



Final Report

Tier II MRV of livestock emissions in China:

**Developing Guidance for Implementation at the
Provincial Level- Dairy cattle and swine**

(C-053-18)

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February 2020

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FOREWORD

The Cancun Agreement, reached at the Sixteenth Conference of the Parties (2010) to the United Nations Framework Convention on Climate Change (UNFCCC), proposed that non-Annex I countries should submit a biennial update report (BUR), including a national greenhouse gas (GHG) inventory. The guidelines for the BUR, agreed at the Seventeenth Conference of the Parties (2011), suggested that developing countries should submit relevant information including mitigation actions and effects, methodology and assumptions adopted. The Twenty-First Conference of the Parties adopted the Paris Agreement (2015), inviting developing countries to report regularly their national GHG inventories and progress on national emission reduction actions. The requirements for the submission of national GHG emission inventories and biennial transparency reports (BTR) were further clarified at the First Conference of the Parties to the Paris Agreement (2018) through the Modalities, Procedures and Guidelines for the Transparency Framework.

China attaches great importance to climate change, green and low-carbon development of agriculture, and explicitly proposes the development of low-carbon agriculture in its nationally determined contribution (NDC) communicated to the UNFCCC. Livestock is an important source of GHG emissions. Major livestock, such as dairy and swine, cause GHG emissions during production and waste management. Scientific measurement, reporting and verification of GHG emissions from livestock, increasing transparency of GHG emission accounting for the effects of actions to reduce emissions from livestock, exploring methods of collaboration on the reduction of GHG emissions, and improving livestock productivity and animal waste resource utilization are important to achieve sustainable development of livestock.

Supported by the CGIAR's Climate Change, Agriculture and Food Security program (CCAFS) and the Global Research Alliance on Agricultural GHGs (GRA), the Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences, in collaboration with the National Center for Climate Change Strategy and International Cooperation, and the Hebei Provincial Livestock Station, took dairy and swine as examples and proposed Provincial Guidance for Measurement, Reporting and Verification of GHG Inventories in China based on the IPCC Tier 2 method (Hereinafter referred to as "Provincial MRV Guidance", M means Measurement, R means Reporting and V means Verification). This Guidance includes 6 parts: introduction, Methodologies of estimation, Data requirement and Monitoring methods, Requirements and formats for reporting, Verification methods and Institutional arrangements for inventory compilation.

In order to verify the applicability of the "Provincial MRV Guidance", the project carried out three case studies including dairy cattle GHG emissions inventory for Hebei province, GHG emissions for an intensive dairy cattle farm and an intensive swine farm GHG emissions, respectively.

Three workshops including inception, consultation and Provincial MRV Guidance training workshop have been held on schedule. Through in-depth exchanges, review by domestic and international experts, and training of provincial MRV guidelines for animal husbandry, deliverables were successfully completed and submitted to Agriculture and Food Security program (CCAFS) and the New Zealand Agricultural Greenhouse Gas Research Centre.

"Provincial MRV Guidance" can be used to guide provinces, counties/cities and enterprises to compile livestock GHG inventories and assess the effectiveness of emission reduction actions. This guidance is expected to provide experience for China and other countries in monitoring, measurement, reporting and verification of GHG emissions from livestock, and to support efforts to tackle climate change and realize green and low-carbon development of livestock.

This Guideline was commissioned by the CGIAR through the international research project "CCAFS" and by the New Zealand Government to support the objectives of the Livestock Research Group of the Global Research Alliance on Agricultural Greenhouse Gases ([www. https://globalresearchalliance.org/](http://www.globalresearchalliance.org/)). *This work was implemented as part of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), which is carried out with support from CGIAR Fund Donors and through bilateral funding agreements, including with USAID. For details please visit <https://ccafs.cgiar.org/donors>. The views expressed in this document cannot be taken to reflect the official opinions of these organizations.*

1. PROJECT OBJECTIVES AND COMPLETION SITUATION

1.1 BACKGROUND

Countries are required to account for greenhouse gas (GHG) emissions and their mitigation under the UNFCCC's Paris Agreement, yet most countries are still developing their systems for the measurement, reporting and verification (MRV) of emissions in agriculture. Guidance from the IPCC exists to estimate impacts, yet implementation of MRV also requires tailoring to country needs and conditions.

In the livestock sector, accurate, comparable, consistent, complete and transparent MRV systems that can capture changes in emissions and sequestration from a range of practices and agroecological conditions are essential to guide the transformation to a low emissions future. Many countries with livestock emissions are seeking advanced GHG accounting to better reflect national circumstances and track mitigation due to productivity changes. To help countries improve accounting, CCAFS and experts across the globe are working together with countries to identify cost-effective technically sound MRV and the guidance, tools, and platforms that support them.

As part of its national accounting, China is now seeking to improve their MRV of emissions from livestock. This project supports that effort.

1.2 PURPOSE AND OBJECTIVES

The purpose of this study is to develop methods and systems for Tier II MRV of livestock emissions at provincial level (Hebei Province) in China.

The objectives of this project are: (1) Produce practical guidance; (2) Build capacity for Tier II MRV among province-level authorities; (3) Develop methods and that can be used to support Tier II MRV elsewhere.

1.3 RESEARCH PLAN

The research period of this project started at June 15th, 2018, and finished at February 29th, 2020. Three main activities were included in this project:

- **Activity 1: Develop IPCC tier II MRV guidance for livestock emissions**
 - **Description:** Review the current inventory system at the identified province, including institute arrangement, data availability and collection system, challenge for applying tier ii methodology; Develop guidance or protocols on how to measure, report and verify GHG emissions from livestock production systems based on Tier II, including identifying an appropriate animal classification, identifying activity data and parameters needs and calculation approach by using IPCC tier II, This activity will also include how to improve MRV system, data collection and the compilation of relevant parameters for the estimation of GHG emissions from livestock.
 - **Deliverables:** Draft Tier II MRV guidance on how to apply IPCC tier II on dairy cattle and pigs

- **Timeline:** June 15th, 2018 to March 30th, 2019
- **Activity 2: Consultation and planning implementation of guidance, through three workshops for project start-up, consultation, and training.**
 - **Description:** There will be three workshops. Details of arrangement will be set on the start-up workshop, including an implementation plan describing the tasks to be performed. On the consultation workshop on the Tier II MRV guidance, experts and government officials from national and provincial level will be invited, and they will evaluate the feasibility and science of the guidance, based on the comments of stakeholder, the Tier II guideline will be improved. On the training workshop, the Tier II MRV guidance will be introduced and studied by GHG inventory compliers from 10 different provinces.
 - **Deliverables:** Improved Tier II MRV Guideline, Trained personnel for using Tier II Guideline at province level. Meeting summary, attendance sheet.
 - **Timeline:** Start up workshop, June 15- July 15, 2018; Consultation workshop, January 1- February 1st, 2019; Training workshop, June 1st - July 1st, 2019;
- **Activities 3: Test implementation of Tier II MRV at provincial level.**
 - **Description:** Tier II MRV guidance of livestock emissions will be tested in Hebei province, to construct an inventory at provincial level and demonstrate the applicability of guidance, this would involve sourcing data, using expert judgment to fill in data gaps and calculating emission. The provincial test should include if the implementation of mitigation and its impact could be captured and where the mitigation impacts are expected. In addition, one pig farm and one dairy farm will be tested to ensure the guidance could be applied at project level and the mitigation option is applicable and impact is visible.
 - **Deliverables:** Analysis Report on the trial implementation at provincial levels
 - **Timeline:** March 1st, 2018 to September 30th, 2019

1.4 THE IMPLEMENTATION OF PROJECT

The implementation of project is in line with the time schedule of agreement, all the activities of the project were completed and reached the goals. three major goals were obtained: (1)Provincial Guidance for Measurement, Reporting and Verification of GHG Inventories in China based on the IPCC Tier 2 method (first version) was developed; (2) Three workshops have been hold on schedule, including inception, consultation and training workshops; (3) Tier II MRV guidance of livestock emissions has been tested at the provincial lever for dairy cattle, at farm level for one intensive pig farm and one intensive dairy farm, respectively. Through the three case studies, the feasibility of the “Provincial MRV Guidance” for animal husbandry was proved. The case study reports also provides a model for the application of “Provincial MRV Guidance” for provinces, counties/cities, other regions and intensive farms in China to MRV GHG inventory and emission reduction.

2. SUMMARY OF THE DELIVERABLES

2.1 THE STITUTION OF CHINA'S PROVINCIAL GHG INVENTORIES COMPILATION AND THE CHALLENGES OF USING IPCC TIER 2

The compilation of provincial-level GHG inventories is of great significance to comprehensively understand the characteristics and trends of GHG emissions in various regions of China, to formulate policies and measures to address climate change according to local conditions, and to reasonably allocate targets for the mitigation for each province.

China officially started the preparation of provincial GHG inventories in 2009, and selected seven provinces or cities as pilot for the compilation of provincial GHG inventories for year 2005. In September 2010, the national climate change authority issued the “Notice on Initiating the Preparation of Provincial GHG Inventory Work” (Climate department of NDRC [2010] No. 2350), which require all provinces to submit the provincial inventory reports of both 2005 and 2010. In January 2015, the national climate change authority further issued the “Notice on the work of the Provincial GHG Inventory in the Next Phase” (Climate department of NDRC [2015] 202), it is required that the all the provinces to start the preparation of provincial GHG inventories of 2012 and 2014 as soon as possible, on the basis of the existing inventory work.

In order to support the compilation of provincial GHG inventories, the national climate change authority invited the members of national experts’ team written and published "Provincial GHG Inventory Guidance (Trial)" in 2011. Provincial GHG Inventory Guidance (Trial) provided the default values of emission factors based on relevant data of China’s national GHG inventory. Based on the Tier 1 method and those default emission factors, the GHG emissions of all provinces for all sectors, including livestock sector were estimated and reported.

In terms of the provincial GHG inventory from livestock sector, 31 provinces have prepared GHG inventories of 2012 and 2014. Among them, only Beijing and Shanghai have adopted IPCC Tier 2 method, while another 29 provinces are currently using Tier 1 method to prepare GHG inventories from livestock sector. Because the current provincial inventory guidelines mainly based on the data of national inventory which use the default emission factors in the 1996 IPCC and IPCC Good Practice Guide, which could not reflect the rapid development of China's livestock industry, and the mitigation contribution of manure utilization policies and actions. Therefore, there is an urgent need to update provincial guidance for GHG inventories from livestock stock, the guidance help the provinces which could support national authority to measurement, reporting and verifying the emission and mitigation for key sources using Tier 2 method of the 2006 IPCC Guidelines.

2.2 DEVELOP IPCC TIER II MRV GUIDANCE FOR LIVESTOCK EMISSIONS

According to the 2006 IPCC Guidelines, Provincial guidance for measurement, reporting and verification of GHG inventories in China based on the IPCC Tier 2 method was developed, the guidance including methodologies of estimation, data collection and monitoring methods, requirements and formats for reporting, verification guidance and institutional arrangements for inventory compilation.

2.2.1 Determination scope of provincial livestock GHG inventory in China

Following the 2006 IPCC Guidelines, the emission sources of provincial GHG inventories in China include methane (CH₄) emissions from enteric fermentation, CH₄ emissions from manure management, and nitrous oxide (N₂O) emissions from manure management.

2.2.2 Methodologies of emissions factors based on IPCC tier 2

According to the 2006 IPCC Guidelines, The Provincial MRV guidance lists the accounting methods for the three emission sources based on Tier 2 methods. The emission factors for CH₄ emissions from enteric fermentation, CH₄ emissions from manure management, and N₂O emissions from manure management are calculated using the equation recommended by the 2006 IPCC guidelines. The selection of the parameter values contained in the calculation equations are provided according to local situation of Hebei Province, energy intakes, volatile solid content and N excretion by feeding situation and growth stage were calculated according to the surveyed data. The usage of manure management systems were also obtained from survey in the province for the provincial case, and from the real situation in the intensive dairy farm and intensive swine farm. Protein content in the feed was considered in the determination of N excretion.

2.2.3 Data requirements, monitoring, collection methods

(1) Steps to define categories and subcategories of livestock

According to the 2006 IPCC Guidelines, taking into account the large population of swine and dairy cattle production in China, the differences in local varieties and production levels, and the variety of feed, the animals should be further classified into subcategories. According to the production characteristics of animal husbandry in China, animals are classified into three feed situations: intensive feeding, backyard feeding and grazing. The effects of different age / growth stages of animals on CH₄ emission from enteric fermentation, CH₄ and N₂O emissions from manure management systems are also considered.

(2) Provided activity data collection method

The activity data (i.e. annual in stock of livestock) used in the provincial livestock GHG emission inventory mainly comes from the livestock statistical data in the Provincial Statistical Yearbook and statistical data on animal industry at provincial level. The year-end stock of swine and dairy cattle need to be compared with the data in the Yearbook of Animal Husbandry and Veterinary Medicine in China for the same year. The guidance provides a reference table for the sources that may provide activity data.

The activity data on dairy cattle and swine needed are the annual average number of livestock in different feeding situations and growth stages. The detailed description on how to obtain activity data under different feeding situations and growth stages is provided in the Provincial MRV Guidance.

(3) Provided key parameters collection method for emission factors

For animal production and feed data, considering the general parameters in the current statistical yearbook, it is recommended that the data of relevant industry associations be consulted first. On the basis of confirming that there is no industry association data, typical surveys, literature data, national inventory or default values of the IPCC guidelines should be adopted. For livestock manure characteristics data, in addition to the above methods, it can also use the national direct reporting system or pollution census data. The order of priority for collecting the three classes of parameters is as follows: Typical surveys/measurement > Literature data > Default values in national inventories > Default values in 2006 IPCC Guidelines.

In order to better reflect the actual production and management situation of the province, it is suggested in the guideline that inventory compilation agencies conduct typical surveys to obtain localized characteristic parameters. This guideline has formulated questionnaires on characteristic parameters, including animal population structure questionnaire, dairy cattle and swine production characteristic parameter questionnaire and animal manure management questionnaire.

2.2.4 Report on provincial GHG inventories for dairy cattle and swine.

The provincial GHG inventory report includes two parts, one is the inventory report, and the other is the inventory report form. The requirements and templates for the inventory compilation report and form are supplied.

The inventory compilation report includes summary, overview, institutional arrangement, description of the measurement and accounting process of three types of emissions (CH₄ emission from enteric fermentation, CH₄ and N₂O emission from manure management systems), uncertainty assessment, detailed description of the verification process for quality assurance and quality control.

In order to ensure the consistency and comparability of emission report, the guidance also gives a template for inventory reports. General information on guidance used, methods, sources of emission, GHG emissions and uncertainty were provided in the abstract section. General information on guidance used, methods, sources of emission, the process on obtaining of activity data, collection of other data, and inventory of GHG emissions, uncertainty, and verification. GHG emissions and uncertainty and the process for verification of the emissions were provided in the overview section. Emissions from different emission sources were separately reported under different chapter. For each chapter, activity data, monitoring and calculation of emission factors and key parameters, and estimation of GHG emissions were included. And finally, aggregated total emissions were conduct and a brief analysis on the composition of emissions was provided.

In the inventory report, there are 7 common format tables, including summary of GHG emissions from dairy cows or swine, activity data under different feeding situations and different growth stages, parameters and data used for the for determining CH₄ emission factors from enteric fermentation of dairy cattle, activity data and key parameters for determining CH₄ emission from manure management, manure management systems and corresponding CH₄ conversion factor and parameters related to dairy cattle and swine manure management and N₂O emissions.

2.2.5 Verification guidelines of provincial GHG inventories for dairy cattle and swine

In order to ensure transparency, accuracy, consistency, comparability, and completeness (TACCC) of the inventory, the coordinating authority or competent authority of the inventory preparation will require the verification of the inventory through the establishment of a quality control and quality assurance system. The verification table was designed for the internal quality control and external expert review of the inventory report.

There are 17 items 55 verification points in the verification checklist. For example, there are 4 verification points for methodological choice, 14 verification points for activity data collection, 29 verification points for emission factors, 4 verification points for calculation of emissions, and 4 for GHG emission reports. The

reviews of the emissions shall give the verification conclusions, description of the issues, and modification suggestions for each verification point.

2.2.6 Institutional arrangements for inventory compilation

The guidelines give suggestions for the establishment of a provincial inventory system for livestock. It is suggested that the inventory should be composed of Provincial coordinating agencies, steering committees and inventory compilation teams. The process and process of inventory preparation are listed in detail, and the key steps and time points required for the periodic compilation of GHG inventories are proposed.

2.3 PROJECT CONSULTING AND METHODOLOGY GUIDE TRAINING

Three workshops including inception, consultation and Provincial MRV Guidance training workshop have been hold on schedule. Through in-depth exchanges, review by domestic and international experts, and training of provincial MRV guidelines for animal husbandry, deliverables were successfully completed and submitted to Agriculture and Food Security program (CCAFS) and the New Zealand Agricultural Greenhouse Gas Research Centre.

(1) The inception workshops

The inception workshop was held on 14 August, 2018. Representatives from Ministry of Agriculture and Rural Affairs (MARA), Ministry of Ecology and Environment (MEE), Hebei Provincial Livestock Station, Chinese Academy of Agricultural Sciences (CAAS), and experts from the team members participated in workshop. Dr. Campbell Bruce and Dr. Lini Wollenberg from CCAFS participated the workshop and delivered presentations on introduction of the CCAFS project and how to implement CCAFS project. Dr. Hongmin Dong, Project investigator of the project reported the project implementation plan, including background, project objectives, activities and roadmap, and deliverables. The participants gave some suggestions for implementation of the project.

(2) Consultation workshop

Consultation workshop was held on 24 April, 2019. Representatives from Ministry of Agriculture and Rural Affairs (MARA), Ministry of Ecology and Environment (MEE), National Bureau of Statistics of China (NBS), National Development and Reform Commission (NDRC), National Center for Climate Change Strategy and International Cooperation (NCSC), Chinese Academy of Agricultural Sciences (CAAS), provincial livestock stations of Hebei, Shandong, Hubei, Sichuan, Tianjin, Inner Mongolia and project team members participated in the workshop. Dr. Sinead Christine Leahy from New Zealand Agricultural Greenhouse Gas Research Centre, Dr. Andreas Joshua Wilkes from Values for Development Ltd participated in the meeting and provided presentations how to implementation of CCAFS project, Dr. Li Yue presented the draft provincial MRV guidance, the participants gave more useful suggestions for improving the guidance.

(3) Training workshop

Training workshop on use of MRV Guidance was organized on 21 October, 2019. Representatives from Ministry of Agriculture and Rural Affairs (MARA), Ministry of Ecology and Environment (MEE), National

Center for Climate Change Strategy and International Cooperation (NCSC), 10 provincial livestock stations, including Beijing, Tianjin, Shanghai, Hubei, Heilongjiang, Hunan, Guangdong, Inner Mongolia, Jilin, Shandong, manager of dairy companies and project team members participated in the training workshop. Dr. Jelle Zijlstra from Wageningen University and Research participated the training workshop provided presentations on the mitigation options and experience of Netherlands. Professor Li Yue presented how to use the guidance for preparing the provincial livestock GHG inventory, and how to verify the emissions. The representatives and the participants from provinces suggested that the guidance should be released as soon as possible. They can use it to prepare the provincial livestock GHG inventory. The participants also expressed the requirement for further training and capacity building.

2.4 TEST IMPLEMENTATION OF TIER II MRV AT PROVINCIAL LEVEL

2.4.1 Case study of GHG inventory of dairy cattle in Hebei province

The case study for application of "Provincial MRV guidance" was carry out in Hebei province, the objective of the case study for dairy cattle is to test the applicability of)and provide examples of GHG inventory MRVs in provinces in China or other countries.

The data source of activity data of dairy cattle is Hebei statistical yearbook 2018. In 2017, the animal population in stock of dairy cattle in Hebei province was 1.246 million heads, the animal population in intensive feeding was 1.126 million heads, and animal population in backyard feeding was 122,400 heads, which accounted for 90.2% and 9.8% of the total dairy stocks, respectively. There was no grazing for dairy cattle in Hebei Province.

In accordance with the requirements of the typical survey of "Provincial MRV guidance" the field survey with sample sizes of 6 intensive dairy farms and 102 backyard dairy farms was conducted in Hebei Province, and the parameters of animal production characteristics, population structure in different growth stage, feeding situation, animal intake, feed quality, feed digestibility and manure management were obtained; Nitrogen excretion from dairy cows came from the second national pollution source survey.

In 2017, the GHG emissions from dairy cattle in Hebei Province were 4085.6 kilotons carbon dioxide equivalent (CO₂e). According to the analysis of emission sources, the CH₄ emission from enteric fermentation was the major emission sources, which contribute to 3035.1 kilotons CO₂e, accounting for 74.3% of total dairy emission; the CH₄ emission from manure management was 576.6 kilotons CO₂e, accounting for 14.1%; and the N₂O emission from manure management was 473.8 kilotons CO₂e, accounting for 11.6%. From the feeding situations, the emission of dairy cattle in intensive feeding was 3740.3 kilotons CO₂e, accounting for 91.5%; the emission of dairy cattle in backyard feeding was 345.3 kilotons CO₂e, accounting for 8.5%. From the type of gases, the main emissions were CH₄, with a total emission of 3611.8 kilotons CO₂e, accounting for 88.4%, and N₂O emissions of 473.8 kilotons CO₂e, and accounting for 11.6%.

The uncertainly of GHG emission was estimated by using error propagation equations provided in IPCC good practice guidance, the uncertainty range of CH₄ emission from enteric fermentation of dairy cattle is $\pm 20.8\%$, the uncertainty range of CH₄ emission from manure management is $\pm 35.0\%$, the uncertainty range of

N₂O direct emission from manure management is $\pm 61.3\%$, and the uncertainty range of N₂O indirect emission from manure management is $\pm 52.1\%$. The overall uncertainty of GHG inventory of dairy cows in Hebei province is $\pm 23.5\%$.

In accordance with the requirements and verification checklist of Provincial MRV guidance, the internal verification on adopted the method, activity data, calculation of emission factors, and related calculations for the preparation of GHG inventories for dairy cows in Hebei Province was implemented by the inventory compilation team. The calculation and value of the parameters, the calculation of the emissions of various GHG sources, and the report of GHG inventory were internally audited, and the problems existing in the data processing and accounting process were corrected. The inventory compilation team also invited the national experts and members of steering committee to conduct external reviews on the rationality of method and relevant parameters choice, emission calculation and GHG inventory report.

The Provincial MRV guidance can be used to analyze the effects of different mitigation scenarios. Taking manure management as an example, the Chinese government paid great attention to the utilization of livestock manure; it is proposed that compost and biogas are the main methods for manure management. By 2020, National livestock manure utilization rate will be reached 75%. Based on The Provincial MRV guidance, If all manure treated by the liquid storage both for intensive feeding situation and backyard feeding situation are treated by biogas digesters, change of manure management system from liquid storage to biogas digesters could reduce GHG emissions by 225.5 kt CO₂e, or reduction by 21.5% (1050.5 kt CO₂e vs 825.0 kt CO₂e), and the total GHG emissions of dairy cattle can be reduced by 5.5% due to the change of manure management system in Hebei province

2.4.2 Case study of GHG emissions from an intensive dairy cattle farm in Hebei province

The case study for application of "Provincial MRV guidance" was carry out in intensive dairy farm in Hebei province, the objective of the case study for intensive dairy farm is to test the applicability of "Provincial MRV Guidance" and provide examples of GHG inventory MRVs in China or in other countries.

This case was carried out on an intensive dairy farm located in Baoding city, Hebei Province. The GHG monitoring and accounting year is 2018. The animal population in stock of dairy cattle in case farm was 1,158 heads, of which 173 were calves, 369 were other cattle, and 616 were mature dairy cow.

In accordance with the requirements of the typical survey of "Provincial MRV Guidance", the parameters of animal production characteristics, population structure, feeding situation, feed intake, feed quality, feed digestibility and manure management were obtained; Nitrogen excretion from dairy cows came from the second national survey on pollution source.

In 2018, the GHG emissions from an intensive dairy cattle farm in Hebei Province were 5299.1 tons CO₂e. According to the analysis of emission sources, the CH₄ emission from enteric fermentation was the major emission sources, which contribute to 3321.0 tons CO₂e, accounting for 62.7% of total dairy emission; the CH₄ emission from manure management was 286.4 tons CO₂e, accounting for 5.4%; and the N₂O emission from manure management was 1691.7 tons CO₂e, accounting for 31.9%. Regarding to the growth stages, the emission of mature dairy cow was the major sources, which contribute to 3974.1 tons CO₂e, accounting for 75.0%; the

emission of other cattle was 1099.9 tons CO₂e, accounting for 20.8%, the emission of calves was 225.1 tons CO₂e, accounting for 4.2%. Regarding to the type of gases, the main emissions were CH₄, with a total emission of 3607.4 tons CO₂e, accounting for 68.1%, and N₂O emissions of 1691.7 tons CO₂e, and accounting for 31.9%.

In accordance with the requirements and verification checklist of "Provincial MRV Guidance", the internal verification on adopted the method, activity data, calculation of emission factors, calculation and value of the parameters, the calculation of the emissions of various GHG sources, and the report of GHG inventory for the preparation of GHG inventories for the intensive dairy farm in Hebei Province was implemented by the inventory compilation team. And the problems existing in the data processing and accounting process were corrected.

In this case study, more than 60 per cent of GHG emissions are from enteric fermentation. Therefore, the priority efforts should be given to reducing CH₄ emissions from enteric fermentation. Based on the production performance of the dairy farm in this case, it is recommended to promote the use of mineral licking bricks for lactating cows. Related studies have shown that adding mineral licking bricks can improve feed conversion efficiency and reduce enteric CH₄ emissions. If this technology is used in this case, the CH₄ conversion rate (Y_m) of mature dairy cows can be reduced from 6% to 5.5%. According to the method of the "Provincial MRV Guidance", the total CH₄ emissions from enteric fermentation can be reduced by 6.4%. The total GHG emissions of the case farm can be reduced by 4.0%.

2.3.3 Case study of GHG emissions from an intensive swine farm in Hebei province

The case study for application of "Provincial MRV guidance" was carry out in Hebei province, the objective of the case study for intensive swine farm is to test the applicability of "Provincial MRV guidance" and provide examples of intensive swine farm's GHG inventory MRVs in China or in other countries.

This case study is an intensive swine farm in Hebei province. The GHG measurement and reporting year is 2018. The main breeds of swine are Changbai and Dabai. The average annual stock of swine was 66,360, of which 15,000 were nursery, 44,160 were growing and finishing, and 7,200 were sows. In 2018, about 139 thousand fattening swine were slaughtered with an average slaughter weight of 110 kg. The average annual temperature of is 12.9 °C in this area in 2018.

Based on "Provincial MRV Guidance", tier 2 method is not used to calculate CH₄ emissions from swine enteric fermentation because swine are monogastric animals. Tier 2 method is used to calculate CH₄ and N₂O emissions from manure management.

The field survey was conducted on the studied farm. Values for the parameters of swine production characteristics, population structure in different growth stages, feed intake, feed quality, feed digestibility and usage of manure management systems were obtained; Nitrogen excretion of swine from different growth stages came from the second national survey on pollution source.

In 2018, the GHG emissions from the studied intensive swine farm were 11,446.9 tons CO₂e. According to the analysis of emission sources, the N₂O emission from manure management was the major emission sources, which contribute to 7567.1 tons CO₂e, accounting for 66.1% of total swine emission; the CH₄ emission from

manure management was 3,879.8 tons CO₂e, accounting for 33.9%. Regarding to the growth stage, the emission of growing-finishing swine was 8057.0 tons CO₂e, accounting for 70.4%; the emission of sows was 2023.2 tons CO₂e, accounting for 17.7%, and the emission of nursery was 1366.7 tons CO₂e, accounting for 11.9%.

In order to ensure the quality of GHG emission inventory in the studied intensive farm, the methods, activity data and emission factors applied in the inventory preparation process were verified in accordance with the requirements of verification check list of Provincial MRV Guidance.

In this case study, more than 65 per cent of N₂O emissions are from manure management. The priority mitigation efforts should be given to reducing N₂O emissions from manure management. Nitrogen excretion is a key factor to influence N₂O emissions from manure management. China is promoting the use of low-protein diet technology. This technology can reduce manure nitrogen excretion. If this technology is applied, then every 1% of reduction in crude protein content can lower 10% of nitrogen excretion in the swine farm. According to the "Provincial MRV Guidance", the total N₂O emission from manure management can be reduced by 10%, the total GHG emissions of the case farm can be reduced by 6.8%.

3. RECOMMENDATIONS

Based on the experience from the development of the Tier II MRV guideline and related case studies, a series of recommendations were proposed by the team.

3.1 RECOMMENDED USING THE PROVINCIAL MRV GUIDANCE FOR PROVINCIAL LIVESTOCK INVENTORY IN CHINA AS SOON AS POSSIBLE

IPCC Tier 2 can better reflect management practices in different production systems or regions. The estimation results using IPCC Tier 2 can reflect the impacts of feed characteristics, animal productivity and manure management. Therefore, the application provincial MRV guidance based on IPCC Tier 2 method is essential to guide the transition of traditional practices to a green, and low-carbon, and circular livestock production system. The provincial MRV guidance will provide support for quantitative evaluation of mitigation effects and actions which committed in the national determined contributions (NDCs). It is recommended that the national climate change authority, based on further consultation with relevant agency and experts, issue the provincial MRV guidance for the implementation at provincial level as early as possible.

3.2 RECOMMEND TO ENHANCE CAPACITY BUILDING OF PROVINCIAL AUTHORITY AND EXPERTS

Due to the large number and wide variety of parameters involved in the compilation of the GHG inventory of livestock sector, it faces challenge to collect and obtain relevant data, such as production performance, feed intake, feed digestibility, identification and determination of manure management system etc. It is recommend to enhance the capacity building through training and case studies, to ensure the inventory compiling institution at provincial level can understand and familiar with provincial MRV guidance based on IPCC Tier 2 method. The provincial inventory compiling institution can scientifically carry out data collection and inventory

calculation. It is recommended to develop software to facilitate the application of provincial MRV guidance for the preparation of GHG inventories of livestock sector.

3.3 RECOMMEND TO OPTIMIZE MITIGATION TECHNOLOGY BASED ON PROVINCIAL MRV GUIDANCE

(1) Improving livestock production management

The case study of this project shows that, although the GHG emission factors of individual animals are high in intensive feeding farms, due to the increase in milk production of cows, but their productivity have been significantly improved and GHG emissions per unit of product has been significantly lowered. It is recommended to increase the proportion of intensive feeding farms to improve dairy industry and mitigation GHG per unit of milk.

(2) Demonstrate application of low protein diets

The case study of the swine farm shows that the promotion of low-protein diet technology can reduce nitrogen excretion, not only improve feed conversion efficiency, but also reduce N₂O emissions.

(3) Improve manure management system

The case study results show that liquid manure collection and storage management systems were applied extensively in intensive feeding farms, which results in CH₄ and N₂O emissions from manure management are significantly higher than those of backyard farming. It is recommended to promote the application of composting and anaerobic digestion with biogas utilization, which could enhance manure land application and GHG mitigation.

4. CONCLUDING REMARKS

Special thanks to CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and the New Zealand Government to support the objectives of the Livestock Research Group of the Global Research Alliance on Agricultural Greenhouse Gases for funding this project.

Special thanks to the Ministry of Agriculture and Rural Affairs, the Ministry of Ecology and Environment, and the National Bureau of Statistics for their guidance and support.

This project delivered a Provincial MRV guidance and three case studies reports. We hope that these deliverables can contribute to the improvement of measurement, reporting and verification of provincial GHG inventory from livestock in China and other regions.

The cooperation between the Chinese Academy of Agricultural Sciences and CGIAR- CCAFS as well as GRA has made good progress. The team hopes to extend the cooperation to make further improvements and develop software tool of Provincial MRV guidance. It is expected that application of guidance in China and in other countries could provide support for promoting low-carbon and green development of the global livestock industry.

5. ANNEX

Annex 1 Provincial Guidelines for Measurement, Reporting and Verification of Greenhouse Gas Inventories in China's livestock based on IPCC Tier 2 approach—— Dairy cattle and Swine

Annex 2 Case study for dairy cattle GHG emissions inventory in Hebei province

Annex 3 Case study for an intensive dairy cattle farm GHG emissions.

Annex 4 Case study for an intensive swine farm GHG emissions.