RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

Final report

Carbon Footprint Assessment and

Mitigation Options of Dairy under Chinese Conditions

（C-067-18）

December 2019

TABLE OF CONTENTS

FOREWORD

With the rapid human population growth and economic development, demand for animal products continues to increase and livestock production rapidly expands. Greenhouse gases (GHG) emission from livestock research 7.52 billion tons CO_2-eq per year, accounting for 50% of agricultural emissions and 18% of global anthropogenic GHG emissions (FAO, 2014), making it become an important source of GHG emissions. The Chinese livestock production emits 373 GHG of million tons CO_2-eq. Methane (CH_4) emitted from enteric fermentation is 10.74 million tons (equivalent to 225.6 million tons CO_2-eq), accounting for 60.7% of total livestock GHG emissions. CH_4 emitted from manure management is 3.33 million tons (equivalent to 69.9 million tons CO_2-eq), accounting for 18.9% of total livestock GHG emissions. Nitrous oxide (N_2O) emitted from manure management is 0.25 million tons (equivalent to 77.2 million tons CO_2-eq), accounted for 20.4% of the total livestock GHG emissions (MEE, 2018). The enteric fermentation and manure management contribute 40% to agricultural GHG emissions.

Expansion of livestock production results in high demand of feedstuffs, bringing greater pressure on natural resources. It is of particular concern that the livestock sector has already been a major user of natural resources. For example, approximately 35% of total cropland and 20% of green water have been used for animal feed production (Opio et al., 2013). Feed-related emissions represent about half of total emissions from livestock supply chains (Gerber et al., 2013). Therefore, it is very important to evaluate GHG emissions from the whole life cycle of livestock production.

Besides improved manure utilization and water usage efficiency, management of carbon emissions and carbon footprint is highlighted as an important research topic. This project is expected to identify and execute appropriate interventions for reducing carbon footprint and economic cost of dairy production.

1. INTRODUCTION

1.1 Background

Large scale dairy farms in China have become the main body and the mainstream model of dairy farming, where milk yields have reached 6.4 tons (cow yr)$^{-1}$ and where the quality of raw milk has been improved largely. However, due to poor manure management and the local but also national mismatch between crop farming and dairy farming, the increase in production at large scale farms, almost always very with limited land has for a large extend been realized through the imports of feeds like alfalfa hay from all over the world. This make Chinese dairy sector faces risks of high price and environmental pressures.

A sustainable livestock development is one of the key issues. Besides improved manure utilization and water resource efficiency, management of carbon emissions and carbon footprint is highlighted as an important research topic. This project is expected to identify and execute appropriate interventions for reducing carbon footprint and economic cost of dairy production.

1.2 Purpose and objectives

The purpose of this study is to develop a model on assessment of carbon footprint and practice inventory to significantly reduce the carbon footprint of the dairy sector in China.

The objectives of this project are: (1) develop a model and tool that can be used to evaluate the carbon footprint of dairy cattle; (2) provide practice inventory of mitigation measures for reducing carbon footprint and cost of milk.

1.3 Research plan

The research period of this project started at July 15th, 2018, and finished at December 15th, 2019. Four main activities were included in this project:

- **Activity 1: Develop carbon footprint model for dairy sector under China conditions**
    - **<u>Description:</u>** Carbon footprint model based on life cycle assessment (LCA) method will be developed to assess greenhouse gas (GHG) emissions or CF associated with the whole process of dairy production, including feed

production (crop planting, feed processing, and transportation), enteric fermentation, manure management and energy consumption.

  - **Deliverables:** Carbon footprint model based on life cycle assessment (LCA) method
  - **Timeline:** July 15th, 2018 to August 30th, 2019

- **Activity 2: Develop a database for carbon footprint assessment of dairy cattle in China**
  - **Description:** Build up a database with baseline information of 100 farms which include different production systems in different regions, such as large scale intensive farms, small-scale farms, and grazing farms in south China, middle China and north China. The database includes information on number of animals, average milk production, feed consumption and feed compositions, manure management, etc. The idea is to use this database to identify a spectrum of representative farms which is used to make assessment of carbon footprint and mitigation intervention.
  - **Deliverables:** A database with data of more than 100 farmers.
  - **Timeline:** July 15th , 2018- December 1st, 2019;
- **Activity 3: Assessment of carbon footprint for respective Dairy farms**
  - **Description:** Based on model and database developed in activity 1 and activity 2, carbon footprint (CF) of different production system in different regions will be assessed based on China's actual production conditions. In this activity, the GHG contribution from feed production (feed crop production, transportation, processing), enteric fermentation, manure management, energy consumption will be carefully analyzed, and hotspots of GHG contribution will be identified.
  - **Deliverables:** carbon footprint and its distribution of the whole production chains
  - **Timeline:** January 1st ,2019- March 1st, 2019
- **Activities 4: Identify the mitigation practice**
  - **Description:** An inventory or handbook on the mitigation practice will be carried out based on the model and identified mitigation measures for hotspot of GHG contribution. To identify the mitigation options, baseline

and projected for current and mitigation practice will be measured and calculated, and the impact of adopted mitigation interventions on cost price of milk production will be estimated bases on case study. The effects of different interventions will be extrapolated to all farms in the database, if appropriate, to estimate their effect at other farms or at a national level.

- **Deliverables:** Hand book and Analysis Report on mitigation practice
- **Timeline:** March 1st, 2019 to December 30th, 2019

1.4 Partner and their roles

- **Partner 1:** China Agricultural University (CAU).
  - Role and deliverables: Lead for whole project, implement activity 2 and 4, Cooperate work with activity 3
  - Responsible person: Li Shengli, Professor of College of Animal Science, CAU

Partner 2: Institute of Environment and Sustainable Development in Agriculture (IEDA), Chinese Academy of Agricultural Sciences (CAAS).

  - Role and deliverables: Co-lead for whole project, implement activity1and 3, cooperate work with activity 4.
  - Responsible person: Dong Hongmin, deputy director general, IEDA-CAAS

- **Partner 3:** Wageningen University & Research (WUR)
  - Role and deliverables: Cooperate work with activity 1, 3 and 4.

  Responsible person: Kees de Koning, Manager Dairy Campus, WUR

- **Partner 4:** Climate Change, Agriculture and Food Security (CCAFS)
  - Role and deliverables: Support on research design, facilitating partnership, support for publications and disseminating results.
  - Responsible person: Lini Wollenberg , Flagship Leader for Low Emissions Development for CCAF

2. SUMMARY OF THE DELIVERABLES

The deliverables and conclusion of the programme between China and Netherlands are summarized in methodology, database, mitigation option and a series of recommendations. The recommendations reflects a summary of findings and evaluation outcomes identified through the project activities completed and project meetings held during the one and half year project period.

2.1 A model and tool of carbon footprint assessment of dairy

Carbon footprint model based on life cycle assessment (LCA) method was developed in this project by the Institute of Agricultural Environment and Sustainable Development (IEDA), Chinese Academy of Agricultural Sciences (CAAS). The methodology guideline aims to introduce a harmonized scientific approach to the assessment of environmental footprint of milk production chain. It aims to promote understanding of milk supply chains and help improve their environmental performance.

Three GHG closely related to livestock production are included in the carbon footprint of milk production, namely CO_2, CH_4 and N_2O. Their global warming potential values are 1, 25 and 298, respectively (IPCC 2007). The annual production cycle was selected as the evaluation period for carbon footprint assessment.

The system boundary of this research covers production processes from “cradle” to “farm-gate” (Figure 2-1), including: (1) Feed planting and processing: direct and indirect emissions of N_2O in the process of N fertilizer manufacture and their subsequent application for feed planting; fossil fuel CO_2 emissions from the manufacture of plastic sheeting and pesticides, application of urea during feed planting, and machinery use during feed planting, such as ploughing, seeding and harvesting; (2) CH_4 emissions from enteric fermentation and manure management; (3) direct and indirect N_2O emissions from the manure management chain (housing, manure storage and treatment); (4) CO_2 emissions from energy generation and consumption on farm, including electricity, coal and gasoline; (5) direct and indirect emission of N_2O from manure application to produce feed (after manure has left the livestock farm); CO_2 emissions from energy consumption during manure application.

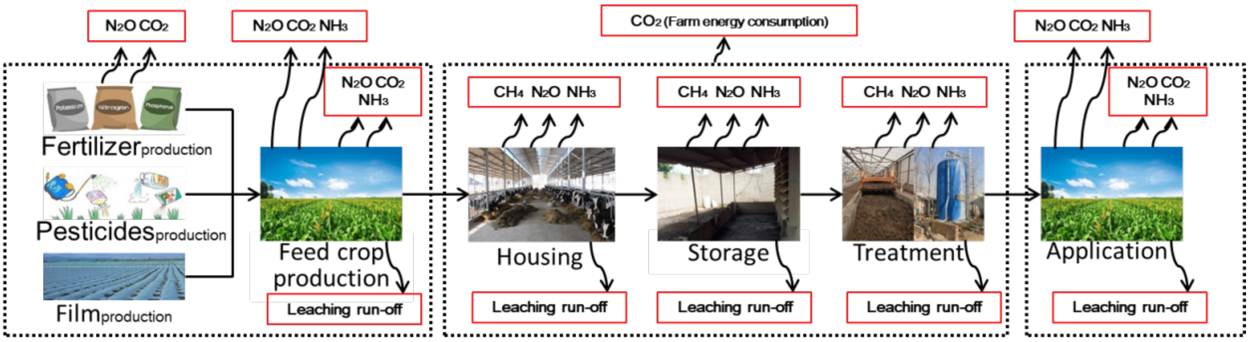

Figure 2-1 System boundary for carbon footprint assessment of dairy production

The total emissions from an intensive dairy production system is the sum of total of greenhouse gas emissions from feed cultivation and processing after allocation, CH_4 emissions from enteric fermentation, manure management and land application of manure, and GHG emissions from energy consumption on the dairy farm. The total system emissions are divided by the value of the standard annual total output of dairy farms. The calculation formula of milk carbon footprint is as follows:

$$CF_{milk} = \frac{[G_{feed} \times AF_{feed\,i} + G_{enteric} + G_{manure} + G_{land} + G_{energy}]}{M_{FPCM}} \times AF_p \qquad \textbf{(1-1)}$$

Where:

CF_{milk} : carbon footprint of milk production on the dairy farm, kg CO_2-eq kg $FPCM^{-1}$ (Fat and protein correction milk)

G_{feed} : GHG emissions from feed production, t CO_2-eq

$AF_{feed\,i}$: allocation factors of main and by-products of feed

$G_{enteric}$: GHG emissions from enteric fermentation, t CO_2-eq

G_{manure} : GHG emissions from manure management, t CO_2-eq

G_{land} : GHG emissions from land application of manure, t CO_2-eq

G_{energy} : GHG emissions from energy consumption, t CO_2-eq

M_{FPCM} : annual standard milk production on the dairy farm, t FPCM

AF_p : allocation factor for greenhouse gas emissions from the whole system.

The guideline "Method for Carbon Footprint Assessment of Milk Production in Intensive Dairy Farms" is shown in Annex 1.

2.2 Software tool of dairy carbon footprint

According to the dairy carbon footprint model, we have developed visual software system for computing model (Annex 2). The functions of the software include: (1) assess the carbon footprint of the individual farm or company; (2) provide GHG emission mitigation options for farms or companies through scenario analysis; (3) provide a report to farms or companies to show their farm carbon footprint performance, and give recommendation to reduce their carbon footprint. The interface of software tool is shown in Figure 2-2.

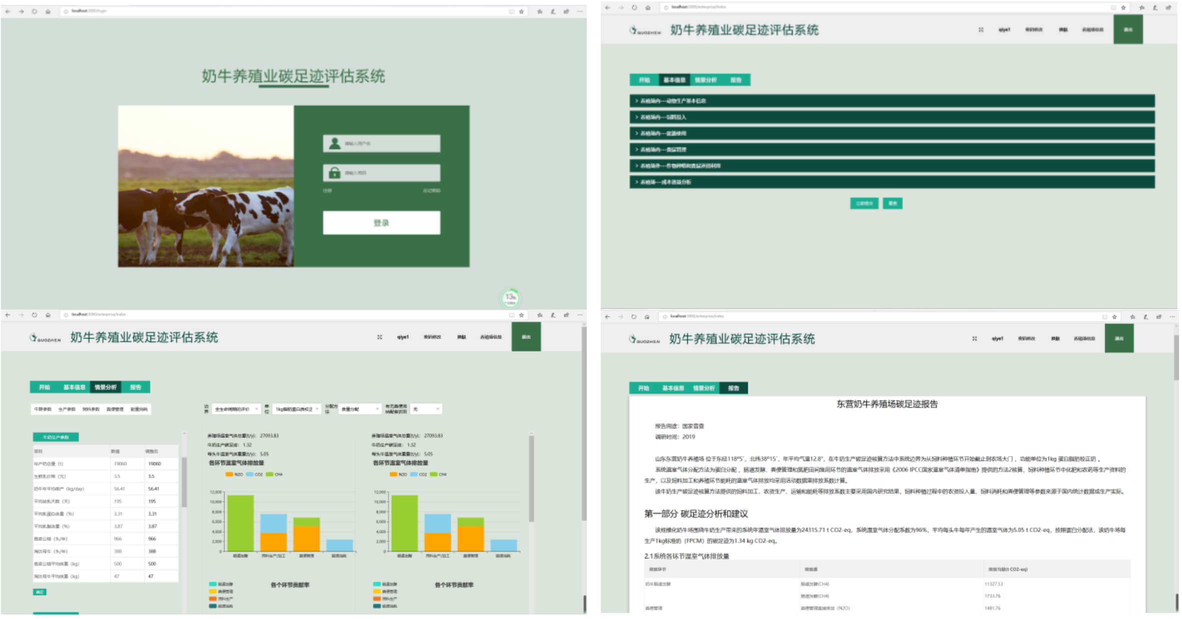

Figure 2-2 Software tool of carbon footprint of milk production in dairy carbon

2.3 A database of 107 dairy farms to support the assessment of carbon footprint

2.3.1 A database of 107 dairy farms

CAAS and CAU cooperated to design questionnaire (Annex 3) and carry out farm survey from May to September, 2019. After completing survey, we built up a database with baseline information of 107 farms which include different production systems in different regions, such as large scale intensive farms, small-scale farms, and grazing farms locating in 6 regions (North, Northeast, East, Central and southern, Northwest and Southwest of China) including 16 provinces/cities. The database includes information on number of animals, average milk production, feed consumption and compositions, energy consumption, manure management, cost-benefit, etc. The summary of the survey farms is shown in Table 2-1.

Table 2-1 Summary of 107 survey dairy farms

Number	Regions	Province	Number of survey farm	Farm size (head per farm)		
				Maximum	Minimum	Mean
1	North China	Beijing	11	1942	217	934
2		Hebei	8	20159	425	4572
3		Tianjin	6	5052	719	2747
4		Shanxi	3	2574	851	1671
5		Inner Mongolia	10	5796	103	1461
6	Northeast	Heilongjiang	17	5188	90	1339
7		Liaoning	1	-	-	307
8	East China	Fujian	3	2020	1380	1767
9		Shandong	15	12218	504	2015
10	Central and southern China	Guangdong	2	2549	1944	2247
11		Henan	11	8566	247	2372
12	Northwest China	Ningxia	7	9162	1144	2988
13		Shaanxi	3	651	172	418
14		Xinjiang	5	2399	891	1575
15	Southwest China	Chongqing	4	1800	263	1057
16		Guizhou	1	-	-	2708
		Total	107			

The basic information of dairy farms was shown in Figure 2-3. The average weight of calves, bred cows, young cows, milking cows and dry cows were 131.7, 318.2, 488.2, 634.0 and 644.5 kg, respectively. The average value of daily weight gain of calves, bred cows, young cows, milking cows and dry cow were 0.79, 0.73, 0.61, 0.12 and 0.32 kg day^{-1}, respectively. The average milk yield was 10.1 t $(head\ yr)^{-1}$ which ranged from 5.4 to 13.2 t $(head\ yr)^{-1}$, and the milk protein and fat were 3.29% and 3.87%. The average proportion of adult cows was 54.4%, ranged from 37.5% to 89.8%. The average value of culling rate was 12.6%, ranged from 0% to 41.5%. The milking day ranged from 218 to 455 with the average value of 331.7 days per year.

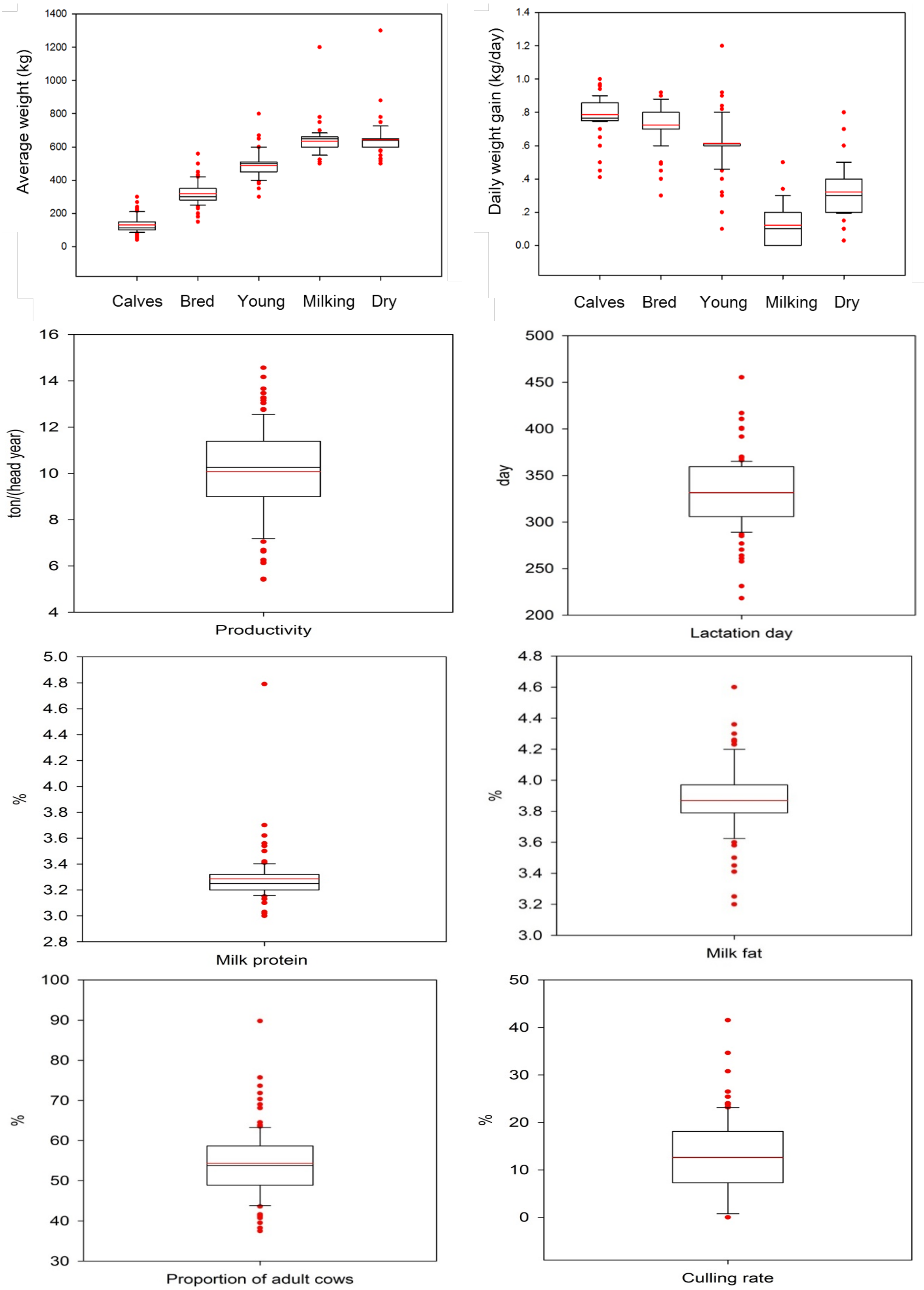

Figure 2-3 Basic information of dairy farms survey

2.3.2 Carbon footprint of survey dairy farms

The carbon footprint of 107 dairy farms in different regions was shown in Figure 2-4. There was a big diversity of carbon footprint between different dairy farms. Considering the manure application, the average value of carbon footprint was 2.1 kg CO_2-eq (kg milk)$^{-1}$, ranged from 0.9 to 4.8 kg CO_2-eq (kg milk)$^{-1}$. Dairy farm in Beijing had the lowest carbon footprint which was 1.58 kg CO_2-eq (kg milk)$^{-1}$, and those in Guizhou had the highest, 2.3 times compared with Beijing. If not considering the manure application, the average value of CF was 1.97, ranged from 0.8 to 4.6 kg CO_2-eq (kg milk)$^{-1}$.

In these dairy farms, the CF is negatively correlated with milk productivity (Figure 2-5).

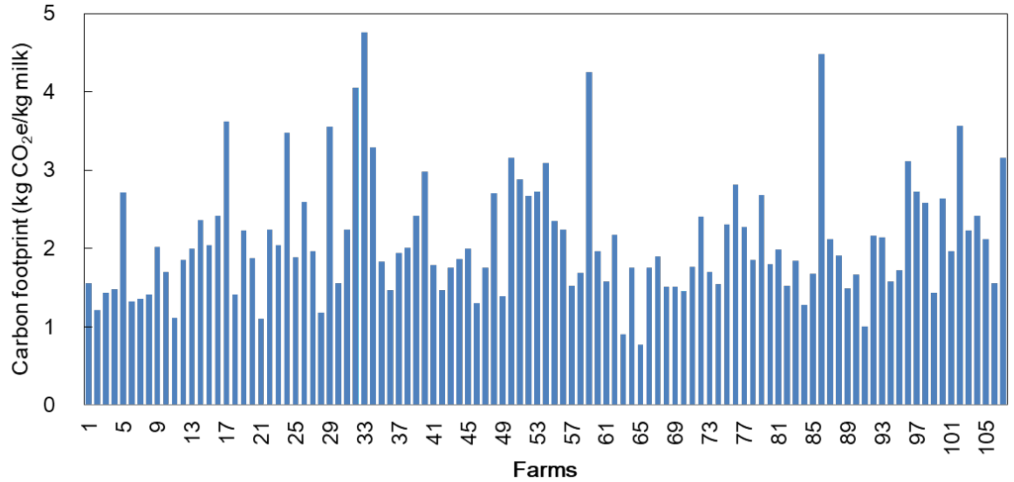

Figure 2-4 Carbon footprint of 107 dairy farm in China

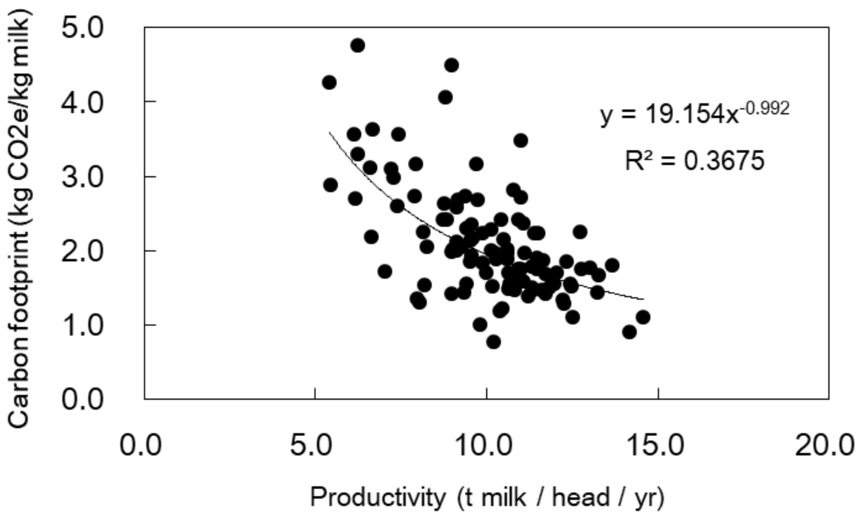

Figure 2-5 Relationship between carbon footprint and productivity

2.3.3 Emission contribution of different gases and processes

The contributions of CF from different stages and gases are shown in Figure 2-6. Enteric fermentation accounted for the largest contribution (26%), followed by feed planting and processing (26%) and manure management (21%). The manure application had the lowest contribution (6%) due to the low land application ratio. When considering gases contribution, CH_4 accounted for the largest contribution (44%), while N_2O had the lowest one (24%).

There are large differences on contribution of carbon footprint between different region and farm types (Figure 2-7). The CF contribution of feed planting and processing is the largest in the main planting regions, like Shandong, Chongqing, Henan and Hebei, due to the high fertilizer and other agricultural materials inputs. The CF contribution of manure management is the largest in the Northeast regions, like Inner Mongolia, Heilongjiang and Xinjiang, due to the poor manure management. What caught our attention was that the main contribution in south region was from transportation, like Guizhou, Fujian and Guangdong.

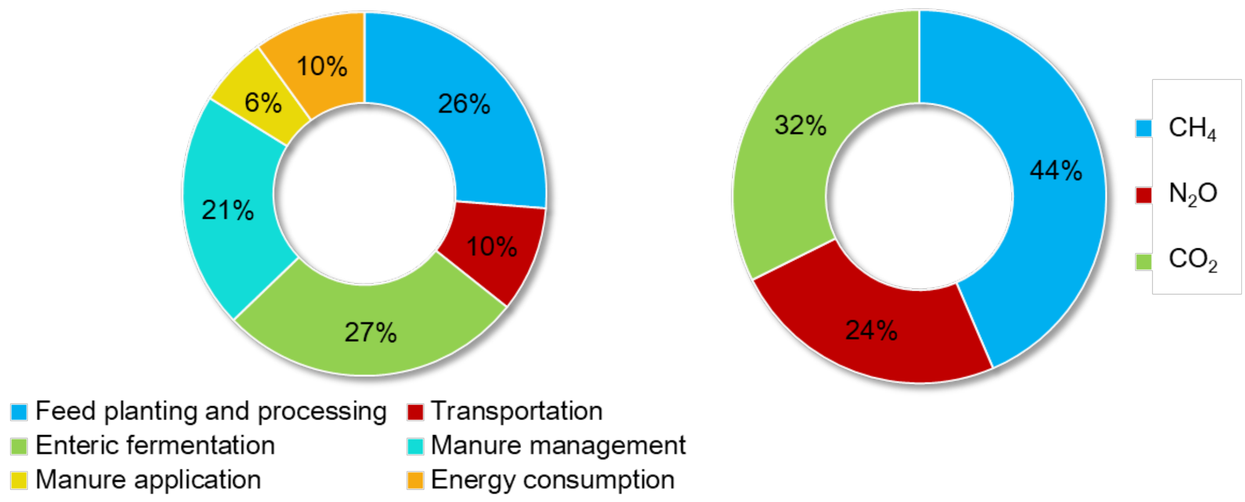

Figure 2-6 Contributions of CF from different stages and gases

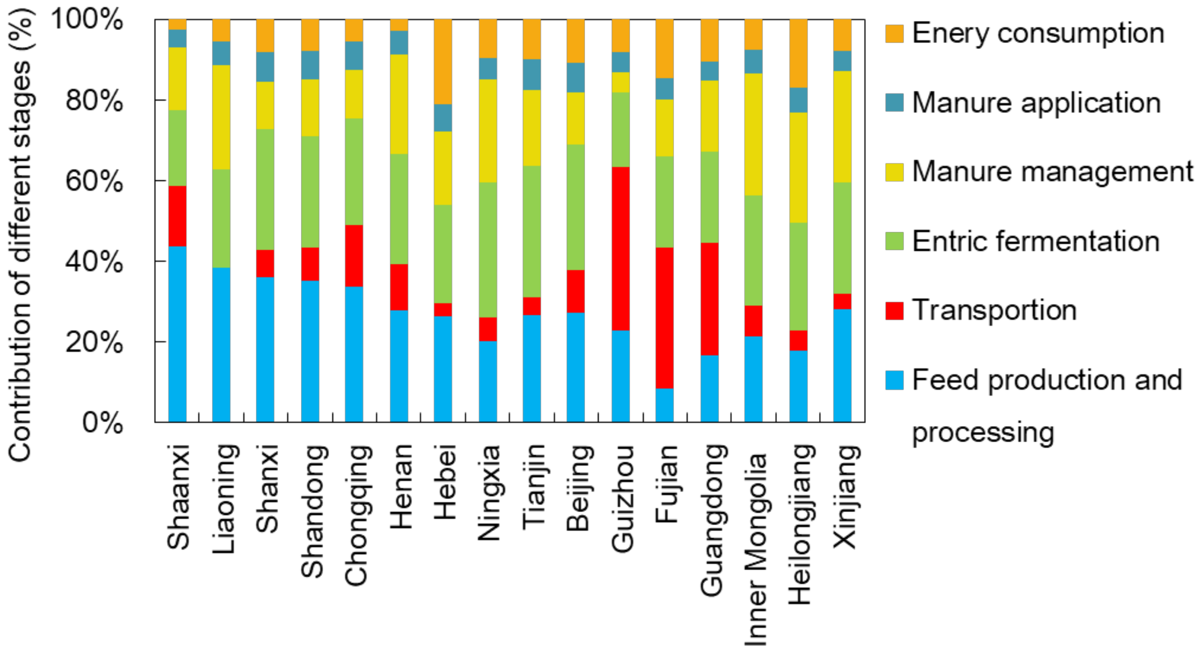

Figure 2-7 Contribution of carbon footprint by different process in different regions

2.3.4 Case study

We chose 5 different dairy farms with different farm size. The basic information of these 5 farms is shown in Table 2-2. The maximum farm size was 9062 cattle, while the minimum farm size was 90 which had the lowest productivity (7.3 ton (head yr)$^{-1}$) and milk protein content (3.25%). There was big difference of manure management in these farms.

Table 2-2 Basic information of different farm size

Items	Unit	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
Number of cows	head	90	1113	2020	5188	9062
Productivity	ton/head/yr	7.30	12.75	12.35	11.37	11.71
Milk protein	%	3.3	3.22	3.28	3.2	3.25
Milk fat	%	3.25	3.8	3.85	4	3.95
Concentrate / Forage input	%	34.1	27.6	46.3	51.1	44.8
Culling rate	%	11.1	12.5	17.1	11.6	0.0
Proportion of mature dairy cows	%	41.1	61.8	47.3	55.1	54.9
Manure management						
01 Grass land	%	0	0	0	0	0
02 Daily spread	%	6	8	0	23	27
03 Solid storage	%	25	6	0	13	0
04 Dry lot	%	0	2	0	0	6
05 Composting (in-vessel)	%	0	0	0	0	0

Items	Unit	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
06 Composting (natural aeration windrow)	%	0	6	0	0	0
07 Composting（static pile）	%	0	0	0	0	0
08 Composting（forced aeration windrow）	%	0	0	0	0	19
09 Cattle deep bedding	%	0	8	31	9	0
10 Aerobic treatment	%	0	0	0	0	0
11 Anaerobic lagoon	%	68	35	35	55	48
12 Anaerobic digester	%	0	35	35	0	0
13 Liquid/slurry stored in tanks or earthen ponds outside animal housing	%	0	0	0	0	0
14 Pit storage below animal confinements	%	0	0	0	0	0

The carbon footprint of chose farm was shown in Figure 2-8. The carbon footprint is negatively correlated with farm size, ranged from 1.4 to 3.0 kg CO_2-eq (kg milk)$^{-1}$. There are huge differences of production management among these five farms. The basic information indicated that carbon footprint closely related to milk yield, concentrate / forage input, culling rate and proportion of mature cows, etc. Therefore, due to the differences of management approach, optimization management has great potential to reduce carbon footprint.

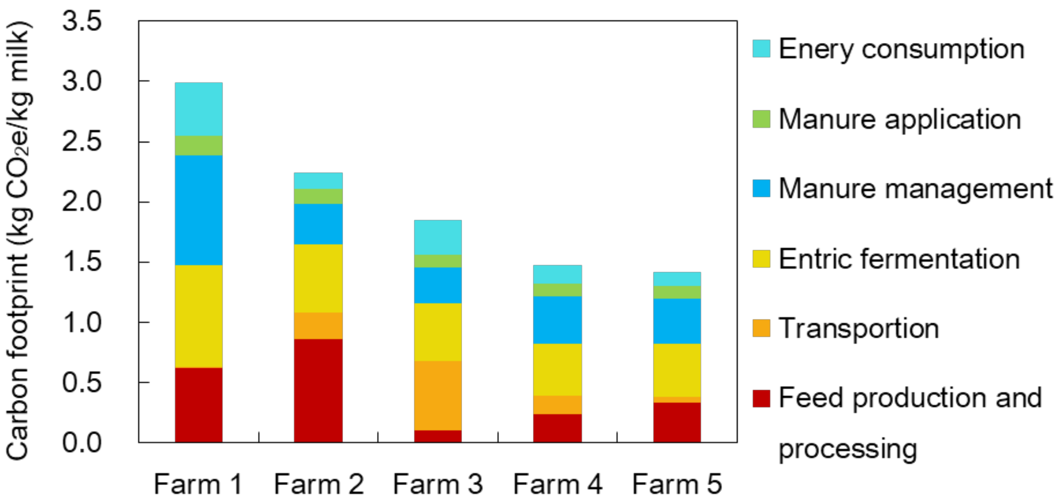

Figure 2-8 Carbon footprint of different dairy farm

2.3.5 GHG mitigation potential

Due to contribution results and case study, we summarized all the results of the 107 dairy farms, and found that those farm had high carbon footprint with the low milk yield, high feed input, long transport distance of feed, high energy use and weak herd management, etc.

We chose farm 1 which had low milk yield and adult cow ratio as case study to explore and compare the different mitigation potential. Based on the comparison of contribution of different stages in different region and case study, we can find that increased milk yield from actual production level of farm (7.3 ton (head yr)$^{-1}$) to average milk yield of 107 dairy farms (10.1 ton (head yr)$^{-1}$). The mitigation potential of increased productivity was 27.8%, followed by increased adult cows (22.3%) from actual ratio to the average ratio. However, the improving feed and management had low potential due to the actual action. Therefore, for farms with different management levels, we need to provide different emission reduction suggestions.

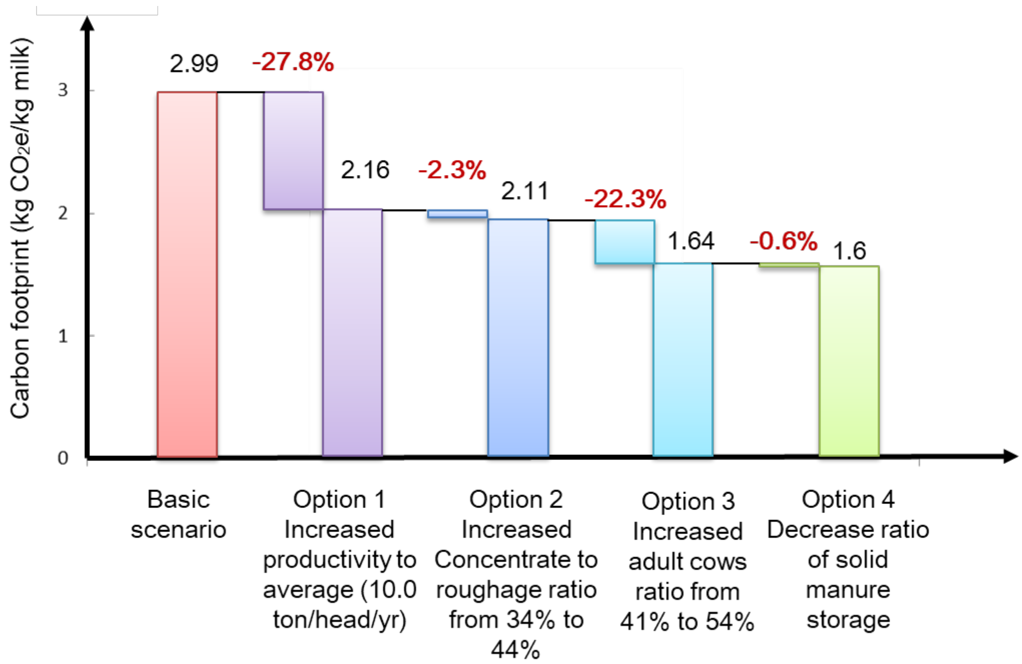

Figure 2-7 Mitigation potential of different options in dairy farm

2.4 Practice inventory of mitigation measures of carbon footprint

WUR and CAAS organized expert meetings (Wageningen) and stakeholder meetings (Beijing), respectively. During these two meeting, options to mitigate the GHG emissions from dairy farm were discussed and voted by experts and stockholders, e.g. staffs from livestock station, manager from dairy company, and researcher related to dairy production (Annex 4).

2.4.1 Expert meeting for mitigation option

During the expert meeting held in Wageningen, Netherlands from June 18 to June 21 in 2019, Chinese and Dutch mitigation experts explained and showed many options to mitigate GHG emissions from dairy farms. Those options were discussed in several meetings. On the last day of the expert meeting the Chinese experts have scored a long list of mitigation options on many criteria. The results of the scores and the corresponding discussion on mitigation options are presented in the Tables 2-3.

Table 2-3 Mitigation options with highest relevance for Chinese dairy farms evaluated by experts

	Relevant to improve in Chinese situation	Explanation of option
Herd management	+++	
• Increase longevity (reduce replacement rate)	++	Older cows produce more milk per year
• Decrease age at first calving	++	Shortening duration of young stock period improves production per life span
• Remove idle cows	+++	Cull unproductive cows
• Improve health management	+++	Reduce mastitis, lameness/claws and fertility -> higher milk production
• Optimise transition period	+	Improved dry cow management (a.o. feeding and housing)
• Optimise young stock management	++	
Stable	+++	Production of cement has large impact (CF of construction of stables and manure storage)
• Good construction contributes to herd performance	+++	Ventilation, light, insulation, etc.
• Close or modify playground	+++	Limit odour, N_2O, NH_3 from hotspot playground
Feeding	+++	
• Optimise rations (match cow requirements)	+++	
• Reduce losses during feed storage	++	Improved management of ensilaging and feed out phase of silage
• Optimise feed quality and composition	++	
• Avoid excess protein feeding	+++	
• Direct feeding of compound ingredients	+++	• Large farms apply total mixed rations (TMR) • Smaller farms use pelleted compound feed
• Additives to reduce enteric CH_4 (e.g. nitrate, 3NOP, fat, etc.)	+++	Reduction of CH_4 production in rumen
Breeding	++	
• Genetic selection on feed efficiency	++	
• Genetic selection on increased milk	+++	

	Relevant to improve in Chinese situation	Explanation of option
production		
• Genetic selection on low enteric CH4	++	Long term option
Feed production	++	National level (feed producers, dairy)
• Increased crop yields	++	• Requires more inputs (fertilizer, water) • Reduce losses during harvest
• Optimize fertilization efficiency	+++	• Important aspect of better integration of crop and livestock production. • Precision fertilization
• Increase nutritional value crops (feed quality)	++	• More emphasise on feed quality, next to feed quantity • Whole crop silage instead of stover
• Improve grazing management	++	
• Grazing management to avoid degradation of soils under natural grasslands	+++	• Nationally Determined Contributions (NDC) goal • 90% of natual grasslands is degraded. Too much pressure from livestock.
• Slow realease fertilizer	+	Slow release of nutrients to soil
Carbon sequestration in soils	0	C sequestration is in NDC! (in grassland)
• Reduced tillage on crops	++	Improves soil organic matter
Manure management	+++	
• Cover lagoon with CH_4 oxidation	+++	• Lagoon cover • Flare gas existing under manure cover
• Anaerobic digestion	+++	
• Innovative techniques to improve manure mangement: primary manure separation, direct removal, and closed storage with thermal/biological oxidation to remove CH_4	+++	All these aspects are on the research agenda in the Netherlands. Neither investigated nor yet applicable results available
• Change manure land application methods from spread to injection		
Energy management	+++	
• Production of renewable energy (wind/solar/manure)	+++	
• Reduce fossil energy use / apply energy saving technologies in	+++	
o Farm (milking, cooling), processing	++	
o Feed cultivation (machines, transport)	++	
o Feed processing	++	
o Milk processing	++	
• Select crops with low energy requirements	++	

2.4.2 Stockholder meeting for mitigation option

During the stockholder meeting held in Beijing from October 21 in 2019, Chinese and Dutch and Chinese experts, Chinese farmer and company manager joined in this meeting. Experts present deliverables, results and plans during stakeholder meeting and the stockholders have scored a long list of mitigation options based on many criteria. The results of the scores and the corresponding discussion about mitigation options are presented in the Tables 3-1 in Annex 3. The extremely important and import options chose by different stockholder were shown in Table 2-4.

Table 2-4 The extremely important and import options chosen by different stockholders

Top 3	Mitigation options	Total votes
Extremely important		
1	• Optimise rations (match cow requirements)	19
2	• Increase nutritional value crops (feed quality)	17
3	• Innovative techniques to improve manure management: primary manure separation, direct removal, and closed storage with thermal/biological oxidation to remove CH_4	16
Important		
1	• Reduce losses during feed storage	17
2	• Avoid excess protein feeding • Improved dry cow management (a.o. feeding and housing)	16
3	• Genetic selection on low enteric CH_4 • Increase nutritional value crops (feed quality) • Reduced tillage on crops	15
Extremely important + Important		
1	• Optimize rations (match cow requirements)	24
2	• Improve health management • Optimise feed quality and composition • Genetic selection on feed efficiency • Genetic selection on low enteric CH_4 • Optimise fertilization efficiency • Anaerobic digestion • Covered lagoon with CH_4 oxidation	23
3	• Reduce losses during feed storage • Avoid excess protein feeding • Increase nutritional value crops (feed quality) • Use slow released fertilizer	22

3. RECOMMENDATIONS

According to results of survey and calculation of dairy carbon footprint and the vote by different stockholders, conclusions from this project are summarized below in a series of recommendations.

3.1 Improving dairy production management

Farm management level includes herd management, stable, feeding, feed production and energy management. These managements had remarkable impact on carbon footprint.

 Herd management, like increase longevity (reduce replacement rate), decrease age at first calving, remove idle cows, improve health management and optimise young stock, were the main options for reduction of dairy carbon footprint by improving productivity.

Optimise rations (match cow requirements), reduce losses during feed storage and feed production can reduce carbon footprint at feed planting and processing stage. Optimising feed quality and composition, direct feeding of compound ingredients and additives in feed can reduce carbon footprint at enteric CH_4. Avoid excess protein feeding and energy management on-farm can reduce the carbon footprint from energy consumption.

For farmer, the economic benefit is the first concerned issue. Meanwhile, improved farm management options can not only reduce the carbon footprint, but also reduce the cost of dairy production, which can be chosen by farmers.

3.2 Utilization of manure and wastewater

Solid and liquid manure are regarded as valuable manure and are collected and used as fertilizer. Liquid manure (slurry) contains the most valuable nitrogen source (ammonium), which has the similar quality to that in the chemical fertilizer. If it is not efficient stored and used as fertilizer in crops production, it can increase the ammonia emissions and be a major contributor to contamination of vital (drinking) water resources, eutrophication of water bodies, which threats public health by air pollution and enhances eutrophication of terrestrial environments. We have the following recommendations to improve the use of solid and liquid manure.

For solid manure, the uncovered manure will be a nitrogen loss, which can be harmful to the environment. A tight plastic cover is needed at least.

An efficient use of the liquid manure can be achieved in several ways. For the livestock farms which had sufficient arable land, it is suggested to implement existing requirements on onsite manure storage, short-distance transport, and effective land application. For the farms without sufficient land, it is suggested to build a biogas plant.

Developing policy/regulation by government and standard by sector is vital to ensure the effective use of manure which is managed in different activities of livestock and crop production, and clarify who should take the responsibility. This policy/regulation has to be implemented before constructing storage facilities to avoid investment failure.

There are possibly pathogens/parasites, antibiotics and heavy metals in the manure which can potentially pose the risk of public health. Storage in 1-2 month combined with the use of modern technology will therefore reduce the risk significantly. It is recommended, that different practices of slurry storage are examined due to the reduction of bacteria, vira and parasites.

3.3 Harmonizing livestock production and crop planting management

To avoid losses of manure nutrients, urine and slurry need to be applied with a good technology (like injection land application) and at times of the year (like winter and rainy season) when the risk of losses of nutrients are low. To find the optimum way to utilize manure, urine and slurry and demonstrate it for the farmers, field trials and demonstrations need to be carried out. On basis of scientific results and knowledge rules, regulations, advices and recommendations need to be developed and made available for authorities and farmers. To avoid unnecessary impact of nutrients on the environment responsible use of manure, urine and slurry from livestock production is needed.

Develop rules, regulations and advices for optimal use of manure, urine, slurry and mineral fertilizers. Develop advices for good/optimal use and applications of manure, urine and slurry. Combinations of mineral fertilizers, manure, urine and slurry - time of application, technology and doses.

Develop a system to calculate the needed plant production area for application of manure, urine and slurry depending on the rules and regulations for use of manure, urine, slurry in different crops on arable land.

The livestock farmers need to make yearly manure, urine and slurry accounts to prove that the manure, urine and slurry is handled and used according to the rules.

3.4 Creating incentive mechanism

To be able to achieve a good utilization and avoid unwanted impact on the environment of manure-, urine-and slurry-investments are needed in: (1) modern stable systems, storage facilities and application equipment; (2) Field trials and demonstrations to document and show the effect of and how to apply manure, urine and slurry in an optimal way; (3) Advisory services for livestock and crop farmers; (4) Education and training of livestock and crop farmers.

4. CONCLUDING REMARKS

This report is a contribution to Phase 1 of Climate Change, Agriculture and Food Security (CCAFS) project 'Low Emissions Development (LED) of the Chinese Dairy Sector'. The objective of phase 1 was to identify effective and locally feasible GHG mitigation options.

The methodology, software tool, database of dairy farm, findings and recommendations in the report can be guidelines and inspiration for future planning of low emissions development of Chinese dairy sector. The report includes recommendations in relevant fields of dairy production from carbon footprint and summarizes the main focal points that must be taken into consideration both from a technical angle and from a regulative angle.

It is a true pleasure for the project group that the collaboration between China and Netherlands in the context of Phase 1 of Low Emissions Development (LED) of the Chinese Dairy Sector period. It is therefore a great achievement that the collaboration between China and Netherlands in the context of Phase 1 of Low Emissions Development (LED) of the Chinese Dairy Sector will continue for a new project period.

5. REFERENCE

1. Opio C., Gerber P., Mottet A., Falcucci A., Tempio G., MacLeod M., Vellinga T., Henderson B., Steinfeld H. Greenhouse gas emissions from ruminant supply chains – a global life cycle assessment. Rome: Food and Agriculture Organization of the United Nations.

2. Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G.2013. Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO), Rome.

3. Food and Agriculture Organization of the United Nations (FAO). Agriculture, Forestry and Other Land Use Emissions by Sources and Removals by Sinks. 2014

4. Ministry of Ecology and Environment of China (MEE). The second biennial report on climate change of China. 2018

6. ANNEX

Annex 1 Guideline "Method for Carbon Footprint Assessment of Milk Production in Intensive Dairy Farms"

Annex 2 Carbon footprint software and operation guide

Annex 3 A databases of 107 dairy farms

Annex 4 List of mitigation inventory