Analysis of Greenhouse Gas Emissions and Feasibility of Mitigations Options for Dairy Farms in China

Working Paper No. 386

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Abstract

Climate change has gained increased attention all over the world. Dairy farming is a significant contributor to the emission of greenhouse gas emissions that cause climate change. This has prompted international dairy sectors to develop plans to reduce the greenhouse gas emission from dairy farming. The Chinese dairy sector is also exploring how to contribute to that reduction, while responding to the growing domestic demand for dairy products. In this study, we collected and analyzed technical data including greenhouse gas emissions of a pilot group of 15 farms where a greenhouse gas reduction method will be tested in the future. Next to that, we held a survey among farmers and stakeholders about the feasibility of mitigation options to reduce greenhouse gases. This was to explore how farmers will respond to recommended mitigation options. The results show that farmers with different herd sizes and different types of stakeholders have different opinions about the feasibility and attractiveness of mitigation options. The results are useful insights to further prepare the application of the tailored made approach to come to dairy farms that combine efficiency with low green house gas emisions.

Keywords

Greenhouse gas emissions; dairy farming; mitigation options; carbon mitigation

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This report is one of the results from the project “Piloting and scaling of low emission development in large scale dairy farms in China”. The institutes China Agriculture University (CAU), Chinese Academy of Agricultural Sciences (CAAS) and Wageningen University & Research (WUR) collaborated in this project on the development of knowledge and tools about the reduction of greenhouse gasses from dairy farms in China. All the work done in this project was funded by CCAFS. We like to thank CCAFS for this great support and also in particular Lini Wollenberg who was the flagship leader of Low Emissions Development (LED) within CCAFS.

1. Introduction

The growing global human population will require more food to meet the continuous rising deman (Godfray et al., 2010). Ruminants could harvest energy from human-inedible food and produce high-value animal proteins, like milk and meat. This can be a promising way to ease the world food security issues (Eisler et al., 2014). However, during the decomposition process of roughage by dairy cows, which makes up a huge percentage of all ruminants, methane (CH_4) is produced in the rumen, and about 2-12% of the gross energy intake by the cows is wasted by CH_4 emissions (Johnson and Johnson, 1995). CH_4 emissions from dairy production systems serve as a key driver for the global greenhouse effect and extreme climate change. Dairy cows also produce a lot of nitrate-related waste that pollute the environment. Emissions of nitrogen- (N) containing compounds such as nitrous oxide (N_2O) and ammonia (NH_3) from ruminant production systems not only challenge environmental sustainability but restrict their further development. Environmental pollution caused by the emissions of N-containing compounds can reduce the growth performance and product quality of ruminants; at the same time, local government may implement policies that restrict the development of the ruminant animal industry based on environmental protection. With the constantly increasing demand for meat and milk, the environmental pollution problems associated with this practice have gradually become serious. Carbon dioxide (CO_2), CH_4, and N_2O are the major greenhouse gases (GHG).

In the milk production process, it is not only the dairy cows' metabolism process that impacts GHG emissions but also the pasture and crop cultivation, feed transportation and processing, feeding, and waste management. Improving production efficiency is an effective way to reduce GHG emissions. Different scale farms have a distinct workflow in all aspects of farm production. Therefore, finding out the different farms' advantages and weakness may help us develop effective mitigation approaches to reduce GHG emissions. Milk production is part of a long dairy industry chain, each step is crucial for healthy dairy products. The feed production need utilization of manure, land, and water resources; besides, understanding how to match planting crops with taking care of the impact on climate as well as forage requirements of the dairy farm is the basis of the dairy cows feeding. Farm managers should understand the animal's metabolism features, which help them optimize diet nutrients to dairy cows. Moreover, how to manage the cows, which is decided by the energy type (electricity or coal), storage of waste, and maximize animal welfare should also be taken into consideration when managing farm production. Experts and consultants should deeply understand the reasons behind the phenomenon of GHG production in the dairy chain. This will help them advise farms on how to improve production efficiency but also to understand the risks of climate change.

2. Goal of this report

Reducing GHG emissions is a key element for reaching sustainable dairy farming and will contribute to the achievement of regional or national GHG reduction targets. Therefore, stakeholders in the dairy sector, including policy makers, dairy farmers, dairy processors, and consumers, require clear and objective information about the basic principle and concepts of GHGs and mitigation application. Results from well-defined and recognized GHG calculation methodologies should be used to show a clear picture of GHG emission situation in the industry.

The purpose of this study is to collect the experiences from using a well-defined method that combines the evaluation of GHG emissions on dairy farms with tailor-made recommendations to dairy farms for the reduction of GHG emissions, while taking into account the impact on farm profitability. This method is called Total Farm Approach (TFA). In this study, the experiences with the application of this method on farms are collected. Several target groups were involved in the application of the method and have contributed to this study: researchers, dairy processor(s) and farm managers.

Feedback was collected from different stakeholders regarding the choice of mitigation options and their view on GHG mitigation in the dairy sector. By analyzing the data from these stakeholders, the developers of the TFA can improve the methodology to better support large scale dairy farms and industry partners to identify cost-effective technical mitigation options and policies to reduce GHG emission from Chinese dairy farms.

3. Target group

The key target groups of this report are consultants, farm managers and experts who support the optimization of dairy farm performance and reduction of GHG on dairy farms. Next to these professionals, other target groups may be interested: stakeholders in the private (dairy processing) sector, policy makers and technicians in governmental and non-governmental organization (NGOs), academia and consumers interested in sustainable dairy farming.

4. Methods

4.1. General description of research setup

This research consisted of two parts:

Part A: Collection of technical farm data from a group of 15 pilot farms:

- Collection of data, relevant to calculate GHG and to understand the technical context of the farm.
- Analyzing the data
- Advice and recommendations to decrease GHG per kg of FPCM

Part B: Survey about the feasibility of mitigation options among farmers and stakeholders
This survey was held among the 15 farmers that participated in part 1 and also under a group of 6 staff members from dairy processors and 4 opinion leaders from government, university and research institute.

4.2. Part A: Collection of technical farm data from selected dairy farms

For Part A, 15 large scale farms were randomly selected for participation in this research. These farms were asked to participate in the data collection (part A) and also in the subsequent research about the feasibility of mitigation options (part B). The herd size on these farms ranged from 422 to 24,289 heads. All selected dairy farms were equipped with free-stall systems. The dairy farms were split into three herd size groups: small-scale (less than 2,000 heads), medium scale (between 2.000 and 5,000 heads), and large-scale (more than 5,000 heads). The goal of the analysis for the collected data was to evaluate the financial and the environmental impacts of all 15 dairy farms, and then give expert advice about mitigation options.

Input and output data were collected in 2021 for the 2019/2020 financial year for all farms. The data included: (1) dairy herd composition, (2) milk yield and composition, (3) breeding data, (4) forage and concentrate resources and nutrient composition, (5) the amount of fuel, electricity and water used, and (6) manure management practices. The collection included herd structure, feed resources and nutrient composition, animal performance, and energy consumption. All these data were necessary to calculate GHG emissions. These calculations were conducted by Institute of Environment and Sustainable Development in Agriculture (IEDA), that is part of the Chinese Academy of Agricultural Science (CAAS), using the life cycle assessment (LCA) method developed by Dong (2019). Five processes related to the dairy farm are covered when giving advice: feed production, feed transportation, animal management, feeding, and manure management. The emissions from feed transportation were determined by multiplying the unit of emissions by the product of feed weight and transportation distance. Corn silage and grain and wheat straw were purchased or obtained locally, and the distance of transport for these local feeds was calculated. GHGs associated with the transport distance for the alfalfa and oat hay from abroad were taken into account. CH_4 emissions from manure were 13 kg/head/year, and N_2O emissions from manure were 0.5% from N excretion (IPPC guidelines in Paustian, 2006). Enteric CH_4 emissions from dairy cattle were calculated from dry matter intake (DMI) using the quadratic regression reported by Shibata et al (1993).

Data were processed in Excel and GraphPad by comparing with the average values of different production parameters, to analyze the determinant factors that affect the emissions of GHG on dairy farms.

4.3. Part B: Survey about feasibility of mitigation options

In total, 30 mitigation options to reduce GHG were assessed by 25 stakeholder respondents using a electronical or paper questionnaire. The 25 stakeholder respondents represented five professional categories: 7 small farm managers, 4 medium farm managers, 4 large farms managers, 6 staff members from dairy processors and 4 opinion leaders from government, university and research institute. The staff members from dairy processors include executive managers and technical managers of giant Chinese processors, including Yili and Mengniu, that rank Top 5 and Top 8, respectively, in the Global Dairy Top 20, reported by RaboResearch (Richard, 2020). Opinions from other important dairy processors in China are also collected. For every mitigation option they had to asses the feasibility, based on four options from which they could select only one: feasible, conditional feasible, not feasible, and not relevant. The survey encompasses 7 categories of mitigation options: animal health and management, feed and feeding management, breeding, feed production (fertilizer management, manure, and commercial fertilizer), soil carbon sequestration, manure management, and energy use at the farm. Within each category, there are several mitigation options that had to be assessed on feasibility by the respondents. The mitigation options that are provided to the respondents were presented to them together with explanations by mitigation experts from the Institute of Environment and Sustainable Development in Agriculture (IEDA), part of Chinese Academy of Agricultural Sciences (CAAS).

5. Results and discussion technical farm data

5.1. Herd structure and herd size of the 15 pilot farms

The differences in herd size are large, with a range from 422 to 24,289 heads per farm (Table 1). As shown in Figure 1, the proportion of milking cows and dry cows are similar for the 3 farms. Therefore, the similar herd structure of the farms with different herd size would not have notably effects on the milk production and carbon footprint of milk.

Table 1. Herd structure of dairy farms

Herd size group	Population	Calves (0-6 Months)	Heifers (before serving)	Heifers (after serving)	Milking cows	Dry cows
Small (n=7)	422	49	54	45	229	45
	521	41	80	69	293	38
	790	790	790	790	790	790
	1303	154	145	429	453	122
	1808	177	406	202	869	154
	1861	197	253	399	887	125
	1960	180	615	397	650	100
Medium (n=4)	2061	331	570	122	840	198
	2400	330	450	280	1180	160
	2440	337	279	656	1055	113
	2574	650	511	192	1015	206
Large (n=4)	5052	340	200	1879	2222	411
	5188	777	1049	506	2507	349
	9062	759	1633	1697	4482	491
	24289	3106	3690	5295	10042	2156

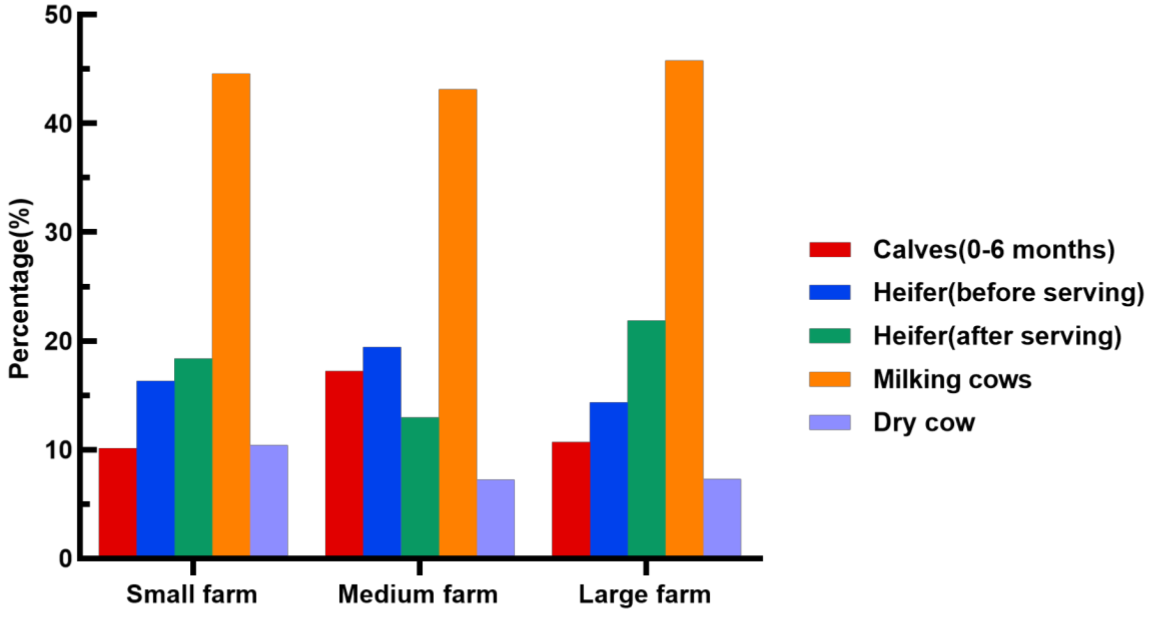

Figure 1. Herd structure of three categories of dairy farms

5.2. Milking performance and milk quality of the farms

The average days in milk and milk fat content were at similar levels for the three dairy groups (Table 2). The milk protein content is highest in medium dairy farms having 2,000-5,000 heads in the herd. Regarding milk yield, the bigger the farm is, the higher the cow productivity. Somatic cells count (SCC) is an indicator for the general health condition of lactating dairy cows, and SCC content in all milk samples was below 300 $\times 10^3$ counts/mL indicating good milk quality; although, some differences existed among the three dairy groups: the larger the herd size, the lower the SCC.

Table 2. Milk production and milk quality of three dairy groups

Item	Small-size farm 400-2000 heads	Medium-size farm 2000-5000 heads	Large-size farm >5000 heads
Number of farms	7	4	4
Average days in milk (d)	194.7	184.1	189.5
Milk protein (%)	3.21	3.30	3.19
Milk fat (%)	3.83	3.94	3.92
Yield (ton/head/year)	8.80	9.02	10.28
Somatic cells count (10^3/mL)	298.1	235.6	213.3

5.3. Feed input

As shown in Table 3 (absolute tons per farm per year) and Figure 2 (amount per head per year), the whole corn silage, imported alfalfa hay, domestical alfalfa hay, and oat hay are the most used roughages in the 15 pilot dairy farms, which is also in consistent with the situation described in the published literatures (Wang et al., 2018). Additionally, the small-size farms and medium-size farms are using large amount of Chinese rye grass, but almost no Chinese rye grass is used in large-size farms (Table 3). All these farms consume similar amounts of imported alfalfa hay per cow per year, while the cows in large-size farms consume the highest amount of domestical alfalfa hay per year (Figure 2). The small farms consume the lowest amount of local forage (Figure 2). As Table 4 shows, all these farms use corn, soybean meal, sugar beet meal and wheat bran as concentrate, and the cows consume almost similar amounts of concentrates per year. But the medium-size farms consume a much lower amount of other by-product concentrates per cow per year compared to small and large-size farms; while in small and large farms, they prefer to use by products to feed cows. The average transportation distance is shown in Figures 4 and 5 either for main roughage (i.e., whole corn silage, imported alfalfa, domestical alfalfa and cottonseed) or for main concentrate feeding (i.e., corn, soybean meal, beat meal and wheat bran).

Table 3. Roughage consumption in three dairy groups (ton/year, as-fed basis)

Roughage	Small-size farm 400-2000 heads	Medium-size farm 2000-5000 heads	Large-size farm >5000 heads
Whole corn silage	6248.5	13650.0	60060.0
Imported alfalfa hay	479.1	1001.7	3083.33
Domestic alfalfa hay	95.0	600.0	10233.3

Oat hay	255.0	753.5	1063.3
Chinese rye grass	499	1622	0
Unconventional roughage	150	1031	2888

Table 4. Concentrate consumption in three dairy groups (ton/year, as-fed basis)

Concentrate	Small-size farm 400-2000 heads	Medium-size farm 2000-5000 heads	Large-size farm >5000 heads
Corn	736	1500	8500
Soybean meal	190	785	2900
Sugar beet pulp	191	504	2288
Wheat bran	297	675	1203
Cottonseed	261	440	3515
Other	984	1300	7950

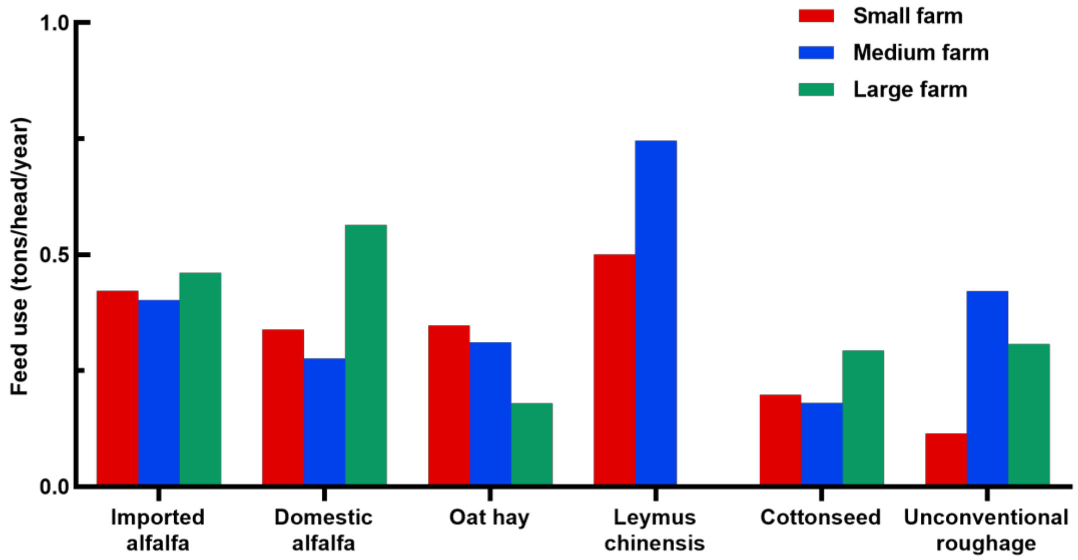

Figure 2. Average amount of roughage used in three dairy groups

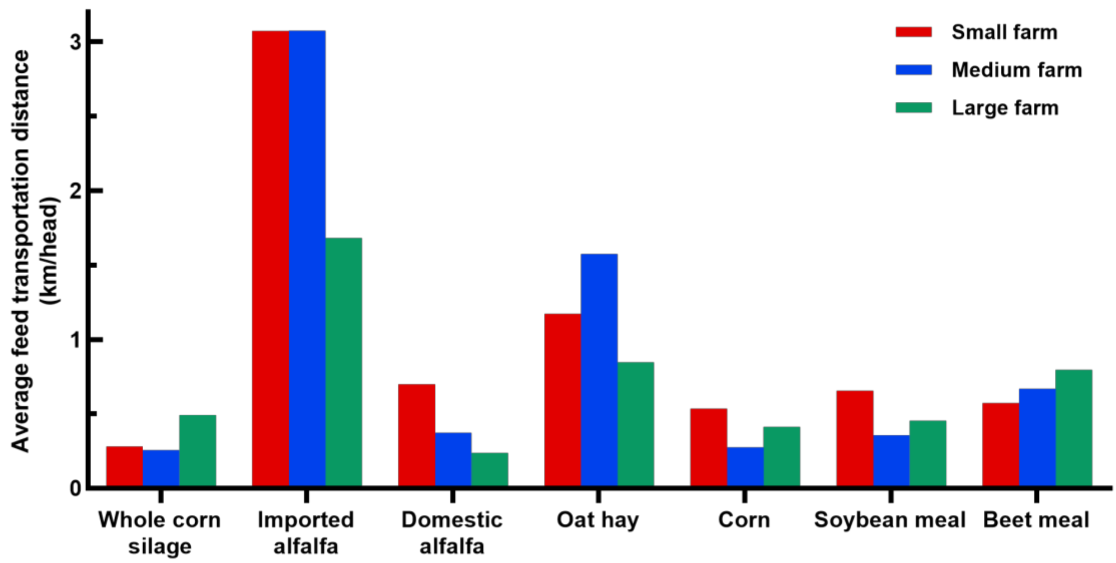

Figure 3. Average amount of concentrates used in three dairy groups

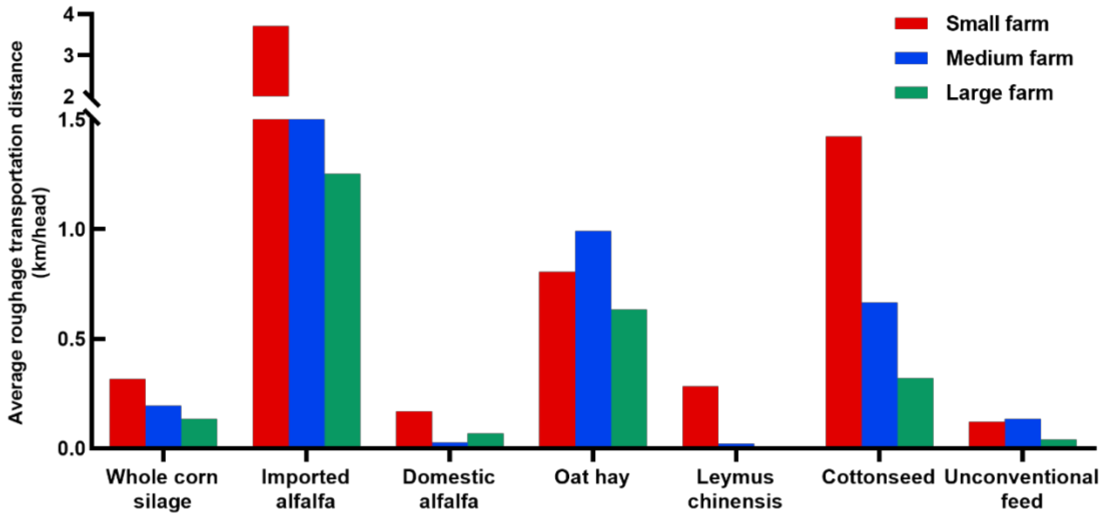

Figure 4. Average transportation distance of roughages in three dairy farm groups

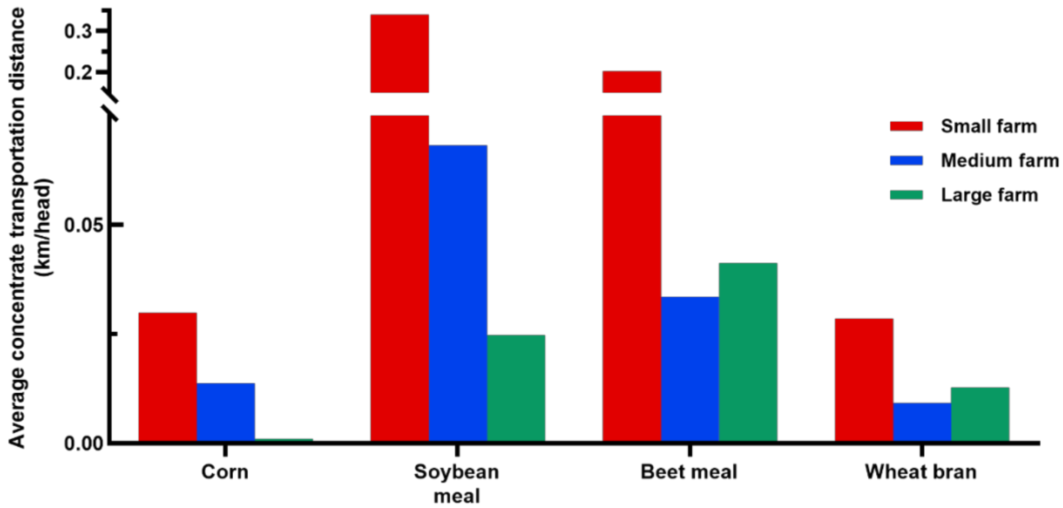

Figure 5. Average transportation distance of concentrate in three dairy farm groups

Table 5. Feed input in three categories of Chinese dairy farms

Item	Small-size farm 400-2000	Medium-size farm 2000-5000	Large-size farm >5000
Average consumption of roughage (ton/head/year)	6.4	7.5	6.7
Average consumption of concentrates (ton/head/year)	1.1	1.4	2.0
Input amount of roughage (calculated) (kg/head/day)	17.37	20.49	18.24
Input amount of concentrates (calculated) (kg/head/day)	5.53	4.67	7.77
Roughage DM input (calculated) (ton feed /farm)	2861.4	7174.7	31137.4
Concentrated feed DM input (calculated) (ton feed/farm)	2079.7	5568.6	25228.2

It can be seen in Table 5 that the larger the size of the dairy farm, the greater the average consumption of concentrates. The average consumption of concentrates in large-size dairy farms reached 2.0 ton/head/year, and the DM inputs of concentrated feed and roughage (both calculated) for large-size dairy farms are significantly higher than that of small- and medium-size dairy farms.

In the large-scale farms, the total amount of roughage input in DM is larger, but the amount of roughage input per per cow is lower compared to medium-size dairy farms. On the opposite, the input of concentrate per cow is the highest in large-size farms, indicating that higher nutrtional concentration in the diet could boost milk production, which will also have the potential to reduce enteric emissions.

5.4. Energy consumption

Table 6. Total energy consumption in three dairy groups

Item	Small-size farm 400-2000	Medium-size farm 2000-5000	Large-size farm >5000
Average consumption of roughage (ton/head/year)	6.4	7.5	6.7
Average consumption of concentrates (ton/head/year)	1.1	1.4	2.0
Input amount of roughage (calculated) (kg/head/day)	17.37	20.49	18.24
Input amount of concentrates (calculated) (kg/head/day)	5.53	4.67	7.77
Roughage DM input (calculated) (ton feed /farm)	2861.4	7174.7	31137.4
Concentrated feed DM input (calculated) (ton feed/farm)	2079.7	5568.6	25228.2

It can be seen in Table 6 that the consumption of electricity, diesel oil, natural gas (large-size farms do not have natural gas usage information) and water consumption all increase with the increased size of dairy cows, while the use of coal and gasoline is generally more related to labor work, so the situation varies from farm to farm. However, if energy consumption is expressed per animal (Table 7), it is found that the consumption of electricity, diesel oil, natural gas and petrol is the lowest for medium-size dairy farms, but the water consumption still increases as the number of cows increases.

Table 7. Average energy consumption per head in three dairy groups

Item	Small-size farm 400-2000 heads	Medium-size farm 2000-5000 heads	Large-size farm > 5000 heads
Electricity (kwh/head)	503.4	419.7	677.0
Coal (ton/head)	0.029	0.316	0.510
Diesel oil (L/head)	33.9	32.3	105.0
Petrol (L/head)	0.74	0.26	0.87
Natural gas (m^3/head)	1.5	1.4	0.0
Water (ton/head)	9.5	44.0	319.3

In summary, the large-size dairy farms consumed more energy and other materials per head compared to the other two groups due to – most likely – more equipment and automation. The average diesel oil consumption of small-size farms is similar to that of medium-size farms, indicating that the mechanization degree is basically the same for them. However, the electrical energy consumption of small-size farms is higher than that of medium-size farms. This may be because the population of cows is too small and the fixed part of electrical energy consumption is relatively high, while the medium-size dairy farms' electrical energy consumption can be divided by a larger number of cows (economies of scale). In terms of water consumption, the large-size dairy farms use significantly more among the three groups for manure management or cleaning the milking parlor.

5.5. Manure management

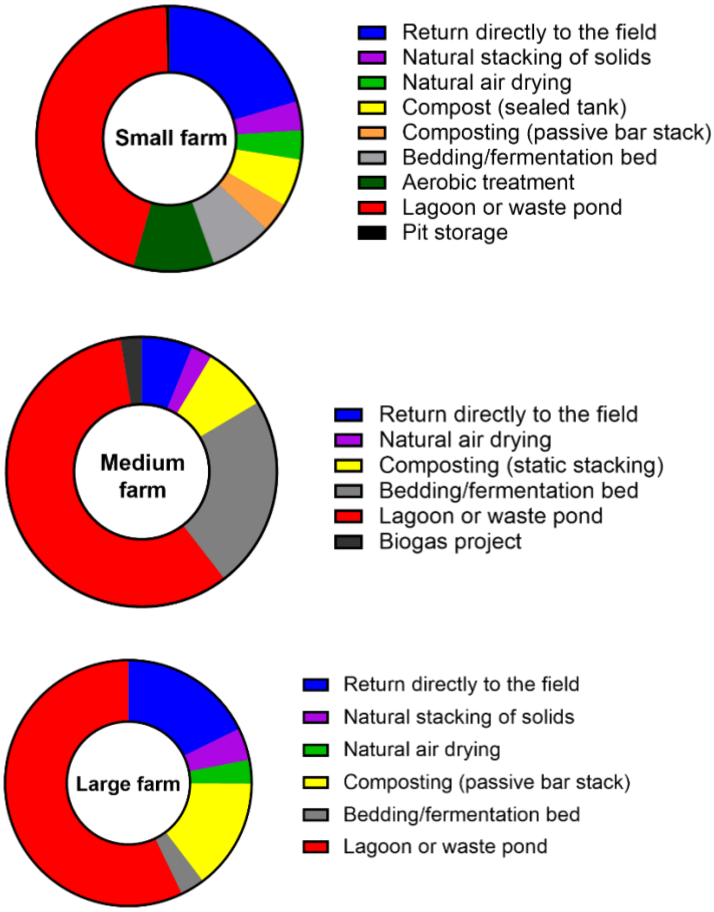

Figure 6. Manure management in three dairy groups

Note: The bedding/fermentation bed is the application of the solid manure fraction as bedding materials

The most popular manure management for Chinese dairy farms is by storing them in a waste pond. The solid fraction of manure is also widely used in the farms as bedding materials. The percentages of farms that reuse the fermented manure as bedding material is 7.61%, 23.10%, and 3.17% for small, medium, and large-size dairy farms, respectively. Direct application of manure to the field is a way to utilize it as fertilizer. The small dairy farms have the highest percentage (20.34%) of this method among the three dairy groups.

5.6. GHG production

As shown in Figure 7, CH_4 is the biggest contributor of GHG emissions in all farms, indicating the emission from enteric fermentation. The different herd size groups also have different GHG emissions. In general, the medium-size dairy farms had the highest values of CH_4, N_2O, and CO_2 emissions per kg of fat-corrected milk yield (FPCM, which refers to standard milk). The large dairy farms had the lowest values of CH_4, and N_2O emissions per kg of FPCM.

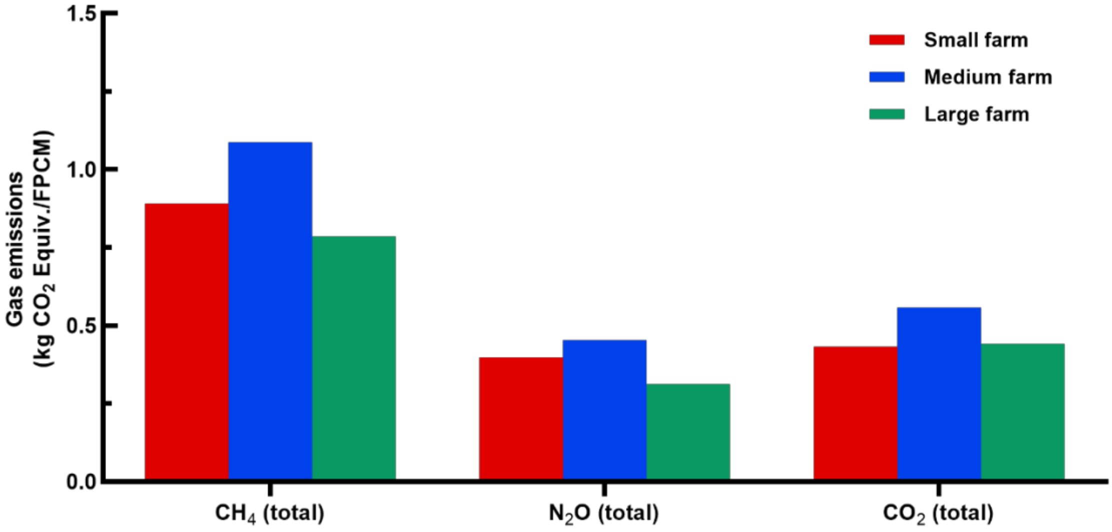

Figure 7. Average GHG emissions in three dairy groups

The sources of GHG emissions in dairy farms are mainly from enteric fermentation (CH_4), manure management (CH_4 and N_2O), and feed production and processing. CH_4 is produced as a by-product during rumen fermentation. The quantity of CH_4 produced in the digestive tract of animal depends on a.o. diet type, feeding practices (e.g., feeding frequency) and the health of the animals. During manure storage and handling, both CH_4 and N_2O can be produced. CH_4 is produced under anaerobic fermentation of manure, and the amount of CH_4 produced is based on the storage facility, the ambient temperature, and the composition of the manure. N_2O emission is also emitted during manure storage and after the application of manure in the field. CO_2 is emitted after fossil fuel consumption for energy production in various processes on the farm, especially in the feed production, transportation, and milking operations.

Figure 8 shows the absolute emission amount of each source in different herd size groups. For each source, except transport and manure application, medium farms show the highest emissions, compared to the large and small farms. The large farms show the highest emission in transport compared to the other two herd size groups. However, in other sources of GHG emission, large farms consequently show the lowest emission, indicating good production efficiencies to convert feed into milk and more efficient use of energy.

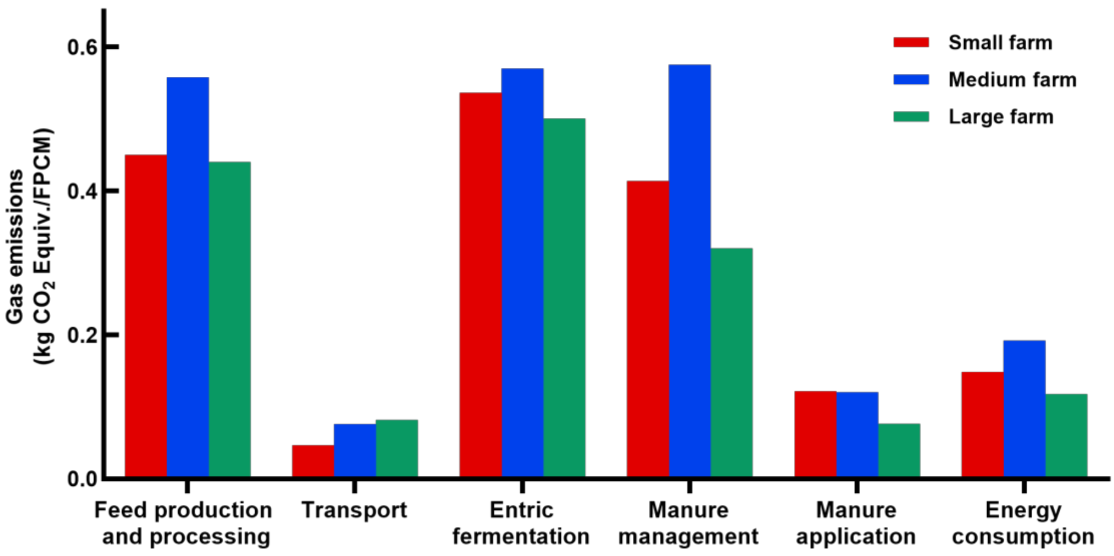

Figure 8. GHG emissions in the three dairy groups.

5.7. Relationship between milk yield and GHG emission

Figure 9 shows a strong negative relationship between daily milk yield, yearly milk yield and GHG emissions. It has been stated that GHG emissions per kg milk decreased with increasing milk yield per cow per year, from 1.06 to 0.89 kg CO_2 equivalents (CO_2eq) for dairy cows with an annual milk yield of 6,000 or 10,000 kg, respectively (Zehetmeier et al., 2012). Based on data in this project, the GHG emission per kg of FPCM dropped from about 3 to 1.8 kg CO_2eq per kg of FPCM when the milk yield increased from 6,000 to 10,000 kg. Meanwhile, considering that the correlation between GHG per kg FPCM and yearly milk yield is not as clear as with daily milk yield, it could be considered that lactating days could be the cause for the less clear relationship for the yearly milk yield. Based on these results it can be expected that the continuous increase in milk yield in the Chinese dairy farming sector could be expected to contribute to the reduction of GHG emissions per kg of FPCM.

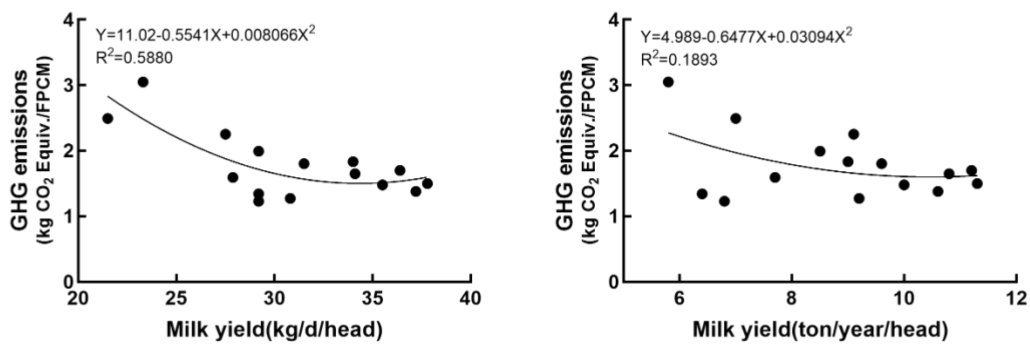

Figure 9. The relationship between milk yield and GHG emissions

(Left: Daily milk yield; Right: Annual milk yield)

5.8. The relationship between feed cost and GHG emissions

Feed cost of milk production is an important sign of the profitability of a dairy farm. Factors influencing the feed cost of milk production include daily milk yield, feed nutritional value and price, feed efficiency and ration formulation. In this project, we found that in small farms, the relationship between feed cost and GHG emissions is not clear (Figure 10). When it comes to medium and large farms, there is a trend that the increase of feed cost coincides with the reduction of GHG emission, probably due to the introduction of more concentrates and better-quality roughage when feed costs per kg milk increase. Also, from Figure 11, we can find a link between the GHG emissions with dietary net energy lactation (NE_l) level or crude protein (CP) level. According to Kirchgeßner (1995), enteric CH_4 emission can be calculated from the crude protein and nitrogen-free extract (NfE) level in the diet. Considering that the nutrient intake level affects the emission intensity, one should keep in mind that DMI also contributes significantly to the emission. Thus, further data needs to be collected to accuratly predict the enteric CH_4 emissions, based on NE_l and diet CP.

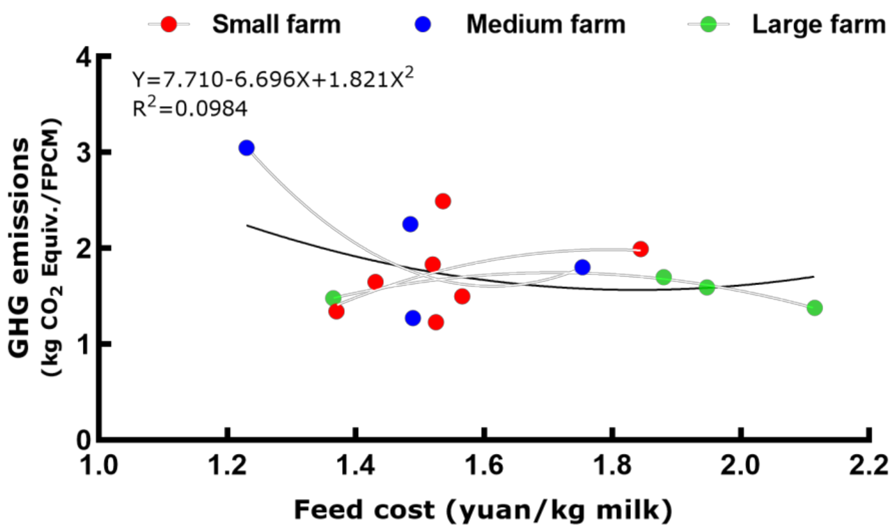

Figure 10. The relationship between milk production cost and GHG emissions in different dairy farms

5.9. The energy and protein supply level in dairy farms in China

We compared the energy and protein supply to NRC requirement of cows during the lactation period (Figure 1). It appears that in the small and medium herd size farm groups, there are still some farms that supply the cows with protein or energy lower than the requirement. Oppositely, in large farms, all farms provide cows with diet protein and energy more than the NRC recommended level. Therefore, it can be speculated that the high production of the cows in large dairy farms is at the expense of surplus nutrtional supply, and it could be that with feeding more close to the NE_l-and CP-standards, the feed energy conversion and protein conversion could be further improved and at the same time GHG emissions will be mitigated.

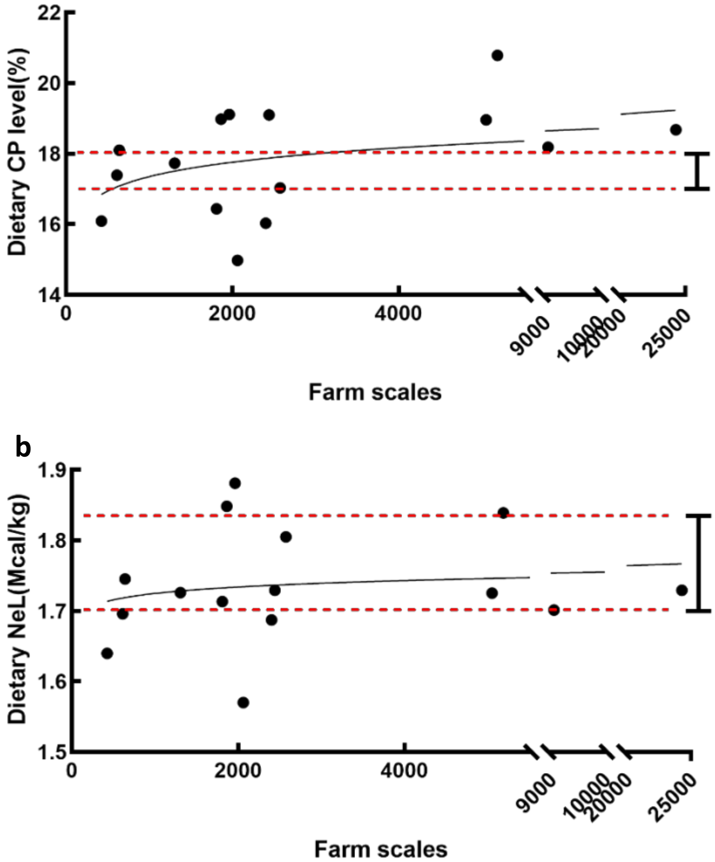

Figure 11. Dietary CP and NeL levels of farms of different scales

*(a: CP levels; b: NeL levels)
**(NRC (2001) Recommended range of TMR nutrition for high-yield dairy cows（range between two red dotted lines）

6. Results survey about the feasibility of mitigation options

6.1. All results in one table

The results of the assessment of mitigation options by 5 groups of stakeholders are presented in Table 8. Generally, the respondents had to asses all mitigation options on feasibility. They had to select one out of these four options: feasible, conditional feasible, not feasible, and not relevant (see 4.2 for further explanation of the method) .

Table 8 shows all the results the survey has delivered. The next 5 paragraphs contain a more in depth description of the results 5 stakeholders groups.

Table 8. Assessment of provided mitigation options on feasibility by different stakeholders

Feasibility	Feasible					Conditional feasible					Not feasible					Not relevant				
Type of respondent	Dairy farmers			Dairy processors	Opinion leaders	Dairy farmers			Dairy processors	Opinion leaders	Dairy farmers			Dairy processors	Opinion leaders	Dairy farmers			Dairy processors	Opinion leaders
	Small	Medium	Large			Small	Medium	Large			Small	Medium	Large			Small	Medium	Large		
Animal Health and Management																				
Improving cow longevity	2	3	4	6	4	5	1													
Improving herd and animal fertility and reproduction	7	4	4	6	4															
Improving heifer management	5	1	3	5	4	2	3	1	1											
Reducing the prevalence of diseases and parasites	7	4	4	6	4															
Feed and feeding management																				
Feeding regime optimization	7	4	4	6	4															
Reducing imported roughage	3	2			2	2	2	4	6	2						2				
Use of precision feeding techniques	5	4	4	6	4	2														
Use more locally produced feed raw material	3	2	1	5	3	3	2	3	1	1						1				
Providing cows TMR																7	4	4	6	4
Use more by-product	1	2	1	1	3	6	2	3	5	1										
Use of additives specific for carbon mitigation(3-NOP)	1			3	2	3	3	4	1	4	3	1								
Breeding																				
Selection of high feed efficiency cows	1	1	2	4	4	0	1	2	1		6	2		1						
Selection of high productive cows	1	1	2	4	4	1	2	2	1		5	1		1						
Selection of low emission cows	1	1	1	3	3	0	1	3	2	1	6	2	0	1						

Feed production (Fertilizer management, manure and commercial fertilizer)																				
Increase crop production					2					2						7	4	4	4	2
Lower manure application frequency and the incorporation of manure into soils		1	1		3					1						7	6	6		
Improve roughage quality	5	2	4	4	4		2	2								2				
Spread fertilizer at the optimum time with better technology		1	1		2					2						7	6	6		
Use commercial fertilizer produced in an environmentally friendly way		1	1		3				6	1	7	3	3							
Soil carbon sequestration																				
Better grassland management										2						7	4	4	6	2
Less tillage										2						7	4	4	6	2
Manure management																				
Use of anaerobic digester				1	1	2	1	1	5	3						5	3	3		
Improve manure collection, storage and utilization (frequent and complete removal of manure from indoor storage)	2			3	2	5	4	4	3	2										
Switch from raw to composted manure				1	1	3	4		5	3	4		4							
Technique innovation in manure treatment						7	4	4	6	4										
Change of manure application on cropland											7	4	4	6	4					
Digestion of manure to produce heat and electricity: Biogas system						7	3	4	6	4							1			
Energy use at the farm																				
Switch to renewable/green energy						5	4	4	6	4	2									
Reduction of fossil energy use						5	4	4	6	4	2									
choose crop that need less energy input							4		6	4						7	4			

6.2. Feedback from small dairy farms

The small dairy farms in this project are defined as herd size between 400 and 2,000 heads. Aforementioned, we concluded that based on the published data the small farms use more local by-products, mainly to reduce the cost, and may have low impact on the environmental parameters like GHG emission in feed transportation. However, when they choose local by-products, their intentions are not related to the environmental impact; in their opinion, fulfilling the basic requirements of local environmental regulation should be enough for running a dairy farm. Just as the medium dairy farms, they lack basic knowledge of the GHG emission issue. Keeping cows healthy and keep milk yield high when the milk price is good and making profit is at their priority.

In choosing the suggested mitigation options, they paid great attention to feed and feeding management. Also, improving herd and animal fertility and reproduction are other concerns. Compared to other mitigation options that are most conditional, mainly due to the cost, farmers are highly concerned about the roughage quality and the impact on the health of cows. Regarding all the mitigation options that require further investment for the sole purpose of decreasing GHGs, farmers would argue that it is not necessary because there is no supervision from the government with respect to the GHG emissions. Thus, improving the educational level of small dairy farmers, will help the farmers to become more aware of the importance of sustainable dairy farming. This would be helpful to conduct the GHG mitigation options in the small dairy farms.

6.3. Feedback from large dairy farms

In EU countries, longevity of cows and life-time milk yield are getting more and more attention. In China, most of the dairy farms are still keen on increasing the annual milk yield. Among all the provided mitigation options, measurements to improve animal health and husbandry, feed and feeding management are the most feasible options. From all the provided mitigation options, improving reproductive performance, reducing the prevalence of diseases, and feeding regime optimization were scored as “feasible” options for all the dairy farms. In the feeding production category, large-size dairy farms would like to improve roughage quality, especially the whole corn silage. Surprisingly, no large-size dairy farms would reduce imported roughage as the domestic roughage quality is considered to be too low. A certain share of imported roughage including oat hay and alfalfa hay is key to production performance. Thus, introduction of local by-products and other feeds are difficult for these farmers. Only when the milk yield performance is not affected, they will consider using some local feeds or ingredients. In the manure treatment category, according to the managers of large-size dairy farms, before deciding about a change in manure management, they would consider the cost of improvement; and only after some environmental regulation of the local government they would decide to change manure management practices.

On the other side, farmers are used to relying on the fact that there is always some subsidy from the government for improving or upgrading manure treatment equipment for environmental purposes. The public relation department and the environment department of big dairy farming groups prefer to choose the options encouraged by the government, such as upgrading the manure treatment to anaerobic digestors for biogas production.

Similar considerations are made regarding the energy use on large dairy farms, when governments provide subsidies to help dairy farms switch to photovoltaic power, or recycling the heat energy from their milking facility. They will take actions under the guidance of the government. Therefore, regarding the manure treatment and energy use categories, the guidance and preference of government will strongly affect their decisions.

Most of the large-size dairy farms believe that breeding low-CH_4 emitting cows is the task of researchers or the technical department of the group, but not the task of a farm. Of course, when the productivity of cows is improved, they are willing to introduce the new breed to the herd; therefore, the mitigation options in this category is conditionally chosen. Since the pilot farms in this project do not have crop land, they rarely consider mitigation options in the feed production and soil sequestration parts. All in all, for large dairy farms, they can easily deal with new concepts to reduce GHG emissions, but their decision depends largely on the productivity of cows and the strategy of the mother company.

6.4. Feedback from medium dairy farms

In this project, we defined the medium-size dairy farms at herd size between 2,000 and 5,000 heads. Compared to the large-size dairy farms, the medium-size dairy farms did not pay attention to the GHG emissions. Similar to the large-size dairy farms, medium-size dairy farms adopted precision feeding techniques as the most feasible mitigation options, which would reduce production cost and improve milk yield. Medium-size dairy farms were more sensitive to the profitability; so looking for the mitigation options that could increase profit. Unlike the large-size dairy farms, medium-size dairy farms tended to choose low-cost feed, but not to choose the best quality feed to pursue the best performance. As for mitigation options that need long-term effort, like breeding, renovating manure treatment machinery, or energy source, their opinions tend to be conditional, mainly depending on regulations, subsidies, and policies of the governments.

6.5. Feedback from dairy processors

For the giant players amongst the dairy processors in China, especially the listed shareholder companies, the GHG emission topics are involved in the environmental, social and governance (ESG) report, that has to be yearly published by a company or organization about ESG impacts. However, from the published reports, we can see that these companies currently focuses on the milk processing part and energy consumption rather than GHG emissions from the supplying farms. In the future, if an enterprise is aiming to move forward on GHG mitigation, they will certainly pay more attention to the farming side.

Regarding the GHG mitigation in dairy farming part, the dairy processors are more concerned about the standard operation procedure for international and domestic carbon inventory evaluation, which will allow them to do benchmarking. Also, they are concerned about the mitigation options which need support from researchers. For example, they would like researchers to investigate how much a certain feed additive in the ration could reduce GHG emissions. They are also keen on seeing some successful examples of mitigating GHGs through improving efficiency.

Although dairy processors are willing to use alternative feeds or optimize the feed nutrient content to reduce production costs, they are not as sensitive as farmers to the cost of applying new techniques as these costs are usually not substantial compared to machinery that has to be purchased or upgraded. Compared to costs, they care more about their social responsibility, to gain positive social impact on applying a GHG mitigation strategy and on the integration of the mitigation options in the overall development of the company. Also, after peaking at carbon emission, as scheduled by the central Chinese government for 2030, how the future will be and what may change in the current policy are some of the most frequently mentioned questions and concerns of dairy processors.

6.6. Feedback from experts and consultants

The feedback from and choices of experts and consultants about GHG emissions in the dairy sector are quite different from those from dairy farmers and processors. For example, experts and consultants are interested in accurate measurement of GHG emissions with innovation technology. For example, officers from governments and breeding experts are very interested in the selection of low emission dairy cattle because it fits the call of the Chinese government to develop breeding in livestock science and crop science.

However, this needs large investment and efforts in research and cannot be applied immediately by the industry. From the general low-carbon experts, we have noticed that they are familiar with the universal measurements of GHG but lack knowledge on emissions from animals and crops and are not used to incorporating the impact of other parts of the dairy chain, as applied in the LCA approach. Thus, the mitigation options they choose are more general options focusing on the reduction of fossil fuels that can be applied in every industry. They lack knowledge on methane and nitrous oxide, the biggest GHG emissions in dairy farming.

6.7. Summarized mitigation strategies that suit different farms

6.7.1. Mitigation strategies that suit all types of farms

In the animal health and husbandry section, it has been concluded that improving the herd and animal fertility and reducing the prevalence of diseases and parasites are the most feasible mitigation options and both score high with different stakeholders. Improving the fertility will bring farmers extra profit, while preventing the animal from diseases, is a compulsory measure. If it will provide extra benefit for GHG emission, these options will certainly be chosen as the most feasible mitigation options. Since enteric fermentation contributes most to the total emissions, this category represents a strong potential for mitigation. Meanwhile, continuous improvement of feed conversion (efficiency) is always the target of every dairy farm. Therefore, this is an attractive strategy that will not only contribute to GHG intensity but also to improved profitability. Both feeding regime optimization and using precision feeding technology are interesting mitigation options for most stakeholders.

Another mitigation option that suits all types of farms is the change of energy source to green energy like solar energy. However, this is conditional because the farms prefer to get compensation from the government when changing energy source to renewable energy sources. The Chinese government offers different supporting policies on different levels. Therefore, the farmers will prefer to get the subsidy for this rather than spending extra money by themselves.

6.7.2. Mitigation strategies that suit large dairy farms in China

For large dairy farms in China, we can see that the productivity of cows is already high, with an average milk yield at 10.28 tons per cow per year. Under such high productivity conditions, the space to further improve milk yield will be limited considering the input/output ratio. Many large farms transport their feed over long distances. Combining the situation that Chinese dairy farming is relying heavily on imported roughage and soybeans as protein sources, we suggest a fairer evaluation of production efficiency instead of pursuing high milk yield be introduced to the industry.

Taking the small farms in this report as example, milk production is not as high as that of large dairy farms. However, they use more local by-products from crop farming and the cost for transportation is saved and the GHG emission is also low in this category.

Feed additives will help modulating the rumen function and could be considered a strategy to improve the health of cows and reduce emissions. There are already a large number of available additives that have pronounced effects on increasing the milk yield through adjusting the rumen function. However, the mitigation effect of these additives needs to be further tested by researchers. As for the manure treatment, it is common in China on large dairy farms, that crop farming and dairy farming are separated. This makes the application of manure as fertilizer for crops impossible and also hinders building integrated dairy farms.

The long-term strategy we offer to large dairy farms will be to consider acquiring crop lands to reduce feed transportation costs as well as to make the best use of nutrients in the manure to grow roughage. However, this will need the support of the land use policy from different departments of the government.

6.7.3. Mitigation strategies that suit medium dairy farms in China

In this project, we found that medium size farms have the lowest efficiency considering the input/output ratio. The milk yield per cow per year in this project is most similar to that on the small farms (9.02 ton/cow/year vs. 8.8 ton/cow/year). However, the impact in feed production and feed processing, energy, and enteric fermentation on GHG emissions is high. Therefore, the most suitable mitigation option to the medium size farms in China is to continue to improve the production efficiency, which requires integrated measures like improving the genetics, improving the feeding regime, and improving the overall farm management. The large emissions from energy consumption also indicates that upgrading machinery efficiency should be considered.

6.7.4. Mitigation strategies that suit small dairy farms in China

The biggest problem existing in small-sized dairy farms is that the basic operating costs are relatively higher than those in large-size farms because of the smaller number of cattle. The small dairy farms prefer to use local by-products as roughage to reduce feed cost even though those materials have relatively low nutrient content that negatively affect production performance. Thus, it will be of great importance to achieve balance of using by-products and increasing productivity.

7. Conclusions

Because of the demand for high quality milk products, the milk processors are accelerating their expansion, trying to obtain more control on good milk resources. The increased social responsibility of big milk processors makes them pay a lot of attention to the sustainable development of the enterprise, including reducing their GHG emissions. In the past decade, Chinese dairy farms have gained big progress in milk yield and milk quality. Milk production per cow per year has increased with the herd size of dairy farms because of the higher educational level of farm managers and better management of the farms in all aspects.

However, GHG mitigation is a new topic and a serious challenge for the dairy sector. Since the lack of basic knowledge of the nature of GHGs, most of the dairy processors leave this issue to the environment controlling department or ESG department, and prefer to make more efforts on choosing eco-friendly packages or switching to green energy sources, but ignoring the fact that the upstream dairy farms are large contributors to GHG emission.

Reducing emissions from dairy farms requires the dairy farming sector to continuously apply improved best practices and use innovative technology in each process of the farming system. Progress in reduction of GHG emissions in China should be tailored for the diverse dairy production systems in the country. Currently, we have identified in this project the mitigation options that suit the different dairy herd size categories. The decisions government policy makers will take on future GHG reduction targets and obligations to apply certain reduction techniques will have great impact on the adoption of GHG mitigation options, especially high-cost ones. Accelerating top-level design and overall planning to reform the dairy sector towards a more sustainable orientation taking into account GHG emissions, is strongly suggested.

All in all, concerted action by all stakeholders is needed as a first step to support, invest and promote innovations that are required to implement efficient low-carbon practices; and as a next step to explore additional innovations to further reduce emissions from the dairy sector.

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