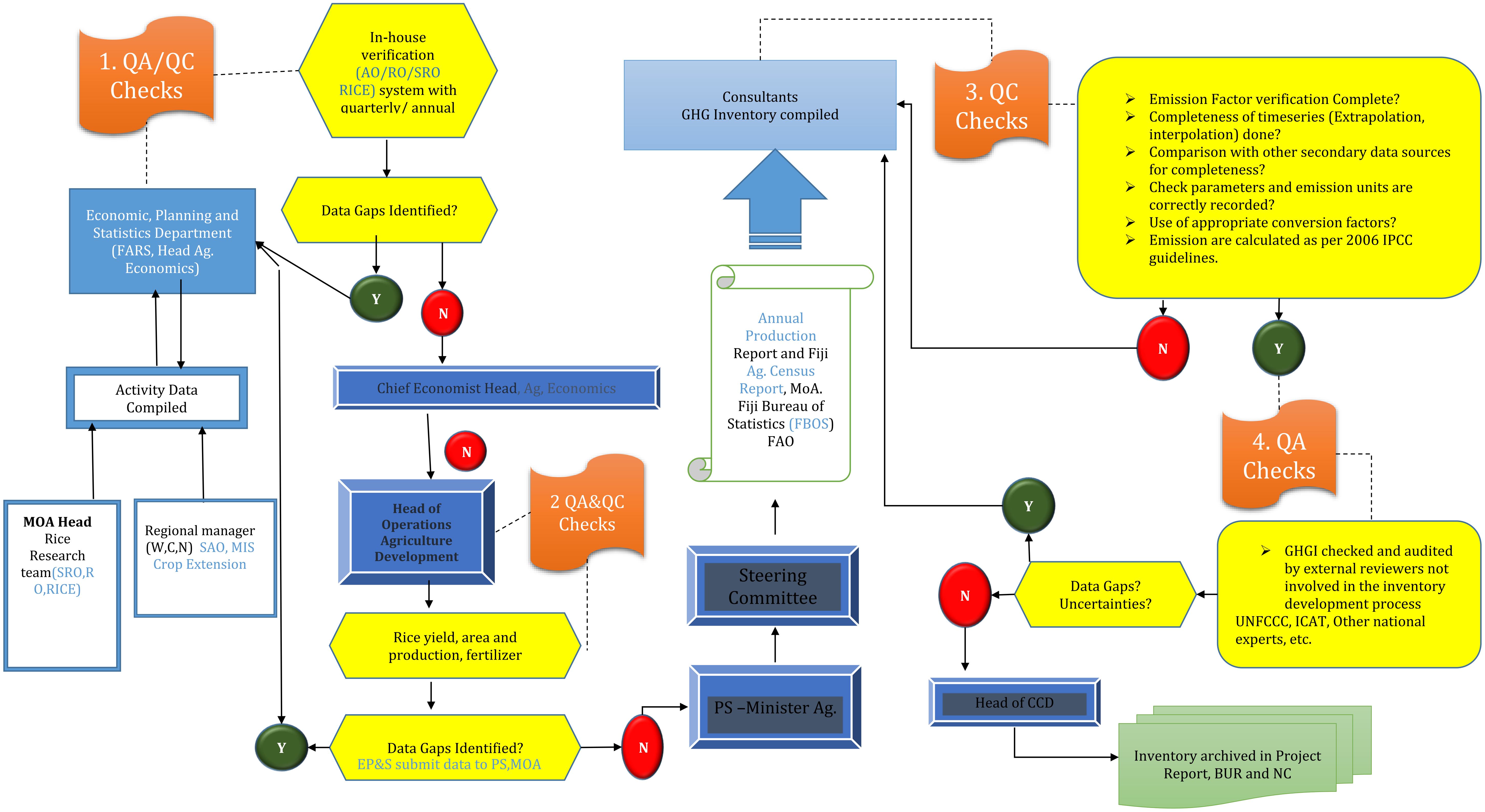


Figure 11: Flowchart for QA/QC Procedure for GHG Inventory on Rice Cultivation

4. Uncertainty Estimation

Estimates of uncertainty are an important part of a complete inventory of greenhouse gas emissions and removals. They should be calculated at both the national and trend levels, as well as the component elements for each category, such as emission factors, activity data, and other estimating parameters. An uncertainty analysis should be viewed first and foremost as a tool for prioritizing national efforts to minimize inventory uncertainty in the future and guiding methodological decisions. As a result, the methodologies used to assign uncertainty values must be practical, scientifically sound, robust enough to apply to a wide range of categories of emissions by source and removals by sinks, methods, and country circumstances, and presented in ways that inventory users can understand. Figure 12 shows a quick overview of the overall framework of uncertainty analysis. Estimates of emissions and removals are dependent on three factors: (1) conceptualization, (2) models, and (3) input data and assumptions (e.g., emission factor and activity data). Each of these factors can create uncertainty. A conceptualization is the first step in the analysis. This is a set of assumptions about how an inventory, or a sector, is structured. The geographic scope, temporal averaging time, categories, emissions or removal methods, and gases that are included are all examples of assumptions. The data and information requirements are determined by assumptions and methodological choices. The two-way arrow in the illustration indicates that there can be some interaction between data, assumptions, and methodological choice. The ability to disaggregate categories, for example, which may be required for higher-tier techniques, is dependent on data availability. Data should go through suitable data collection and QC methods, such as Quality Assurance/Quality Control and Verification, whether empirical or based on expert judgment. For use in an emission inventory uncertainty analysis, these data comprise % uncertainty estimates and underline probability density functions. Combining input uncertainties to arrive at a solution
Two Approaches are given for combining uncertainties.

Approach 1 is a relatively simple spreadsheet-based calculation procedure based upon some assumptions to simplify the calculations.

Approach 2 is based upon Monte Carlo simulation and can be applied more generally. Either approach provides an estimate of the overall uncertainties associated with the total greenhouse gas inventory.

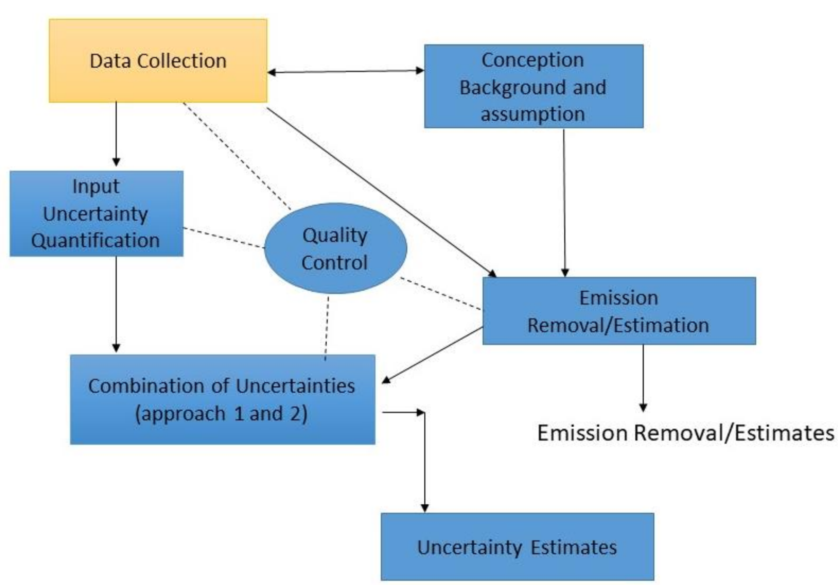


Figure 12:Evaluating uncertainties in emission inventories

4.1. Causes of uncertainty

1. Incompleteness: In this scenario, measurement or other data are unavailable because the process has not yet been recognized or a measurement method has not yet been developed. This causes insufficient conceptualization, which leads to prejudice, but it can also contribute to random error depending on the situation. For example, the lack of completeness -Bias can be in methane emissions from enteric fermentation for dairy cows.
2. Model: Models can be as simple as a constant multiplier (e.g., an emission factor) and increase in complexity, such as for complicated process models.
3. Data scarcity: In rare cases, data sufficient to characterize a specific emission or removal may just be unavailable. In these cases, a frequent strategy is to use proxy (or surrogate) data for analogous or similar categories, or to make estimates using interpolation or extrapolation. The lack of data headcount for some animal types, for example, is not reflected in the statistics.
4. Data representativeness: This sort of uncertainty is caused by a lack of a complete link between the conditions associated with available data and the conditions associated with real emissions/removals or activities. A lack of representativeness is frequently the source of bias. Example Data representativeness - Biomass growth rate bias is sample dependent Random sampling error in statistics: This type of uncertainty relates to data that is a random sample of limited size, and it is often determined by the variance of the population from which the sample was taken, as well as the sample size (number of data points). Increasing the number of independent samples taken can typically minimize it. It's a good idea to make the distinction between variability and uncertainty, as previously established.
5. Measurement error: Errors in measuring, recording, and transmitting data; finite instrument resolution; inexact values of measurement standards and reference materials; inexact values of constants and other parameters obtained from external sources and used in the data-reduction algorithm (e.g., default values from the IPCC Guidelines); approximations and assumptions incorporated in the measurement.
6. Misreporting or misclassification: This could be due to an insufficient, ambiguous, or incorrect definition of emission or removal. This source of uncertainty frequently results in bias. Missing data: Uncertainties may result where measurements were attempted but no value was available. An example is measurements that are below a detection limit. This cause of uncertainty can lead to both bias and random error. When measured values are below a detection limit, an upper bound on the uncertainty can be estimated.

All GHG inventories have associated uncertainty; understanding, transparently reporting, and reducing this uncertainty through targeted inventory methodological improvements is one of the fundamental duties of GHG inventory compilers. The uncertainties and key category analysis are used to help prioritize research to improve inventory quality and minimize overall uncertainties, guarantee that published inventory data is as accurate as possible, and build the evidence base for policymakers.

In Fiji, the GHG inventory improvement program is managed by CCCID(MoE) in consultation with other Ministries, EP&S, agencies, and inventory experts. Most emission estimation methodologies in Fiji can be represented by a calculation: Emission = emission factor (EF) x activity data (AD) Therefore, when considering the uncertainty of the inventory the starting point is to establish the uncertainty of the emission factors and activity data used.

GHG emission inventory estimates are based on a variety of data sources, including reference data, country-specific research, and expert judgments or assumptions. Many emission sources have incomplete local data on activities and emission factors, making it difficult to estimate GHG emissions for Fiji.
Internal evaluation, methodology, and information utilized to create an emission inventory serve as the foundation for identifying inaccuracies and assessing them qualitatively or quantitatively. Internal uncertainty is assessed using six different tools: qualitative discussion, data quality ratings, calculation check, expert estimation, error propagation, and important analysis. External assessment of inaccuracy, the differences between the emission

inventory and other, independent, information is used to identify or quantify inaccuracies in the emission inventory.

4.2. Why doing uncertainty estimation in GHG emission important?

Accuracy Data should be detailed enough to allow intended users to make decisions with reasonable certainty that the presented information is accurate. As far as is possible, GHG measurements, estimates, or calculations should be systemically neither above nor under the actual emissions number, and uncertainties should be minimized. The quantification process should be carried out with the least amount of uncertainty possible. Reporting on steps taken to assure accuracy in emissions accounting can boost confidence while also increasing openness. Additional information and recommendations on evaluating uncertainty, including alternative techniques to creating quantitative uncertainty estimates and eliciting expert assessments— can also be found in EPA's Emissions Inventory Improvement Program, Volume VI: Quality Assurance/Quality Control (1999) and in chapter 6 of the IPCC's Good Practice Guidance (2006).

TABLE 3.1 TYPICAL STRATEGIES FOR DEALING WITH DIFFERENT CAUSES OF UNCERTAINTIES				
	Strategy			
Causes of Uncertainty	Evaluated Conceptualization and Model Formulation	Empirical and Statistical	Expert judgment	Other Comments
Lack of completeness	√			Have key components of the system been omitted? If so, what is the quantifiable or non-quantifiable effect on systematic error? Proper QA/QC should help avoid this.
Model (bias and random errors)	√	√	√	Is the model formulation complete and accurate? What is the uncertainty in model? predictions based on validation of the model? What is the estimate of model accuracy and precision based on expert judgment if statistical validation data are not available?
Lack of data			√	If data are lacking, can expert judgment be used to make inferences based on analogous (surrogate, proxy) data or theoretical considerations? May be related to lack of completeness and model uncertainty
Lack of representativeness of data	√	√	√	If data are lacking, can expert judgment be used to make inferences based on analogous (surrogate, proxy) data or

				theoretical considerations? May be related to lack of completeness and model uncertainty.
Statistical random sampling error		√		E.g., statistical theory for estimating confidence intervals based on variability in the data and sample size
Measurement error: random component		√	√	
Measurement error: systematic component (bias)	√		√	QA/QC and verification may provide insight
Misreporting or Misclassification		√	√	Proper QA/QC should help avoid this
Missing data		√	√	Statistical or judgment-based approaches to estimating uncertainty because of non-detected measurements or other types of missing data
Source: IPCC document 2006(Uncertainties)				

Steps in the uncertainty assessment are:
Gathering or collection of the information -Collection of uncertainty information based on activity data and emission factors.

1. The first step in collecting data should be to investigate existing national statistics, industry sources, research studies, and FAO statistics. for each category and identify if country-specific uncertainty values are available for each data type – AD, EFs, parameters. Document this for each category in a form of a simple table, for example:

Data type	Annual Animal population	Average animal mass	…
Category			
3A1			
Dairy cows	Default (Ref]		
Non-dairy cows	Fiji [ref, value]		
Sheep	Fiji [ref, value]		
Etc.	…		

2. For the country-specific values, ensure the references are provided; where expert judgement was used, fill-in the expert judgement protocol as recommended in section 3.5 of chapter 3, 2006 IPCC Guidelines[7]
3. The Second step is error propagation –
    a. convert all known uncertainties to percentages
    b. fill-in the Ag sector portion of the excel-based IPCC uncertainty tool[8] as far as possible;

[7] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_3_Ch3_Uncertainties.pdf
[8] Addendum to Chapter 3: IPCC tool for Approach 1 uncertainty analysis https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/1_Volume1/19R_V1_Ch03_Ad_IPCC_Tool_for_Approach_1_Uncertainty_Analys

4. The Third step is the inventory analysis using the spreadsheet. If emissions are estimated, a full uncertainty analysis on the Ag sector using the IPCC uncertainty tool can be run.Prepare the uncertainty note for the inventory explaining the methods used supported by the references, include the uncertainty value for the total emissions from each category as a table and a total uncertainty for the sector. Identify the highest contributors to the total uncertainty value (for both AD and EFs).
5. If this is not the first inventory, compare the uncertainty value (the overall for each big category like 3.A.1, 3.A.2, etc.) with the previous year, comment on the numerical value of the differences in uncertainty and describe the factors that largely contributed the observed changes.

APPROACH 1: PROPAGATION OF ERROR

Approach 1 is based upon error propagation and is used to estimate uncertainty in individual categories, in the inventory, and in trends between a year of interest and a base year. The key assumptions, requirements, and procedures are described here. Approach 1 should be implemented using Table 3.2, Approach 1 Uncertainty Calculation, which can be set up on commercial spreadsheet software. The table is completed at the category level using uncertainty ranges for activity data and emission factors consistent with the sectoral good practice guidance. Different gases should be entered separately as CO2 equivalents.

In the case of Livestock GHG Emissions:

The uncertainty associated with populations will vary widely depending on the source but should be known within +20%. Often, national livestock population statistics already have associated uncertainty estimates in which case these should be used. If published data are not available from these sources, interviews of key industry and academic experts can be undertaken. Uncertainty estimates for digestibility estimates may be as high as +20%. Volume 1, Chapter 3 (Uncertainties) describes how to elicit expert judgment for uncertainty ranges. Similar expert elicitation protocols can be used to obtain the information required for the livestock characterization if published data and statistics are not available.

Emission factors

The purpose of this step is to select emission factors that are most appropriate for the country's livestock characteristics. Default emission factors for enteric fermentation have been drawn from previous studies and are organized by region for ease of use. The data used to estimate the default emission factors for enteric fermentation are presented in Table 10.10 of the 2006 IPCC Guidelines where the uncertainty estimate for the Emission factor is mentioned. As the emission factors for the Tier 1 method are not based on country-specific data, they may not accurately represent a country's livestock characteristics and may be highly uncertain as a result. Emission factors estimated using the Tier 1 method are unlikely to be known more accurately than +30% and may be uncertain to +50%.

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Table 10.10 Enteric fermentation emission factors for Tier 1 method[1] (kg CH_4 head^{-1} yr^{-1})			
Livestock	**Developed countries**	**Developing countries**	**Liveweight**
Buffalo	55	55	300 kg
Sheep	8	5	65 kg - developed countries; 45 kg - developing countries
Goats	5	5	40 kg
Camels	46	46	570 kg
Horses	18	18	550 kg
Mules and Asses	10	10	245 kg
Deer	20	20	120 kg
Alpacas	8	8	65 kg
Swine	1.5	1.0	
Poultry	Insufficient data for calculation	Insufficient data for calculation	
Other (e.g., Llamas)	To be determined[1]	To be determined[1]	

All estimates have an uncertainty of ±30-50%.

Sources: Emission factors for buffalo and camels from Gibbs and Johnson (1993). Emission factors for other livestock from Crutzen *et al*., (1986), Alpacas from Pinares-Patino *et al*., 2003; Deer from Clark *et al*., 2003 .

[1] One approach for developing the approximate emission factors is to use the Tier 1 emissions factor for an animal with a similar digestive system and to scale the emissions factor using the ratio of the weights of the animals raised to the 0.75 power. Liveweight values have been included for this purpose. Emission factors should be derived on the basis of characteristics of the livestock and feed of interest and should not be restricted solely to within regional characteristics.

Activity data

There will be an added uncertainty associated with the livestock and feed characterization. Improving the livestock and feed characterization will often be the priority in reducing overall uncertainty. Accurate estimates of feed digestibility (DE%) are also critical for reducing the degree of uncertainty. Uncertainty estimates can be derived from the good practice approach to agricultural census data outlined in the uncertainty section for livestock and feed characterization (see Section 10.2).

There are large uncertainties associated with the default emission factors for Tier 1 (see IPCC 2006 document Tables 10.14 to 10.16). The uncertainty range for the default factors is estimated to be +30%. Accurate and well-designed emission measurements from well-characterized types of manure and manure management systems can help reduce these uncertainties further. These measurements must account for temperature, moisture conditions, aeration, VS content, duration of storage, and other aspects of treatment. The default values may have a large uncertainty for a particular country because they may not reflect the specific manure management conditions present within the country. Uncertainties can be reduced by developing and using MCF, Bo, and VS values that reflect country/region-specific conditions

Methane (CH_4) Emission in Rice

Important activity data necessary to assign scaling factors (i.e., data on cultural practices and organic amendments) are not available in current databases/statistics. Estimates of the fraction of rice farmers using a particular practice or amendment must then be based on expert judgment, and the uncertainty range in the estimated fraction should also be based on expert judgment. A default value for the uncertainty in the fraction is estimated as ± 0.2 (e.g., the fraction of farmers using organic amendment is estimated at 0.4, the uncertainty range being 0.2 - 0.6). Volume 1, Chapter 3 provides advice on quantifying uncertainties in practice including combining expert judgments and empirical data into overall uncertainty estimates. In the case of CH4 emissions from rice cultivation, the uncertainty ranges of Tier 1 values (emission and scaling factors) can be adopted directly from Tables 5.11-5.14. Ranges are defined as the standard deviation about the mean, indicating the uncertainty associated with a given default value for this source category. The exponent in Equation 5.3 is provided with an uncertainty range of 0.54 - 0.64. good practice to apply general principles of statistical analysis as outlined in Volume 1, Chapter 3.

In the current inventory, uncertainty assessment and management practice are based on Tier 1 approach. Currently, the uncertainty assessment of activity data and emission factors is derived from expert judgment within the default IPCC uncertainty ranges provided in the emission factor database and 2006 guidelines. Specifically:

Table 10:IPCC Default Values of Uncertainty

Category	Gas	AD uncertainty*	EF and parameters uncertainty*
Enteric Fermentation	CH_4	Section 10.2.3, 10.3.4	Section 10.3.4
Manure Management	CH_4	Section 10.2.3; tbl 10A-5, 10A-7, and 10A-8 (footnote a)	Section 10.4.4; tbl 10A-5, 10A-7, and 10A-8 (footnotes b and c)
Manure Management (direct emissions)	N_2O	Section 10.2.3 (for animal population); Section 10.5.5 (for MMS usage)	Section 10.5.3 (tbl 10.21)
Manure Management (direct emissions) (volatilization of NH_3 and NOx)	N_2O	Section 10.5.5	Section 10.5.4 (tbl 10.22), 10.5.5 (tbl 10.23)
Rice cultivation**	CH_4	Section 5.5.4	Section 5.5.4
Synthetic fertilizers	N_2O	Section 11.2.1.4 for direct emissions, and Section 11.2.2.4 for indirect emissions.	Section 11.2.1.4 for direct emissions, and Section 11.2.2.4 for indirect emissions.

*-all sections for the livestock categories are from chapter 10, vol. 4 of the 2006 IPCC GLs [9]

**-for rice cultivation, the references are from chapter 5, vol. 4 or the 2006 IPCC GLs[10]

4.3. Quantifying Uncertainties

After identifying the causes of uncertainties associated with inventory estimates, the inventory compiler should collect the appropriate information to develop national, and category-specific estimates of uncertainty at the 95 percent confidence interval. Ideally, emission and removal estimates and uncertainty ranges would be derived from category-specific measured data. Since it may not be practical to measure every emission source or sink category in this way, other methods for quantifying uncertainty may be required. The pragmatic approach for producing quantitative uncertainty estimates is to use the best available estimates, which are often a combination of measured data, published information, model outputs, and expert judgment. Although uncertainties determined from measured data are often perceived to be more rigorous than uncertainty estimates based on models, and similarly,

[9] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf
[10] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf

model-based estimates are often perceived as more rigorous than those based on expert judgment, the actual hierarchy depends on the category and/or country-specific circumstances. (Volume 1: General Guidance and Reporting 3.14, 2006 IPCC Guidelines for National Greenhouse Gas Inventories).

For example, In the IPCC guidelines, direct N_2O emissions from manure handling are calculated by multiplying the amount of nitrogen in the manure on an annual basis by an emissions factor (in kg N_2O-N per kg nitrogen in the manure) that varies for different manure management systems. The IPCC guidelines provide default excretion rates for different animal species in different regions (Tier 1), but in most studies, the excretion rate is calculated using the feed intake and the retention rate. The nitrogen content in manure can be accurately determined by analyzing the manure for different nutrients. The uncertainty in the IPCC emissions factors for N_2O emissions is estimated to be a factor of 2 (IPCC, 2006). For indirect N_2O emissions, the amount of nitrogen volatilized as ammonia is multiplied by the same emissions factor used for calculating indirect N_2O emissions from soils (0.01 kg N2O-N per kg NH3-N volatilized). The uncertainty range is 0.002-0.05. Emissions of ammonia from manure, especially urine, on pasture can be substantial, especially in warm climates. Leakage of nitrogen into soils from manure storage directly on the ground also causes indirect N2O emissions. However, very few measurements of such leakage have been conducted, so calculations of these emissions using the default values in the IPCC guidelines are highly uncertain. The emission factor is the same as for N2O leakage from soils, 0.0075 kg N2O-N per kg nitrogen leaked, with an uncertainty interval of 0.005-0.025 (IPCC, 2006).

Uncertainties Associated with Activity Data

TABLE 3.2
APPROACH 1 UNCERTAINTY CALCULATION

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	Gas	Base year emissions or removals	Year *t* emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year *t*	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data Note A	Input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\lvert\frac{D}{\sum C}\right\rvert$	$I \bullet F$ Note C	$J \bullet E \bullet \sqrt{2}$ Note D	K^2+L^2
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
E.g., 1.A.1. Energy Industries Fuel 1	CO_2											
E.g., 1.A.1. Energy Industries Fuel 2	CO_2											
Etc...	...											
Total		$\sum C$	$\sum D$				$\sum H$					$\sum M$
					Percentage uncertainty in total inventory:		$\sqrt{\sum H}$				Trend uncertainty:	$\sqrt{\sum M}$

Enter Emission

4.3. Guiding Principles for the Assessment of Activity Data

1. Use expert information to validate activity data reported by the district assemblies through research.
2. Select data that have a clear source and can be referenced (dated and attributed to a source)
3. Select or use nationally approved sources when there are variations in the same data from international sources.
4. Use data from the (MoA) in the case where there is variation in the same data from multiple agencies unless the authenticity is not in doubt using any available documentary evidence.
5. Use official data, however, in the event, the data would have to expand to include "informal activities", use peer-reviewed data.
6. In cases where it is not possible to access disaggregated data from MoA and academic sources, for reasons of

confidentiality, use the aggregated data and default values.

Table 11: Personnel Responsible for Uncertainty Assessment Activities

Title	Uncertainty Assessment Responsibility	Name	Organization
Inventory Lead	All aspects of the inventory program	Ms. Zahra Nizbat	National Project Manager
Coordinator	Implementing the overall Tier 1 approach method of estimating uncertainties	Dr. Francis Mani Dr. Deeksha Krishna	National Expert Consultant
Category Lead(s)	Uncertainties in individual source categories Implementing category specific procedures (Tier 1)	Quality Assurance Officers-Agriculture and Head Rice team	EP&S and MoA-Rice team
Outside Expert(s)	Expert review of the inventory	Dr. Olia Glade Ms. Jeanette Mani	GHGMI WFP

5. GHG Emission Estimation for the Agriculture Sector

The processes involved in inventory estimation first involve the training of national inventory compilers by national experts who have the knowledge and experience of calculation GHG emissions from enteric fermentation, MMS and rice cultivation (Section 5.1) using the Tier 1 methodology. Upon receiving adequate training, the inventory compilers from MoA would be able to develop an inventory for the Ag sector, which is transparent, accurate, consistent, complete, and comparable. This section will also focus on the processes involved in the development of the inventory in the 2nd year of the inventory cycle, discussed under section 5.2.

5.1. Training of GHG Inventory Compilers

Given that the GHG inventory for Fiji's Agriculture sector will be compiled biennially, the first year of the inventory cycle will focus on providing adequate training to national inventory compilers, with primary focus on emission estimation from enteric fermentation, MMS, and rice cultivation.

To be able to compile the GHG inventory for the Ag sector, inventory compilers must receive adequate training and attend refresher programmes to ensure that they are aware of the best practices and apply the knowledge to accurately estimate emissions from enteric fermentation, MMS and rice cultivation. The various categories under GHG inventory estimations and the key personnel who can be contacted to provide this training are outlines in the following table.

Table 12: AG Sector Inventory Training Programme for Inventory Compilers

Training programme	Facilitators/ coordinators	Organisation	Contact
Use of IPCC Guidelines for GHG estimation from: • Enteric Fermentation (EF) • MMS • Rice Cultivation	Enteric Fermentation: Ms. Zahra Nizbat MMS: Dr. Francis Mani Rice Cultivation: Dr. Deeksha Krishna	USP USP Consultant	zahranizbat@gmail.com francis.mani@usp.ac.fj dikshakrishna@gmail.com
Use of Calculation Tools (IPCC Tool, ATMO, ALU, SAGE)	Experts (Dr. Olia Glade)	GHGMI	olia.glade@ghginstitute.org

Use of IPCC GHG Calculation Templates: • Template 3A1: Enteric Fermentation • Template 3A2: Manure Management • Template 3C3: Urea Fertilization • Template 3C4: Direct N_2O Emissions from Managed Soils • Template 3C5: Indirect N_2O Emissions from Managed Soils • Template 3C7: Rice Cultivation	Enteric Fermentation: Ms. Zahra Nizbat MMS: Dr. Francis Mani Rice Cultivation: Dr. Deeksha Krishna	USP USP Consultant	zahranizbat@gmail.com francis.mani@usp.ac.fj dikshakrishna@gmail.com
Use of Common Reporting Tools	Experts	GHGMI	TBC
Inventory Chapter Writing	Dr. Francis Mani Ms. Jeanette Mani	USP National Expert	francis.mani@usp.ac.fj jeanette93.jm@gmail.com
QA/QC Checks	Dr. Francis Mani	USP	francis.mani@usp.ac.fj
Uncertainty Estimation	Experts	GHGMI	TBC

The training provided by the relevant experts mentioned in Table 10 above have been trained to use the 2006 IPCC Guidelines to develop the GHG inventory for Fiji's Agriculture Sector. These experts are aware of the national circumstance and what are the best practices that could be used to accurately estimate the emissions. Thus, the inventory compilers will receive training which would allow them to be able to select emission factors or key parameters from the IPCC guidelines that best suit the current situation in Fiji, making the inventory more "Fiji-specific".

5.2. Emission Calculation

Upon receiving adequate training on inventory compilation, the following steps (plan) outlined in Figure can be followed to estimate GHG emissions from the Ag sector.

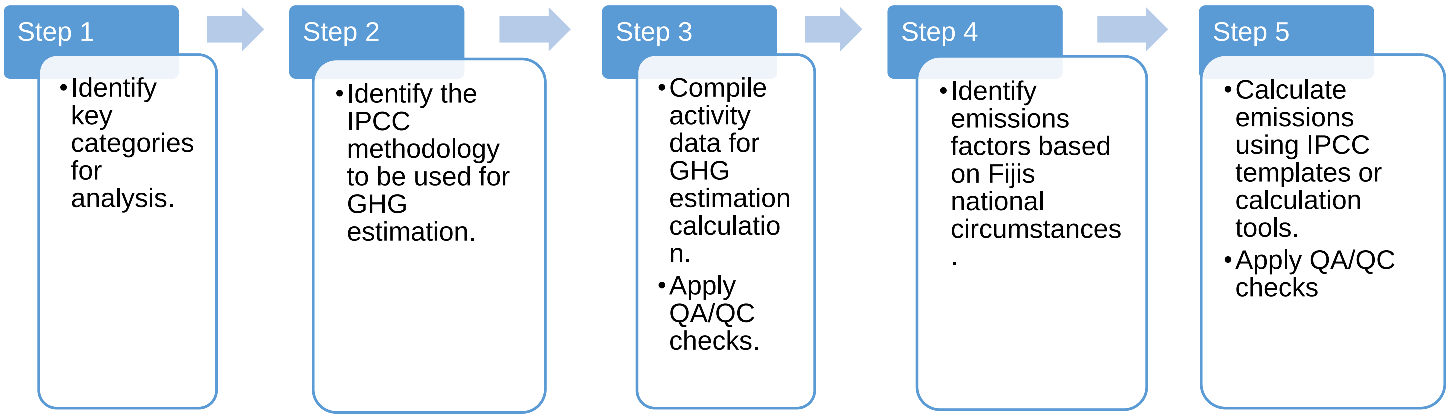

Figure 13: Steps for GHG emission estimation for the agriculture sector.

Moreover, the Guidance Document and User Manual to Estimate GHG Emissions from Livestock and Rice Cultivation have been compiled by national experts. The guidance document and user manual provide step-by-step instructions on how to calculate GHG emissions from livestock and rice cultivation. These steps consider national circumstances for Fiji and the good practices used to estimate emissions using the Tier 1 IPCC methodology,

Additionally, the following tables can also be used in conjunction with the guidelines to document the relevant data required to develop the GHG inventory.

A. Category Information

The table below provides information on the key categories (enteric fermentation, MMS and rice cultivation) that are considered for emission estimation from Fiji's Agriculture sector.

Table 13: Category Information

Sector	Agriculture
Category	Enteric Fermentation
Key Category? [Yes or No]	Yes
Category Description/Definition	Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream. The amount of methane that is released depends on the type of digestive tract, age, and weight of the animal, and the quality and quantity of the feed consumed. Ruminant livestock (e.g., cattle, sheep) are major sources of methane with moderate amounts produced from non-ruminant livestock (e.g., pigs, horses). The ruminant gut structure fosters extensive enteric fermentation of their diet.
Country Detail	Fiji
Sector	Agriculture
Category	Manure Management
Key Category? [Yes or No]	Yes
Category Description/Definition	This category focuses on methane and nitrous oxide emissions from manure management systems.

Country Detail	Fiji
Sector	Agriculture
Category	Rice Cultivation
Key Category? [Yes or No]	Yes
Category Description/Definition	This category focuses on methane and nitrous oxide emissions that arise due to rice cultivation. This also includes soil management practices (such as urea application) which would result in nitrous oxide emissions.
Country Detail	Fiji

B. Method Choice and Description

The table below provides information on the methodology chosen to estimate GHG emissions. It also provides information on the equations used to calculate emissions from each source category.

Table 14: Description of IPCC methodology applied to determine emissions from Enteric Fermentation

Equation (Describe variables for method used.)	Equation 10.19 and 10.20 from the 2006 IPCC GLs.
Reference	Chapter 10 of 2006 IPCC Guidelines and Annex 3
Describe How and Why this Method Was Chosen	Refer to Annex 3 for detailed description on the choice of methodology (Tier 1)and its application towards emission estimation.

Table 15: Description of IPCC methodology applied to determine emissions from MMS

Equation (Describe variables for method used.)	Equation 10.22, 10.25, 10.30 from the 2006 IPCC GLs.
Reference	Chapter 10 of 2006 IPCC Guidelines and Annex 3
Describe How and Why this Method Was Chosen	Refer to Annex 3 for detailed description on the choice of methodology (Tier 1) and its application towards emission estimation.

Table 16: Description of IPCC methodology applied to determine emissions from Rice Cultivation

Equation (Describe variables for method used.)	Equation 5.1, 5.2 and 5.11 from the 2006 IPCC GLs.
Reference	Chapter 5 of 2006 IPCC Guidelines and Annex 4
Describe How and Why this Method Was Chosen	Refer to Annex 4 for detailed description on the choice of methodology (Tier 1) and its application towards emission estimation.

Table 17: Description of IPCC methodology applied to determine emissions from managed soils under Rice Cultivation

Equation (Describe variables for method used.)	Equation 11.1, 11.6, 11.7, 11.7A and 11.13 from the 2006 IPCC GLs.
Reference	Chapter 11 of 2006 IPCC Guidelines and Annex 4
Describe How and Why this Method Was Chosen	Refer to Annex 4 for detailed description on the choice of methodology (Tier 1) and its application towards emission estimation.

The information provided in the tables above play a significant role in the inventory estimation process, especially when it comes to identifying the method and equations that need to be used for inventory estimation. Moreover, the process of inventory estimation, capturing Steps 1 – 5 (Figure 10) are illustrated in the flowchart below for enteric fermentation, MMS and Rice Cultivation.

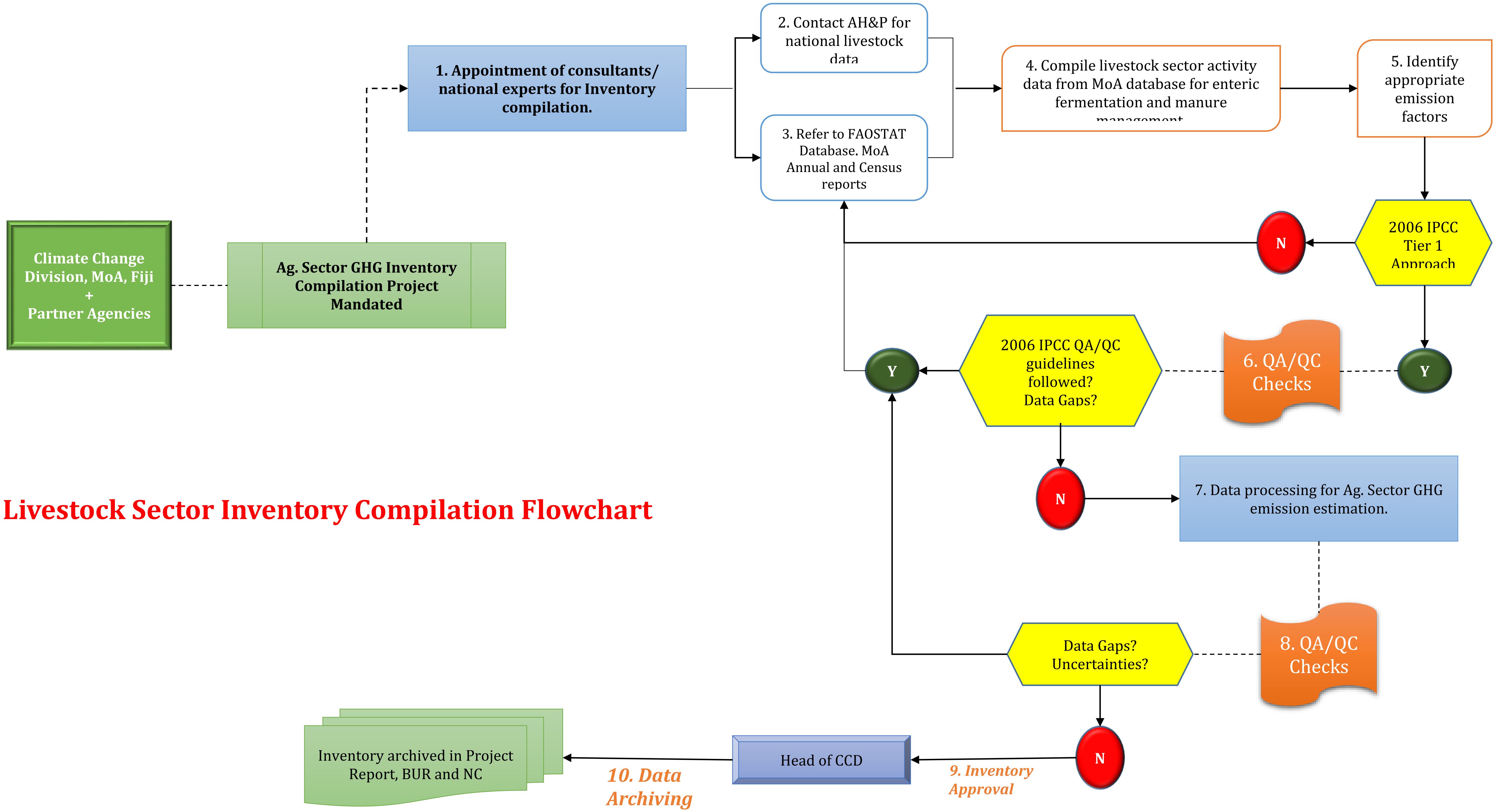

Figure 14: Inventory compilation process for enteric fermentation and MMS

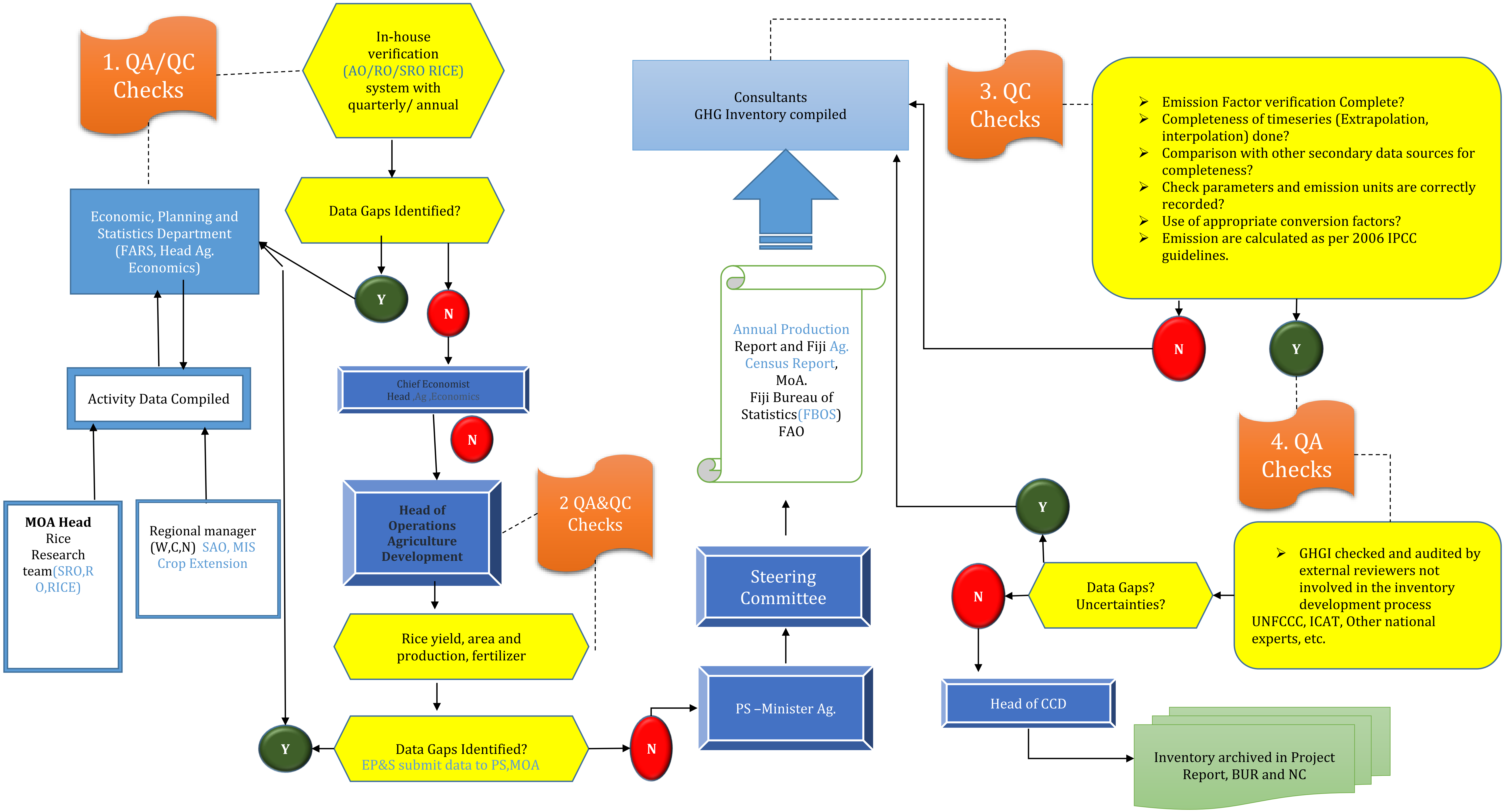

Figure 15: Inventory compilation process for Rice Cultivation

Once the inventory has been compiled, the inventory lead/coordinator is required to write an Inventory Chapter for the Agriculture sector that would be submitted to UNFCCC. The guidelines for writing the Inventory Chapter are outlined in Section 5.3.

5.3. Inventory Chapter Writing

This section provides guidance in writing the inventory chapter for emissions from the Agriculture sector. The chief purpose is to provide a general outline of the chapter that could be used consistently as a structure for all reporting of GHG inventory. The Inventory chapter should contain the following sections:

1.0 Sector Overview
2.0 Key Category Analysis
3.0 Inventory preparation: data collection, processing and storage
4.0 Methodologies and data sources used
5.0 Emission Estimates
    5.1 Enteric fermentation
    5.2 Manure Management
    5.3 Rice Cultivation
    5.4 Agricultural soils
    5.5 Liming
    5.6 Urea application
6.0 Uncertainty Analysis
7.0 Sectoral Emission trend analysis
8.0 QA/QC procedures followed
9.0 Recommendations for Improvements

6. Description of Inventory Archiving System for Fiji

The Archiving System is eminent to sustaining a National Inventory and is considered a critical component of the inventory development process. The information and data collated during the development of the inventory (references, methodological choice, expert comments, revisions, etc.), as well as documenting the location where these records are kept ensures that the national inventory is transparent, reproducible, contributes to effective planning, and leads to the effective use of limited resources for the subsequent inventory.

This section describes the existing archiving programme and procedures, an archiving system plan, and a checklist for archiving procedures. This protocol ensures that all information used to create the inventory is archived in a single location in both electronic and/or hard copy (paper) storage so that future inventory managers can reference all relevant files to respond to reviewer feedback including questions about methodologies. Archived information should include all emission factors and activity data at the most detailed level, and documentation of how these factors and data have been generated and aggregated for the preparation of the inventory. This information should also include internal documentation on QA/QC procedures, external and internal reviews, documentation of annual key categories and key category identification, and planned inventory improvements.

6.1. Assessing Existing Archiving Programme and Procedures

Documents and files available from the previous inventory include activity data and emission calculation excel sheets, annual reports and data collection forms and records, however, have been maintained sporadically. The Mitigation team at CCICD have access to this information which are stored electronically, and few reports and data collection forms which are also available as hard copy. This, however, is not organized in a systematic way nor based on a specific catalogue system. It is also likely that some information may be missing or is incomplete. The final copies are available however, the draft copies may not have been recorded or archived. Also, the contact names in list by category/sector are not available. It is also noted that emission factors used are not recorded or are not clearly indicated in the reports. The activity data are also not reported adequately with missing information on assumptions and units.

Current Inventory:
For the current inventory all data are stored electronically in excel sheets on a shared folder between the Mitigation team and the Consultants. This is on a cloud server which is being managed by the consultants. Documents are currently saved as four different folders, each folder is for each sector that is Energy, IPPU, AFOLU and Waste which contains the MS Excel files (which were the survey templates). These survey templates were filled in by secondment officers (staff from the line Ministries leading the BUR Technical Working Groups). These officers collated information from different stakeholders of their respective sectors in excel sheets. The excel sheets from the different stakeholders were then compiled by sector and maintained in an excel sheet for each sector. Each sector MS Excel sheets had data arranged by year in each tab. This data was then submitted to the consultants for analysis and is currently named as Data for Consultant folder which contains four folders named according to each of the four sectors.

The following templates are currently being managed by the Biennial Update Report Project Coordinator – Mr. Ravneeth Dewan, however, is being filled in by the consultants and the technical working group leads (seconded officers) for their respective sectors.

- Institutional Arrangements Template
- Methods and Data Documentation (MDD) Template
- QA/QC Measures Template
- Archiving System Template
- Key Category Analysis Template
- National Inventory Improvement Plan Template

6.2. Archive System Plan

The following sections describe the Archive System Plan that Fiji plans to follow to ensure a high-quality national inventory based on an assessment of existing practices as described in Section 6.1.

6.2.1. Archiving Coordinator (Climate Change Mitigation Specialist) Role & Responsibilities

The Climate Change Mitigation Specialist (CCMS) will perform the role of an Archiving Coordinator at the beginning of the inventory process. The CCMS is responsible for ensuring that all archiving procedures are performed for the inventory and all supporting documents and spreadsheets are retained appropriately. The CCMS is also responsible for clarifying who is responsible for carrying out archive procedures at various levels, as well as for ensuring that all team members know their archiving responsibilities, including which documents should be archived. These responsibilities require that the CCMS:

- Communicate archiving system plan, procedures, and responsibilities to other staff.
- Determine archiving tasks and assign tasks to staff, create a checklist of archiving procedures for team members to follow.
- Ensure that the archive procedures (see section 4.3.2 below) are carried out effectively.
- Serve as the keeper of the permanent archive and respond to future requests to view archive materials.

This task is the general responsibility of the CCMS and team in charge of compiling the Inventory Chapter for the National Communications for Fiji. She/he is with the Climate Change and International Cooperation Division of the Ministry of Economy.

6.2.2. Archiving Procedures

It is essential to outline each aspect of the archiving process so that these procedures can be effectively implemented. The archive plan developed by the CCMS for Fiji that considers the following:

Management of Files.

- Save files with IPCC category name and inventory year and track the file version by including the date the file was last saved. For example, use a category-year naming convention such as "N2O soils 2000.23_0523_05_2001.xls" or "KEY-CO2 stat combus-2000.23_0505_2001.xls."
- Clearly establish and communicate the file management procedures and naming conventions for version control.

Data Retention. Spreadsheets and other electronic files used to create inventory estimates should be provided to the BUR/BTR/NATCOM Project Coordinator.
The following are essential components of the archive:

- Data and calculation spreadsheets and other electronic files for every category used to create inventory estimates.
- QA/QC plan with completed checklists.
- Key category analysis spreadsheets.
- Internal and external review comments and responses.
- Latest draft and final electronic versions of the inventory document (for use as a starting point to update the inventory in the future).
- Updated MDD templates, which should be used to list and check references (references provided in STEP 2 through STEP 4 in the MDD template).

The files listed above are most easily archived by saving to the Ministry of Economy server and backed up on a flash drive and should be given to the BUR/BTR/NATCOM Coordinator. If it is not possible to store the data archive in electronic format, files should be printed, catalogued, and placed in the inventory archive. The contents of the flash drive should be clearly labeled for easy reference.

- The archived items should be catalogued by sector. For example, the data related to the first new source in the energy sector would be labeled "E-1-dat," the second source "E-2-dat," etc. The sources for waste would be "W-1-dat," "W-2-dat," etc. Dates should also be included in the labels for proper version control.

Document Retention. Source documents and references used to create the inventory will be collected and provided to the BUR/BTR/NATCOM Project Coordinator. Vital information from publications, contacts, and other sources must be included in the documents provided to the BUR/BTR/NATCOM Project Coordinator. This information includes, at a minimum, the title page with the name of the author(s), pages of actual data used, pages explaining data used, and pages describing methodologies used.
These documents should include:

- All new reference documents for the current year's inventory records file. The files retained in storage from any given inventory year are known as the inventory archive. The CCMS is responsible for reviewing the references cited in the inventory and collecting all new documents with the of the Mitigation Officer 2 (MO2) and the BUR/BTR/NATCOM Project Coordinator. It is not necessary to include duplicate copies of references that are already in the records file from the previous inventory cycle.
- Draft versions (either electronic or hard copy) used for major internal and external peer reviews, as well as the final submitted versions of the inventory.
- Final version of the National Systems Report (compilation of completed templates including Institutional Arrangements, QA/QC Plan, Description of Archiving System, Key Category Analysis Report, and National Inventory Improvement Plan).
- Documents created to address comments received during any official review periods (or from expert reviews). These documents typically include both, comments received verbatim, as well as the response and subsequent actions taken by the inventory staff.

Storage Mechanisms. Archived inventory files are stored under the climate change mitigation folder on the server and identified by the BUR/BTR or NATCOM project sub-folder under the mitigation folder on the Ministry of Economy server. The hardcopies are filed by the inventory year under the Climate Change Mitigation catalogue system in CCICD.

- The master copies of the archive files are stored in CCICD under the Mitigation section (hard copies) and electronic files in the Ministry of Economy server under the CCICD folder, sub folder Climate Change Mitigation by Nimish Nikita (MO2) and Ravneeth Dewan (BTR/BUR/ NATCOM Project Coordinator in charge of master files).
- Duplicate copies of the archive files are stored in flash drives by Nimish Nikita in charge of copied files.

All archive materials should be duplicated (two copies of each document), catalogued and placed in the archive file. An index describing the contents of the archive should be placed at the front. The CCMS will choose a centralized and secure location for the placement of the hard copy and electronic archive.

6.2.3. Overall Archive Procedures Checklist

To ensure a successful archiving system, the BUR/BTR or NATCOM Coordinator should use a comprehensive checklist. Checklists help to ensure that all archiving procedures occur in a timely and complete manner.

The final archiving task list and schedule will show all archiving tasks, corresponding task leaders, and due dates. The CCMS will ensure that all tasks are outlined prior to the start of any archive procedure. The CCMS is also responsible for assigning task leaders to accomplish each archive task prior to the due date. Staffing for each task and date due will be completed by the CCMS at the beginning of the inventory process. The following table provides the comprehensive checklist to be used by the CCMS for Fiji.

Table 18: Archiving Tasks, Responsibilities and Schedule for Fiji

Subtask	Date Due	Task Completed	
		Initials	Date
Archiving Coordinator			
Create official archive located in Ministry of Economy sever and the password protected folder on the shared folder. Also create a folder for hard copies for the inventory year under the CCICD filing system.		BUR/BTR/NATCOM PC	
Communicate archiving plan and set deadlines.		CCMS	
Collect copies of all data references.		BUR/BTR/NATCOM PC	
Request missing references from category leads.		BUR/BTR/NATCOM PC	
Compile electronic versions of spreadsheets used to estimate net emissions by sector.		MO2	
Collect copies of draft versions of inventory document.		MO2	
Collect copies of final versions of inventory document.		MO2	
Compile electronic versions of final versions of inventory document and scan any hardcopy documents		MO2	
Collect copies of expert review comment response documents from each category lead.		MO2	
Collect copies of public review comment response documents from each category lead.		MO2	
Catalogue all documents using a unique tracking number and index.		MO2	
Collect completed Institutional Arrangements and Methods and Data Documentation templates.		BUR/BTR/NATCOM PC	
Compile electronic versions of Key Category analyses. (Some files will be duplicated from the previous subtask.)		BUR/BTR/NATCOM PC	
Compile electronic versions of QA/QC checklists.		BUR/BTR/NATCOM PC	
Save all electronic files on archive Flash drives and on the server.		BUR/BTR/NATCOM PC	
Ensure all hard copy materials are present in official archive by reviewing contents against index.		CCMS	

Subtask	Date Due	Task Completed	
		Initials	Date
Ensure all necessary electronic files are contained on the server, CD-ROM or flash drive and ensure that it is placed with other official archive materials.		CCMS	
Distribute electronic files at start of next inventory update.		MO2	
Category Lead			
Send electronic versions of spreadsheets used to estimate net emissions to Inventory Coordinator (using naming convention).			
Send final text documents for sector or category to CCMS.			
Send Methods and Data Documentation reports for category.			
Create index of draft documents and files for electronic and hard copy storage.			
Create index of final documents and files for electronic and hard copy storage.			
Compile and send electronic versions of any Key Category analyses and documents to CCMS (add "key" to naming convention).			
Send summary or list of QA/QC steps and corrective actions (by category) to CCMS.			
Save all final electronic files on archive CD-ROM/ Flash drive. Label as "FINAL" with name of category/sector, date, and contact information, and send copy to CCMS.			

7. National Inventory System (NIS) Improvement Plan

The NIS Improvement Plan aims to provide recommendations that would help improve the current inventory system for Fiji. It will guide future efforts to increase the transparency, consistency, comparability, completeness, and accuracy of future inventories. The plan addresses many of the shortcomings of the previous inventory and will inform future inventory teams of needed improvements. These improvements have been identified through documentation of existing institutional arrangements, QA/QC procedures and developing archiving systems in Fiji.

Table 19: Potential priority areas for the improvement of the NIS

Strengths in Management Structure of National Inventory System	Potential Improvements in Management Structure of National Inventory System
• Climate Change Act is endorsed. • Extensions officers are established and have a good connection with primary sources of raw data (farmers). • MoA is willing to establish a new team for climate change reporting. • The data collection system and templates exist, however, need updating. • The CBIT Project incorporated financing for development of information system support for NDC tracking (currently for energy, will be extended for the Agriculture and other sectors), and	• Request and receive financial support for NC4 and BTR • Establish the Climate change team at MoA (with the focal point for each of Livestock and Rice Cultivation) dedicated to the GHGI. • The roles and responsibilities for MoA, MoE are clearly established and agreed upon with the relevant formal provisions • The roles and responsibilities of the extension offices will be clearly defined in accordance with the MoUs (including the timeframes and frequency) established above. • Development of data collection templates for farmers and extension officers. • Provide training to farmers and extension officers on

inventory. • The activity data collection systems (e.g., SAGE) is being developed and will be available for preliminary data processing for BTR. • Emission calculations systems exist and are available FOC or for a small annual fee and are available for use. (ALU, IPCC Software, Atmo,) • Data collection templates for the Agriculture sector exist and are made available through the ICAT project. • Fiji experts received training of the Agriculture sector methodologies (theoretical and practical for Tier 1) through the ICAT project. • The instruction manuals for the Agriculture sector emission estimations using Tier 1 from 2006 IPCC GLs have been developed by Fiji Experts through the ICAT project. • The NS GLs are being developed by Fiji Experts. • The institutional arrangements, QA/QC systems and data flows have been discussed with MoA and MoE representatives (19th – 20th April, 2022) – feedback was received and implemented through the ICAT project. • Climate Change Division at MoE is established. • ACAIR project will be supporting development of emission factors for T2 emission estimations for livestock	the use of these templates. • Secure relevant funding to create data documentation templates and archiving system. • The data governance and data transfer agreements need to be established and signed. • The surveys for data collection for both Livestock and Rice cultivation are designed and piloted, and the relevant funding is secured for implementation (e.g., through ICAT phase 2) • The QA/QC plan is produced and QA, QC & Verification responsibilities are assigned, and the relevant personnel has received the training and template support • The approval mechanism to ensure timely GHGI approvals need to be established and put in place. • Uncertainty training is needed to develop and use country-specific uncertainty values, and relevant templates are required. • The templates for data collection need to be updated to minimize the efforts for data collection. • The information support system needs to be designed and developed; the interfaces between the main repository system, data collection tool and emission calculation tools need to be developed (e.g., through ICAT phase 2 and ACAIR projects). • The personal need to be trained on how to use data collection tool (e.g., SAGE) and emission calculation systems (e.g., IPCC tool, ALU, or Atmo) • Development of country specific EF's and potential shift to Tier 2 is considered where applicable, and relevant training provided (e.g., ACAIR project). • The proposals for financial support to support research for higher Tiers for the Agriculture sector reporting should be produced and submitted to the relevant funding organizations. • Training for the mandatory elements of GHGI reporting is needed (for example, chapter writing, CRT software use) • The mandatory data reporting systems for UNFCCC and Enhanced Transparency Framework under the Paris Agreement (NC, BUR, BTR) need to be introduced and national experts need to be trained. • Include archiving procedures and responsibilities in the job descriptions of the CCMS, BUR/BTR/NATCOM Project Coordinator. • Review all available information and data for previous inventory by applying the plan and procedures for the archiving system.

Annex 1

Initiative for Climate Action Transparency – ICAT
Deliverable title: *GHG MRV Set-up Training – Workshop Report*

Deliverable: 3

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Date: 10 May 2022

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Initiative for Climate Action Transparency (ICAT) project supported by the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, the Children´s Investment Fund Foundation (CIFF), the Italian Ministry for Ecological Transition, and ClimateWorks

The ICAT project is hosted by the United Nations Office for Project Services (UNOPS)

Table of content

1. Introduction

The **Agriculture Institutional MRV System Development Workshop** was organized to provide training and support to relevant personnel from the Ministry of Agriculture and National Experts in agriculture under the Initiative for Climate Action and Transparency (ICAT) Project. The workshop was organized by the Climate Change and International Cooperation Division (CCICD) from the Ministry of Economy in collaboration with the Greenhouse Gas Management Institute (GHGMI). The workshop was conducted in hybrid mode where the face-to-face sessions were conducted at The Pearl Resort, Pacific Harbour, Fiji. Participants from GHGMI and Ministry of Agriculture – Northern Division joined the workshop virtually through Zoom. The two-day workshop was held on the 19th and 20th of April 2022.

The pre-workshop preparatory activity involved the national experts consulting with the personnel from Ministry of Agriculture (MoA) to prepare process flow charts on activity data collection, QA/QC processes and institutional arrangements for livestock and rice cultivation as part of developing the MRV system for Fijis Agriculture sector. These processes were presented by the National Experts and validated by the participants form MoA during the workshop. Additionally, the workshop was facilitated by Dr. Olia Glade (GHGMI), Ms. Zahra Nizbat (ICAT Fiji Project Coordinator and National Expert), Dr. Francis Mani (National Expert) and Dr. Deeksha Krishna (National Expert).

Furthermore, the welcome address and introduction to the workshop was delivered by Ms. Katie Goldman (GHGMI) and Mr. Izhar Ali (CCICD) followed by and overview of the ICAT Fiji Project, delivered by Dr. Olia Glade. Additionally, to understand the importance of developing the MRV system for Fijis Agriculture Sector and the significance of MoA's role in it, Ms. Jeanette Mani (ICAT Consultant) presented on the operationalization of the Climate Change Act in relation to the Agriculture Sector. This was followed by a presentation on the ICAT Fiji Project Progress to Date by Ms. Zahra Nizbat. This concluded the workshop introductory session. The agenda for this workshop can be found in Annex 1. Details on the remaining workshop presentations are provided under Section 2.

A total of 38 participants attended the workshop, of which 26 were from the Ministry of Agriculture, 1 National Expert from Fiji National University, 2 National Experts from The University of the South Pacific, 3 from GHGMI, 3 from CCICD and 2 from GGGI. A detailed participant list is provided in Annex 2. Upon further analysis of the participants list, there was a 50-50 representation of males and females during the workshop. This is also illustrated in the figure below.

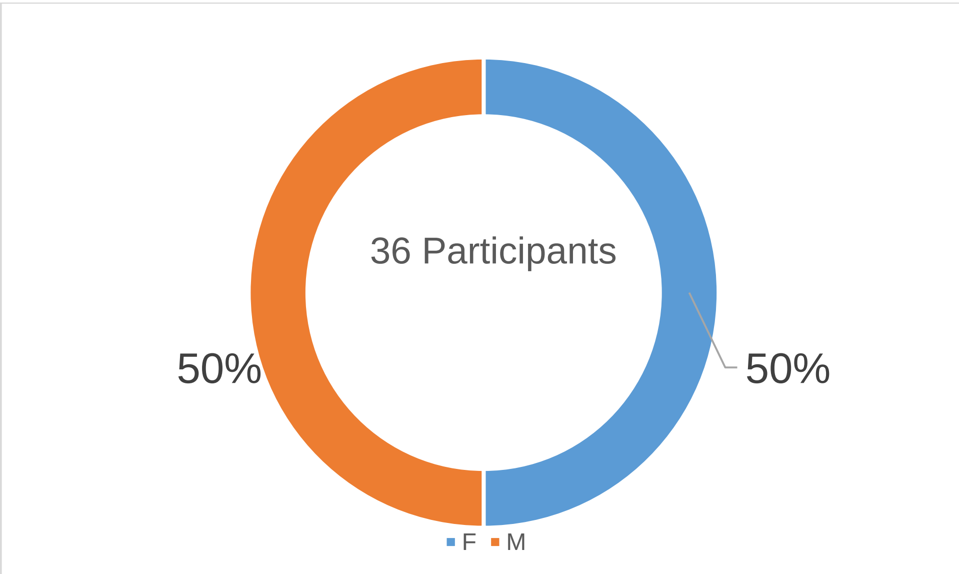


Figure1: Total participants, disaggregated by gender

2. Workshop Presentations

The workshop was divided into three core sessions, spread over the two days, and facilitated through presentations and group discussions. The presentations made during the workshop provided the participants with an overview of the data collection flows for preparing Agriculture sector GHG inventory for Fiji, establishment of QA/QC Systems for Fiji's Agriculture Sector and setting up the institutional arrangements for Fiji's Agriculture Sector. Each presentation was followed by recommendations for improvement of the systems to develop a robust MRV system for estimating the GHG inventory for Fijis Agriculture sector.

2.1. Day 1 Presentations

Day 1 – Session 1 of the workshop began with an introductory presentation on data collection flows for inventory estimations delivered by Dr. Olia Glade. This provided the participants with a general understanding of the needs and significance of data collection flows and processes for inventory estimations. The data collection flows for inventory estimations for Fiji was divided into 2 categories, which were ***Livestock*** and ***Rice Cultivation***. The first data collection flow presentation was delivered by Dr. Francis Mani for Livestock. The presentation provided a brief background on Fijis animal data collection for inventory estimation, activity data collection processes for the livestock sector and data compilation processes for inventory estimations. The activity data collection flowchart as well as the inventory compilation flowchart were also presented. This was followed by a presentation my Ms. Zahra Nizbat on the possible recommendations that could help to improve the data collection and inventory compilation processes for Fijis Agriculture sector. A similar format was also followed for the data collection flows for rice cultivation which was presented by Dr. Deeksha Krishna. Session 1 concluded with a group discussion where personnel from MoA analysed the data collection flowcharts for livestock and rice cultivation and provided feedback on how it could be improved or to fill in any gaps (processes that may have been missed out on).

Furthermore, Session 2 of the workshop began with an introductory presentation by Dr. Olia Glade on the establishment of QA/QC systems for inventory estimation. This was followed by a presentation by Ms. Zahra Nizbat and Dr. Deeksha Krishna on the current QA/QC processes in place for activity data collection and inventory compilation for livestock and rice cultivation, concluding with recommendations on how the QA/QC system could be improved for the agriculture sector. Session 2 concluded with a group discussion where personnel from MoA analysed the QA/QC system flowcharts for livestock and rice cultivation and provided feedback on how it could be improved or to fill in any gaps (processes that may have been missed out on).

This concluded the presentations and activities for Day 1 of the workshop.

2.2. Day 2 Presentations

Day 2 of the workshop began with Session 3 with an introductory presentation by Dr. Olia Glade on setting up the institutional arrangements for GHG inventory estimations. This was followed by a presentation by Dr. Francis Mani on the current and proposed institutional arrangements for the agriculture sector to carryout inventory compilation for livestock. The presentation concluded with recommendations for improvement of the institutional arrangements for livestock. Similarly, Dr. Deeksha has presented in the institutional arrangements for inventory compilation for rice cultivation and concluded the presentation with recommendations for improvement. Session 3 concluded with a group discussion where personnel from MoA analysed the proposed institutional arrangement flowcharts for livestock and rice cultivation and provided feedback on how it could be improved or to fill in any gaps (processes that may have been missed out on).

The next segment of the workshop was focused in developing a blueprint for the National Inventory Systems (NIS) Guidelines. The national experts also presented and validated revised flowcharts for livestock and rice cultivation after incorporating the feedback and suggestions provided by the participants from various departments within the MoA. After the validation of the flowcharts, Dr. Olia Glade presented on the draft blueprint of the NIS for institutional arrangements followed by concluding remarks and closure of the workshop.

3. Key Outcomes of the Workshop

The following are key outcomes arising from the GHG MRV Set-Up workshop:

1. MoA participants have a clearer understanding of how the data they collect fit into the bigger picture of inventory estimation.
2. The recommendations on the improvement of the data collection flow were received through participants feedback and discussion during the workshop. These recommendations were incorporated into the flowcharts for data collection.
3. The QA/QC processes for data collection and inventory compilation were explained to the participants. Their recommendations on improvement of the QA/QC processes have been incorporated into the QA/QC flow chart and have been endorsed by the participants from MoA.
4. There is now a strong sense of data ownership from the participants as they have a better understating of the importance of activity data in inventory estimation.
5. For institutional arrangements, the current and proposed systems were presented to the participants. Proposed institutional arrangement has been verified and endorsed by the participants from MoA.
6. Participants proposed the development of a steering committee embedded within the institutional arrangements to oversee the inventory compilation processes.

4. Conclusion

The two-day work ended on a positive note. Dr. Olia Glade thanked all the presenters for the excellent delivery of the workshop as well as the participants for their enthusiasm and active participation.

Annex 1

AGENDA

ICAT Agriculture Institutional MRV System Development Workshop
April 19 & 20, 2022

DAY 1

Tuesday, 19 April, 2022

Participants: Internal Climate Change Working Group, ICAT National Consultants, ICAT Technical Support Team from the Greenhouse Gas Management Institute Location: The Pearl Resort, Pacific Harbour.

Join Zoom Meeting https://us02web.zoom.us/j/86461137253?pwd=RWVmL0QyVCtDajBqRUpmLzJYd0ZOQT09

Meeting ID: 864 6113 7253
Passcode: 451019

TIME (FIJI)	TOPIC	PRESENTER
Agriculture GHG Emissions and Policies Discussion		
8.30 AM	Registration	Participants to Sign-in
9:00 AM	Welcome and Introductions	Mr. Izhaar Ali, MOE
9:15AM	ICAT Project – Workshop Overview	Dr. Olia Glade, GHGMI
9.25 AM	Operationalization of the Climate Change Act in Relation to the AG Sector	Jeanette Mani, GHGMI
9:45 AM	ICAT Fiji Project Progress to Date	Zahra Nizbat, Consultant
Session 1: Data Collection Flows for Preparing Ag Sector GHG Inventory for Fiji		
10.00 AM	Introduction to Data Collection Flows for Inventory Estimations	Dr. Olia Glade, GHGMI
10.20 AM	Data Collection Flows for Fiji – Livestock Sector	Dr. Francis Mani/Zahra Nizbat, National Consultants
10:40 AM	Recommendations for Improvement of Livestock Sector Data Flows	Dr. Francis Mani/Zahra Nizbat, National Consultants
Morning Tea Break @ 11:00AM		

11:20 AM	Group Discussions for Livestock Sector ▪ Please designate one person who will be typing the suggested changes from the sticky notes and submit the list to nikitanamisha@gmail.com and zahranizbat@gmail.com once the discussion is complete. ▪ Ice - breaker: Put yourself on the map: can you see yourself/your organization at any step identified in the chart. If yes, put a green sticky note with your organization and name there. If not, do we need to add the relevant step to the chart? (5 min. max) ▪ In your opinion, is something (e.g., data source, data processing step, important data approval steps/stages) missing in the chart? It's OK if nothing is amiss, but please let us know if it is. Please write your suggestions on the pink sticky note and pin them to the relevant points of the chart. (5 min) ▪ In your opinion, who should be taking responsibility for each step on the chart (including those you have added)? Please use the yellow sticky notes to add responsibilities. (5 min). ▪ Do you believe that a well-structured template for data collection can be a good resource in recording and submitting your data to help you understand what exactly is asked of you, in what form and by when? Would you appreciate some training on how to use the template? Please write the answer on the data flow chart provided to your group. (5 min) ▪ Do you have any additional feedback? (5 min)	All Participants Ravneeth (Moderator), CCD
11:50 PM	Data Collection Flows for Fiji – Rice Cultivation	Dr. Deeksha Krishna, National Consultant
12.15 PM	Recommendations for Improvement of Data Collection Flows for Rice Cultivation	Dr. Deeksha Krishna, National Consultant

12.30 PM	Group Discussions for Rice Cultivation Please designate one person who will be typing the suggested changes from the sticky notes and submit the list to nikitanamisha@gmail.com and zahranizbat@gmail.com once the discussion is complete. Ice - breaker: Put yourself on the map: can you see yourself/your organization at any step identified in the chart. If yes, put a green sticky note with your organization and name there. If not, do we need to add the relevant step to the chart? (5 min. max) In your opinion, is something (e.g., data source, data processing step, important data approval steps/stages) missing in the chart? It's OK if nothing is amiss, but please let us know if it is. Please write your suggestions on the pink sticky note and pin them to the relevant points of the chart. (5 min) In your opinion, who should be taking responsibility for each step on the chart (including those you have added)? Please use the yellow sticky note to add responsibilities. (5 min). Do you believe that a well-structured template for data collection can be a good resource in recording and submitting your data to help you understand what exactly is asked of you, in what form and by when? Would you appreciate some training on how to use the template? Please write the answer on the data flow chart provided to your group. (5 min) Do you have any additional feedback? (5 min)	All Participants Ravneeth (Moderator), CCD
Lunch Break @ 1:00 PM		
Session 2: Establishment of QA/QC Systems for Fiji's Ag Sector		
2.00 PM	Introduction to Establishing QA/QC Systems for the Ag Sector	Dr. Olia Glade, GHGMI
2.05 PM	QA/QC Systems for Fiji's Livestock and Rice Cultivation Sector	Zahra Nizbat & Dr. Deeksha Krishna, National Consultants
2.30 PM	Recommendations for Improvement of QA/QC Systems for Livestock and Rice Cultivation.	Zahra Nizbat, National Consultants

2.40 PM	Group Discussions on QA/QC Systems for Livestock and Rice Cultivation. ▪ Please designate one person who will be typing the suggested changes from the sticky notes and submit the list to nikitanamisha@gmail.com and zahranizbat@gmail.com once the discussion is complete. ▪ Ice - breaker: Put yourself on the map: can you see yourself/your organization at any step identified in the chart. If yes, put a green sticky note with your organization and name there. If not, do we need to add the relevant step to the chart? (5 min. max) ▪ In your opinion, is something (e.g., a check procedure, responsibility, or an approval step) missing in the chart? It's OK if nothing is amiss, but please let us know if it is. Please write your suggestions on the pink sticky note and pin them to the relevant points of the chart. (5 min) ▪ In your opinion, who should be taking responsibility for each step on the chart (including those you have added)? Please use the yellow sticky notes to add responsibilities. (5 min). ▪ Do you believe that a well-structured template for quality control and quality assurance can be a good resource in recording and submitting the checks and assessment results? Would you appreciate some training on how to use the template? Please write the answer on the data flow chart provided to your group. (5 min). ▪ Do you have any additional feedback? (5 min)	All Participants Ravneeth (Moderator), CCD
3.10 PM	Day 1 Wrap-up	Dr. Olia Glade, GHGMI
Afternoon Tea Break @ 3:20 PM		

DAY 2

Wednesday, 20 April, 2022

TIME (FIJI)	TOPIC	PRESENTER
Agriculture GHG Emissions and Policies Discussion		
8.30 AM	Registration and Housekeeping	Participants to Sign-in
9:00 AM	Recap of Day 1	Dr. Olia Glade, GHGMI
Session 3: Setting Up the Institutional Arrangements for Fiji's Ag Sector		

9:05 AM	Introduction to Setting Up the Institutional Arrangements for the Ag Sector	Dr. Olia Glade, GHGMI
9:35 AM	Institutional Arrangements for the Livestock Sector Recommendations for Improvement	Dr. Francis Mani, National Consultant
10.10 AM	Group Discussion on Institutional Arrangements for the Livestock Sector ▪ Please designate one person who will be typing the suggested changes from the sticky notes and submit the list to nikitanamisha@gmail.com and zahranizbat@gmail.com once the discussion is complete. ▪ Ice - breaker: Put yourself on the map: can you see your organization at any of the stages identified in the chart. If yes, put a green sticky note with your organization and name there. If not, do we need to add the relevant step to the chart? (5 min. max) ▪ In your opinion, is something (e.g., processes, roles, and responsibilities of source/sector) missing in the chart? It's OK if nothing is amiss, but please let us know if it is. Please write your suggestions on the pink sticky note and pin them to the relevant points of the chart. (5 min) ▪ In your opinion, who should be taking responsibility for each step on the chart (including those you have added)? Please use the yellow sticky notes to add responsibilities. (5 min). ▪ Do you have any additional feedback? (5 min)	All Participants Moderator, CCD
Morning Tea Break @ 10.40AM		
11.00 AM	Institutional Arrangements for the Rice Cultivation Sector	Dr. Deeksha Krishna, National Consultant
11.20 AM	Recommendations for the Improvement of Institutional Arrangements for the Rice Cultivation Sector	Dr. Deeksha Krishna, National Consultant

11:40 AM	Group Discussion on Institutional Arrangements for the Rice cultivation Please designate one person who will be typing the suggested changes from the sticky notes and submit the list to nikitanamisha@gmail.com and zahranizbat@gmail.com once the discussion is complete. ▪ Ice - breaker: Put yourself on the map: can you see your organization at any of the stages identified in the chart. If yes, put a green sticky note with your organization and name there. If not, do we need to add the relevant step to the chart? (5 min. max) ▪ In your opinion, is something (e.g., processes, roles, and responsibilities of source/sector) missing in the chart? It's OK if nothing is amiss, but please let us know if it is. Please write your suggestions on the pink sticky note and pin them to the relevant points of the chart. (5 min) ▪ In your opinion, who should be taking responsibility for each step on the chart (including those you have added)? Please use the yellow sticky notes to add responsibilities. (5 min). ▪ Do you have any additional feedback? (5 min)	Dr. Deeksha Krishna, National Consultant
12.00 PM	Session 3 Wrap-up	Dr. Olia Glade, GHGMI
12.10 PM	Breakout Session – Develop a Blueprint for the National Systems	National Consultants to Lead the Discussions
Lunch Break @ 1:00 PM		
2.00 PM	National Experts compile results from breakout session	Dr Francis Mani, Zahra Nizbat, Dr. Deeksha Krishna, National Experts
2.30 PM	Outcome1: Draft Blueprint for the Flowcharts and Recommendations for the Livestock Sector	Dr. Francis Mani, National Consultant
2.45 PM	Outcome 2: Draft Blueprint for the Flowcharts and Recommendations for Rice Cultivation	Dr. Deeksha Krishna, National Consultant
3.00 PM	Concluding Remarks and Closing of the Workshop	Dr. Olia Glade, GHGMI
Afternoon Tea Break @ 3.30 PM		

Annex 2

ICAT Agriculture Institutional MRV System Development Workshop

Participants List for 19th and 20th April 2022

No.	Name	Gender	Organisation	Designation	Email
1	Elenoa Sauvadua	F	MoA	Field Assistant [AH&P Desk Officer -Fiji Agriculture & Rural Statistics Section	e.sauvadua@agriculture.gov.fj
2	Ms. Titilia W. Davetanivalu	F	MoA	Economic and Statistics – Policy Team	titilia.davetanivalu@govnet.gov.fj
3	Helen Mua	F	MoA	Senior Agriculture Officer - Project & Budget	helen.mua@govnet.gov.fj
4	Mr Jese Gade	M	MoA	Economic Planning Officer	jese.gade@govnet.gov.fj
5	Noa Qaqa	M	MoA	Agriculture Officer- Dairy	knoagaga@yahoo.com
6	Marie Kaitu	F	MoA	Agriculture Officer- Sheep	mariefiromena@yahoo.com
7	Mr Avinesh Dayal	M	MoA	Principal Agriculture Officer	avinesh.dayal@govnet.gov.fj
8	Joanna Veisamasama	F	MoA	Agriculture Assistant (MIS)	joana.veisamasama@govnet.gov.fj
9	Inoke Cakautini	M	MoA	Agriculture Assistant Pig	jucakautini@gmail.com
10	Paulina Rawaqa	F	MoA	Agriculture Officer- Beef	prawaqa@yahoo.com
11	Dr Tekini Nakitakida	M	MoA	Principal Research Officer- Land Use	lostbreedtekini@gmail.com
12	Mereoni Covaduadua	F	MoA	Agriculture Technical Officer- Dairy	mereonituilevukana@yahoo.com
13	Dr Mereia Fong	F	MoA	Principal Research Officer – Plant Protection	mereia.fong@govnet.gov.fj
14	Sanjeev K Mani	M	MoA	Senior Research Officer- Operations	sanjeev.mani@govnet.gov.fj
15	Penaia Mua	M	MoA	Senior Research Officer – Agronomy	pvosawai@yahoo.com
16	Irene Chand	F	MoA	Technical Officer Research – Rice	irenerozika@yahoo.com
17	Nileshni Devi	F	MoA	Senior Technical Assistant – Rice	devinileshni12@yahoo.com
18	Inosi Sugucolo Vulawalu	M	MoA	Senior Agriculture Officer - Serua/Namosi	Inosi.vulawalu@govnet.gov.fj; Inosivula8@gmail.com
19	Ronil Prasad	M	MoA	Senior Research Officer- Livestock	ronrox_4u@yahoo.com
20	Morien Prasad	F	MoA	Agricultural Technical Officer- Tavua	prasad.morien@yahoo.com
21	Naveen Chand	M	MoA	Agricultural Officer-Ba	nvcsc5@gmail.com
22	Davendra Nath	M	MoA	Agricultural Technical Officer - Rice Northern Division	Davendra_nath_2005@yahoo.com
23	Krishneel Chand	M	MoA	Research Officer- Rice Dreketi	Krishneel1993@gmail.com
24	Arvind Chetty	M	MoA	Agricultural Technical Officer Savusavu	chettyarvind@ymail.com
25	Fouziya Nisha	F	MoA	Agricultural Assistant Bua	fouziyanisha7@gmail.com
26	Binesh Prasad	M	MoA	Senior Agriculture Officer	binesh.prasad@govnet.gov.fj

27	Dr Francis Mani	M	Consultant	National Expert	francis.mani@usp.ac.fj
28	Zahra Nizbat	F	Consultant	Project Coordinator ICAT	zahranizbat@gmail.com
29	Dr. Deeksha Krishna	F	Consultant	National Expert	dikshakrishna@gmail.com
30	Dr Olia Glade	F	GHGMI	Director for MRV Systems GHGMI	olia.glade@ghginstitute.org
31	Jeanette Mani	F	Consultant	National Expert	jeanette93.jm@gmail.com
32	Ravneeth Dewan	M	CCICD	National Coordinator	ravneeth.dewan@economy.gov.fj
33	Namisha Nikita	F	CCICD	Mitigation Officer II	namisha.nikita@economy.gov.fj
34	Josefa Takalaivuna	M	CCICD	EDF 11- Programme Support Officer.	jtakalaivuna@economy.gov.fj
35	Rajnil Prasad	M	GGGI	Senior Climate Smart Agriculture Project Officer	rajnil.prasad@gggi.org
36	Dr. Noim Uddin	M	GGGI	Senior Officer, MRV & NDC Enhancement – Pacific	sknoim.uddin@gggi.org
37	Ms Katie Goldman	F	GHGMI	Senior Fellow, Senior Technical Advisor to the project, and ICAT Program Manager	katie.goldman@ghginstitute.org
38	Ms Alissa Benchimol	F	GHGMI	Project Officer	Alissa.benchimol@ghginstitue.org

Annex 2

Table A2-1. Personnel Responsible for QA/QC Activities

Role	QA/QC Responsibility	Name	Organization	Contact Information
National Inventory Coordinator	All aspects of the inventory program, cross-cutting QA/QC			
QA/QC Coordinator	Develop and implement the overall QA/QC plan			
Sector or Category Lead(s)	Develop and implement general, sector-specific (as appropriate) and/or category specific (as appropriate) QA/QC procedures listed in Tables 4-2 and 4-3 below. Focus on Key Categories			
Outside Expert(s)	Expert review of the inventory. Ensure the role of the expert is carefully defined and agreed upon. The expert can be within the country, or an international expert			

Table A2-2. QA/QC plan distribution timeline

Task	Timeline (when the task will occur)	Outcome (description of the results of the task)	Potential Improvements (how the task may be modified to produce a better outcome)
Create (or update) the QA/QC plan			
Identify the best way to distribute the plan to each team member or external expert			
Distribute the QA/QC plan			

Table A2-3: General QC Activities

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
Data Gathering, Input, and Handling Checks					
Check that assumptions	• Cross check descriptions of activity data and emission factors				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
and criteria for the selection of activity data, emission factors, and other estimation parameters are documented.	with information on categories and ensure that these are properly recorded and archived. • Record if there are multiple sources of the same activity data, and if possible document the reasons for any differences.				
Check for transcription errors in data input and references	• Confirm that bibliographical data references are properly cited in the internal documentation (see completed Template 3, Methods and Data Documentation, if applicable). • Cross check a sample of input data from each category (either measurements or parameters used in calculations) for transcription errors. Record the findings of these cross checks. Pay particular attention to systematic differences. Identify steps to reduce the error rate in the future. Add these improvement steps to the QA/QC development plan. • Utilize electronic data where possible to minimize transcription errors. • Check that spreadsheet features are used to minimize user/entry error:[11] ○ Do not "hardwire" factors into formulas. ○ Create automatic look-up tables for common values used throughout calculations. ○ Use cell protection so fixed data cannot accidentally be changed. ○ Build in automated checks, such as computational				

[11] The guidance at https://www.gov.uk/government/collections/quality-assurance-tools-and-guidance-in-decc may prove useful

QC Activity	Procedures	Task Completed Name/ Initials	Task Completed Date	Corrective Measure Taken (if applicable)	Supporting Documents
	checks for calculations, or range checks for input data, mass balance checks, internal consistency checks within and between spreadsheets. ○ Ensure spreadsheets have clear instructions for updating and a description of how the spreadsheet works. ○ Ensure spreadsheets include a record of how they have been implemented and checked.				
Check that emissions/removals are calculated correctly	• Reproduce a representative sample of emissions/removals calculations. • If higher-tier methods or models are used, selectively reproduce complex model calculations with abbreviated calculations to judge relative accuracy. This could be done using IPCC Tier 1 methods. • In all cases, record the work done and the findings. Record any improvements identified (in the appropriate Templates, if applicable).				
Check that parameter and emission/removal units are correctly recorded and that appropriate conversion factors are used	• Check that units are properly labeled in calculation sheets and the completed Template 3, Methods and Data Documentation, if applicable. • Check that units are correctly carried through from beginning to end of calculations. • Check that conversion factors are correct. • Check that temporal and spatial adjustment factors are used correctly.				
Check the integrity of database files	• Confirm that the appropriate data processing steps are correctly represented in the database.				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
	• Confirm that data relationships are correctly represented in the database. • Ensure that data fields are properly labeled and have the correct design specifications. • Ensure that adequate documentation of database and model structure and operation are archived.				
Check for consistency in data between categories	• Identify parameters (e.g., activity data, constants) that are common to multiple categories and confirm that there is consistency in the values used for these parameters in the emissions/removals calculations. • If using Excel, establish a "master set" of constants that all spreadsheets refer to rather than a set of constants in each spreadsheet.				
Check that the movement of inventory data among processing steps is correct	• Check that emissions/removals data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries. • Check that emissions/removals data are correctly transcribed between different intermediate products.				
Check that confidential data are appropriately protected	• Check that only the GHG inventory compilation team can handle/access confidential data. • Check that such data are reported in compliance with requirements agreed on with the data source (if applicable).				
Check that uncertainties in emissions and removals are estimated and calculated correctly.	• If using expert judgement, check that qualifications of individuals providing expert judgement for uncertainty estimates are appropriate. • Check that qualifications, assumptions and expert judgements are recorded.				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
	• Check that calculated uncertainties are complete and calculated correctly. • If necessary, duplicate uncertainty calculations on a small sample of the probability distributions used by Monte Carlo analyses (for example, using uncertainty calculations according to Approach 1).				
Data Documentation					
Review internal documentation and archiving	• Check that there is detailed internal documentation to support the estimates and enable duplication of calculations, using completed Template 3, Methods and Data Documentation, if applicable. • Check that every primary data element has a reference for the source of the data (via cell comments or another system of notation). • Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review. • Check that the archive is closed and retained securely following completion of the inventory. • Check integrity of any data archiving arrangements of outside organizations involved in inventory preparation.				
Calculation Checks					
Check methodological and data changes resulting in recalculations	• Check for temporal consistency in time series input data for each category. • Check for consistency in the algorithm/method used for calculations throughout the time series. • Reproduce a representative sample of emission/removal calculations to ensure mathematical correctness.				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
Check time series consistency	• Check for temporal consistency in time series input data for each category. • Check for consistency in the algorithm/method used for calculations throughout the time series. • Check methodological and data changes resulting in recalculations. • Check that the effects of mitigation activities have been appropriately reflected in time series calculations. Higher IPCC methodologies might be needed to accurately capture the effects of mitigation activities				
Check completeness	• Confirm that estimates are reported for all categories and for all years from the appropriate base year over the period of the current inventory. • For subcategories, confirm that the entire category is being covered. • Confirm that if an emissions or removal estimate is omitted for any given category, documentation to explain or clarify the omission is included, and notation keys are used for that category. (This may include categories that were also omitted from the previous inventory.) • Provide clear definitions of "Other" type categories. • Check that known data gaps that result in incomplete category emissions/removals estimates are documented, including qualitative evaluation of the importance of the estimate in relation to total net emissions (e.g., subcategories classified as "not estimated").				
Trend checks	• For each category, compare current inventory estimates to previous estimates, if available (e.g., archived Template 2). If				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
	there are significant changes or departures from expected trends, re-check estimates and explain any differences. Significant changes in emissions or removals from previous years may indicate possible input or calculation errors. • Check value of implied emission factors (aggregate emissions/removals divided by activity data) across time series to confirm that changes in emissions or removals are being reported. • Check if there are any unusual or unexplained trends in activity data or other parameters across the time series.				

Table A2-4: Category-specific QC Procedures

Category code and name: Note "KC" if it is a key category					
QC Activity	**Procedures**	**Task Completed**		**Corrective Measure Taken (if applicable)**	**Supporting Documents**
		Name / Initials	**Date**		
Emission Factor QC					
Assess the applicability of IPCC default emission factors	• Evaluate whether national conditions are similar to those used to develop the IPCC default factors. • Compare default factors to site or plant-level factors. • Consider options for obtaining country-specific factors. • Document results of this assessment.				

Review country-specific emission factors	• QC the background data used to develop the country-specific factor to assess adequacy of the emission factors and the QA/QC performed during their development
	  ○ E.g., if based on measurement studies, did measurement program included QC procedures
	  ○ E.g., understand characteristics of data (e.g. completeness, etc.)
	• Assess whether secondary studies used to develop country-specific factors used (at a minimum) general QC activities.
	• Compare country-specific factors to IPCC defaults; document any significant discrepancies.
	• Compare country-specific factors to site or plant-level factors.
	• Compare to factors from other countries (using UNFCCC review tools, reported factors in inventory submissions, and/or IPCC Emission Factor Database).
	• Conduct reference calculations that use stoichiometric ratios and conservation of mass and land.
	• Document results of this assessment.				

Review measurement s	• Determine if national or international (e.g., ISO) standards were used in measurements. • Ensure measurement equipment is calibrated and maintained properly. • Compare direct measurements with IPCC or other published default factors; document any significant discrepancies.				
Activity Data QC					

Review national-level activity data	• Determine the level of QC performed by the data collection agency. If inadequate, consider alternative data sources such as IPCC defaults and international activity data sets (e.g., IEA, FAO). Adjust the relevant uncertainty accordingly. • Compare activity data from multiple references (e.g., other independently compiled data) if possible (e.g., IEA, FAO, etc.), including data time series				
Review site-specific activity data	• Determine if national or international (e.g., ISO) standards were used in collecting or generating data. • Compare aggregated site-specific data (e.g., production) to national statistics/data. • Compare data across similar sites. • Compare top-down and bottom-up estimates for similar orders of magnitude.				
Trend checks of activity data	• Compare data to previous year's data and review any sharp increases or decreases. ○ If national activity data for any year diverge greatly from the historical trend, they should be checked for errors. ○ If a calculation error is not detected, the reason for the sharp change in activity should be confirmed and documented.				
QC uncertainty estimates	• Apply QC techniques to uncertainty estimates. • Review uncertainty calculations. • Document uncertainty assumptions and qualifications of any experts consulted.				
GHG Estimate QC/Verification					

Verify GHG estimates	• Compare estimates to other independently compiled national estimates as available. • If using higher-tier methods or models, apply lower-tier methods (e.g., Energy sector comparison of reference and sectoral approach). • Compare intensity indicators between countries • Document, report, and archive verification findings and any further actions (e.g., additional QC, improvement plans).				

Table A2-5: External Reviewers

Name	Organization	Area of Expertise	Contact Information	Date Comments Received	Comment Summary

Table A2-6: Potential Improvements to the GHG inventory

Topic	Category Code and Name	Issue	Relevant Inventory Quality Principle	Improvement Option

Annex 3

Fiji Agriculture Livestock Emissions – ***Guidance Document & User Manual***

The following is a deliverable which was the outcome of the ICAT project. Two National Experts, Dr. Francis Mani and Ms. Zahra Nizbat, were engaged during the project to develop the guidance document and user manual to estimate GHG emissions from livestock. This document focuses on estimating methane emissions from enteric fermentation as well as methane and nitrous oxide emissions from manure management systems.

1. Introduction

The National Greenhouse Gas Inventory (NGGI) is compiled using the 2006 IPCC Guidelines for NGGI that has been divided into 5 volumes. This guidance document focuses primarily on Volume 4, Agriculture, Forestry and Other Land Uses (AFOLU), looking particularly at Enteric Fermentation and Manure Management as key category[12] sources for methane (CH_4) and nitrous oxide (N_2O) emission from the agriculture sector in Fiji.
There are three different methodologies[13] that are used to determine the GHG emissions from enteric fermentation and manure management: Tier 1, Tier 2 and Tier 3. The pros and cons of each methodology are discussed in Table 1.

Table A3-1: IPCC Inventory Tier Structure

Tier Level	Pros	Cons
Tier 1	• Basic • Require minimum information regarding activity data • Use default values provided in the 2006 IPCC Guidelines for NGGI.	• Does not capture country specific national circumstances • Potentially have large uncertainties
Tier 2	• Use country and region-specific emission factors • Has reduced uncertainty compared to Tier 1.	• Is more complex, thus requires detailed activity data.
Tier 3	• Detailed country specific modelling • Has the ability to test mitigation strategies using simulations. • Potentially low uncertainties.	• Model calibration/ validation may lack diversity. • It is considerably difficult to collect high resolution spatial data.

2. Emissions from Livestock and Manure Management

2.1. Methane Emissions from Enteric Fermentation

Herbivores produce methane as a by – product of enteric fermentation where food is broken down in the digestive system of animals by micro – organisms. The amount of CH_4 emitted depends on:

- Digestive tract
- Age
- Weight of the animal
- Quality and quantity of feed consumed by the animal.

NOTE: ruminant animal (cattle, buffalo, sheep, goats, deer, camels) produce more CH_4 compared to non – ruminants (horses, mules/asses, swine) due to the presence of rumen (a chamber in the fore – part of the digestive tract that allows for intensive microbial fermentation of the food intake, particularly cellulose).

2.1.1 Choice of Methodology

The choice of methodology is influenced by the availability of country-specific data for key category species. The appropriate method for the determination of CH_4 emissions from enteric fermentation can be selected using the flowchart below:

[12] Prominent source or sink for GHG's
[13] "Good Practice" is to use advanced methodologies (Tier 2 or Tier 3) for Key Categories (depending on data availability for the specific country)
https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf

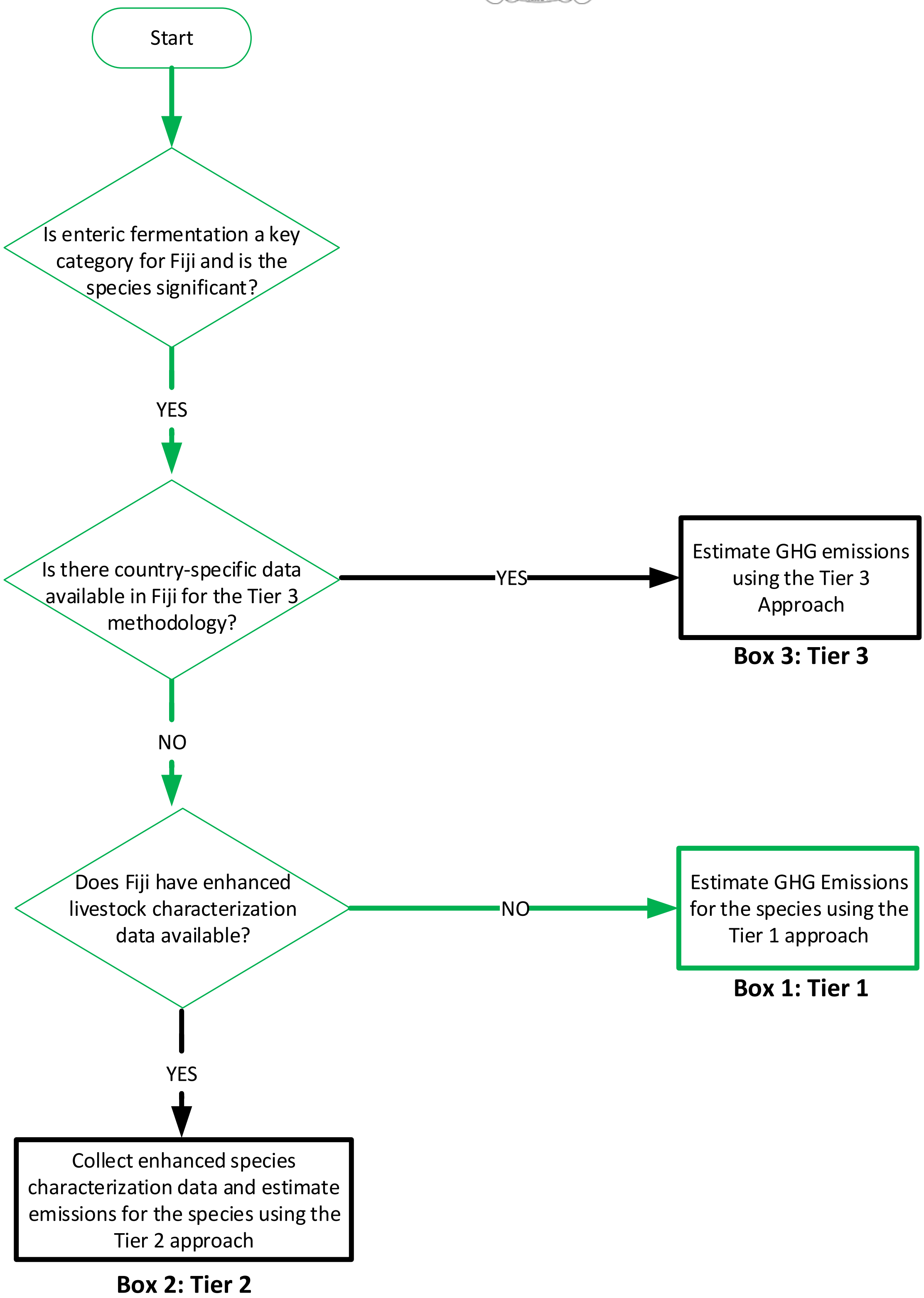


Fig.1: Fiji – Specific decision tree for methane emissions from enteric fermentation

The decision tree provided in the 2006 IPCC Guidelines for NGGI for CH_4 emissions from enteric fermentation was redesigned using the country – specific information available for Fiji in Fig.1 with the decision pathway highlighted in green. Given that methane emission from enteric fermentation is a key category with a significant livestock population in Fiji, the emissions must be included in the NGGI. The Tier 1 approach is generally used for non – key categories whereas Tier 2 and Tier 3 approaches are used for key categories. However, if enhanced characterisation data or country specific information (such as emission factors) are unavailable, the Tier 1 approach can be used for a key category. Moreover, when the emission estimates for enteric fermentation are derived by extrapolation from the main livestock category, it should be considered as a Tier 1 method as well. Therefore, the Tier 1 approach will be applied to estimate CH_4 emissions from enteric fermentation using default values from the 2006 IPCC guidelines.

2.1.2 Steps for Estimating CH_4 Emission from Enteric Fermentation – Tier 1 Method

As illustrated in the decision tree for CH_4 emissions from enteric fermentation, the Tier 1 approach is most applicable for Fiji due to the lack of country specific data. When estimating emissions, the generic equation that is used to calculate GHG emissions is:

$$\boldsymbol{GHG\ Emissions = Activity\ Data\ \times Emission\ Factors}$$

Where:
Activity Data: magnitude of human activity (number of animals, fertilizer applied, etc).
Emission Factor: coefficients for the emissions or removals per unit of activity data.

The generic equation is further simplified to estimate the CH_4 emissions from enteric fermentation. Prior to emission estimation, a number of steps must be followed to ensure correct data and default values are chosen for calculation. These steps are discussed as follows:

Step 1: Divide the livestock population into subgroups and characterise them as per Section 10.2. For the Tier 1 approach, the basic characterisation method is used for livestock population and it is a good practice to collect the following livestock characterisation data to support the emission estimates:

a. *Livestock Species Characterization:* develop a complete list of all livestock population that have a default emission factor available as per the IPCC guidelines (e.g., dairy cows, other cows, swine, horses, sheep, goat, poultry, etc.). If more detailed category data is available for Fiji, these can be further classified to sub – categories (breeding swine, market swine, broilers, layers, ducks, other poultry, etc.).

b. *Animal population:* For the Tier one approach, readily available animal population data is needed to estimate the emissions. The Annual Average Population (AAP) must be used to take into consideration the production cycle and seasonal influences on the population numbers. For static animals (dairy cows, breeding swine, layers), the AAP may be equivalent to the one – time annual animal inventory data. However, the AAP for growing population (meat animals such as beef cattle, turkey, market swine) would require more evaluation as these populations are alive only for a portion of the year. Animals should be included in the populations regardless of whether it was slaughtered for human consumption or died due to natural causes. The equation below can be used to calculate the AAP:

$$AAP = Days_{alive} \times \left(\frac{NAPA}{365}\right)$$

Where:
AAP = Average annual population (number per year)
NAPA = number of animals produced annually

Source: Equation 10.1 from Chapter 10 of the 2006 IPCC Guideline for NGGI.

The accurate recording and reporting of livestock species characterisation and animal population should be the responsibility of the Director Animal Health and Production. The Director must delegate the task of identifying the respective livestock categories as per IPCC guidelines and total population headcount to the respective officers within the Animal Health and Production department, while providing guidance and supervision.

Example

Broiler chicken are typically grown for 60 days before slaughter. If the operation grew 60,000 broilers over a period of one year, calculate the AAP.

The equation for this example would be:

$$AAP = Days_{alive} \times \left(\frac{NAPA}{365}\right)$$

$$AAP = 60 \times \left(\frac{60000}{365}\right)$$

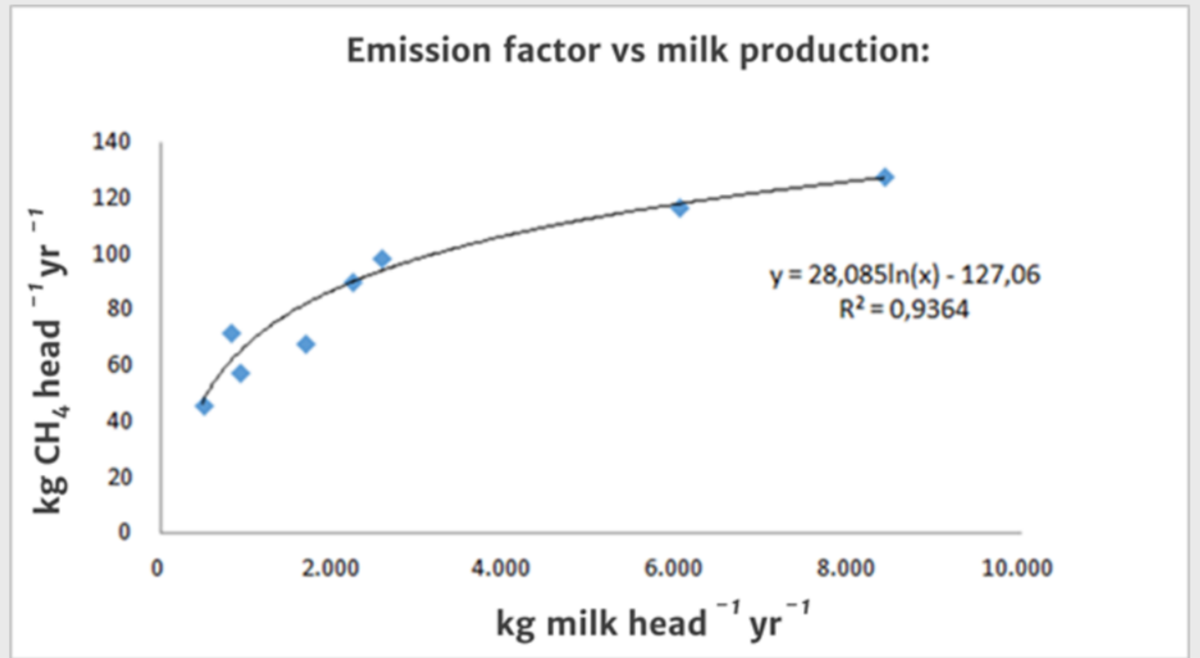
$$\underline{\boldsymbol{AAP = 9863\ Broilers}}$$

NOTE: if official or national data is not available, use reliable data from other sources (e.g., FAOSTAT), interpolation, extrapolation, surrogate data, seek expert advice from people in the industry and check whether the numbers look realistic or not (adjust if necessary).

Step 2: Estimate the emission factors for each subgroup in terms of kg CH_4 animal^{-1} yr^{-1}. For the Tier 1 method, the default emission factors are presented for each of the recommended population groups. The default emission factors have been drawn from previous studies and are organised by region for ease of use (refer to Table 10.11 from Chapter 10 of the 2006 IPCC Guideline for NGGI for the default emission factors. These default emission factors have been estimated using the data available in Annex 10A.1 in Chapter 10 of the 2006 IPCC Guideline for NGGI). Table 10.11 only represents the default emission factors for cattle (dairy and other cattle) and Table 10.10 shows default emission factors from enteric fermentation for the other animal species.

IMPORTANT: When selecting emission factors from Table 10.10 and 10.11, identify the region that is most applicable to the country being evaluated. Scrutinise the tabulations in Annex 10A.1 to ensure that the underlying animal characteristics such as weight, growth rate and milk production used to develop the emission factors are similar to the conditions in the country. The data collected on the average annual milk production by dairy cows is a good proxy to help select the dairy cow emission factor. If necessary, interpolate between dairy cow emission factors shown in Table 10.11 using the data collected on average annual milk production per head for Fiji.

Example:
For Fiji, the default emission factor for dairy cattle that can be identified form Table 10.11 as 100 kg CH_4 head^{-1}yr^{-1}. However, this value is applicable if the dairy cattle have an average milk production of 2200 kg head^{-1} yr$^{-1.}$ According to FAOSTAT, the annual milk production is 1200 kg head^{-1} yr^{-1}. Using the milk production data from Table 10.11 (refer to column on Comments), it can be interpolated to determine the emission factor at 1200 kg head^{-1} yr^{-1}.



Using the equation $y = 28.085\ln(x) - 127.06$, the adjusted EF is 72. The readjusted EF is in line with that of Latin America (Table 10.11) and also indicated that milk production in Fiji is 2.2 kg milk day^{-1} as opposed to 6.0 kg milk day^{-1}. Adjustment of the emission factor allows the eradication of over or under estimation of methane emission for the purpose of the NGGI.

STEP 3: Calculate the total emission by using the selected emission factors and multiplying it to the associated animal production (Equation 10.19) and, finally, sum the values to get the total emissions (Equation 10.20).

NOTE: the IPCC provides worksheets in MS Excel spreadsheet to assist users of the guidelines for estimating

GHG emissions for NGGIs.

EQUATION 10.19
ENTERIC FERMENTATION EMISSIONS FROM A LIVESTOCK CATEGORY

$$Emissions = EF_{(T)} \bullet \left(\frac{N_{(T)}}{10^6} \right)$$

Where:

Emissions = methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = the number of head of livestock species / category T in the country

T = species/category of livestock

EQUATION 10.20
TOTAL EMISSIONS FROM LIVESTOCK ENTERIC FERMENTATION

$$\text{Total } CH_{4_{Enteric}} = \sum_i E_i$$

Where:

Total $CH_{4_{Enteric}}$ = total methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}

E_i = is the emissions for the i^{th} livestock categories and subcategories

Example 1

Using the data provided below, calculate the total methane emission for dairy and beef cattle. Conduct the calculations using the emission factor stated in Table 10.11 and the readjusted value for comparison.
There are 309000 cows where 50% are dairy cattle and 50% are beef cattle. Assume that the beef cattle have a life span of more than a year.

Solution

Sector	**Agriculture, Forestry and Other Land Use**				
Category	**Methane Emissions from Enteric Fermentation and Manure Management**				
Category code	**3A1 and 3A2**				
Sheet	**1 of 1**				
Equation	**Equation 10.19**		**Eq. 10.19 and 10.20**	**Using re - adjusted values**	
Species/Livestock category	Number of animals	Emission factor for Enteric Fermentation	CH_4 emissions from Enteric Fermentation	Emission factor for Enteric Fermentation	CH_4 emissions from Enteric Fermentation
	(head)	(Kg $head^{-1}$ yr^{-1})	(Gg CH_4 yr^{-1})	(Kg $head^{-1}$ yr^{-1})	(Gg CH_4 yr^{-1})
		Tables 10.10 and 10.11	$CH_{4\ Enteric} = N_{(T)} * EF_{(T)} * 10^{-6}$	Tables 10.10 and 10.11	$CH_{4\ Enteric} = N_{(T)} * EF_{(T)} * 10^{-6}$
T	**$N_{(T)}$**	**$EF_{(T)}$**	**$CH_{4\ Enteric}$**	**$EF_{(T)}$**	**$CH_{4\ Manure}$**
Dairy Cattle	154500	100	15.45	72	11.124

Beef Cattle	154500	60	9.27	60	9.270
Total Emission			24.72		20.394

The total emission would be overestimated by 4.33 Gg CH_4 yr^{-1}.

NOTE: Using country specific data that may be available allows accurate estimate of the methane emissions. The emission factor for beef cattle is not readjusted and is for the Oceania region.

Example 2

Using the information provided below, determine the total methane emissions. Also incorporate the adjusted emissions from the earlier example.

There are a total of 11268 sheep, 250500 goats, 46000 Horses and 145700 swine (50% breeding and 50% for market with a lifespan of 6 months before slaughter).

Solution

Sector	**Agriculture, Forestry and Other Land Use**		
Category	**Methane Emissions from Enteric Fermentation**		
Category code	**3A1 and 3A2**		
Sheet	**1 of 1**		
Equation	**Equation 10.19**		**Eq. 10.19 and 10.20**
Species/Livestock category	Number of animals	Emission factor for Enteric Fermentation	CH_4 emissions from Enteric Fermentation
	(head)	(Kg $head^{-1}$ yr^{-1})	(Gg CH_4 yr^{-1})
		Tables 10.10 and 10.11	$CH_{4\ Enteric} = N_{(T)} * EF_{(T)} * 10^{-6}$
T	**$N_{(T)}$**	**$EF_{(T)}$**	**$CH_{4\ Enteric}$**
Dairy Cattle	154500	72	11.124
Beef Cattle	154500	60	9.270
Sheep	11268	5	0.056
Goats	250500	5	1.253
Horses	46000	18	0.828
Swine (breeding)	72850	1	0.073
Swine (Market)	36425	1	0.036
Total Emissions			**22.640**

NOTE: For swine, the AAP has to be calculated for those that are bred for market and are slaughtered within 6 months. The avian population, such as poultry and ducks, are given but it is not used to calculate emission for enteric fermentation but is used in manure management calculations.

2.2. Methane Emissions from Manure Management

In addition to enteric fermentation, CH_4 is also produced during the storage and treatment of manure[14] as well as from manure that has been deposited on pasture during grazing. The decomposition of manure under anaerobic[15] conditions, during storage and treatment, leads to the production of CH_4. Such conditions occur more readily when large numbers of animals are managed in a confined area (e.g., dairy farms, feedlots and swine and poultry farms) and where manure is deposited into a liquid – based manure management system

[14] includes both dung and urine, i.e. he solid and liquid waste produced by livestock.
[15] Absence of oxygen

[16](MMS).

The main factors affecting CH_4 emissions include the:

- Amount of manure produced by livestock – depends on the rate of waste production per animal and the number of animals (per each category or sub - category.
- Feed composition.
- Portion of manure that decomposes anaerobically – depends on the MMS.

What is impact of MMS's on CH_4 production?

a. When manure is stored or treated as a liquid[17], it decomposes anaerobically and produces a significant amount of CH_4.
b. When manure is stored or treated as a solid or when deposited on pastures and rangelands, it tends to decompose under aerobic conditions, thus, producing less CH_4.
c. Temperature, pH and retention time affect the amount of CH_4 production – increase in temperature and low pH (acidic condition) provides favourable conditions for anaerobic micro – organisms to decompose manure and produce high amounts of CH_4.
d. Chemical composition – high nitrogen content in the manure promotes anaerobic conditions. this is also influenced by the feed composition.

NOTE: emissions from the burning of dung for fuel are reported under "Energy" or under "Waste" if it is burned without energy recovery. However, biomass energy from cow dungs is not relevant to Fiji.

2.2.1. Choice of Methodology

There are three tiers that can be used to estimate CH_4 emissions from livestock manure management. The guidance provided in the figure below form Chapter 10 of the 2006 IPCC Guidelines on NGGI can be used to determine the appropriate method.

[16] The definition for the different MMS can be found in Table 10.18 of the 2006 IPCC Guidelines for NGGI.

[17] In lagoons, ponds, tanks or pits.

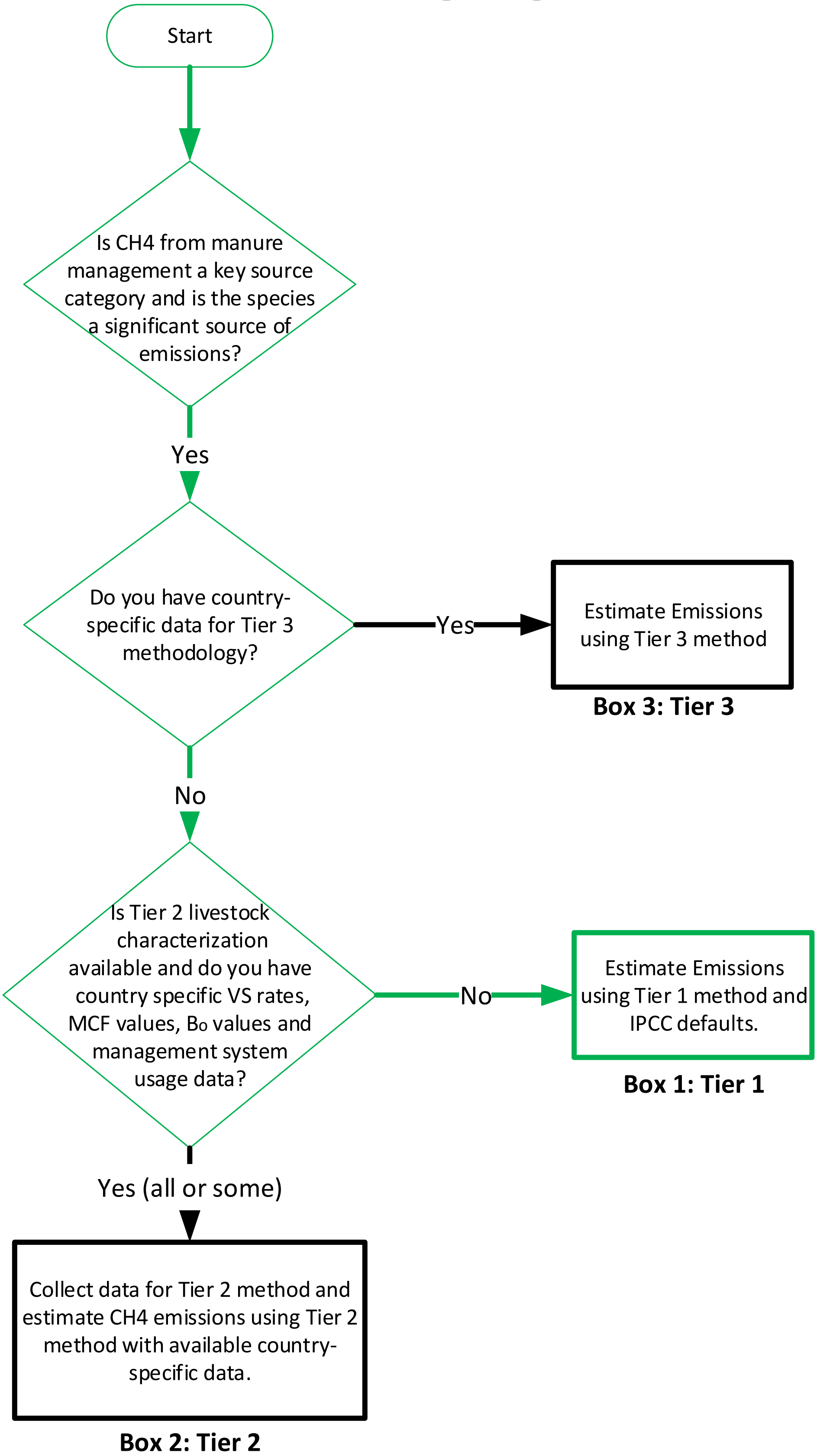


Fig.2: Fiji – Specific decision tree for methane emissions from manure management
Source: https://www.ipccnggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf, pg. 10.36

For a country like Fiji, the Tier 1 method is most applicable. It is a simplified method that only requires livestock population data by animal species/ category and climate region or temperature, in combination with IPCC default emission factors, to estimate emission. Considering some emissions from MMS are highly temperature dependent, it is good practice to estimate the average temperature associated with the locations where manure is managed.

2.2.2. Steps for Estimating Methane Emissions from Manure Management – Tier 1 Method

Step 1: Collect population data for the livestock and divide them into sub – categories as per Section 10.2. and section 2.1.2. of this document. The accurate recording and reporting of livestock species characterisation and animal population should be the responsibility of the Director Animal Health and Production. The Director must delegate the task of identifying the respective livestock categories as per IPCC guidelines and total population headcount to the respective officers within the Animal Health and Production department, while providing guidance and supervision.

Step 2: Use the default values or the country specific emissions factors (if available) for each livestock category and/or subcategory in kg CH_4 animal^{-1} yr^{-1}. Since temperature plays a key role in decomposition and production of CH_4, the emission factors by average temperature are presented in Tables 10.14, 10.15 and 10.16 for each of the recommended population subcategories. The underlying assumptions that were used to estimate the default emission factors for the different regions and the average mean temperature are detailed in Table 10A – 4 through to Table 10A – 9.

NOTE: Countries using a Tier 1 method to estimate methane emissions from manure management should review the regional variables in these tables to identify the region that most closely matches their animal operations and use the default emission factors for that region.

STEP 3: Calculate the CH_4 emissions for each livestock sub – category from manure management using Eq. 10.22 and the sum to find the total emissions.

EQUATION 10.22
CH_4 EMISSIONS FROM MANURE MANAGEMENT

$$CH_{4\,Manure} = \sum_{(T)} \frac{\left(EF_{(T)} \bullet N_{(T)}\right)}{10^6}$$

Where:

$CH_{4Manure}$ = CH_4 emissions from manure management, for a defined population, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 head^{-1} yr^{-1}

$N_{(T)}$ = the number of head of livestock species/category T in the country

T = species/category of livestock

Example

Use the information provided below to determine the total CH_4 emissions from manure management.

a. There are 309000 cattle were 50% are dairy cattle and 50% are beef cattle.
b. There are a total of 11268 sheep, 250500 goats, 46000 Horses and 145700 swine (50% breeding and 50% for market with a lifespan of 6 months before slaughter).
c. There are 5097000 chicken where 2000000 are layers (dry system for manure) and 3097000 broilers that are alive for 47 days.
d. The population data provided is for a developing country located in the Oceania region with an average annual temperature of 26°C.

Solution

Sector	Agriculture, Forestry and Other Land Use

Category	Methane Emissions from Enteric Fermentation and Manure Management		
Category code	3A1 and 3A2		
Sheet	1 of 1		
Equation	**Equation 10.19**	**Equation 10.22**	
Species/Livestock category	Number of animals	Emission factor for Manure Management	CH_4 emissions from Manure Management
	(head)	(Kg head^{-1} yr^{-1})	(Gg CH_4 yr^{-1})
		Tables 10.14 - 10.16	$CH_{4\ Manure} = N_{(T)} * EF_{(T)} * 10^{-6}$
T	**$N_{(T)}$**	**$EF_{(T)}$**	**$CH_{4\ Manure}$**
Dairy Cows	154500	31	4.790
Beef Cattle	154,500	2	0.309
Sheep	11,268	0.2	0.002
Goats	250500	0.22	0.055
Horses	46,000	2.19	0.101
Swine - Breeding	72,850	24	1.748
Swine - Market	36,425	13	0.474
Chickens - layers	2,000,000	0.02	0.040
Chickens - Boilers	398,792	0.02	0.008
Total			7.580

NOTE: you will need to determine the Annual Average Population (AAP) for Market Swine and Broiler Chicken.

2.3. Nitrous Oxide Emissions from Manure Management

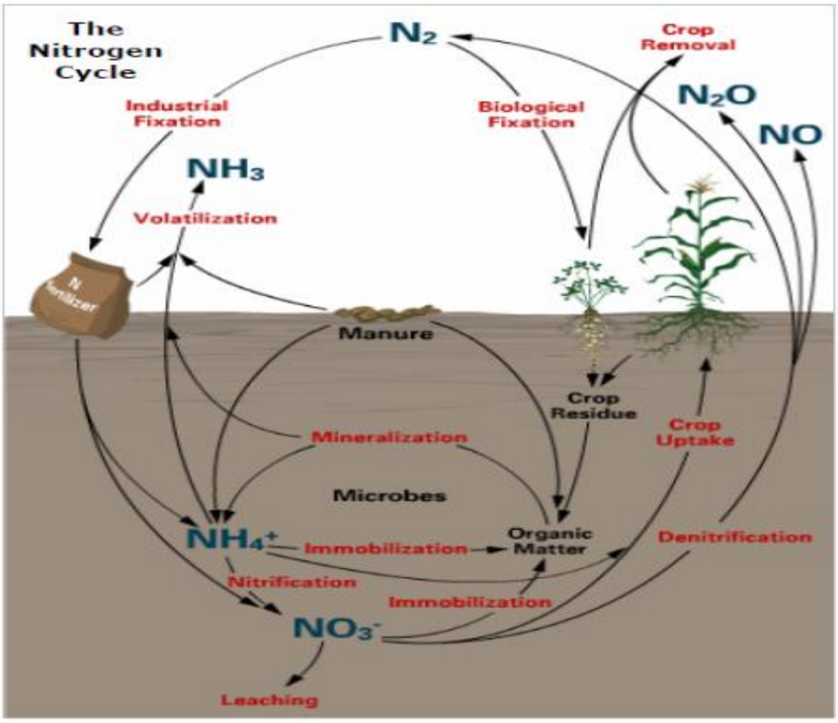
Nitrous oxide, N_2O, is produced directly and indirectly during storage and treatment of livestock manure before it is used as organic fertilizer, feed, fuel or construction purposes. The N_2O emissions generated by manure in the system 'pasture, range, and paddock' occur directly and indirectly from the soil and are therefore reported under the category 'N_2O Emissions from Managed Soils'. The emissions associated with the burning of dung for fuel are to be reported under 'Fuel Combustion' (Energy), or under 'Waste Combustion' (Waste) if burned without energy recovery.

Direct N_2O Emissions: arise from the manure as a by-product of nitrogen (N) transformations during nitrification and denitrification (Biological processes that continuously change the form in which nitrogen is present in the soil leading to the release of N_2O). The direct emission of N_2O during storage and treatment of manure depends on:

- Nitrogen and carbon content of the manure.
- Duration of storage
- Type of treatment – aerobic conditions (solid storage and treatment) lead to nitrification whereas anaerobic conditions (liquid storage and treatment) lead to denitrification.
- pH and moisture – increasing acidity, nitrate concentration and moisture leads to an increase in the ratio of N_2O: N_2

In summary, the production and emission of N_2O from managed manures requires the presence of either nitrites or nitrates in an anaerobic environment preceded by aerobic conditions necessary for the formation of these oxidized forms of nitrogen. In addition, conditions preventing reduction of N_2O to N_2, such as a low pH or limited moisture, must be present.

Indirect N_2O Emissions: occur when N, that is converted to other gases such as ammonia and nitrogen oxides (NO_x) (volatile N losses) or lost via leaching, is later converted to N_2O. The fraction of excreted organic nitrogen that is mineralized to ammonia during manure collection and storage depends primarily on time, and to a lesser degree temperature. Simple forms of organic nitrogen are rapidly mineralized to ammonia, which is highly volatile and easily diffused into the surrounding air. Nitrogen losses begin at the point of excretion in houses and other animal production areas (e.g., milk parlours) and continue through on-site management in storage and treatment systems (i.e., manure management systems). Nitrogen is also lost through runoff and leaching into soils from the solid storage of manure at outdoor areas, in feedlots and where animals are grazing in pastures. Pasture losses are considered separately under Agriculture Soils: N_2O Emissions from Managed Soils, as are emissions of nitrogen compounds from grazing livestock.

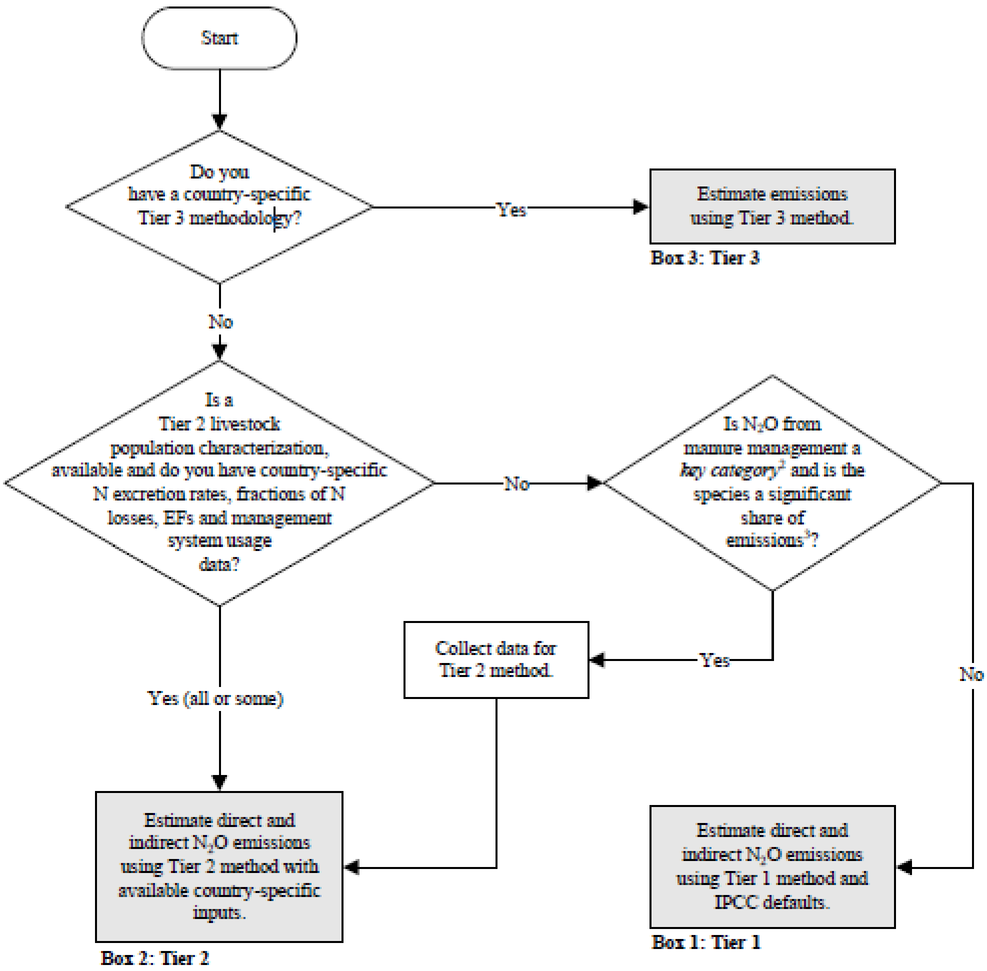


The Nitrogen Cycle

2.3.1. Choice of Methodology

The level of detail and methods chosen for estimating N_2O emissions from manure management systems will depend upon national circumstances and the decision tree in Figure 10.4 describes good practice in choosing a method accordingly.

Figure 10.4 Decision tree for N_2O emissions from Manure Management (Note 1)



Note:
1: N_2O emissions from manure management systems include both direct and indirect sources
2: See Volume 1 Chapter 4, "Methodological Choice and Identification of Key Categories" (noting Section 4.1.2 on limited resources), for discussion of *key categories* and use of decision trees.
3: As a rule of thumb, a livestock species would be significant if it accounts for 25-30% or more of emissions from the source category.

For a country like Fiji, the Tier 1 method is most applicable as N2O from manure management is not a key source category. The Tier 1 method is applied using IPCC default N_2O emission factors (Table 10.21), default nitrogen excretion data (Table 10.19), and default manure management system data (see Annex 10A.2, Tables 10A-4 to 10A-8 for default management system allocations).

2.3.2. Steps for Estimating Direct Nitrous Oxide Emissions from Manure Management – Tier 1 Method

Step 1: Collect population data for the livestock and divide them into sub – categories as per Section 10.2. and section 2.1.2. of Annex 2.

Step 2: Using the default values for daily N excretion rate from Table 10.19 (kg N (1000 kg animal mass)$^{-1}$ day^{-1}) for the geographical region of interest and Eq. 10.30, determine the default values for **annual** average nitrogen excretion rate per head ($Nex_{(T)}$) for each defined livestock sub –category.

EQUATION 10.30
ANNUAL N EXCRETION RATES

$$Nex_{(T)} = N_{rate(T)} \bullet \frac{TAM}{1000} \bullet 365$$

Where:

$Nex_{(T)}$ = annual N excretion for livestock category *T*, kg N animal^{-1} yr^{-1}

$N_{rate(T)}$ = default N excretion rate, kg N (1000 kg animal mass)$^{-1}$ day^{-1} (see Table 10.19)

$TAM_{(T)}$ = typical animal mass for livestock category *T*, kg animal^{-1}

NOTE: Default TAM values are provided in Tables 10A-4 to 10A-9 in Annex 10A.2. However, it is preferable to collect country-specific TAM values due to the sensitivity of nitrogen excretion rates to different weight categories. For example, market swine may vary from nursery pigs weighing less than 30 kilograms to finished pigs that weigh over 90 kilograms. By constructing animal population groups that reflect the various growth stages of market pigs, countries will be better able to estimate the total nitrogen excreted by their swine population.

This data is not currently available as per the discussions with officials from MoA. Such data can be collated annually should there be sufficient staffing within the relevant departments within MoA. Currently, the total annual population headcount is only conducted for census reporting, while annual reporting is only carried out for livestock on supervised farms. To have a more categorised reporting for livestock characteristics (weight at different stages, total animal headcount, etc.), the Director Animal Health and Production needs to identify staffing gaps and appoint more livestock officers (where necessary) to collate the necessary national data for annual reporting.

Step 3: Determine the default values for the fraction of total annual nitrogen excretion for each livestock sub – category that is managed in each MMS ($MS_{(T, S)}$) from Tables 10A-4 to 10A-8.

Step 4: Determine the default N_2O emission factors for each MMS for each livestock sub – category from Table 10.21.

Step 5: Calculate the N_2O emissions for each livestock sub – category from each MMS using Eq. 10.25 followed by calculating the sum of the overall manure management systems.

EQUATION 10.25
DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28}$$

Where:

$N_2O_{D(mm)}$ = direct N_2O emissions from Manure Management in the country, kg N_2O yr^{-1}

$N_{(T)}$ = number of head of livestock species/category *T* in the country

$Nex_{(T)}$ = annual average N excretion per head of species/category *T* in the country, kg N animal^{-1} yr^{-1}

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless

$EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system *S* in the country, kg N_2O-N/kg N in manure management system *S*

S = manure management system

T = species/category of livestock

44/28 = conversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$ emissions

NOTE: In some cases, manure nitrogen may be managed in several types of manure management systems. For example, manure flushed from a dairy free stall barn to an anaerobic lagoon may first pass through a solid separation unit where some of the manure nitrogen is removed and managed as a solid. Therefore, it is important to carefully consider the fraction of manure nitrogen that is managed in each type of system.

Example

Country A is a developing country in Oceania whose primary livestock production include dairy cattle, swine, and poultry, with some non-dairy cattle and sheep. The average annual temperature of Country A is 24^{o}C.

Dairy cattle are predominantly pasture grazing with 5% of their time in the milking shed. Manure from the milking shed is collected and spread daily onto pasture. Dairy cows average about 400kg in weight and produce on average 2.2 kg of milk per day, which equates to 800 kg milk per year.

All **non-dairy cattle and sheep** are 100% pasture grazed. Other than that, there is no other information available for non-dairy cattle and sheep.

Twenty-five percent of the **swine population** are kept for breeding purposes, while the remainder are grown for 6 months before being slaughtered. The breeding population are 50% pasture grazed and 50% in crates where their manure is collected and managed in dry lot. Market swine spend 50% of their time in crates and 50% of their time on pasture. Manure from the crates is managed mainly in dry lot MMS (80%) and small proportion in solid storage systems (20%). Breeding swine weight on average is 172kg and market swine are 47kg.

Population Data:
Cattle: 1,682,690 dairy cattle and 397,901 other cattle.
Sheep: 248,319
Swine: 652,864
For the year 2015, calculate the direct nitrous oxide from manure management for Country A.

Solution

Using the information provided, determine the MMS that was used for each animal subcategory. This can be represented as in the table below.

	Solid storage	Dry lot	Daily Spread	PR&P	Total
Dairy Cows	0	0	**5**	**95**	100
Other Cattle	0	0	0	**100**	100
Sheep	0	0	0	**100**	100
Swine – Breeding	0	**50**	0	**50**	100
Swine – Market	**10**	**40**	0	**50**	100

Determine the total head count for each animal subcategory
Cattle: 1,682,690 dairy cattle and 397,901 other cattle.
Sheep: 248,319
Swine: Breeding Swine: 25% of total swine population – 163,216
Market Swine: 75% of total swine population – 489,648. Remember that market swine is not alive for the whole year. Therefore, the AAP will need to be calculated. The market swine head count now becomes 244,824.
Determine the $N_{rate(T)}$, $MS_{(T,S)}$ and $EF_{3(s)}$ form Tables 10.19, Tables 10A4 – A8 and Table 10.21, respectively.
Note that according to Table 10.21, N_2O emissions from Pasture/ Range/ Paddock are reported under Managed Agricultural Soils. Also, daily spread has an emission factor of zero, thus, making the emissions zero as well. Therefore, the emissions will only need to be determined for solid storage and dry lot.

Sector		**Agriculture, Forestry and Other Land Use**								
Category		**Manure Management: Direct N_2O Emissions from Manure Management Systems**								
Category code		**3A2**								
Sheet		**1 of 1**								
Equation		**Eq. 10.25**	**Equation 10.30**			**Equation 10.25**				
Manure Management System (MMS)[1]	Species/ Livestock category	Number of animals	Default N excretion rate	Typical animal mass for	Annual N excretion per head of	Fraction of total annual nitrogen	Total nitrogen excretion for the MMS [4]	Emission factor for direct N_2O-N emissions from MMS	Annual direct N_2O emissions from Manure Management	
		(head)	[kg N (1000 kg animal)$^{-1}$ day^{-1}]	(kg)	(Kg N animal^{-1} year^{-1})	(-)	(Kg N yr^{-1})	[kg N_2O-N (Kg N in MMS)$^{-1}$]	kg N_2O yr^{-1}	Gg N_2O yr^{-2}
			Table 10.19	Tables 10A-4 to 10A-9	$Nex_{(T)} = N_{rate(T)} * TAM * 10^{-3} * 365$	Tables A4-A8	$NE_{MMS} = N_{(T)} * Nex_{(T)} * MS_{(T, S)}$	Table 10.21	$N_2O_{(mm)} = NE_{MMS} * EF_{3(S)} * 44/28$	N_2O_D (mm) = $N_2O_{D(mm)}$*10
S	**T**	**$N_{(T)}$**	**$N_{rate(T)}$**	**TAM**	**$Nex_{(T)}$**	**$MS_{(T, S)}$**	**NE_{MMS}**	**$EF_{3(S)}$**	**$N_2O_{D(mm)}$**	
Solid Storage	Swine - Market	244,824	0.53	47	9.09215	0.03	66,779.30	0.005	524.6944682	0.000525
Total										0.000525

[1] The calculations must be done by Manure Management System, and for each management system, the relevant species/livestock category (ies) must be selected. For the Manure Management Systems, see Table 10.18.
[2] Specify livestock categories as needed using additional lines (e.g., llamas, alpacas, reindeers, rabbits, fur-bearing animals etc.)
[3] Country-specific values are preferred to directly enter into this column. If these are not available, use default values of $N_{rate(T)}$ and TAM to calculate this variable.
[4] This value will be input to worksheet in Indirect N_2O emissions from Manure Management (see category 3C6).

Sector		Agriculture, Forestry and Other Land Use								
Category		Manure Management: Direct N_2O Emissions from Manure Management Systems								
Category code		3A2								
Sheet		1 of 1								
Equation		Eq. 10.25	Equation 10.30			Equation 10.25				
Manure Management System (MMS)[1]	Species/Livestock category	Number of animals	Default N excretion rate	Typical animal mass for livestock category	Annual N excretion per head of species/livestock category[3]	Fraction of total annual nitrogen excretion managed in MMS for each ...	Total nitrogen excretion for the MMS [4]	Emission factor for direct N_2O-N emissions from MMS	Annual direct N_2O emissions from Manure Management	
		(head)	[kg N (1000 kg animal)$^{-1}$ day^{-1}]	(kg)	(Kg N animal^{-1} year^{-1})	(-)	(Kg N yr^{-1})	[kg N_2O-N (Kg N in MMS)$^{-1}$]	kg N_2O yr^{-1}	Gg N_2O yr^{-2}
			Table 10.19	Tables 10A-4 to 10A-9	$Nex_{(T)} = N_{rate(T)} * TAM * 10^{-3} * 365$	Tables A4-A8	$NE_{MMS} = N_{(T)} * Nex_{(T)} * MS_{(T, S)}$	Table 10.21	$N_2O_{(mm)} = NE_{MMS} * EF_{3(S)} * 44/28$	$N_2O_D = N_2O_{D(mm)} * 10^{-6}$
S	**T**	**$N_{(T)}$**	**$N_{rate(T)}$**	**TAM**	**$Nex_{(T)}$**	**$MS_{(T, S)}$**	**NE_{MMS}**	**$EF_{3(S)}$**	**$N_2O_{D\ (mm)}$**	
Dry Lot	Swine - Breeding	163,216	0.46	172	28.8788	0.15	4.33182	0.02	0.136142914	1.36E-07
	Swine - Market	244,824	0.53	47	9.09215	0.15	1.3638225	0.02	0.042862993	4.29E-08
Total									0.179005907	1.79E-07

[1] The calculations must be done by Manure Management System, and for each management system, the relevant species/livestock category (ies) must be selected. For the Manure Management Systems, see Table 10.18.

[2] Specify livestock categories as needed using additional lines (e.g., llamas, alpacas, reindeers, rabbits, fur-bearing animals etc.)

[3] Country-specific values are preferred to directly enter into this column. If these are not available, use default values of $N_{rate(T)}$ and TAM to calculate this variable.

[4] This value will be input to worksheet in Indirect N_2O emissions from Manure Management (see category 3C6).

3. User Manual for Calculating GHG Emissions from Livestock in Fiji

In order to determine the GHG inventory to capture emissions from enteric fermentation and manure management systems, activity data for the different livestock categories need to be collected and validated for use. The three main sources of activity data that were analysed for validation were from the Ministry of Agriculture (MoA) Officials, Fiji National Agriculture Census Reports (1991, 1999, 2009 & 2020) and FAOSTAT and were used to generate the data time series from 1995 – 2020. As there were significant activity data gap for the years from 1990 – 1994 for key categories such as horses, goats and poultry, expert judgement was made and it was decided that the time series would be from 1995 – 2020, representing a 25 – year emissions trend for the inventory.

This section outlines the steps that can be taken to generate the time series data from the three sources and to determine the GHG emissions from enteric fermentation and manure management for the different livestock categories in Fiji. It also describes the steps taken to select the default emission factors from the 2006 IPCC

Guidelines for NGGI for the Tier 1 Approach.

3.1. Activity Data Time Series

The key livestock categories that are used to determine the GHG emissions from consists of cattle (dairy and other cattle), swine, chicken, goat, horses, sheep and ducks. Upon sourcing the population count from FAOSTAT and Ministry of Agriculture for the National Data, the data must be analysed for discrepancies and data gaps to for validation.

For the purpose of this project, it was deduced that there were various discrepancies in the population count for the different years and the National Data received from MoA were only for the years from 2009 – 2019. Also, the data trend for the population count from FAOSTAT was erratic and the numbers did not follow a standard population trend. Therefore, using expert judgement, the Fiji National Agriculture Census Report for the years 1991, 1995, 2009 and 2020 for the population count were extrapolated and interpolated (depending on the livestock species) to determine the population count for the years 1995 – 2020 for dairy cattle, other cattle, swine and goat. The census data that was used are outlined in the Table 2 below:

Table 3A-2: Fiji Agriculture Census Data for Cattle, Swine and Goat

Livestock Species	Year			
	1991	1999	2009	2020
Dairy Cattle[18]	36805	22583	22551	49680
Other Cattle	243416	262104	11187	70041
Swine	90850	92251	73698	58420
Goat	187235	251765	101196	143853

(Source: Fiji National Agriculture Census Report for 1991, 1999, 2009 & 2020).

It is also important to note that the national data provided by MoA are only for supervised farms and does not take into consideration subsistence or non-supervised farms. Thus, extrapolating or interpolating the census data allows experts to get a more realistic annual population count for the different livestock species. The following figure is a representation of the animal population time series data ranging from the year 1995 – 2020.

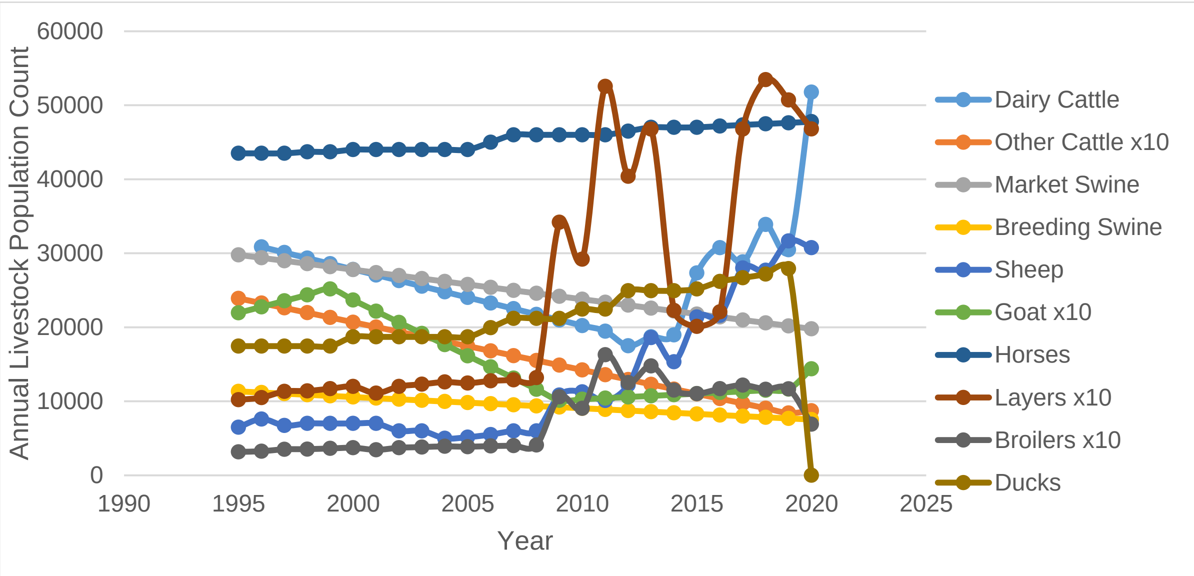


Fig. 1: Annual livestock population trend for the years 1995-2020.

The activity data time series for the different livestock species was determined using the following approach:

a. Dairy Cattle

The national dairy cattle population count was made available for the years 2011 – 2020 by MoA while the

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[18] Commercialized dairy sector based on grazing. Growing amount of feedlot feeding with grains. Dairy cows are a small part of the population.

population count for the years 1995 – 2010 were unavailable. In this case, the National Agriculture Census data was used and extrapolated using liner regression to calculate the dairy cattle population count. This is represented in the figure below:

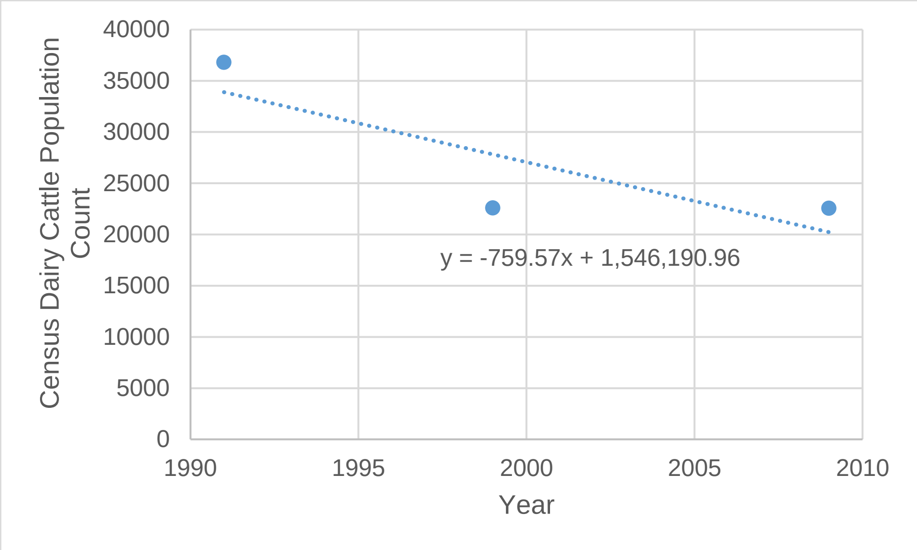


Fig.2: Linear Regression to determine the annual population count for dairy cattle from 1995-2010.

Using the equation $y = -759.57x + 1{,}546{,}190.96$ the annual dairy cattle population count for the years 1995-2010 were calculated and recorded in the activity data time series. Furthermore, given that dairy cattle are defined as cattle that used for commercial purposes and are subjected to a specific diet, the census data was not used for the 2020 annual dairy cattle population data as it also includes those that are from unsupervised or subsistence. Thus, the annual dairy cattle population for 2020 was taken from the national data provided by MoA; having an annual population count of 32620. This value was subtracted from the census data and added to the “other cattle” livestock category ($49650 - 32620 = 17030\ dairy\ cattle\ for\ subsistence\ farming$).

b. Other Cattle

The national data provided by MoA for “other cattle” only consisted of those that were grazed for commercial purposes or from supervised farms; mainly for meat production (beef cattle). It did not take into account the cattle that were grazed in unsupervised farms. The census data provided the annual population count for total cattle and dairy cattle grazed in Fiji in 1991, 1999 and 2009. This was used to determine the total “other cattle” population by subtracting the dairy cattle population from the total cattle population. This method was not used for the year 2020 as the total cattle headcount was not provided in the census. For the year 2020, the remaining subsistence dairy cattle headcount from the 2020 census were added to the 2020 census data for beef cattle to get the holistic “other cattle” head count ($70041 + 17030 = 87071$). Thereafter, the census data for “other cattle” was extrapolated to determine the linear regression and calculate the annual “other cattle” population for the years 1995 – 2019 and is represented in the figure below.

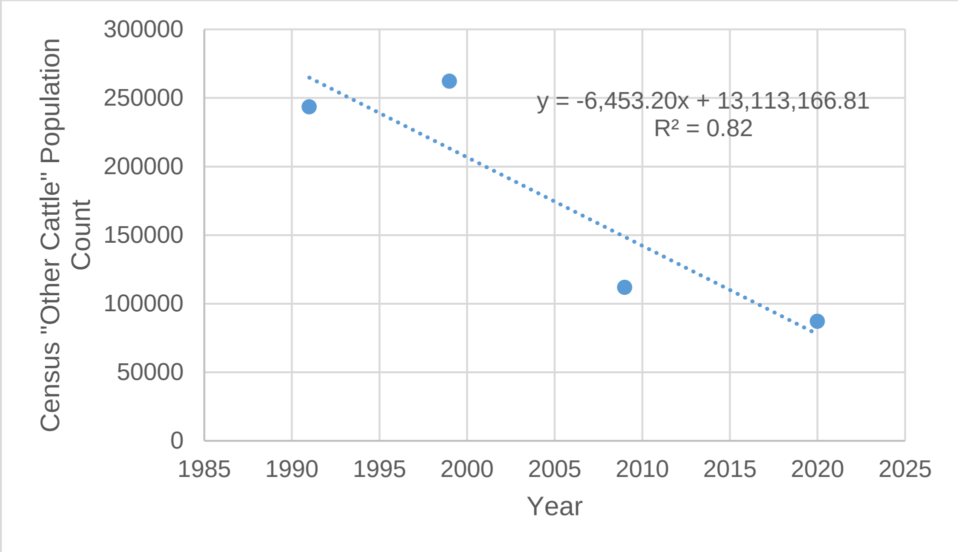


Fig.3: Linear Regression to determine the annual population count for "other cattle" from 1995-2019

Using the equation $y = -6{,}453.20x + 13{,}113{,}166.81$, the annual "other cattle" population count for the years 1995-2019 were calculated and recorded in the activity data time series.

c. Swine

The National Data provided by MoA for the annual swine population count was only for the years 2009 – 2019 from supervised farms. Since the data was not inclusive of the swine population from unsupervised, it did not provide appropriate headcount for the holistic GHG emissions from swine. Therefore, the census data was extrapolated a linear regression was used to calculate the total annual swine population count for the years 1995-2020. This is represented in the figure below.

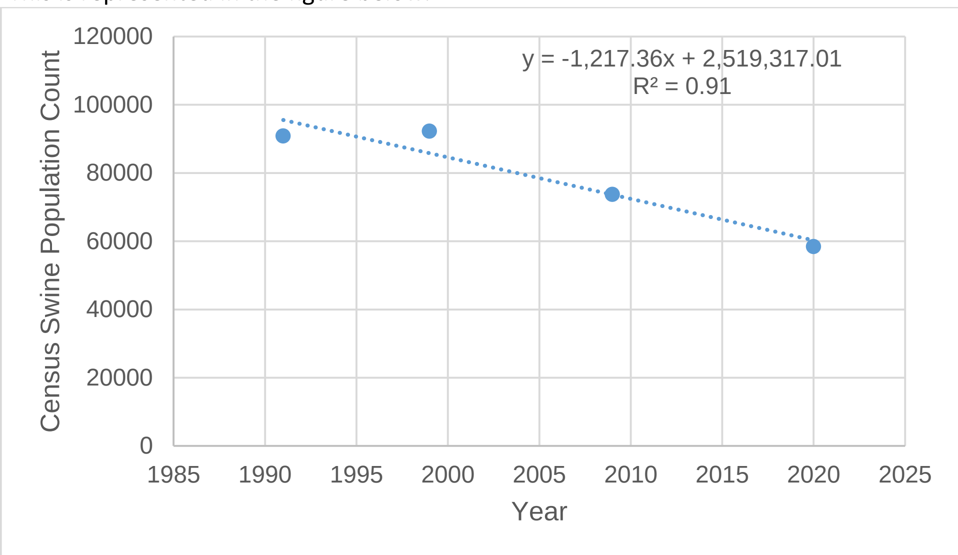


Fig.4: Linear Regression to determine the annual population count for swine from 1995-2020.

Using the equation $y = -1{,}217.36x + 2{,}519{,}317.01$, the annual swine population count for the years 1995-2020 was calculated and recorded in the activity data time series. However, this livestock category must be further disaggregated into breeding and market swine as the lifespan for each sub-category is different. The disaggregated annual swine population data was not available within the MoA, FAOSTAT or in the census reports. Upon consultation with the officials from the livestock department within the MoA, it was deduced that 87.5% of the total swine population was raised for market while 12.5% were for breeding. This information was used to disaggregate the swine population data into breeding and market sub-categories and recorded in the activity data time series.

Additionally, as mentioned under the guidance section, the GHG emissions using the IPCC guidelines for Tier 1 requires activity data (animal headcount) for a species that is grazed for an entire annual cycle. Therefore, for market swine, the AAP needs to be calculated to readjust the annual market swine population. The life span for market swine as per the livestock officials from MoA is 137 days (~4.5 months). This information was used to readjust the total market swine population count and was recorded in the activity data time series.

d. Goat

Similar to the other livestock categories, the national data provided by MoA cannot be used to estimate GHG emissions from goats as it only takes into consideration the goat population grazed in supervised farms. Therefore, the census data was used to determine the total annual goat population headcount for the years 1995-2020. However, extrapolation of the data and the linear regression approach cannot be used for goats as it did not show a linear trend. Therefore, the census data was interpolated to determine the annual goat population count. The annual population count and the census data are illustrated in the figure below.

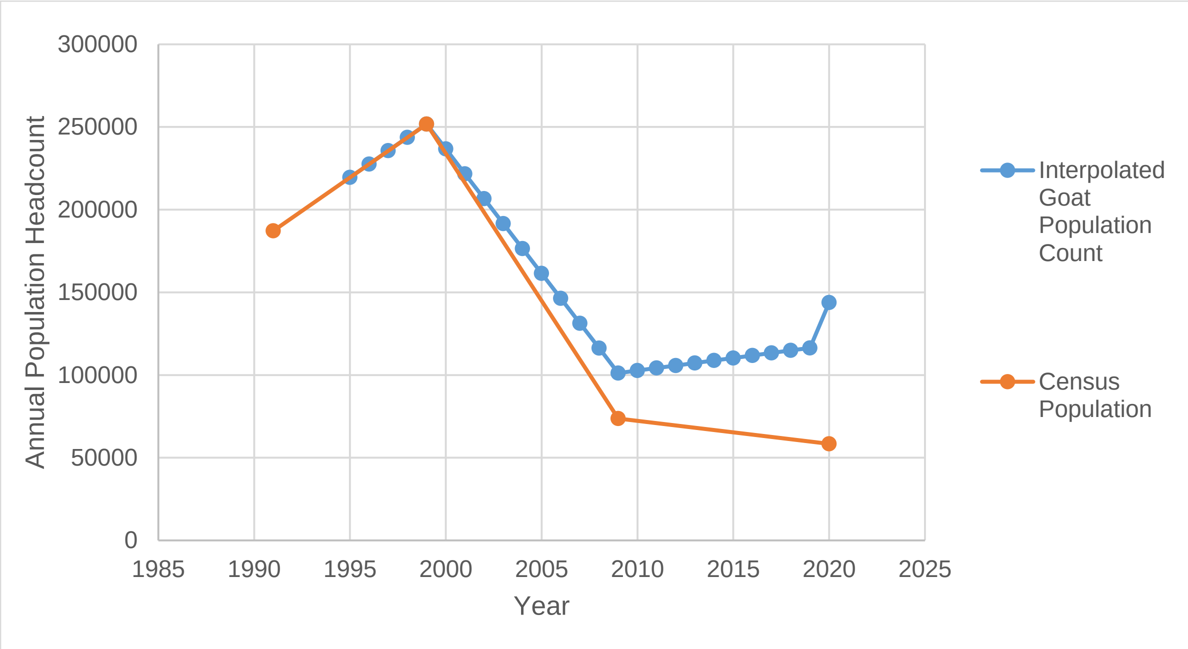


Fig. 5: Comparison between census and interpolated goat population count.

The interpolated population data was used to calculate the GHG emissions from goat as per the IPCC guidelines for the Tier 1 approach.

e. Horses

The total annual population count for horses is not recoded by MoA, nor is it reported in the agriculture census report for Fiji. Therefore, the population data for this animal category was retrieved directly from FAOSTAT for the years 1995 – 2019. The population data for 2020 was not available on the FAOSTAT database, therefore, the horse population count from 2015 – 2019 was plotted to find a linear regression and extrapolated to calculate the population count for 2020. This is illustrated in the figure below.

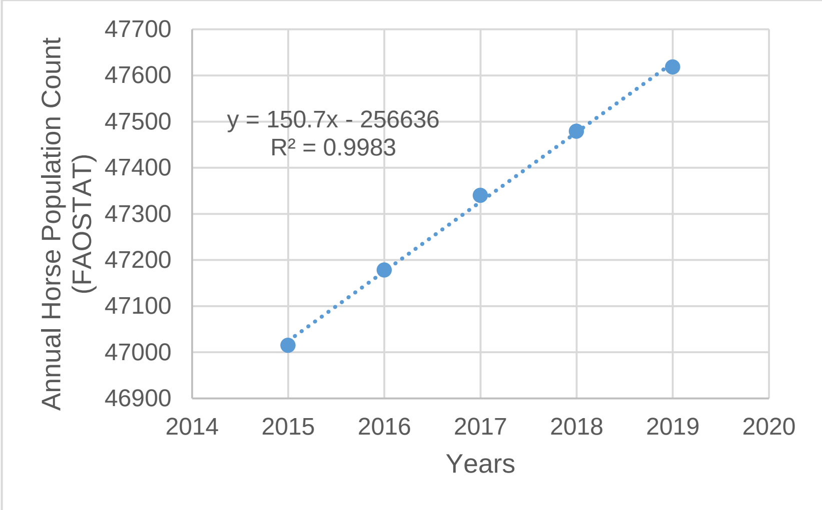


Fig.6. Linear Regression to determine the annual population count for horses in 2020.

The equation $150.7x - 256636$ was used to calculate the total horse population count for the year 2020 and was recorded in the activity data time series.

f. Sheep

The total annual sheep population count sourced from MoA was limited to the years 2009-2020. Since the national census data did not report the sheep population count, this activity data was sourced from the FAOSTAT database for the years 1994 – 2008 and was recorded in the activity data time series.

g. Chicken

This livestock category has to be disaggregated into layers and broilers as the lifespan for each sub-category is different. The disaggregated population numbers for layers were available for the years 2013-2020 while the broiler annual population count was available for the years 2009-2020. This data was sourced from the MoA. However, there still remained data gaps for the remaining years from 1995-2008 for broilers and 1995-2021 for layers. In addition, upon comparison between the total chicken population count and the disaggregated population count, it was deduced that layers made up ~97% of the total chicken population while ~3% are broilers. Using this ratio and the total annual chicken population count from FAOSTAT, the disaggregated population count was calculated and reported in the activity data time series.

Additionally, as mentioned under the guidance section, the GHG emissions using the IPCC guidelines for Tier 1 requires activity data (animal headcount) for a species that is grazed for an entire annual cycle. Therefore, for broilers, the AAP needs to be calculate to readjust the annual broiler chicken population. The life span for broiler chicken as per the livestock officials from MoA is 35 days. This information was used to readjust the total broiler chicken population count and was recorded in the activity data time series.

h. Ducks

The total annual duck population count sourced from MoA was limited to the years 2013-2020. Since the national census data did not report the duck population count, this activity data was sourced from the FAOSTAT database for the years 1994 – 2012. However, a comparison between the national data and the FAOSTAT data showed significant discrepancies between the two data sets. Therefore, the FAOSTAT data was reported in the activity data time series for the years 1995 – 2019.

3.2. Calculation of GHG Emissions from Enteric Fermentation & Manure Management.

The three categories for which the GHG emissions were calculated for were:

1. CH_4 from Enteric Fermentation.

2. CH_4 from manure management systems.
3. N_2O from Manure Management Systems

In order to calculate the emissions, the default emission factors for each of the categories were selected from the 2006 IPCC Guidelines for NGGI upon expert judgement and analysing national circumstances. The steps which were involved in this process are outlined in this section for the respective categories.

3.2.1. Emission factors - CH_4 from Enteric Fermentation

a. Dairy Cattle

The default emission factor for CH_4 emissions from Enteric Fermentation is reported in Table 10.11. Guiding information provided in the table for Enteric Fermentation EF for cattle states that "values represent averages within region, where applicable the use of more specific regional milk production data is encouraged" (Dong , et al., 2006). Upon analysis Table 10.11, it was deduced that the EF for dairy cattle in Oceania is on the basis that cattle have an average milk production of 2,200 kg head^{-1} yr^{-1}. Upon comparison of the national data with the FAOSTAT data for average milk production in Fiji, it was deduced that there were inconsistencies in the values reported, especially since the national data only took into consideration milk production form large commercial farms. Therefore, the FAOSTAT data was used and reported in the activity data time series from 1995-2019. The milk production data for the years 2015-2019 were extrapolated to calculate the average milk production for the year 2020. This is also illustrated in the figure below.

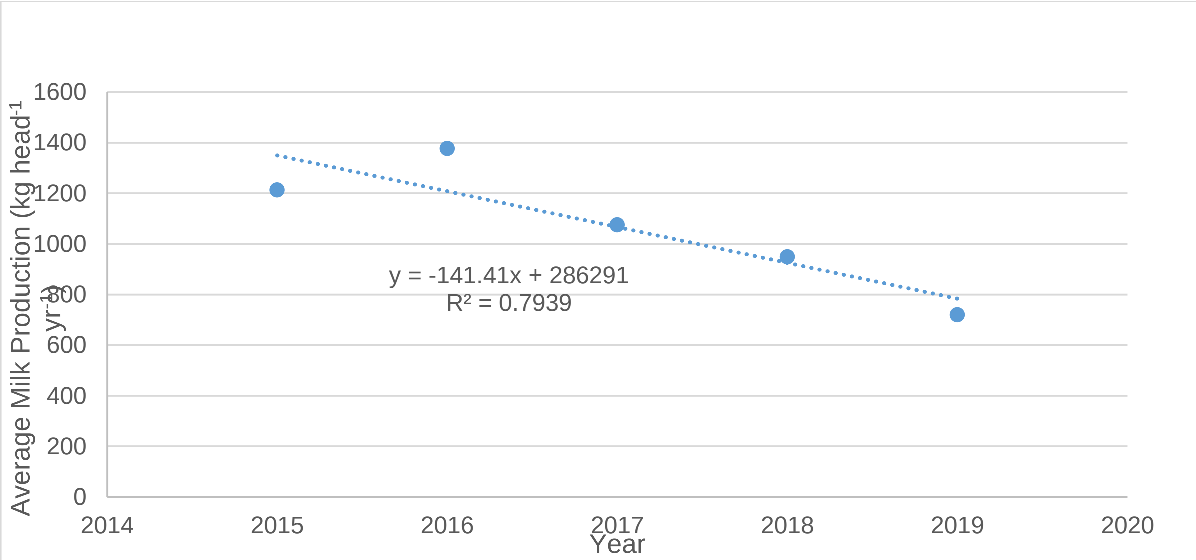


Fig. 7. Average annual milk production (kg head^{-1} yr^{-1}) data from FAOSTAT for the years 2015-2020

In addition, the default EF values reported were determined using the Tier 2 approach and the information represented in Table 10 A.1 and 10 A.2. Given that Fiji is located in Oceania, the Tier 2 data used to determine the EF were not consistent with the FAOSTAT data. Table 10.11 also indicates that an EF of 90 kg CH_4 head^{-1} yr^{-1} for Oceania was deduced on the assumption that dairy cattle have an average milk production of 2,200 kg head^{-1} yr^{-1}. However, this is not applicable for Fiji as the annual milk production data is much lower than 2,200 kg head^{-1} yr^{-1}. Since Table 10.11 provides the EF at for different regions at varying milk production rates, this information can be used to readjust the EF for Fiji based on the local annual milk production data provided by FAOSTAT. The following steps can be followed to readjust the EF for Fiji:

1. Plot a graph of Default EF vs. Average Annual Milk Production (from Table 10.11) to find the linear regression as illustrated in the figure below:

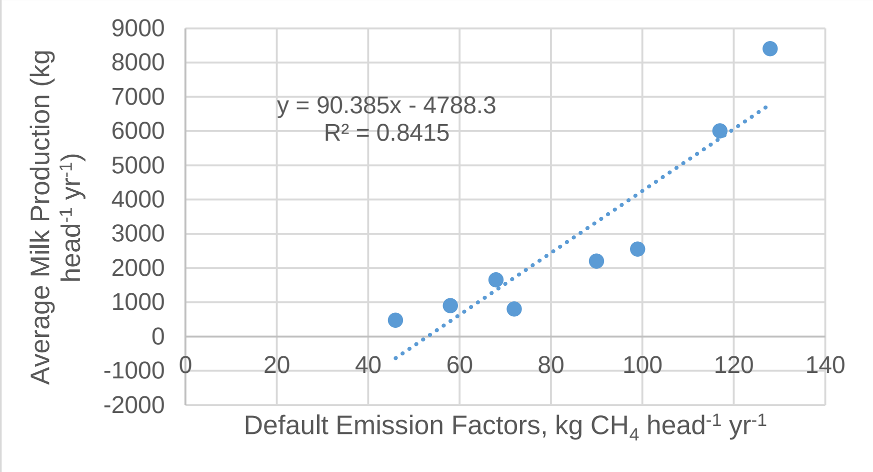


Fig. 8. Readjustment of the default emission factor using the information from Table 10.11.

2. Using the equation $y = 90.385x - 4788.3$, find the readjusted EF for the years 1995-2020 and record in the activity data time series. The readjusted EFs are illustrated in the figure below.

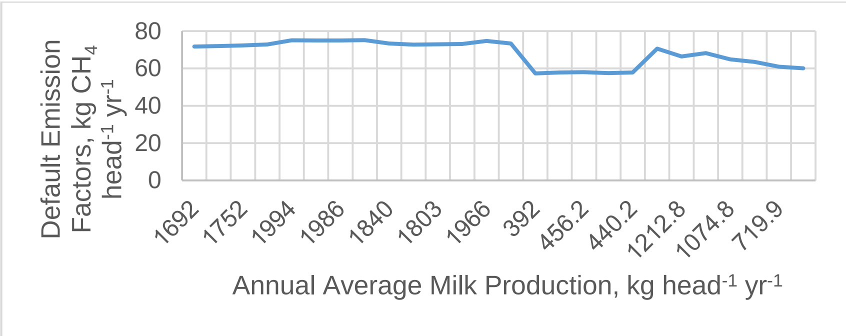


Fig. 9. Readjusted EF for the respective annual average milk production from dairy cattle in Fiji.

b. Other Cattle

The default emission factor for other cattle is derived based on animal characteristics (such as live-weight) and feed intake. Since this information was not available, the default EF of 60 kg CH_4 head^{-1} yr^{-1} for Oceania from Table 10.11 was used for "other cattle" to calculate its total CH_4 emissions from 1995 – 2020.

c. Goats, Sheep, Horses & Swine

The default emission factors for goats, horses, sheep and swine were selected from Table 10.10 of the 2006 IPCC Guidelines for NGGI. The table has different EF's for developed and developing countries as the EF's are deduced based on animal characteristics and feed. Therefore, the EF's from the "developing Countries" column is most appropriate for Fiji (also because Fiji is considered a developing country). The following table outlines the respective EF's chosen to calculate the CH_4 emissions from goats, sheep, horses and swine for the years 1995-2020.

Table 3A-3: Enteric Fermentation Default EF's for the Tier 1 Method, *kg CH_4 head^{-1}yr^{-1}*

Livestock	Default EF *kg CH_4 head^{-1}yr^{-1}*
Goat	5
Sheep	5
Horse	18
Swine	1

3.2.1.1. Calculation for CH_4 Emissions from Enteric Fermentation

The following equations are used to calculate the total CH_4 emissions from enteric fermentation for each livestock category for the years 1995-2020:

Enteric Fermentation Emissions from Each Livestock

$$Emissions = EF_{(T)} \cdot \left(\frac{N_{(T)}}{10^6}\right)$$

Where:

Emissions= CH_4 emissions from Enteric Fermentation, Gg CH_4 yr^{-1}

$EF_{(T)}$= emission factor for the defined livestock population, kg CH4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = the number of head of livestock species / category T in the country

T = species/category of livestock

Total Emissions from Livestock Enteric Fermentation

$$Total\ CH_{4\ Enteric} = \sum_i E_i$$

Where:

Total $CH_{4Enteric}$=total methane emissions from Enteric Fermentation, $GgCH_4$ yr^{-1}

E_i = is the emissions for the i^{th} livestock categories and subcategories

The total CH_4 emissions from enteric fermentation was calculated and reported in the time series for the years 1995-2020 for Fiji.

3.2.2. Emission Factors – CH_4 from Manure Management

An important characteristic to be considered when determining EF for CH_4 emissions from manure management is the ***average annual temperature*** as it plays a key role in decomposition and production of CH_4. The average annual temperature for Fiji for the years 1995 – 2020 was sourced from the Fiji Meteorological Services through MoA and was reported to be ***26 ℃***. Using this information and the default EFs provided in Table 10.14 for Cattle and Swine (for the respective regions) and Table 10.15 for sheep, goats, horses and poultry, the following EFs were deduced for Fiji:

Table 3A-4: Manure Management CH_4 EFs by Temperature for Cattle and Swine in Fiji

Regional Characteristic	Livestock	EF at 26°C *kg CH_4 $head^{-1}$ yr^{-1}*
Oceania: Most cattle manure is managed as a solid on pastures and ranges, except dairy cows where there is some usage of lagoons. About half of the swine manure is managed in anaerobic lagoons.	Dairy Cattle	31
	Other Cattle	2
	Market Swine	13
	Breeding Swine	24

(Source: (Dong , et al., 2006))

Table 3A-5: <u>Manure Management CH_4 EFs by Temperature for Sheep, Goat, Horse and Poultry in Fiji</u>

Livestock	Developing Country EF at 26°C *kg CH_4 $head^{-1}$ yr^{-1}*
Sheep	0.2
Goats	0.22
Horses	2.19
Poultry	0.02

(Source: (Dong , et al., 2006))

The EF's noted in Tables 4 & 5 were used to calculate the total CH_4 emissions from manure management for the key livestock categories from 1995-2020.

3.2.2.1. Calculation for CH_4 Emissions from Manure Management

The following equations are used to calculate the total CH_4 emissions from enteric fermentation for each livestock category for the years 1995-2020:

CH_4 Emissions from Manure Management

$$CH_{4\ Manure} = \sum_{T} \frac{(EF_{(T)}.N_{(T)})}{10^6}$$

Where:

$CH_{4Manure}$ = CH_4 emissions from manure management, for a defined population, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = the number of head of livestock species/category T in the country T = species/category of livestock

The total CH_4 emissions from manure management was calculated and reported in the time series for the years 1995-2020 for Fiji.

3.2.3. Emission Factor and Key Parameters – N_2O Emission from Manure Management

Steps to calculate direct N_2O emissions from Manure Management Systems (MMS)

Step 1: Collection of Activity Data

Population Data: Could be sourced from the national agriculture animal census reports and a timeline data series could be prepared through linear regression or official data from MoA could be obtained. This is discussed in detail in Section 3.1

Usage of Manure Management System

This activity data was aggregated from calculating the number of animal population in commercial farms, semi-commercial and household subsistence farming. According to expert judgement only manure from intensive commercial and semi commercials farms were managed whereas household/subsistence farming manure was left on pasture/range/paddock except for swine reared for subsistence farming whereby manure was managed in a pit storage below animal confinement (See Table 6 below).

Table 3A-6: <u>Manure Management Systems used for the different category of animals in Fiji</u>

Animal category	% use of Manure Management System (MMS)						
	Pasture/ Range/ Paddock	Daily Spread	Pit Storage below confinement	Dry lots	Uncovered anaerobic Lagoon	Manure with litter	Manure without litter
Dairy Cattle	96	4	0	0	0	0	0
Other Cattle	100	0	0	0	0	0	0
Sheep	100	0	0	0	0	0	0
Goats	100	0	0	0	0	0	0
Horses	100	0	0	0	0	0	0
Swine -Market	0	0	50	30	20	0	0
Swine- Breeding	0	0	50	30	20	0	0
Poultry - Broilers	20	0	0	0	0	80	0
Poultry - Layers	20	0	0	0	0	0	80

From Table 6 it is apparent that the Pasture/range/paddock MMS has an emission factor of zero and is considered in Direct N_2O emissions from managed soil and is not calculated under agriculture. The emission factor for daily spread and uncovered anaerobic lagoon is also zero and therefore would result in zero direct N_2O emissions and therefore not included in the calculation. Given the MMS usage data provided by Animal Health and Production Division of Ministry of Agriculture the Direct N_2O emissions were calculated for Swine (Market and Breeding) and Poultry (Broilers and Layers).

Typical Animal Mass (TAM)

The average life weight data for Cattle (dairy and other cattle), Swine (Market and Breeding) sheep, goat and Poultry (Broilers and Layers) are given in the table below

Table 3A-7: Animal Average Live Weight for Key Categories

Animal Category	Animal Average Live weight (Kg)
Dairy Cattle	270
Other Cattle	350
Swine- Market	70
Swine - Breeding	115
Sheep	33
Goat	28
Poultry- Broilers	2.0
Poultry - Layers[19]	1.3

(Source of data: Ministry of Agriculture, 2021)

Step 2: Calculation of Annual N excretion per head of species/livestock category (kg N animal^{-1} yr^{-1})

To enable calculation of annual N excretion rate per head of species/livestock category, default excretion rate, $N_{rate\ (T)}$, (kg N (1000 kg animal)$^{-1}$ day^{-1}) given in table below was used:

Table 3A-8: Default Excretion Rate, $N_{rate\ (T)}$

Livestock category	N_{rate}
Swine – Market	0.53
Swine - Breeding	0.46
Poultry - Layers	0.82
Poultry - Broilers	1.10

(Source: Extracted from Table 10.19)

The above $Nrate_{(T)}$ and TAM data provided by MoA will be used in equation 10.30 to calculate $Nex_{(T)}$ as follows:

EQUATION 10.30
ANNUAL N EXCRETION RATES

$$Nex_{(T)} = N_{rate(T)} \bullet \frac{TAM}{1000} \bullet 365$$

Where:

$Nex_{(T)}$ = annual N excretion for livestock category T, kg N animal^{-1} yr^{-1}

$N_{rate(T)}$ = default N excretion rate, kg N (1000 kg animal mass)$^{-1}$ day^{-1} (see Table 10.19)

$TAM_{(T)}$ = typical animal mass for livestock category T, kg animal^{-1}

Step 3: Determine the fraction of total annual nitrogen excretion for each livestock sub – category that is managed in each MMS (MS $_{(T,\ S)}$) from Table 6. For example, market swine uses 50% Pit storage below confinement, 30% drylots, 20% uncovered anaerobic lagoon and this equates to 0.5, 0.3 and 0.2 fractions respectively for each MMS used.

Step 4: Determine the default N_2O emission factors for each MMS for each livestock sub – category from Table 10.21. According to Table 6 only following MMSs were used and its respective N_2O emission factors that should be used is given below:

Table 3A-9: Default Emission Factors for MMS's

MMS	Emission factor (Kg N-N_2O Kg Nitrogen Excreted
Dry lot	0.02
Pit Storage below animal confinement	0.002
Poultry manure with litter	0.001
Poultry manure without Litter	0.001

Step 5: Calculate the N_2O emissions for each livestock sub – category from each MMS using Eq. 10.25 (given below) followed by calculating the sum of the overall manure management systems.

EQUATION 10.25
DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28}$$

Where:

$N_2O_{D(mm)}$ = direct N_2O emissions from Manure Management in the country, kg N_2O yr^{-1}

$N_{(T)}$ = number of head of livestock species/category T in the country

$Nex_{(T)}$ = annual average N excretion per head of species/category T in the country, kg N $animal^{-1}$ yr^{-1}

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless

$EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system S in the country, kg N_2O-N/kg N in manure management system S

S = manure management system

T = species/category of livestock

44/28 = conversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$ emissions

4. Current Status of GHG Emissions in Fiji

The calculation of GHG emissions from enteric fermentation and manure management for the years 1995-2020 was carried out using national activity data specific to Fiji as well as form the FAOSTAT database. The country specific parameters such as temperature, manure management systems, annual average dairy milk production, etc. were also important factors that were useful in deducing the appropriate default values to apply the Tier 1 approach. Moreover, the current status of Fiji's GHG emissions as per the time series from 1995-2020 is illustrated in the figures below:

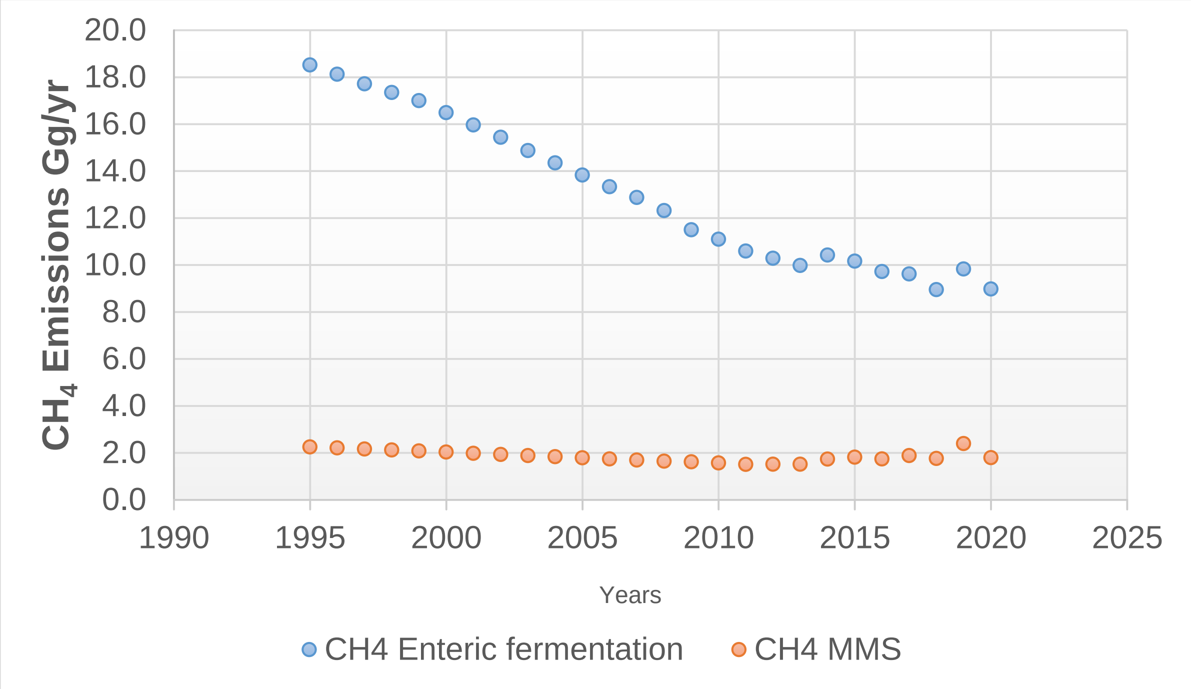


Fig.10. CH_4 Emissions from Enteric Fermentation and Manure Management from 1995 – 2020.

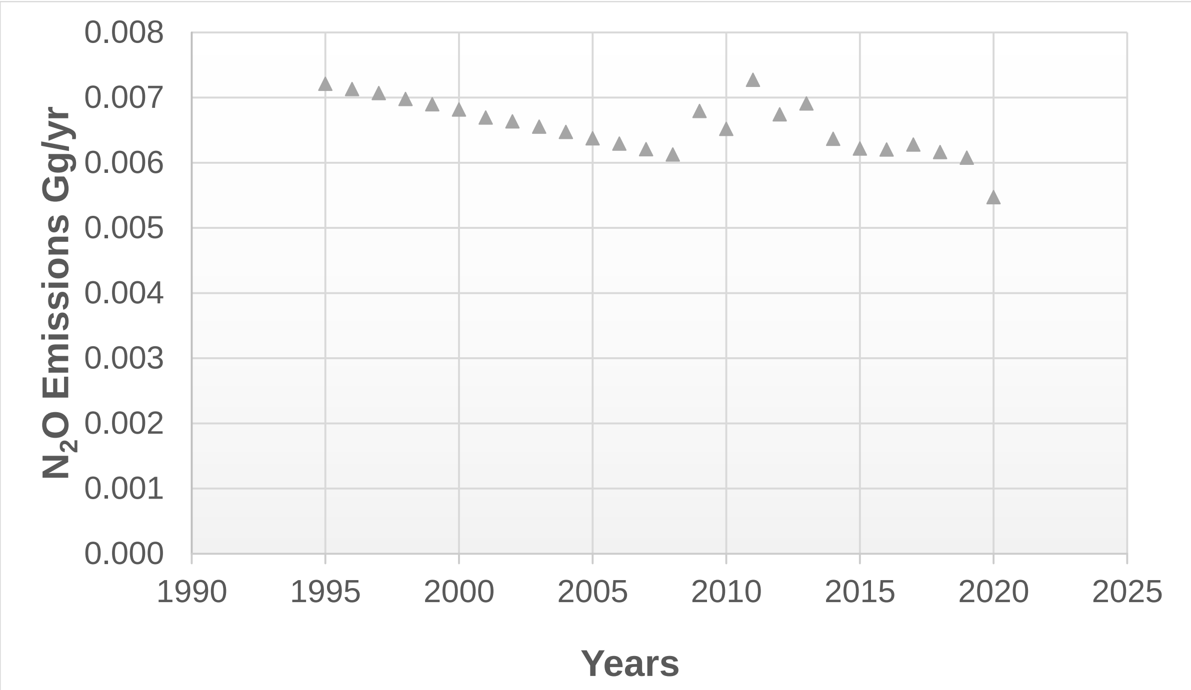


Fig.11. N_2O Emissions from Manure Management from 1995 – 2020.

The total GHG emissions from enteric fermentation and manure management is in the range of 227 – 438 Gg/yr CO_2 eq. from 1995 – 2020. Table 9 suggest that the total emissions from enteric fermentation and manure management is steadily declining and is about 52% of 1995 level. Two main reasons for the observed decline are due to declining population number for other cattle, and the declining re-adjusted EF for dairy cows based on annual milk production. The main contributory factor is declining other cattle population data, and this could emanate from actual loss of animals due to diseases or incorrect capturing of data.

Table 3A-10: Annual GHG Emissions Time Series Data from 1995 - 2020

Year	CH4 Emissions Enteric Fermentation		CH4 Emissions MMS		Direct $N_2$0 Emission MMS		Total GHG emissions
	CH4 emission (Gg yr^{-1})	CO2 eq (Gg yr^{-1})	CH4 emission (Gg yr^{-1})	CO2 eq (Gg yr^{-1})	N_2O emission (Gg yr^{-1})	CO2 eq (Gg yr^{-1})	CO_2 eq (Gg/yr)
1995	18.5	388.9	2.2	47.2	0.007	2.2	438
1996	18.1	380.6	2.2	46.3	0.007	2.2	429
1997	17.7	372.0	2.2	45.4	0.007	2.2	420
1998	17.3	364.3	2.1	44.5	0.007	2.2	411
1999	17.0	357.0	2.1	43.6	0.007	2.1	403
2000	16.5	346.2	2.0	42.6	0.007	2.1	391
2001	16.0	335.3	2.0	41.6	0.007	2.1	379
2002	15.4	324.2	1.9	40.6	0.007	2.1	367
2003	14.9	312.3	1.9	39.5	0.007	2.0	354
2004	14.3	301.3	1.8	38.5	0.006	2.0	342
2005	13.8	290.4	1.8	37.5	0.006	2.0	330
2006	13.3	279.9	1.7	36.5	0.006	2.0	318
2007	12.9	270.4	1.7	35.6	0.006	1.9	308
2008	12.3	258.6	1.6	34.5	0.006	1.9	295
2009	11.5	241.4	1.6	34.0	0.007	2.1	277
2010	11.1	233.0	1.6	32.9	0.007	2.0	268
2011	10.6	222.5	1.5	31.6	0.007	2.3	256
2012	10.3	216.0	1.5	31.8	0.007	2.1	250
2013	10.0	209.6	1.5	31.8	0.007	2.1	243
2014	10.4	218.9	1.7	36.4	0.006	2.0	257
2015	10.2	213.4	1.8	38.1	0.006	1.9	253
2016	9.7	204.1	1.7	36.5	0.006	1.9	242
2017	9.6	201.9	1.9	39.5	0.006	1.9	243
2018	9.0	188.0	1.8	36.9	0.006	1.9	227
2019	9.8	206.5	2.4	50.3	0.006	1.9	259
2020	9.0	188.4	1.8	37.7	0.005	1.7	228

Figure 12 illustrates the individual contributions of sub-sectors to the total GHG emissions estimated from enteric fermentation and manure management. It shows clearly that methane emissions from enteric fermentation dominates the total GHG emissions by 86.6% followed by methane emissions from manure management (12.7%) and then direct N_2O emissions from manure management (0.7%). From the historic data it can inferred that enteric fermentation is the key category source in the agricultural sector and improvements in data activity and estimation process needs to be more robust.

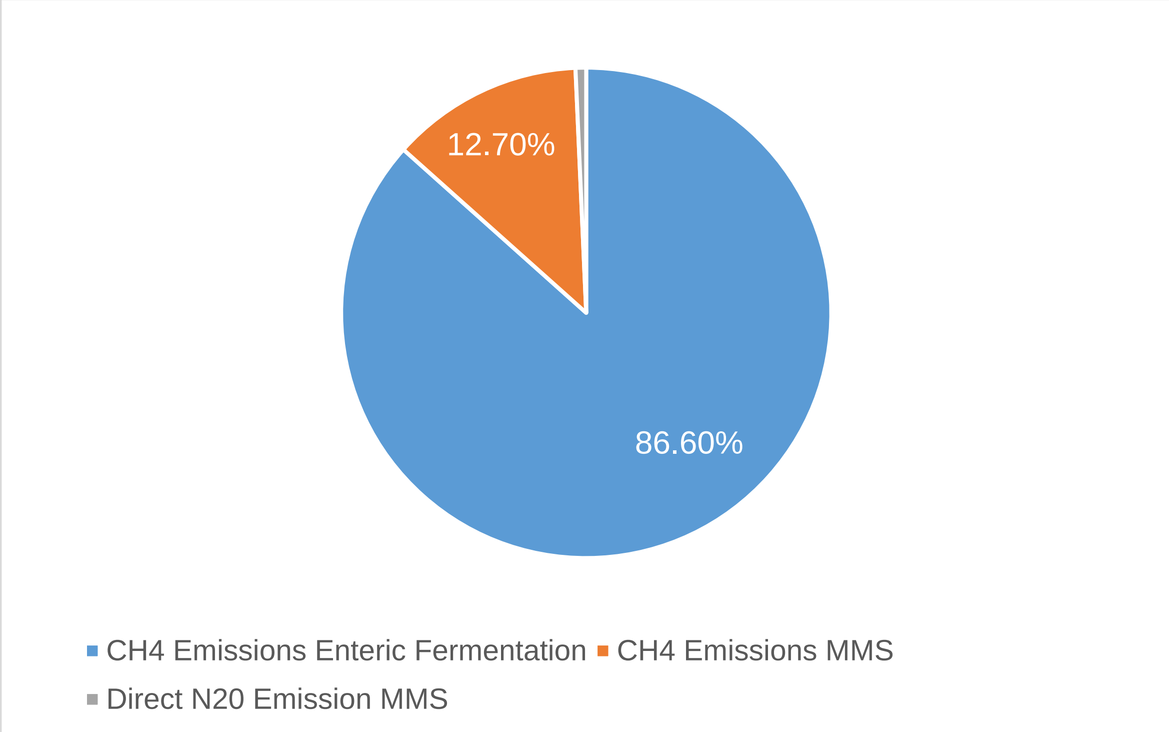


Fig. 12. Sub-sectoral contribution in percentage to the total GHG emissions reported in CO_2 eq.

5. Recommendations for Improvement

- Correct capturing and recording of animal population is very critical for a more robust GHGI for agricultural emissions. The FAOSTAT database could not be reconciled with the national animal survey, hence animal population data was estimated (linear regression or interpolation) using the national census data. There should be a dedicated section within the Ministry of Agriculture to generate database on animal population and data should be disaggregated in a format to enable GHG calculations. For example the data needs to be segregated into Dairy cattle, other cattle, breeding swine and marketing swine, Poultry- layers and Poultry – broilers. Also data should be collected for all farms rather than just supervised farms.
- Data on live weight, milk production should be noted so that EF could be corrected and a more appropriate EF could be used.
- The methane emissions from enteric fermentation is significant and is classified as a key source category for Fiji. In future the ruminant animal population is going to increase and perhaps Fiji should look into Tier 2 methodology for CH_4 emissions from enteric fermentation.
- For emissions from manure management it is critical to know the % usage of a particular manure management system, data needs to be captured correctly that reflects the nationwide practice. This data has been very poorly recorded to date.

6. Checklist

Methane Emission from Enteric Fermentation

	The following steps must be followed to collect data and calculate emissions from enteric fermentation:	**Status**	**Task completed by:**
1	Identify the approach as per the 2006 IPCC guidelines for National Greenhouse Gas Inventory to calculate CH_4 emissions from enteric fermentation. Also refer to the Decision tree for guidance. ☐Tier 1 ☐Tier 2 ☐Tier3		
2	Identify the key livestock categories for which the emissions need to be calculated for based on national data.		
3	Liaise with relevant stakeholders and list the total population		

	headcount for all key livestock categories for the last 20 years (you can go back even further if the data is available). ☐Dairy Cattle ☐Other Cattle ☐Swine (further disaggregate into breeding and market swine) ☐Sheep ☐Goats ☐Horses *Key stakeholder is the Ministry of Agriculture, Fiji.		
4	For each livestock category, document: ☐lifespan, years ☐ average annual live-weight, kg ☐feed intake, kg Also, for dairy cattle, document: ☐average annual milk production per head.		
5	Using the livestock category data in 7 and Table10.10, Table 10.11, Table 10A. 1 and Table 10A.2, select the default emission factor for each livestock category. ☐Dairy Cattle ☐Other Cattle ☐Swine (further disaggregate into breeding and market swine) ☐Sheep ☐Goats ☐Horses		
6	Calculate the Average Annual Population for all livestock that have a lifespan of less than one annual cycle.		
7	Calculate the total methane emissions from enteric fermentation using Equation 10.19 & 10.20 and the IPCC Workbook.		
8	Review the livestock data collection method, especially to see whether the livestock sub-species data were collected and aggregated (or disaggregated) correctly.		
9	Compare the data with those from previous years to ensure that the data is reasonable and consistent with the expected trend.		
10	Document the data collection method(s), identify potential areas of bias and comment on the representativeness of the data. If population modelling is used (extrapolation, interpolation, etc.), document this process as well for each livestock category. In cases where activity data was not available directly from databases, document the information and assumptions that were used to determine the activity data.		
11	List the source used to collect all activity data.		

Methane Emission from Manure Management

	The following steps must be followed to collect data and calculate emissions from manure management:	Status	Task completed by:
1	Identify the approach as per the 2006 IPCC guidelines for National Greenhouse Gas Inventory to calculate CH_4 emissions from manure management. Also refer to the Decision tree for guidance. ☐Tier 1 ☐Tier 2 ☐Tier3		

2	Identify the key livestock categories for which the emissions need to be calculated for based on national data.		
3	Liaise with relevant stakeholders and list the total population headcount for all key livestock categories for the last 20 years (you can go back even further if the data is available). ☐Dairy Cattle ☐Other Cattle ☐Swine (further disaggregate into breeding and market swine) ☐Sheep ☐Goats ☐Horses ☐Poultry (further disaggregated into layers and broilers) *Key stakeholder is the Ministry of Agriculture, Fiji.		
4	For each livestock category, document: ☐lifespan, years ☐ average annual live-weight, kg ☐feed intake, kg		
5	Document the average annual temperature (°C) for all the years as per the time series. *key source is the Fiji Meteorological Services.		
6	Using the information from 4 & 5 with reference to and Table10.14, Table 10.15, Table 10A.2 and Table 10A.4 – Table 10A.8, select the default emission factor for each livestock category. ☐Dairy Cattle ☐Other Cattle ☐Swine (further disaggregate into breeding and market swine) ☐Sheep ☐Goats ☐Horses ☐Poultry (further disaggregated into layers and broilers)		
7	Calculate the Average Annual Population for all livestock that have a lifespan of less than one annual cycle.		
8	Calculate the total methane emissions from manure management using Equation 10.22 and the IPCC Workbook.		
9	Review the livestock data collection method, especially to see whether the livestock sub-species data were collected and aggregated (or disaggregated) correctly.		
10	Compare the data with those from previous years to ensure that the data is reasonable and consistent with the expected trend.		
11	Document the data collection method(s), identify potential areas of bias and comment on the representativeness of the data. If population modelling is used (extrapolation, interpolation, etc.), document this process as well for each livestock category. In cases where activity data was not available directly from databases, document the information and assumptions that were used to determine the activity data.		
12	List the source used to collect all activity data.		

Nitrous Oxide Emissions from Manure Management.

	The following steps must be followed to collect data and calculate	Status	Task

	emissions from manure management:		**completed by:**
1	Identify the approach as per the 2006 IPCC guidelines for National Greenhouse Gas Inventory to calculate N_2O emissions from manure management. Also refer to the Decision tree for guidance. ☐Tier 1 ☐Tier 2 ☐Tier3		
2	Identify the key livestock categories and the manure management systems (refer to Table 10.18) for which the emissions need to be calculated for based on national data.		
3	Liaise with relevant stakeholders and list the total population headcount for all key livestock categories for the last 20 years (you can go back even further if the data is available). ☐Dairy Cattle ☐Other Cattle ☐Swine (further disaggregate into breeding and market swine) ☐Sheep ☐Goats ☐Horses ☐Poultry (further disaggregated into layers and broilers) *Key stakeholder is the Ministry of Agriculture, Fiji.		
4	Calculate the Average Annual Population for all livestock that have a lifespan of less than one annual cycle.		
5	For each livestock category, document: ☐lifespan, years ☐ average annual live-weight, kg		
6	Determine the default nitrogen excretion rate ($N_{rate(T)}$) form Table 10.19 and use Equation 10.30 to calculate the annual nitrogen excretion ($Nex_{(T)}$) for each livestock category.		
7	Determine the fraction of total annual nitrogen excretion for each livestock category that is managed in specific manure management systems.		
8	Determine the default emission factors for each manure management system identified from Table 10.21.		
9	Calculate the total nitrous oxide emissions from manure management using Equation 10.25 and the IPCC Workbook.		
10	Review the livestock data collection method, especially to see whether the livestock sub-species data were collected and aggregated (or disaggregated) correctly.		
	Document the process of manure management system allocation as per stakeholders.		
11	Compare the data with those from previous years to ensure that the data is reasonable and consistent with the expected trend.		
12	Document the data collection method(s), identify potential areas of bias and comment on the representativeness of the data. If population modelling is used (extrapolation, interpolation, etc.), document this process as well for each livestock category. In cases where activity data was not available directly from databases, document the information and assumptions that were used to determine the activity data.		
13	List the source used to collect all activity data.		

Annex 4

Fiji Agriculture Rice Cultivation Emissions – *Guidance Document & User Manual*
The following is a deliverable which was the outcome of the ICAT project. A National Expert, Dr. Deeksha Krishna, was engaged during the project to develop the guidance document and user manual to estimate GHG emissions from rice cultivation. This document focuses on estimating methane and nitrous oxide emissions that arise due to rice cultivation.

1. Introduction

The National Greenhouse Gas Inventory (NGGI) is compiled using the 2006 IPCC Guidelines for NGGI that has been divided into 5 volumes. This guidance document for greenhouse gas (GHG) emissions from rice cultivation has been developed with reference to Chapters 5 and 11 of the 2006 IPCC Guidelines for NGGI. Emphasis is placed on key categories[20] for methane (CH_4), nitrous oxide (N_2O) and carbon dioxide emissions from rice cultivation. This Manual provides methodology to help identify, build, and access the minimum set of activity data needed for GHG estimation. Required data is largely drawn from MOA, Fiji; Fiji Bureau of Statistics; Fiji National Agricultural Census and FAOSTAT Statistical Database,2021. Users are provided with step-by-step guidance on how to use this minimum set to build a default, yet complete national GHG emission dataset for agriculture and land use, which follows the default, Tier 1 approach of the Intergovernmental Panel on Climate Change (IPCC) Guidelines on National GHG Inventories. There are three different methodologies[21] that are used to determine the GHG emissions from rice cultivation: Tier 1, Tier 2 and Tier 3. The pros and cons of each methodology is discussed in Table 1.

Table A4-1: IPCC Inventory Tier Structure

Tier Level	Pros	Cons
Tier 1	• Basic • Require minimum information regarding activity data • Use default values provided in the 2006 IPCC Guidelines for NGGI.	• Does not capture country specific national circumstances • Potentially have large uncertainties
Tier 2	• Use country and region-specific emission factors • Has reduced uncertainty compared to	• Is more complex, thus requires detailed activity data.

[20] Prominent and significant source or sink of GHG in a country's NGGI
[2] "Good Practice" is to use advanced methodologies (Tier 2 or Tier 3) for Key Categories (depending on data availability for the specific country)
https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf

	Tier 1.	
Tier 3	• Detailed country specific modelling • Has the ability to test mitigation strategies using simulations. • Potentially low uncertainties.	• Model calibration/ validation may lack diversity. • It is considerably difficult to collect high resolution spatial data.

Principles for quality of GHG Inventory

It should have followed the below principles:

- **Transparency** : Sufficient information (Can the data be readily documented and shared with the public?)
- **Accuracy**: reduce bias (How close to reality is any of the estimated data being used?)
- **Completeness** : Documentation (Does the data adhere to the methods of the GHG inventory? Can the same methods be used year over year?
- **Consistency**: Between years Does the data adhere to the methods of the GHG inventory? Can the same methods be used year over year?
- **Comparability**: Between countries (allows it to be compared with national GHG inventories for other countries)

The GHG Inventory Compilation Cycle

The GHG Inventory management system helps inventory compilers manage the following seven stages of the GHG inventory compilation cycle.

1. Plan
2. Collect
3. Estimate
4. Write
5. Review
6. Finalize and submit report
7. Archive

Table A4-2- Sequence for task and schedule of GHG Inventory Preparation

Process	Relevant Organizations	Jan.	Feb.	Mar.	Apr	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec
1.Preparation	MOA,Fiji	→	→										
2 Data request	MOA,Fiji			→									
3 Data preparation	MOA,Fiji and MOE,Fiji				→								
4 Data Collection	MOA,Fiji				→	→							
5 Preparation of draft GHG inventory	MOA,Fiji					→	→						
6 Feedback on draft GHG inventory	Data Providing Organizations					→	→	→	→				
7 Finalizing GHG inventory	MOA,Fiji								→	→			
8 Publishing GHG inventory	PC										→	→	→

Aggregated Sources and Non-CO2 Emission Sources from Land (3C)

The "Aggregated sources and non-CO2 emission sources from Land" (3C) category comprise activities that produce emissions which are not covered under 3A or 3B. The GHG emissions activities under 3C are subdivided into:

- **Biomass Burning (3C.1)**
- **Liming (3C.2)**
- **Urea application (3C.3)**
- **Direct N2O emissions from managed soil (3C.4)**
- **Indirect N2O emissions from managed soil (3C.5)**
- **Rice cultivations (3C.7)**

*There is no biomass burning and lime application in rice cultivation in Fiji.

Data, sources, and methodology

This section provides an overview of the data, data sources and the description of the methodology applied in the inventory.

Data and data sources

The data used in this inventory were obtained from the Ministry of Agriculture and the FAOSTAT. The datasets were in different formats and had varying publishing periods. While some of the datasets were readily available online, those that were not readily available required special requests to the data providers. In cases, where the dataset was completely unavailable at the national, regional and international levels, expert judgement was used. In some cases, the data were available both nationally and internationally, but they were at variance. In such instances, the country-specific dataset was used instead of the one acquired from international sources. Table 3 provides an overview of the data, data source and data providers.

Table A4-3: Overview of the data and data sources in the inventory in Rice Cultivation (Fiji)

Categories		**Sub-categories**	**Data Type**	**Data Source**	**Principal Data Providers**	**Remarks**
3.C Aggregated and non-CO2 emissions on land						
3.C3		Urea application	Annual Urea consumption figures	Agric Facts and Figures	Ministry of Agriculture, Koronivia, Economic Planning and Stats department ,Raiwaqa	Data on Urea application from MOA and urea application rate were used to fill missing data for the time series
3.C4		Direct N2O emissions from manage soils	Annual generic NPK consumption	Agric Facts and Figures	Ministry of Agriculture, Koronivia , Economic Planning and Stats department ,Raiwaqa	Data on crop production from FAOSTAT were used to fill missing data for the time series
3.C5		Indirect N2O emissions from manage soils	Annual crop production in tonnes per annum			Data on crop production from FAOSTAT were used to fill missing data for the time series
3.C7		Rice cultivation	Annual rice production areas		Ministry of Agriculture, Koronivia , Economic Planning and Stats department ,Raiwaqa	Data on rice production from FAOSTAT were used to fill missing data for the time series. Expert judgement was used to split the proportions of rice cultivation areas under different production systems (upland rice, valley-bottom rise and rice under irrigation.

2. Methane Emissions from Rice Cultivation

1) Rice Cultivation

Definition: Greenhouse gas (GHG) emissions from rice cultivation consist of methane gas from the anaerobic decomposition of organic matter in paddy fields.

The anaerobic decomposition of organic material such as rice straw in flooded rice fields produce methane (CH4) by methanogenic bacteria. This methane escapes to the atmosphere primarily by transport through the rice plants. From the submerged soils, methane also escapes to the atmosphere through diffusion of dissolved methane and ebullition of gas bubbles. The annual amount of methane emitted from a given area of rice field is a function of the number and duration of crops grown, water regime before and during growing period, and the amount of organic and inorganic soil amendments. Soil type, temperature, and rice cultivar or variety also affect methane emissions.

Rice cultivation, for instance, also emits CH4 depending on where the rice cultivation occurs (ecosystem – upland rice, irrigated rice, and rainfed rice). Most of the CH4 emissions are from rainfed and irrigated rice cultivation based on rice flooding regime. The applicable data for the 3C in Fiji's situation is as follows:

- Quantities of nitrogen fertiliser and urea consumption and mode of application
- Areas of rice cultivations and quantities produced per year.

The main data source for this category was the Agriculture Facts and Figures published by the Ministry of Agriculture and the FAOSTAT.

2.1 Methodology and Quality Information Inform

As methane emissions from rice cultivation is not a significant source and country-specific emission factors were also not available, Fiji has applied the Tier 1 approach. Equations 5.1. and 5.3 in chapter 5.5, volume 4 of IPCC148 were applied to determine the methane emissions from rice production.149 Area and production data were taken over from a review of rice production. It is assumed that 50% of the total area planted is irrigated and the other 50% is rain fed. A total of 90 days cultivation was taken into consideration. Based on the production data, a rice-straw ratio of 1:2 is assumed to calculate the amount of straw produced. The amount of straw absorbed into the soil is determined on the basis of an equal mass basis equal to the dry weight of the straw

2.2 Basic GHG Emissions Calculation

The generic equation to calculate GHG emissions is:

$$GHG\ Emissions = Activity\ Data \times Emission\ Factors$$

Where:

Activity Data: magnitude of human activity (number of animals, tonnes of fertiliser applied, area of rice collected each year etc).

Emission Factor: coefficients for the emissions or removals per unit of activity data. (e.g., kg of CH_4 per area of rice). Tier 1, default IPCC emission factors, in g CH4 m-2 yr-1

Normally constant across the time series unless changes in technologies (e.g., change in management practice). For most emission factors, default values are available in the 2006 IPCC Guidelines, and other values are contained in the IPCC Emission Factor Database.

CH4 emissions from rice

Anaerobic decomposition of organic material in flooded rice fields produces methane (CH4), which escapes to the atmosphere primarily by transport through the rice plants.

The annual amount of CH4 emissions from a given area of rice is a function of:

- Cultivation period (days).
- Water regimes (before and during cultivation period).
- Organic amendments applied to the soil.
- Others (soil type, temperature, rice cultivar).

It is important to note that upland rice fields do not produce significant quantities of CH4.

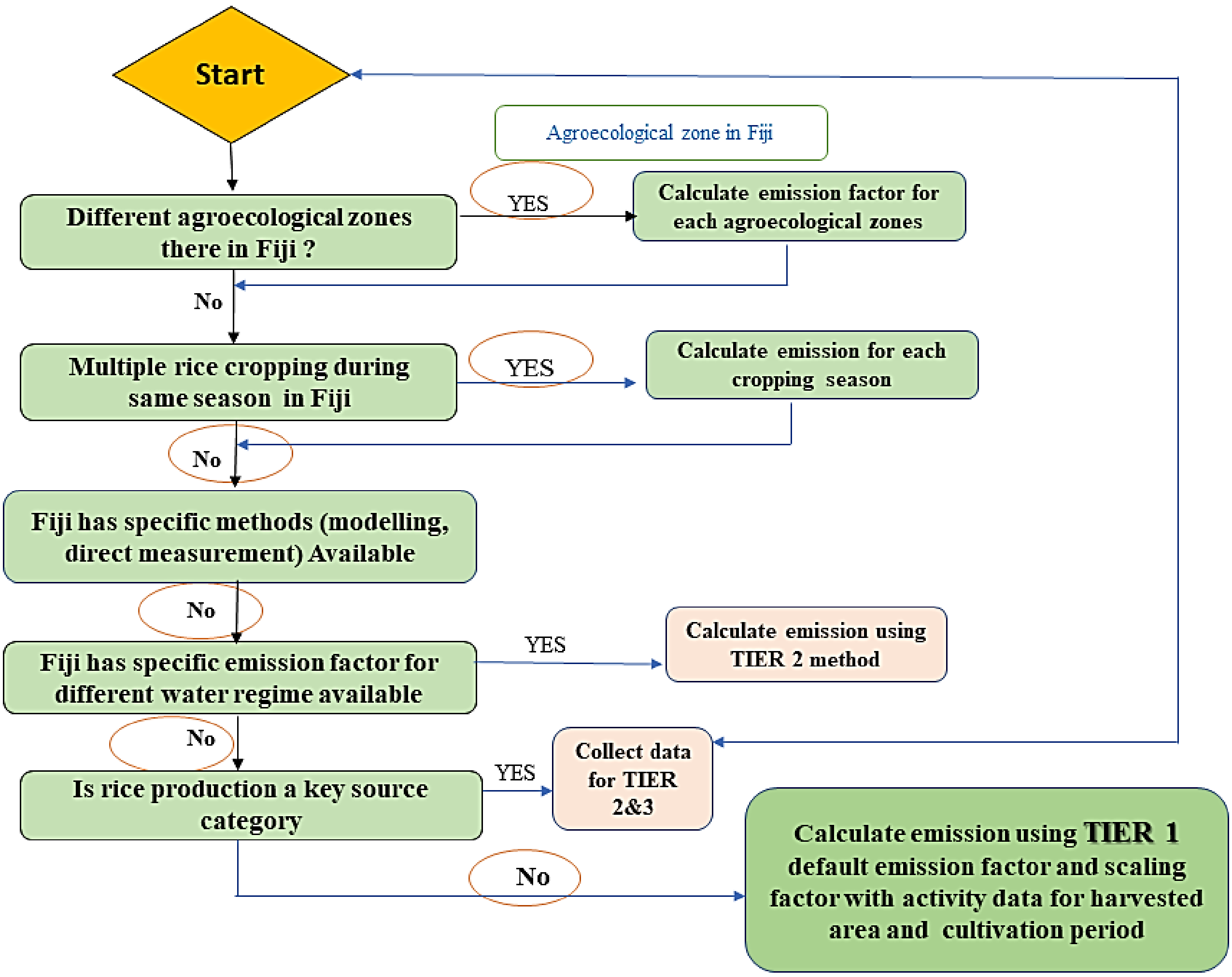


Fig 1. Decision tree for CH4 emission from rice production for Fiji

Note: Pathway indicated in green has been followed for Fiji calculation

CH4 emissions from rice cultivation are given by the basic equation follows Equation 5.1

$$CH_{4\ Rice} = \sum_{i,j,k} (EF_{i,j,k} \bullet t_{i,j,k} \bullet A_{i,j,k} \bullet 10^{-6})$$

Where:

CH4 Rice = annual methane emissions from rice cultivation, Gg CH4 yr-1

EFijk = a daily emission factor for i, j, and k conditions, kg CH4 ha-1 day-1

tijk = cultivation period of rice for i, j, and k conditions, day

Aijk = annual harvested area of rice for i, j, and k conditions, ha yr-1

i, j, and k = represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH4 emissions from rice may vary

What do the conditions **i, j,** and **k** represent in equation 5.1?

These variables represent the conditions that influence CH4 emissions from rice cultivation

Variable i - Water Regime	**Variable j - Organic Amendment to Soils**	**Variable k - Other Conditions**
Combination of (i) ecosystem type (i.e., irrigated, rainfed, and deep water rice production) and, (ii) flooding pattern (continuously/ intermittently flooded, regular	The impact on CH4 emissions depends on type and amount of the applied material, that can either be of (i) endogenous (straw, green manure, etc.) or (ii) exogenous origin (compost, farmyard manure, etc.)	It is known that other factors, such as soil type, rice cultivar or sulphate containing amendments can significantly influence CH4 emissions

rainfed, drought prone, and deep water).		

In order to estimate emissions from rice cultivation, use equation 5.1 (2006 GL)and apply the following steps:

- Due to the complexity and variability of rice production management, it is good practice to stratify the total harvested area into sub-units according to the i, j and k conditions, as well as the cultivation period and the emission factor (e.g., harvested areas under different water regimes).
- For each sub-unit, calculate the emissions by multiplying the respective emission factor by the cultivation period (t) and the annual harvested area (A).
- Then, sum the emissions from each sub-unit of harvested area to determine the total annual national emissions in rice cultivation

Calculating the adjusted daily emission factor requires applying equation 5.2 shown below equation 5.1 and 5.2 .

$$CH_{4\ Rice} = \sum_{i,j,k} (EF_{i,j,k} \bullet t_{i,j,k} \bullet A_{i,j,k} \bullet 10^{-6})$$

EQUATION 5.2
ADJUSTED DAILY EMISSION FACTOR

$$EF_i = EF_c \bullet SF_w \bullet SF_p \bullet SF_o \bullet SF_{s,r}$$

Where:

EF_i = adjusted daily emission factor for a particular harvested area

EF_c = baseline emission factor for continuously flooded fields without organic amendments

SF_w = scaling factor to account for the differences in water regime during the cultivation period (from Table 5.12)

SF_p = scaling factor to account for the differences in water regime in the pre-season before the cultivation period (from Table 5.13)

SF_o = scaling factor should vary for both type and amount of organic amendment applied (from Equation 5.3 and Table 5.14)

$SF_{s,r}$ = scaling factor for soil type, rice cultivar, etc., if available

EFi is calculated by multiplying a baseline emission factor EFc by various scaling factors (SF). Default values and methods needed to calculate the daily emission factors are provided by the 2006 IPCC Guidelines

CH4 emissions from rice: Components of Equation 5.2 The Baseline emission factor is for continuously flooded fields without organic amendments. The default value for EFc could be found in Table 5.11 shown below.

EF_c

Baseline emission factor

$$EF_i = EF_c \bullet SF_w \bullet SF_p \bullet SF_o \bullet SF_{s,r}$$

DEFAULT CH_4 BASELINE EMISSION FACTOR ASSUMING NO FLOODING FOR LESS THAN 180 DAYS PRIOR TO RICE CULTIVATION, AND CONTINUOUSLY FLOODED DURING RICE CULTIVATION WITHOUT ORGANIC AMENDMENTS

	Emission factor	Error range
CH_4 emission (kg CH_4 ha^{-1} d^{-1})	1.30	0.80 - 2.20

Source: Yan et al., 2005

This variable is used as a starting point and is then adjusted according to the scaling factors. It applies to areas with no flooded fields for less than 180 days, prior to rice cultivation and continuously flooded during the rice cultivation period without organic amendments.

Scaling factor to account for the differences in water regime during the cultivation period

SF_w

Water during cultivation

$$EF_i = EF_c \bullet SF_w \bullet SF_p \bullet SF_o \bullet SF_{s,r}$$

If Activity data are only available for rice ecosystem types, and not disaggregated for flooding patterns, use aggregated scaling factor.

apply disaggregated scaling factors whenever possible

Ecosystem	Water regime	Aggregated	Disaggregated
Upland		0	0
Irrigated	Flooded		1
	Single drainage	0.78	0.6
	Multiple drainage		0.52
Rainfed	Regular		0.28
	Drought	0.27	0.25
	Deep water		0.31

It is good practice to collect more disaggregated activity data on water regime during the cultivation and apply disaggregated scaling factors whenever possible. When activity data are only available for rice ecosystem types, and not disaggregated for flooding patterns, use aggregated scaling factor. For Inventory (Fiji) due to absence of data on different water regime (continuously flooded, intermediated single aeration , multiple aeration etc.) the aggregated a value for SFw is taken for calculation but once the values for water regime in 2022 will be available disaggregated scaling factors can be taken into account.

Scaling factor to account for the differences in water regime in the pre-season before during the cultivation period.

SF_p

Water before cultivation

$$EF_i = EF_c \cdot SF_w \cdot SF_p \cdot SF_o \cdot SF_{s,r}$$

apply disaggregated scaling factors whenever possible

CH_4 Emissions from Rice – SFp

Water regime	Aggregated	Disaggregated
Non flooded < 180 days		1
Non flooded > 180 days	1.22	0.68
Flooded > 30 days		1.90

It is good practice to collect more disaggregated activity data and apply disaggregated scaling factors whenever possible. For Inventory (Fiji) due to absence of data on different water regime prior to rice cultivation the aggregated a value for SFp is taken for calculation but once the values for water regime in 2022 will be available disaggregated scaling factors can be taken into account.

Scaling factor to account for type and amount of organic amendment applied.

Organic amendments applied to rice cultivation include compost, farmyard manure, green manure and rice straw. Equation 5.3 (2006 GL) below is used to find the value of organic amendments.

SF_0

Organic amendment

$SF_o = (1 + \sum_i ROA_i \cdot$

$$EF_i = EF_c \cdot SF_w \cdot SF_p \cdot SF_o \cdot SF_{s,r}$$

ROA $_i$ Application rate of organic amendment i, in dry weight for straw and fresh weight for others, tonne ha^{-1}. No default value is provided. National statistics, specific surveys and expert judgement should be used It is good practice to collect data Application rate of organic amendment in dry weight for straw and fresh weight. For Inventory (Fiji) due to absence of data on different application rate of organic amendment in dry weight for straw and fresh weight rice cultivation based on the production data, a rice-straw ratio of 1:2 is assumed to calculate the amount of straw produced. The amount of straw absorbed into the soil is determined on the basis of an equal mass basis equal to the dry weight of the straw taken for calculation but once the values for application rate of organic amendment in 2022 will be available disaggregated scaling factors can be taken into account.

$CFOA_i$ Conversion factor for organic amendment i (in terms of its relative effect with respect to straw applied shortly before cultivation) as shown in

TABLE 5.14
DEFAULT CONVERSION FACTOR FOR DIFFERENT TYPES OF ORGANIC AMENDMENT

Organic amendment	Conversion factor (CFOA)	Error range
Straw incorporated shortly (<30 days) before cultivation[a]	1	0.97 - 1.04
Straw incorporated long (>30 days) before cultivation[a]	0.29	0.20 - 0.40
Compost	0.05	0.01 - 0.08
Farm yard manure	0.14	0.07 - 0.20
Green manure	0.50	0.30 - 0.60

[a] Straw application means that straw is incorporated into the soil, it does not include case that straw just placed on the soil surface, nor that straw was burnt on the field.

Source: Yan *et al.*, 2005

Screenshot Added

Scaling factor to account for soil type, rice cultivar, etc.

$SF_{s,r}$ Other conditions

$$EF_i = EF_c \bullet SF_w \bullet SF_p \bullet SF_o \bullet SF_{s,r}$$

Both experiments and mechanistic knowledge confirm the importance of these factors, but large variations within the available data do not allow to define reasonably accurate default values.
IPCC guidance suggests that country-specific scaling factors should only be used if they are based on well-researched and documented measurement data, and if they are stratified by soil type and rice cultivar, at least.
Activity Data, is primarily based on harvested area statistics and should be available from a national statistics agency, as well as complementary information on cultivation period and agronomic practices.

$$CH_{4\ Rice} = \sum_{i,j,k} (EF_{i,j,k} \bullet t_{i,j,k} \bullet A_{i,j,k} \bullet 10^{-6})$$

- ✓ The activity data should be stratified according to the stratification of the scaling factors (i.e. cropping practices and water regime).
- ✓ Harvested area should, at a minimum, be disaggregated by three baseline water regimes as listed below:
- ✓ Irrigated.
- ✓ Upland
- ✓ Rainfed and Deep Water

If these data are not available in-country, they can be obtained from international data sources: e.g., International Rice Research Institute (IRRI), which include harvest area of rice by ecosystem type for major rice producing counties, a rice crop calendar for each country, and other useful information, and the FAOSTAT. Moreover table 4-11 of the Revised 1996 IPCC Guidelines provides data on harvested area and on ecosystem type by country or region.

Methodological Tier used for CH4 emission from rice cultivation in Fiji

Tier 1 **Applies to Fiji and countries in which either CH_4 emissions from rice cultivation are not a key category or country specific emission factors do not exist.** **The disaggregation of the annual harvest area for at least three baseline water regimes including irrigated, rainfed, and upland.** **Emissions adjusted by multiplying a baseline default emission factor by scaling factors**
Choice of emission factors
Tier 1 **A baseline emission factor for no flooded fields for less than 180 days prior to rice cultivation and continuously flooded during the rice cultivation period without organic amendments (EFc).Scaling factors are used to adjust the EFc to account for the various conditions, e.g..: water regime during and before cultivation period and organic amendments**
Choice of activity data
Activity data are primarily based on harvested area statistics, available from a national statistics agency as together with information on cultivation period and agronomic practices. **The activity data should be broken down by regional differences in rice cropping practices or water regime.** **National data is preferable but if not available, international datasets e.g., FAOSTAT can be used especially with Tier 1 methods.** **The use of locally verified areas correlated with available data for emission factors under differing conditions such as climate, agronomic practices, and soil properties is very useful especially for higher tier methods.**

In addition to the essential activity data requested above, it is good practice to match data on organic amendments and soil types to the same level of disaggregation as the activity data. It may be necessary to complete a survey of cropping practices to obtain data on the type and amount of organic amendments applied. The use of locally verified areas would be most valuable when they are correlated with available data for emission factors under differing conditions such as climate, agronomic practices, and soil properties. Therefore, it may be necessary to consult local experts for a survey of agronomic practices relevant to methane emissions (organic amendments, water management, etc.).

Fiji: The rice area and production data were taken over from a review of rice production paper (Bong et al 2017) the data was also taken from MPI and FAOSTAT.

1.	**Check list for Agriculture information compilers**
2.	**Activity Data**
✓ ✓ ✓ ✓	**Harvested area of rice ecosystems for each type rice cultivations and quantities produced per year. disaggregated by three baseline water regimes as listed below:** **Irrigated.** **Upland** **Rainfed and Deep Water**
✓ ✓ ✓ ✓	**Cultivation period (number of days) of rice for different ecosystems** **Irrigated.** **Upland** **Rainfed and Deep water**
✓	**water regime during the cultivation period different water regime (continuously flooded, intermediated single aeration, multiple aeration**
✓	**Organic amendments/ crop residues applied – type and amount**
✓	**Type of drainage for each area and ecosystem type**
✓	**Pre-season flooding (time/days)**
✓	**Rice cultivar**

✓ **Fraction of crop residue burnt**
✓ **Soil carbon change (if available)**
✓ **soil type,**

Moreover, the information on activity data that may be required to estimate CH_4 emissions from rice cultivation can be holistically outlined as:

2.3 Applicability to Fiji

In the GHG for Rice cultivation, this category refers to the anaerobic decomposition of organic material in flooded rice fields that produces methane, which escapes to the atmosphere primarily through air-bubbles and by being transported through the rice plants. The amount emitted is a function of the rice species, the number and duration of harvests, the soil type and temperature, the irrigation method, and fertilizer use.

The emission factor (EF) used to determine CH4 emission is the default value which is produced by IPCC. There are several regional (ecosystem) applicable to Fiji under which rice is planted. they are upland, continually flooded and rainfed.

Table A4-4: Activity data currently available Fiji

Data		**Data used for rice GHG inventory**	**Sources**
Available data	Aggregated data	• Number of crops • Duration of crops grown • Soil type • Air temperature • Rice cultivar • Area • Rice ecosystem type • Fertilizer applied rate	Rice division Ministry of Agriculture, Koronivia
		• Area • Yield	FAOSTAT/MPI,Fiji
		• Climate Data	Fiji Metrological data
Currently not available	Disaggregated data	• Water regimes before the cultivation period • Water regime during the cultivation period' • Organic and inorganic soil amendments • Type of drainage for each area • Soil temperature • flooding pattern before and during the cultivation period • Soil pH • Soil Eh (Redox potential) • *Production data will be available from Fiji Bureau of Statistics from 2022	*Not available in FAOSTAT and National Stats or expert advise

***Data may be available from 2022 -2023 by Rice division of Ministry of Agriculture, Koroniva will record this information.**

2.4 Examples of such calculations and the tables with results using Fiji's Activity Data for Rice Cultivation – Fiji**

1.Worked Example 1 with Fiji datasets * Data Source: Production data Fiji Census 2020

For calculation we use 3C7 Excel spreadsheet 1 and 2 from IPCC. Additional sheet can be inserted for rough calculations as done below.

Ar ea(ha)	300	ield(t)	Pr oduction	Fw	Fp	CFOA	SFo	esidu e	I	T otal Biomass	Cultiv ation days
Irr igated	.2	.5	1 150	.78	.22		.8781			7 .5	70

							22				
R ainfed	.44	.5	2 530	.27	.22					7 .5	90
Dr yland	.36		3 312							1 2	90

The solution is given below .

2.Worked Example 2:

Using the information below for the 4 ecosystems, calculate the CH_4 emissions from rice production.

<table>
<tr><td>Ecosystem 1
Irrigated continuously flooded ecosystem
No flooding pre-season < 180 day
Straw 4 t/ha incorporated 30 days' prior cultivation
150 days' cultivation period
500 ha area</td><td>Ecosystem 2
Rainfed deep water ecosystem
No flooding pre-season < 180 day
Straw 4 t/ha incorporated, 30 days' prior cultivation
120 days' cultivation period
100 ha area</td></tr>
<tr><td>Ecosystem 3
Rainfed deep water ecosystem
No flooding pre-season < 180 day
Farm yard manure 2 t/ha incorporated, 30 days prior cultivation
100 days cultivation period
50 ha area</td><td>Ecosystem 4
Irrigated multiple drainage ecosystem
No flooding pre-season < 180 day
Straw 4 t/ha incorporated, 30 days prior cultivation
150 days cultivation period
500 ha area</td></tr>
</table>

The solution is provided below.

Sector	**Agriculture, Forestry and Other Land Use**										
Category	**Rice Cultivation: Annual CH_4 emission fro*m rice(Example data for Fiji)***										
Category code	**3C7**										
Sheet	**1 of 2**										
Equation	**Eq. 2.2**	**Equation 5.1**		**Equation 5.2**			**Equation 5.3**			**Equation 5.2**	**Equation 5.1**
Rice Ecosystem	Subcategories for reporting year[1]	Annual harvested area	Cultivation period of rice	Baseline emission factor for continuously flooded fields without organic amendments	Scaling factor to account for the differences in water regime during the cultivation period	Scaling factor to account for the differences in water regime in the pre-season before the cultivation period	Application rate of organic amendment in fresh weight	Conversion factor for organic amendment	Scaling factor for both types and amount of organic amendment applied	Adjusted daily emission factor for a particular harvested area	Annual CH_4 emission from Rice Cultivation
		(ha yr^{-1})	(day)	kg CH_4 ha^{-1} day^{-1}	(-)	(-)	(tonnes ha^{-1})	(-)	(-)	(kg CH_4 ha^{-1} day^{-1})	Gg CH_4 yr^{-1}
				Table 5.11	Table 5.12	Table 5.13		Table 5.14	$SF_o = (1+ROA_i * CFOA_i)^{0.59}$	$EF_i = EF_c * SF_w * SF_p * SF_o * SF_{s,r}$	$CH_{4Rice} = A * t * EF_i * 10^{-6}$
		A	**t**	**EF_c**	**SF_W**	**SF_p**	**ROA_i**	**$CFOA_i$**	**SF_o**	**EF_i**	**CH_{4Rice}**
Irrigated		460	70	1.3	0.78	1.22	5	1	2.878	3.56	0.1146
	Sub-total										
Rainfed and deep water		1012	90	1.3	0.27	1.22	5	1	2.878	1.232	0.112
	Sub-total										
Total											**0.23**

[1] Rice ecosystem can be stratified according to water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary.

Sector	**Agriculture, Forestry and Other Land Use**
Category	**Rice Cultivation: Annual CH_4 emission fro*m rice***
Category code	**3C7**

Sheet	1 of 2										
Equation	**Eq. 2.2**	**Equation 5.1**		**Equation 5.2**			**Equation 5.3**			**Equation 5.2**	**Equation 5.1**
Rice Ecosystem	Subcategories for reporting year[1]	Annual harvested area	Cultivation period of rice	Baseline emission factor for continuously flooded fields without organic amendments	Scaling factor to account for the differences in water regime during the cultivation period	Scaling factor to account for the differences in water regime in the pre-season before the cultivation period	Application rate of organic amendment in fresh weight	Conversion factor for organic amendment	Scaling factor for both types and amount of organic amendment applied	Adjusted daily emission factor for a particular harvested area	Annual CH_4 emission from Rice Cultivation
		($ha\ yr^{-1}$)	(day)	$kg\ CH_4\ ha^{-1}\ day^{-1}$	(-)	(-)	($tonnes\ ha^{-1}$)	(-)	(-)	($kg\ CH_4\ ha^{-1}\ day^{-1}$)	$Gg\ CH_4\ yr^{-1}$
				Table 5.11	Table 5.12	Table 5.13		Table 5.14	$SF_o = (1+ROA_i * CFOA_i)^{0.59}$	$EF_i = EF_c * SF_w * SF_p * SF_o * SF_{s,r}$	$CH_{4Rice} = A * t * EF_i * 10^{-6}$
		A	**t**	$\mathbf{EF_c}$	$\mathbf{SF_W}$	$\mathbf{SF_p}$	$\mathbf{ROA_i}$	$\mathbf{CFOA_i}$	$\mathbf{SF_o}$	$\mathbf{EF_i}$	$\mathbf{CH_{4Rice}}$
Irrigated		500	150	1.3	1	1	4	0.29	1.58	2.05	0.15
		500	150	1.3	0.52	1	4	0.29	1.58	1.06	0.08
	Sub-total								3.15	3.11	0.23
Rainfed and deep water		100	120	1.3	0.31	1	4	0.29	1.58	0.63	0.01
		50	100	1.3	0.31	1	2	0.14	1.16	0.47	0.00
	Sub-total								2.73	1.10	0.01
Total											**0.24**

[1] Rice ecosystem can be stratified according to water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary.

3. Nitrous Oxide Emissions from Rice Cultivation

Nitrous oxide is produced naturally in soils through the processes of nitrification and denitrification.

Nitrification is the aerobic microbial oxidation of ammonium to nitrate, and **denitrification** is the anaerobic microbial reduction of nitrate to nitrogen gas (N_2). Nitrous oxide is a gaseous intermediate in the reaction sequence of denitrification and a by-product of nitrification that leaks from microbial cells into the soil and ultimately into the atmosphere. One of the main controlling factors in this reaction is the availability of inorganic N in the soil. This methodology, therefore, estimates N_2O emissions using human-induced net N additions to soils.

The emissions of N_2O that result from anthropogenic N inputs or N mineralisation occur through both a direct pathway (i.e., directly from the soils to which the N is added/released) and indirect pathways.

Direct emissions of N_2O from managed soils are estimated separately from indirect emissions, though using a common set of activity data. The Tier 1 methodologies do not take into account different land cover, soil type, climatic conditions or management practices (other than specified above). Neither do they take account of any lag time for direct emissions from crop residues N, and allocate these emissions to the year in which the residues are returned to the soil. These factors are not considered for direct or (where appropriate, indirect) emissions because limited data are available to provide appropriate emission factors.

3.1 Direct N2O emissions from managed soils

Nitrous oxide is produced naturally in soils through the processes of nitrification and denitrification.

The emissions of N2O due to anthropogenic N inputs occur through both a direct pathway (i.e. directly from the soils to which the N is added), and through two indirect pathways (i.e. through volatilisation as NH3 and NOx and subsequent redeposition, and through leaching and runoff)

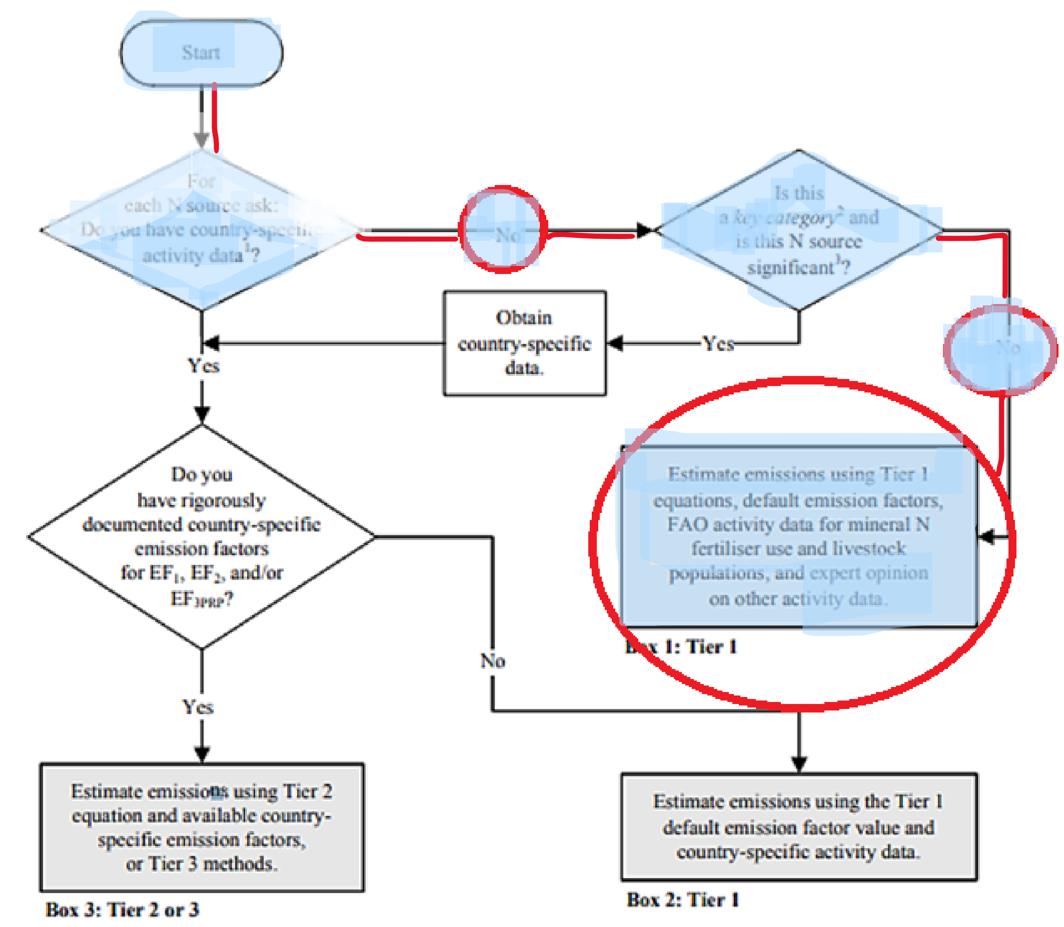
Full sectoral coverage of direct/indirect N2O emissions.

Revised emission factors for nitrous oxide from agricultural soils based on extensive literature review; and Removal of biological nitrogen fixation as a direct source of N2O because of the lack of evidence of significant emissions arising from the fixation process.

Decision tree

Upon considering the various conditions and analysing the country specific data available for Fiji, the decision tree illustrated in Fig. 2 is used to outline the pathway to choosing Tier 1 as the appropriate method to determine N_2O emissions from rice cultivation.

Figure 11.2 Decision tree for direct N_2O emissions from managed soils



Note:
1: N sources include: synthetic N fertiliser, organic N additions, urine and dung deposited during grazing, crop/forage residue, mineralisation of N contained in soil organic matter that accompanies C loss from soils following a change in land use or management and drainage/management of organic soils. Other organic N additions (e.g., compost, sewage sludge, rendering waste) can be included in this calculation if sufficient information is available. The waste input is measured in units of N and added as an additional source sub-term under F_{ON} in Equation 11.1 to be multiplied by EF_1.
2: See Volume 1 Chapter 4, "Methodological Choice and Identification of Key Categories" (noting Section 4.1.2 on limited resources), for discussion of *key categories* and use of decision trees.
3: As a rule of thumb, a sub-category would be significant if it accounts for 25-30% of emissions from the source category.

Fig 1 Decision tree for direct N2O emissions from rice cultivation

The pathway in the decision tree for Fiji is shown in blue colour for deciding the use of TIER 1 approach.

3. 3.2 Methodological tiers - Direct N2O emissions from managed soils used in Fiji 4.
5. Tier 1. 6. -Applies to countries in which either N2O emissions managed soils are not a key category or country-specific emission factors do not exist. 7. -use of IPCC defaults with national statistics or data from international datasets 8.
9. Choice of emission factors 10. Three emission factors required: 11. EF1 represents the amount of N2O emitted from the various nitrogen additions to soils; 12. EF2 represents the amount of N2O emitted from cultivation of organic soil; and 13. EF3PRP) estimates the amount of N2O emitted from urine and dung N deposited by grazing animals on pasture, range and paddock. 14. Country-specific factors should be used as far as possible in order to reflect the specific conditions of a country and the agricultural practices involved with suitable disaggregation

15.	**Data from countries with similar conditions or IPCC defaults can be used if national data is unavailable.**
16.	**Choice of Activity Data**
17.	**Several types of activity data are required, including:**
18.	**N inputs from application of synthetic fertilisers (FSN), animal manure (FAM)**
19.	**mineralisation of crop residues returned to soils (FCR)**
20.	**soil nitrogen mineralisation due to cultivation of organic soils (FOS)**
21.	**Urine and dung from grazing animals (FPRP)**
22.	**The data sources are:**
23.	**Synthetic fertiliser consumption data (FSN) should be collected from official statistics (e.g. national bureaux of statistics) or International Fertiliser Industry Association (IFIA), FAO.**
24.	**FAM should be calculated from the manure excreted and managed in MMS**
25.	**FCR from crop production data (national or FAO) and IPCC default fractions.**
26.	**The area (in hectares) of organic soils cultivated annually (FOS) can be obtained from official national statistics.**
27.	**Urine and dung from grazing animals (FPRP) can be calculated from number of livestock, N excretion rates and fractions of manure deposited on pastures.**

Direct N2O emissions from managed soils

$$N_2O_{Direct}\text{–}N = N_2O\text{–}N_{N\,inputs} + N_2O\text{–}N_{OS} + N_2O\text{–}N_{PRP}$$

$$N_2O\text{–}N_{N\,inputs} = \begin{bmatrix} \left[\left(F_{SN} + F_{ON} + F_{CR} + F_{SOM} \right) \bullet EF_1 \right] + \\ \left[\left(F_{SN} + F_{ON} + F_{CR} + F_{SOM} \right)_{FR} \bullet EF_{1FR} \right] \end{bmatrix}$$

$$N_2O\text{–}N_{OS} = \begin{bmatrix} \left(F_{OS,CG,Temp} \bullet EF_{2CG,Temp} \right) + \left(F_{OS,CG,Trop} \bullet EF_{2CG,Trop} \right) + \\ \left(F_{OS,F,Temp,NR} \bullet EF_{2F,Temp,NR} \right) + \left(F_{OS,F,Temp,NP} \bullet EF_{2F,Temp,NP} \right) + \\ \left(F_{OS,F,Trop} \bullet EF_{2F,Trop} \right) \end{bmatrix}$$

$$N_2O\text{–}N_{PRP} = \left[\left(F_{PRP,CPP} \bullet EF_{3PRP,CPP} \right) + \left(F_{PRP,SO} \bullet EF_{3PRP,SO} \right) \right]$$

Where:

N2ODirect –N = annual direct N2O–N emissions produced from agricultural soils, kg N2O–N yr-1

N2O–NNinputs = annual direct N2O–N emissions from N inputs to agricultural soils, kg N2O–N yr-1

N2O–NOS = annual direct N2O–N emissions from agricultural organic soils, kg N2O–N yr-1

N2O–NPRP = annual direct N2O–N emissions from urine and dung inputs to grazed soils, kg N2O–N yr-1

FSN = annual amount of synthetic fertiliser N applied to agricultural soils, kg N yr-1

FON = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to agricultural soils, kg N yr-1

FCR = annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N yr-1

FSOM = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N yr-1

FOS = annual area of managed/drained agricultural organic soils, ha (Note: the subscripts CG, Temp, Trop, NR and NP refer to Cropland and Grassland, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)

FPRP = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr-1 (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

EF1 = emission factor for N2O emissions from N inputs, kg N2O–N (kg N input)-1 (Table 11.1)

EF1FR is the emission factor for N2O emissions from N inputs to flooded rice, kg N2O–N (kg N input)-1
(Table 11.1) 5

EF2 = emission factor for N2O emissions from drained/managed organic soils, kg N2O–N ha-1 yr-1; (Note: the subscripts CG, Temp, Trop, NR and NP refer to Cropland and Grassland, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)

EF3PRP = emission factor for N2O emissions from urine and dung N deposited on pasture, range and
paddock by grazing animals, kg N2O–N (kg N input)-1; (Note: the subscripts CPP and

SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

3.3 N2O emissions factor from Flooded Cultivated Rice fields in Fiji

Nitrous oxide from flooded rice cultivated fields are different than N2O emission from other categories. Therefore, if you have flooded cultivated rice fields in Fiji you need to use this formula which includes an emission factor specific to rice wit N inputs computed for flooded rice.

EF_1 = emission factor for N2O emissions from N inputs, kg N2O–N (kg N input)-1(Table 11.1)

EF_{1FR} is the emission factor for N2O emissions from N inputs to flooded rice, kg N2O–N (kg N input)-1(Table11.1)*

Although there is some evidence that intermittent flooding can increase N2O emissions, current scientific data indicate that EF1Fr also applies to intermittent flooding situations.

Upland rice should be classified as a traditional crop (EF1).

$$N_2O\text{-}N_{N\,inputs} = (F_{ON} + F_{CR} + F_{SOM} + F_{SN}) \times EF_1 + (F_{ON} + F_{CR} + F_{SOM} + F_{SN})_{FR} \times EF_{1FR}$$

TABLE 11.1
DEFAULT EMISSION FACTORS TO ESTIMATE DIRECT N_2O EMISSIONS FROM MANAGED SOILS

Emission factor	Default value	Uncertainty range
EF_1 for N additions from mineral fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon [kg N_2O–N (kg N)$^{-1}$]	0.01	0.003 - 0.03
EF_{1FR} for flooded rice fields [kg N_2O–N (kg N)$^{-1}$]	0.003	0.000 - 0.006
$EF_{2\,CG,\,Temp}$ for temperate organic crop and grassland soils (kg N_2O–N ha^{-1})	8	2 - 24
$EF_{2\,CG,\,Trop}$ for tropical organic crop and grassland soils (kg N_2O–N ha^{-1})	16	5 - 48
$EF_{2F,\,Temp,\,Org,\,R}$ for temperate and boreal organic nutrient rich forest soils (kg N_2O–N ha^{-1})	0.6	0.16 - 2.4
$EF_{2F,\,Temp,\,Org,\,P}$ for temperate and boreal organic nutrient poor forest soils (kg N_2O–N ha^{-1})	0.1	0.02 - 0.3
$EF_{2F,\,Trop}$ for tropical organic forest soils (kg N_2O–N ha^{-1})	8	0 - 24
$EF_{3PRP,\,CPP}$ for cattle (dairy, non-dairy and buffalo), poultry and pigs [kg N_2O–N (kg N)$^{-1}$]	0.02	0.007 - 0.06
$EF_{3PRP,\,SO}$ for sheep and 'other animals' [kg N_2O–N (kg N)$^{-1}$]	0.01	0.003 - 0.03

Sources:
EF_1: Bouwman et al. 2002a,b; Stehfest & Bouwman, 2006; Novoa & Tejeda, 2006 in press; EF_{1FR}: Akiyama *et al.*, 2005; $EF_{2CG,\,Temp}$, $EF_{2CG,\,Trop}$, $EF_{2F,Trop}$: Klemedtsson *et al.*, 1999, IPCC Good Practice Guidance, 2000; $EF_{2F,\,Temp}$: Alm *et al.*, 1999; Laine *et al.*, 1996; Martikainen *et al.*, 1995; Minkkinen *et al.*, 2002: Regina *et al.*, 1996; Klemedtsson *et al.*, 2002; $EF_{3,\,CPP}$, $EF_{3,\,SO}$: de Klein, 2004.

3.4 N from Crop Residues

EQUATION 11.6
N FROM CROP RESIDUES AND FORAGE/PASTURE RENEWAL (TIER 1)

$$F_{CR} = \sum_T \left\{ \begin{array}{l} Crop_{(T)} \bullet Frac_{Renew(T)} \bullet \\ \left[\left(Area_{(T)} - Areaburnt_{(T)} \bullet C_f \right) \bullet R_{AG(T)} \bullet N_{AG(T)} \bullet \left(1 - Frac_{Remove(T)}\right) + Area_{(T)} \bullet R_{BG(T)} \bullet N_{BG(T)} \right] \end{array} \right\}$$

Where:

F_{CR} = annual amount of N in crop residues (above and below ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually, kg N yr^{-1}

$Crop_{(T)}$ = harvested annual dry matter yield for crop T, kg d.m. ha^{-1}

$Area_{(T)}$ = total annual area harvested of crop T, ha yr^{-1}

Area burnt $_{(T)}$ = annual area of crop T burnt, ha yr^{-1}

C_f = combustion factor (dimensionless) (refer to Chapter 2, Table 2.6)

$Frac_{Renew\,(T)}$ = fraction of total area under crop T that is renewed annually [15]. For countries where pastures are renewed on average every X years, $Frac_{Renew}$ = 1/X. For annual crops $Frac_{Renew}$ = 1

$R_{AG(T)}$ = ratio of above-ground residues dry matter ($AG_{DM(T)}$) to harvested yield for crop T ($Crop_{(T)}$), kg d.m. (kg d.m.)$^{-1}$,

= $AG_{DM(T)}$ ● 1000 / $Crop_{(T)}$ (calculating $AG_{DM(T)}$ from the information in Table 11.2)

$N_{AG(T)}$ = N content of above-ground residues for crop T, kg N (kg d.m.) $^{-1}$, (Table 11.2)

$Frac_{Remove(T)}$ = fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding and construction, kg N (kg crop-N)$^{-1}$. Survey of experts in country is required to obtain data. If data for $Frac_{Remove}$ are not available, assume no removal.

$R_{BG(T)}$ = ratio of below-ground residues to harvested yield for crop T, kg d.m. (kg d.m.)$^{-1}$. If alternative data are not available, $R_{BG(T)}$ may be calculated by multiplying $R_{BG\text{-}BIO}$ in Table 11.2 by the ratio of total above-ground biomass to crop yield (= [($AG_{DM(T)}$ ● 1000 + $Crop_{(T)}$) / $Crop_{(T)}$], (also calculating $AG_{DM(T)}$ from the information in Table 11.2).

$N_{BG(T)}$ = N content of below-ground residues for crop T, kg N (kg d.m.)$^{-1}$, (Table 11.2)

T = crop or forage type

EQUATION 11.7
3.5 DRY-WEIGHT CORRECTION OF REPORTED CROP YIELDS

EQUATION 11.7
DRY-WEIGHT CORRECTION OF REPORTED CROP YIELDS

$$Crop_{(T)} = Yield\ Fresh_{(T)} \bullet DRY$$

Where:
Crop(T) = harvested dry matter yield for crop T, kg d.m. ha-1
Yield_Fresh(T) = harvested fresh yield for crop T, kg fresh weight ha-1
DRY = dry matter fraction of harvested crop T, kg d.m. (kg fresh weight)-1
The regression equations in Table 11.2 may also be used to calculate the total above-ground residue dry matter,and the other data in the table then permit the calculation in turn of the N in the above-ground residues, the below-ground dry matter, and the total N in the below-ground residues. The total N addition, FCR, is the sum of the above-

and below-ground N contents. With this approach, FCR is given by Equation 11.7A

EQUATION 11.7A
ALTERNATIVE APPROACH TO ESTIMATE F_{CR} (USING TABLE 11.2)

$$F_{CR} = \sum_{T} \left\{ \begin{array}{l} Frac_{Renew(T)} \bullet \\ \left[\left[\left(Area_{(T)} - Area\,burnt_{(T)} \bullet CF \right) \bullet AG_{DM(T)} \bullet 1000 \bullet N_{AG(T)} \bullet \left(1 - Frac_{Remove(T)} \right) + Area_{(T)} \bullet \left(AG_{DM(T)} \bullet 1000 + Crop_{(T)} \right) \bullet R_{BG-BIO(T)} \bullet N_{BG(T)} \right] \right] \end{array} \right\}$$

It is recommended approach for crop residues.
Convert N2O–N emissions to N2O emissions.
N2O = N2O–N * 44/28.
Where :
Fcr= Residues returned to soil (kg dm ha-1)
Fcr= (Area -Area burnt * Cf) * AGdm* 1000 * Nag * (1-Frre) + (AGdm* 1000 + Yield) * Rbg* Nbg
Yield (kg dm ha-1)
Area (ha)
Area burnt (ha)
Cf (combustion factor) (Table 2.6)
AGdm(Mg/ha) = (Yield / 1000) * Slope + Intercept
Nag –N content of aboveground residues
Frre–fraction of aboveground residues removed
Rbg–ratio of roots to yield
Nbg–N content of roots

3.6 Example Calculation for N from Crop Residues

Fcr= Residues returned to soil (kg dm ha-1) = 18799
Fcr= (Area -Area burnt * Cf) * AGdm* 1000 * Nag * (1-Frre) + (AGdm* 1000 + Yield) * Rbg* Nbg
Yield (kg dm ha-1) = 2000(Yield wmha-1) * 0.89 (DRY) = 1780
Area (ha) = 500
Area burnt (ha) = 0
Cf (combustion factor) (Table 2.6) = 1
AGdm(Mg ha-1) = (Yield dm / 1000) * 0.95 + 2.46 = 4.36 (Table 11.2)
Nag –N content of aboveground residues (Table 11.2) = 0.007
Frre–fraction of aboveground residues removed = 0
Rbg–ratio of roots to yield (Table 11.2) = 0.16
Nbg–N content of roots (Table 11.2) = 0.009

Table 11.2
Default factors for estimation of N added to soils from crop residues [a]

Crop	Dry matter fraction of harvested product (DRY)	Above-ground residue dry matter $AG_{DM(T)}$ (Mg/ha): $AG_{DM(T)} = (Crop_{(T)}/1000) * slope_{(T)} + intercept_{(T)}$					N content of above-ground residues (N_{AG})	Ratio of below-ground residues to above-ground biomass (R_{BG-BIO})	N content of below-ground residues (N_{BG})
		Slope	± 2 s.d. as % of mean	Intercept	± 2 s.d. as % of mean	R^2 adj.			
Major crop types									
Grains	0.88	1.09	± 2%	0.88	± 6%	0.65	0.006	0.22 (± 16%)	0.009
Beans & pulses[b]	0.91	1.13	± 19%	0.85	± 56%	0.28	0.008	0.19 (± 45%)	0.008
Tubers[c]	0.22	0.10	± 69%	1.06	± 70%	0.18	0.019	0.20 (± 50%)	0.014
Root crops, other[d]	0.94	1.07	± 19%	1.54	± 41%	0.63	0.016	0.20 (± 50%)	0.014
N-fixing forages	0.90	0.3	± 50% default	0	-	-	0.027	0.40 (± 50%)	0.022
Non-N-fixing forages	0.90	0.3	± 50% default	0	-	-	0.015	0.54 (± 50%)	0.012
Perennial grasses	0.90	0.3	± 50% default	0	-	-	0.015	0.80 (± 50%)[l]	0.012
Grass-clover mixtures	0.90	0.3	± 50% default	0	-	-	0.025	0.80 (± 50%)[l]	0.016[p]
Individual crops									
Maize	0.87	1.03	± 3%	0.61	± 19%	0.76	0.006	0.22 (± 26%)	0.007
Wheat	0.89	1.51	± 3%	0.52	± 17%	0.68	0.006	0.24 (± 32%)	0.009
Winter wheat	0.89	1.61	± 3%	0.40	± 25%	0.67	0.006	0.23 (± 41%)	0.009
Spring wheat	0.89	1.29	± 5%	0.75	± 26%	0.76	0.006	0.28 (± 26%)	0.009
Rice	0.89	0.95	±19%	2.46	± 41%	0.47	0.007	0.16 (± 35%)	NA
Barley	0.89	0.98	± 8%	0.59	± 41%	0.68	0.007	0.22 (± 33%)	0.014
Oats	0.89	0.91	± 5%	0.89	± 8%	0.45	0.007	0.25 (± 120%)	0.008
Millet	0.90	1.43	± 18%	0.14	± 308%	0.50	0.007	NA	NA
Sorghum	0.89	0.88	± 13%	1.33	± 27%	0.36	0.007	NA	0.006
Rye[e]	0.88	1.09	± 50% default	0.88	± 50% default	-	0.005	NA	0.011

Table 11.2 (continued)
Default factors for estimation of N added to soils from crop residues [a]

Crop	Dry matter fraction of harvested product (DRY)	Above-ground residue dry matter $AG_{DM(T)}$ (Mg/ha): $AG_{DM(T)} = (Crop_{(T)}/1000) * slope_{(T)} + intercept_{(T)}$					N content of above-ground residues (N_{AG})	Ratio of below-ground residues to above-ground biomass (R_{BG-BIO})	N content of below-ground residues (N_{BG})
		Slope	± 2 s.d. as % of mean	Intercept	± 2 s.d. as % of mean	R^2 adj.			
Soyabean[f]	0.91	0.93	± 31%	1.35	± 49%	0.16	0.008	0.19 (± 45%)	0.008
Dry bean[g]	0.90	0.36	± 100%	0.68	± 47%	0.15	0.01	NA	0.01
Potato[h]	0.22	0.10	± 69%	1.06	± 70%	0.18	0.019	0.20 (± 50%)[m]	0.014
Peanut (w/pod)[i]	0.94	1.07	± 19%	1.54	± 41%	0.63	0.016	NA	NA
Alfalfa[j]	0.90	0.29[k]	± 31%	0	-	-	0.027	0.40 (± 50%)[n]	0.019
Non-legume hay[j]	0.90	0.18	± 50% default	0	-	-	0.015	0.54 (± 50%)[n]	0.012

[a] Source: Literature review by Stephen A. Williams, Natural Resource Ecology Laboratory, Colorado State University. (Email: stevewi@warnercnr.colostate.edu) for CASMGS (http://www.casmgs.colostate.edu/). A list of the original references is given in Annex 11A.1.

[b] The average above-ground residue:grain ratio from all data used was 2.0 and included data for soya bean, dry bean, lentil, cowpea, black gram, and pea.

[c] Modelled after potatoes.

[d] Modelled after peanuts.

[e] No data for rye. Slope and intercept values are those for all grain. Default s.d.

[f] The average above-ground residue:grain ratio from all data used was 1.9.

[g] Ortega, 1988 (see Annex 11A.1). The average above-ground residue:grain ratio from this single source was 1.6. default s.d. for root:AGB.

[h] The mean value for above-ground residue:tuber ratio in the sources used was 0.27 with a standard error of 0.04.

[i] The mean value for above-ground residue: pod yield in the sources used was 1.80 with a standard error of 0.10.

[j] Single source. Default s.d. for root:AGB.

[k] This is the average above-ground biomass reported as litter or harvest losses. This does not include reported stubble, which averaged 0.165 x Reported Yields. Default s.d.

[l] Estimate of root turnover to above-ground production based on the assumption that in natural grass systems below-ground biomass is approximately equal to twice (one to three times) the above-ground biomass and that root turnover in these systems averages about 40% (30% to 50%) per year. Default s.d.

[m] This is an estimate of non-tuber roots based on the root:shoot values found for other crops. If unmarketable tuber yield is returned to the soil then data are derived from Vangessel and Renner, 1990 (see Annex 11A.1) (unmarketable yield = 0.08 * marketable yield = 0.29 * above-ground biomass) suggest that the total residues returned might then be on the order of 0.49 * above-ground biomass. Default s.d.

[n] This is an estimate of root turnover in perennial systems. Default s.d.

[p] It is assumed here that grass dominates the system by 2 to 1 over legumes.

Example calculation:

Rice	Synthetic fertilizer used	Area(ha)	Crop residue
Managed	70 Kg N in 2 splits Calculated as 70*2=1400 112000	800ha	(500 tonnes) 19000*800/500= 30400
Flooded Rice	1500 ha X 140 Kg N fertilizer =210000	1500	57000

From Table 11.2 most of the information of all crops for N2O is provided and it also have some uncertainty covered in it depicted.

3.6 Worked Example (Direct N2O emission from Residue)

Sector		**Agriculture, Forestry and Other Land Use**							
Category		**Direct N_2O Emissions from Managed Soils**							
Category code		**3C4**							
Sheet		**1 of 2**							
Equation		**Equation 11.1**							
Anthropogenic N input type		Annual amount of N applied		Emission factor for N_2O emissions from N inputs		Annual direct N_2O-N emissions produced from managed soils			
		(kg N yr^{-1})		[kg N2O-N (kg N $input)^{-1}$]		(kg N_2O-N yr^{-1})			
				Table 11.1		N_2O-$N_{N\ inputs}$ = F * EF	G9*44/28	H9*298	I9/1000
		F		**EF**		**N_2O-$N_{N\ inputs}$**	**N2O(kg)**	**CO2e(Kg)**	CO2e(kt)
Anthropogenic N input types to estimate annual direct N_2O-N emissions produced from managed soils	synthetic fertilizers	F_{SN}: N in synthetic fertilizers	112000	EF_1	0.01	1120	1760	524480	524.48
	animal manure, compost, sewage sludge	F_{ON}: N in animal manure, compost, sewage sludge, other							
	crop residues	F_{CR}: N in crop residues	30400		0.01	304	478	142444	142.444
	changes to land use or management	F_{SOM}: N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management							

	synthetic fertilizers	F_{SN}: N in synthetic fertilizers	210000		0.003	630	990	262350	
	animal manure, compost, sewage sludge	F_{ON}: N in animal manure, compost, sewage sludge, other							
Anthropogenic N input types to estimate annual direct N_2O-N emissions produced from flooded rice	crop residues	F_{CR}: N in crop residues	57000		0.003	171	269	71209	
	changes to land use or management	F_{SOM}: N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management		EF_{1FR}					
Total									

28.	**3.7 Check list for Agriculture information compilers**
29.	**Activity Data for Direct N2O emission in Managed soils**
✓	**Harvested area and yield of rice ecosystems for each type rice cultivations and quantities produced per year. disaggregated by three baseline water regimes as listed below:**
✓	**Irrigated.**
✓	**Upland**
✓	**Rainfed and Deep Water**
✓	**Nitrogen applied per year and amount of synthetic fertilizers, animal manure, compost, sewage sludge, crop residues changes to land use or management added for different ecosystems per year**
✓	**Irrigated.**
✓	**Upland**
✓	**Rainfed and Deep water**

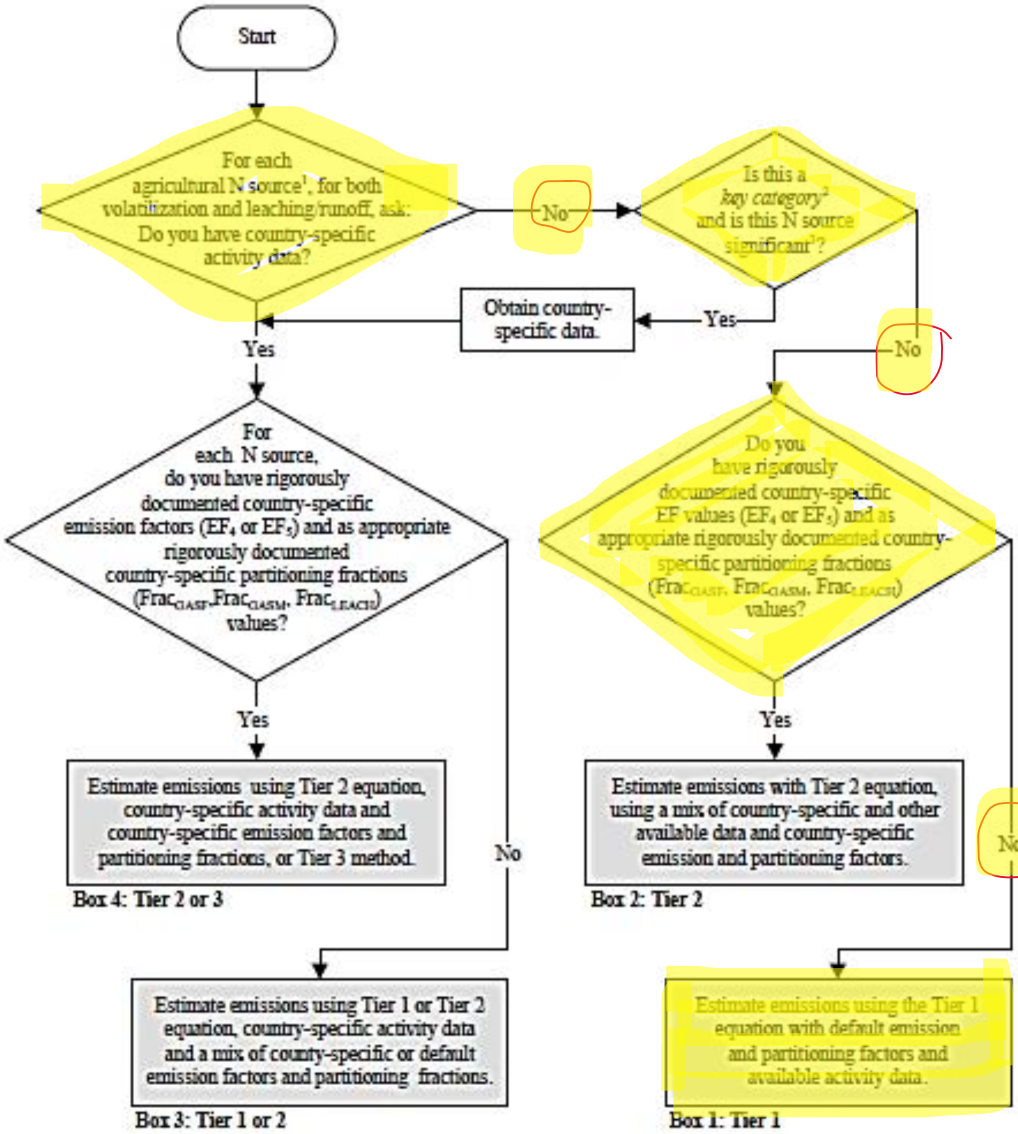
4.0 Indirect N2O emissions from managed soils

In addition to the direct emissions of N2O from managed soils that occur through a direct pathway (i.e., directly from the soils to which N is applied), emissions of N2O also take place through two indirect pathways:

volatilisation of N as NH3 and oxides of N (NOx), and the re-deposition as NH4+ and NO3 onto soils and the surface of lakes and other waters;

leaching and runoff from land of N.

Figure 11.3 Decision tree for indirect N_2O emissions from managed soils



Note: Pathway indicated in yellow has been followed for Fiji calculation.

TABLE 11.3 DEFAULT EMISSION, VOLATILISATION AND LEACHING FACTORS FOR INDIRECT SOIL N_2O EMISSIONS		
Factor	Default value	Uncertainty range
EF_4 [N volatilisation and re-deposition], kg N_2O–N (kg NH_3–N + NO_X–N volatilised)$^{-1}$ [22]	0.010	0.002 - 0.05
EF_5 [leaching/runoff], kg N_2O–N (kg N leaching/runoff) $^{-1}$ [23]	0.0075	0.0005 - 0.025
$Frac_{GASF}$ [Volatilisation from synthetic fertiliser], (kg NH_3–N + NO_x–N) (kg N applied) $^{-1}$	0.10	0.03 - 0.3
$Frac_{GASM}$ [Volatilisation from all organic N fertilisers applied , and dung and urine deposited by grazing animals], (kg NH_3–N + NO_x–N) (kg N applied or deposited) $^{-1}$	0.20	0.05 - 0.5
$Frac_{LEACH-(H)}$ [N losses by leaching/runoff for regions where Σ(rain in rainy season) - Σ (PE in same period) > soil water holding capacity, OR where irrigation (except drip irrigation) is employed], kg N (kg N additions or deposition by grazing animals)$^{-1}$	0.30	0.1 - 0.8
Note: The term $Frac_{LEACH}$ previously used has been modified so that it now only applies to regions where soil water-holding capacity is exceeded, as a result of rainfall and/or irrigation (excluding drip irrigation), and leaching/runoff occurs, and redesignated as $Frac_{LEACH-(H)}$. In the definition of $Frac_{LEACH-(H)}$ above, PE is potential evaporation, and the rainy season(s) can be taken as the period(s) when rainfall > 0.5 * Pan Evaporation. (Explanations of potential and pan evaporation are available in standard meteorological and agricultural texts). For other regions the default $Frac_{LEACH}$ is taken as zero.		

4.1 Volatilisation (N2O) – Tier 1

$$N_2O_{(ATD)}\text{–}N = \left[\left(F_{SN} \bullet Frac_{GASF} \right) + \left(\left(F_{ON} + F_{PRP} \right) \bullet Frac_{GASM} \right) \right] \bullet EF_4$$

Where:
N2O(ATD)–N = annual amount of N2O–N produced from atmospheric deposition of N volatilised from soils, kg N2O–N yr-1
FSN = annual amount of synthetic fertiliser N applied to soils, kg N yr-1
FracGASF = fraction of synthetic fertiliser N that volatilises as NH3 and NOx, kg N volatilised (kg of N applied)-1
FON = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N yr-1
FPRP = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr-1
FracGASM = fraction of applied organic N fertiliser materials (FON) and of urine and dung N deposited by grazing animals (FPRP) that volatilises as NH3 and NOx, kg N volatilised (kg of N applied or deposited)-1
EF4 = emission factor for N2O emissions from atmospheric deposition of N on soils and water surfaces, [kg N–N2O (kg NH3–N + NOx–N volatilised)-1]

Equation 11.9 (2006 GL)

4.2 Leaching/Runoff (N2O) – Tier 1

$$N_2O_{(L)}\text{–}N = \left(F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM} \right) \bullet Frac_{LEACH-(H)} \bullet EF_5$$

Where:
N2O(L)–N = annual amount of N2O–N produced from leaching and runoff of N additions to agricultural soils in regions where leaching/runoff occurs, kg N2O–N yr-1
FSN = annual amount of synthetic fertiliser N applied to soils in regions where leaching/runoff occurs, kg N yr-1
FON = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils in regions where leaching/runoff occurs, kg N yr-1
FPRP = annual amount of urine and dung N deposited by grazing animals in regions where leaching/runoff occurs,

kg N yr-1
FCR = amount of N in crop residues (above- and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually in regions where leaching/runoff occurs, kg N yr-1
FSOM = annual amount of N mineralised in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land use or management in regions where leaching/runoff occurs, kg N yr-1
FracLEACH-(H) = fraction of all N added to/mineralised in soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N (kg of N additions)-1
EF5 = emission factor for N2O emissions from N leaching and runoff, kg N2O–N (kg N leached and Runoff)-1 Equation 11.10 (2006 GL)

○	**4.3 Methodological Tiers**
○	**Tier 1.**
○	**-Applies to countries in which either indirect N2O emissions managed soils are not a key category or country-specific emission factors do not exist.**
○	**-Uses IPCC defaults with national statistics or data from international datasets.**
○	**Choice of emission factors**
○	**Emission factors and parameters required for indirect N2O from soils are:**
○	**EF associated with volatilised and re-deposited N (EF4)**
○	**EF associated with N lost through leaching/runoff (EF5)**
○	**fractions of N that are lost through volatilisation (FracGASF and FracGASM) or leaching/runoff (FracLEACH-(H))**
○	**Country-specific values for EF4 should be used with great caution because of the special complexity of trans-boundary atmospheric transport.**
○	**Choice of Activity Data**
○	**The activity data requirements for indirect N2O are the same as those for direct N2O from managed soils.**

30.	**4.4 Check list for Agriculture information compilers**
31.	**Activity Data for INDIRECT N2O emission in Managed soils**
✓	**Harvested area and yield of rice ecosystems for each type rice cultivations and quantities produced per year. disaggregated by three baseline water regimes as listed below:**
✓	**Irrigated.**
✓	**Upland**
✓	**Rainfed and Deep Water**
✓	**Annual amount of synthetic fertilizer N applied to soil in each ecosystems per year**
✓	**Irrigated.**
✓	**Upland**
✓	**Rainfed and Deep water**

5. CO2 Emissions from Urea Fertilization

Adding urea to soils during fertilisation leads to a loss of CO2 that was fixed in the industrial production process. Urea (CO(NH2)2) is converted into ammonium (NH4 +), hydroxyl ion (OH-), and bicarbonate (HCO3 -), in the presence of water and urease enzymes. Similar to the soil reaction following addition of lime, bicarbonate that is formed evolves into CO2 and water. This source category is included because the CO2 removal from the atmosphere during urea manufacturing is estimated in the Industrial Processes and Product Use Sector (IPPU Sector). Inventories can be developed using Tier 1, 2 or 3 approaches, with each successive Tier requiring more detail and resources than the previous. It is good practice for countries to use higher tiers if CO2 emissions from urea are a key source category

EQUATION 11.13
ANNUAL CO_2 EMISSIONS FROM UREA APPLICATION

$$CO_2\text{–}C\ Emission = M \bullet EF$$

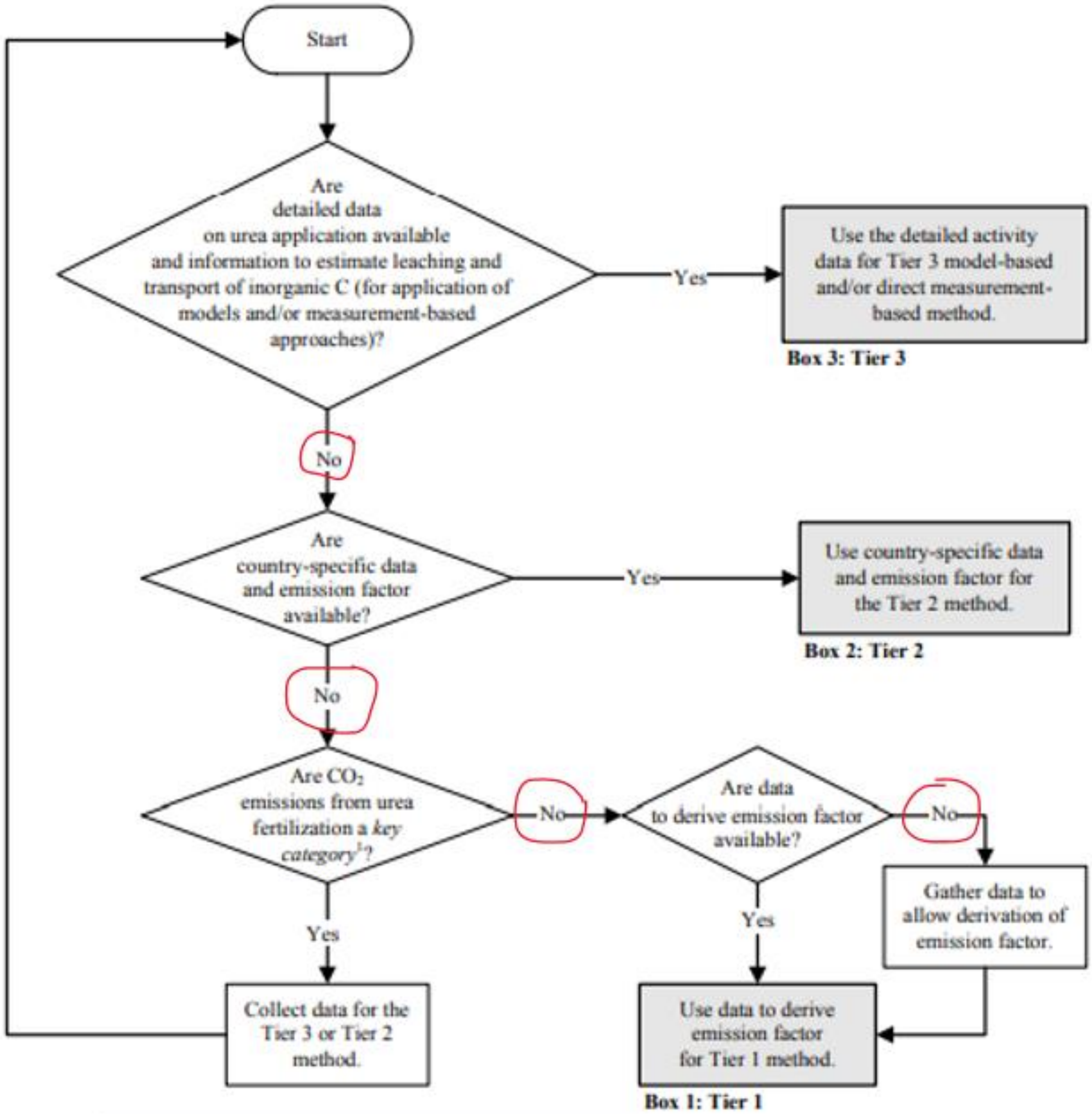
Where:

CO_2–C Emission = annual C emissions from urea application, tonnes C yr^{-1}

M = annual amount of urea fertilisation, tonnes urea yr^{-1}

EF = emission factor, tonne of C (tonne of urea)$^{-1}$

Figure 11.5 Decision tree for identification of appropriate tier to estimate CO2 emissions from urea fertilization.



Note: Highlight Fiji pathway.

Urea is applied to soils during fertilization and leads to loss of CO2 that was fixed in the industrial production process

- CO2 recovered for urea production is estimated in IPPU sector, CO2 emissions from the application of urea are estimated and reported where they occur (Energy, AFOLU, Waste)
- Inventories can be developed using tier 1, 2 and 3 approaches
- It is good practice for countries to use higher tiers if CO2 emissions from Urea fertilisation are a key source

category.

5.1 Methodological Tier 1 used for CO2 emissions from Urea fertilization in Fiji
- Estimate the total amount of urea applied to soils in the country (M) -Apply an overall EF of 0.20 for urea (equivalent to the carbon content of urea on atomic weight basis. -Estimate the total CO2-C emission based on the product of the amount of urea applied and the emission factors Multiply by 44/12 to convert CO2-C into CO2
Choice of emission factors Tier 1 The default emission factor (EF) is 0.20 for carbon emissions from urea applications
Choice of Activity Data Tier 1 Domestic production records and import/export data on urea can be used to obtain an approximate estimate of the amount of urea applied to soils on an annual basis (M) Supplemental data on sales and/or usage of urea can be used to refine the calculation, instead of assuming all available urea in a particular year is immediately added to soils

32.	5.2 Check list for Agriculture information compilers
33.	Activity Data for CO2 emissions from Urea fertilization in Managed soils
✓	Harvested area and yield of rice ecosystems for each type rice cultivations and quantities produced per year. disaggregated by three baseline water regimes as listed below:
✓	Irrigated.
✓	Upland
✓	Rainfed and Deep Water
✓	Annual amount of Urea applied for different ecosystems per year
✓	Irrigated.
✓	Upland
✓	Rainfed and Deep water

Uncertainty assessment

- ✓ Uncertainty assessment (Volume 1, Chapter 3)
- ✓ Cause of Uncertainty
- ✓ Lack of completeness
- ✓ Inappropriate models
- ✓ Lack of data
- ✓ Lack of representative data
- ✓ Statistical random sampling error
- ✓ Measurement error
- ✓ Misclassification

6.0 QA/QC and Verification (Volume 1, Chapter 6)

Quality Control (QC) are routine technical activities to assess and maintain the quality of the inventory:Consistency checks to ensure data integrity, correctness, and completeness.

Identify and address errors and omissions.

Document and archive inventory material, accuracy checks on data acquisition and calculations, and the use of approved standardised procedures.

Quality Assurance (QA) is a system of review procedures preferably by independent third parties upon a completed inventory.

Verification is a collection of activities and procedures normally conducted after completion of an inventory that can help to establish its reliability for the intended applications of the inventory.

7.0 COMPLETENESS Tier 1 Tier 1 inventories are complete if emissions are computed based on a full accounting of all urea that is applied to soils. Urea usage statistics or sales provide the most direct inference on applications to soils, but production and import/export records are sufficient for making an approximate estimate of the amount of urea applied to soils. If current data are not sufficient due to incomplete records, it is good practice to gather additional data for future inventory reporting, particularly if urea-C emissions are a key source category.

8.0 TIME SERIES CONSISTENCY Tier 1 The same activity data and emissions factors should be applied across the entire time series for consistency. At the Tier 1 level, default emission factors are used so consistency is not an issue for this component. However, the basis for the activity data may change if new data are gathered, such as a statistical survey compiling information on urea applications to soils versus older activity relying strictly on domestic production and import/export data. While it is good practice for the same data protocols and procedures to be used across the entire time series, in some cases this may not be possible, and inventory compilers should determine the influence of changing data sources on the trends. Guidance on recalculation for these circumstances is presented in Volume 1, of Chapter 5.