Analysis of low carbon development strategies in the livestock and poultry industry from an international economic perspective

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Abstract. Climate change is a common concern worldwide. In order to avoid the deterioration of the earth's climate and ecosystem, there is an urgent need to explore measures to reduce carbon emissions. Livestock and poultry farming is an important source of agricultural greenhouse gas emissions, and scientific assessment of carbon emissions in its production process is of great significance for the selection of emission reduction technologies and the development of low-carbon agriculture. This study introduces the relevant research progress of carbon emissions from livestock and poultry farming in China from 1997 to 2018 and introduces the measurement methods, spatial and temporal distribution, and emission reduction measures of carbon emissions from livestock and poultry farming. Hope to provide some new ideas for the relevant industries.

Keywords: Livestock farming; Spatial and temporal distribution; Emission equivalents; Low carbon development strategy

1 Introduction

Climate change is a global issue facing humanity and with carbon dioxide (CO_2) emissions and greenhouse gas (GHG) emissions soaring in all countries, countries around the world are reducing GHG emissions in a global compact [1]. Agricultural production systems play an important role in the long-term journey towards peak carbon and carbon neutrality. Research on agricultural carbon emissions has focused on GHG emissions from agricultural production and land use [2]. According to statistics, GHG emissions from agricultural activities and land use amounted to nearly 11.1 billion tonnes in the period 2007 to 2016, accounting for approximately 20% of total global anthropogenic GHG emissions. Methane (CH_4) emissions from agricultural production processes accounted for approximately 1/2 of total sector-wide emissions in the period 2010 to 2016, while nitrous oxide (N_2O) emissions accounted for approximately 3/4 of total emissions [3, 4, 5]. Therefore, in-depth research on agricultural carbon emission technologies and the development of feasible carbon reduction and sequestration solutions for agriculture are of strategic importance to achieve sustainable economic and social development [6].

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The livestock industry is an important source of GHG emissions from agriculture, and scientific assessment of carbon emissions from livestock production is important for the selection of emission reduction technologies and the development of low-carbon agriculture [7]. Globally, CH_4 emissions from agriculture account for 50% of the total CH_4 emissions from human activities, and N_2O accounts for 60% of the total N_2O emissions from human activities [8, 9]. China is a large livestock country, and the total CH_4 and N_2O emissions in China in 2014 were 55.29 million tonnes and 1.97 million tonnes respectively, of which 13.01 million tonnes of CH_4 were emitted by livestock and poultry farming, accounting for 23.5% of China's total CH_4 emissions, and 233,000 tonnes of N_2O, accounted for 11.8% of total N_2O emissions [10,11,12]. As the demand for livestock products grows, the number of ruminants and non-ruminants is expected to continue to grow in the coming years, which will further increase GHG emissions from the livestock sector [13]. Therefore, the study of carbon emissions from livestock is of great importance to the sustainable development of the global livestock industry [14].

Based on this, this study provides a statistical accounting of the carbon emission equivalents of the livestock and poultry farming industry in China from 1997 to 2018, and analyses them in terms of spatial and temporal distribution, influencing factors, and future development trends. This study may provide a theoretical basis for the relevant departments to formulate policies on emission reduction in the livestock and poultry farming industry in order to achieve green, low-carbon and high-quality development of the livestock and poultry farming industry in China.

2 Carbon emissions accounting methods

This section presents the calculation of GHG emissions from livestock farming processes in China, mainly including CH_4 emissions from enteric fermentation processes in ruminants, and CH_4 and N_2O emissions from livestock manure management processes [15] (Figure 1).

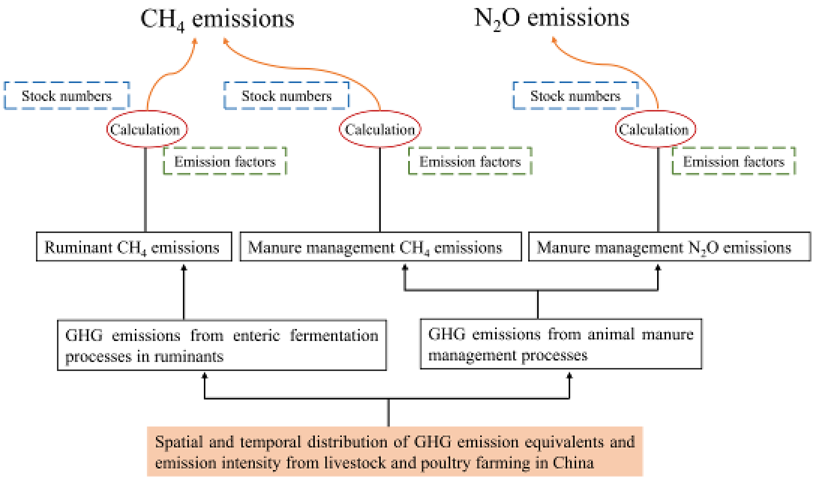

Fig. 1. Calculation of GHG emissions from livestock farming processes

2.1 CH_4 emissions during animal enteric fermentation process

CH_4 emissions from intestinal fermentation in animals are produced by the fermentation of feed by microorganisms living in the animal's digestive tract during normal metabolic processes, which only included CH_4 emissions from the mouth, nose, and rectum of the animal, not from faces [16]. Ruminants have large rumen volumes, host a variety of cellulose-degrading microorganisms that produce large amounts of CH_4 gas, and are therefore the main source of CH_4 emissions from the animal's enteric fermentation [17]. Non-ruminants emit less CH_4 from enteric fermentation, particularly poultry, as their small body weight means that CH_4 emissions from their enteric fermentation are negligible [18, 19].

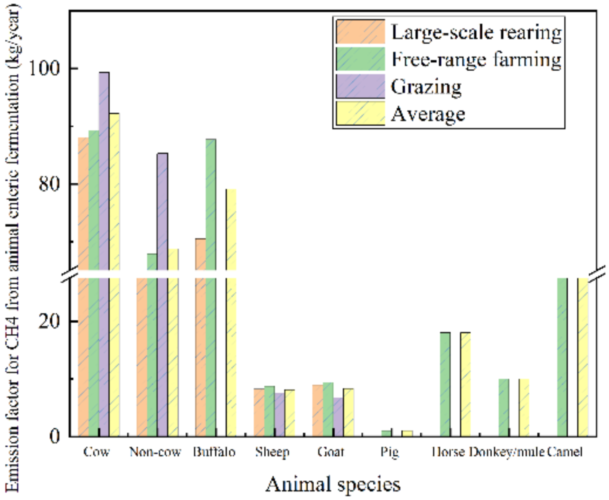

Fig. 2. CH4 emission factors from animal enteric fermentation for different livestock feeding practices (data come from the National Bureau of Statistics)

In this study, the sources of CH_4 emissions from intestinal fermentation in animals include dairy cows, non-dairy cows, goats, sheep, pigs, horses, donkeys, mules, and camels. CH_4 emissions from enteric fermentation were calculated for each species of animal production using Eq. (1), and total CH_4 emissions from enteric fermentation in the livestock were calculated using Eq. (2) [20].

$$E_{CH4,enteric,i} = EF_{CH4,enteric,i} \times AP_i \times 10^{-7} \tag{1}$$

where $E_{CH4,\,enteric,\,i}$ is the CH_4 emissions from animal i (million tones CH_4/year); $EF_{CH4,\,enteric,\,i}$ is the CH_4 emission factor for animal, kg/year; AP_i is the number of the i-th species.

$$E_{CH_4} = \sum E_{CH_4,enteric} \tag{2}$$

where E_{CH4} is total CH_4 emissions from enteric fermentation in animals, million tones CH_4/year; E_{CH4}, enteric, i is CH_4 emissions from the i-th animal, million tones CH_4/year.

2.2 CH_4 emissions during animal manure management process

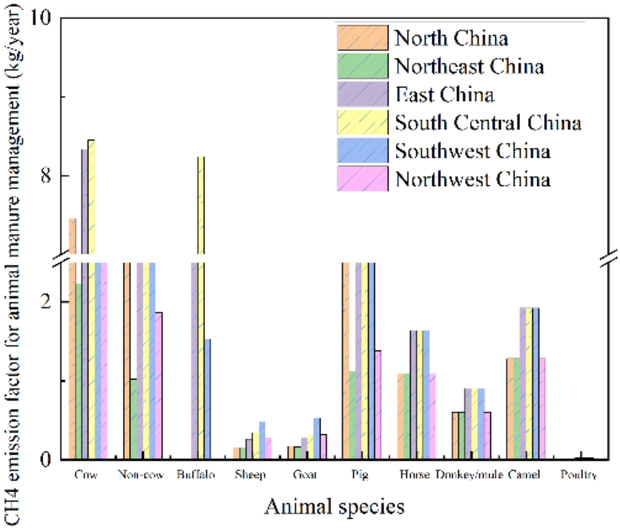

Fig. 3. CH4 emission factors for animal manure management for livestock farming in different regions (data come from the National Bureau of Statistics)

CH_4 emissions from animal manure management in livestock farming are generated from the storage and handling of animal manure before it is applied to the soil, and its emission factors depend on manure characteristics, manure management practices, the proportion of different manure management practices used, and local climatic conditions [21]. CH_4 emissions from specific animal manure management are calculated using Eq. (3) and total CH_4 emissions from livestock farming manure management are calculated using Eq. (4).

$$E_{CH_4,manure,i} = EF_{CH_4,manure,i} \times AP_i \times 10^{-7} \quad (3)$$

where $E_{CH4,\,manure,\,i}$ is the emissions of managed CH_4 from animal manure of species i (million tons of CH_4/year); $EF_{CH4,\,manure,\,i}$ is the emission factor for the i-th animal manure management CH_4, kg/year; AP_i is the number of the i-th species.

$$E_{CH_4} = \sum E_{CH_4,manure\,,i} \quad (4)$$

where E_{CH4} is the total CH_4 emissions from animal manure management (million tons of CH_4/year); $E_{CH4,\,manure,\,i}$ is the CH_4 emissions from animal i (million tons of CH_4/year).

2.3 N_2O emissions during animal manure management process

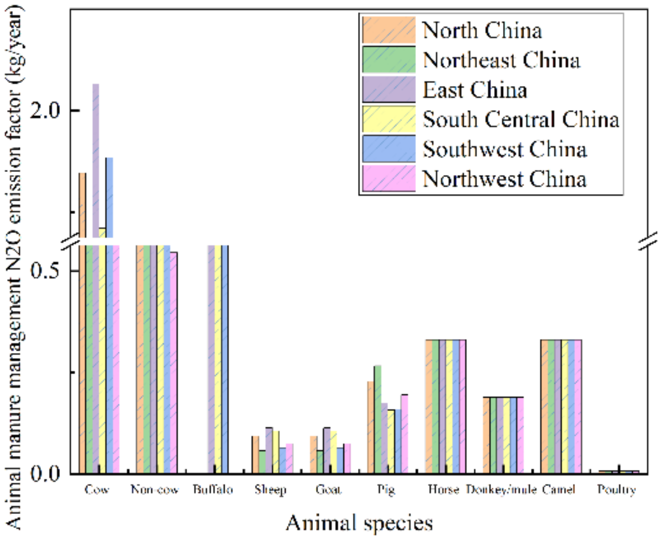

Fig. 4. N2O emission factors for animal manure management for livestock farming in different regions (data come from the National Bureau of Statistics)

N_2O emissions from animal manure management during livestock farming are generated during the storage and handling of animal manure before it is applied to the soil [22]. The N_2O emission factors for animal manure management depend on the daily nitrogen content of the manure excreted by different animals and on different manure management practices. Animal-specific manure management N_2O emissions were calculated using Eq. (5) and total N_2O emissions were calculated using Eq. (6) [23].

$$E_{N_2O,manure,i} = EF_{N_2O,manure,i} \times AP_i \times 10^{-7} \tag{5}$$

where $E_{N2O,\,manure,\,i}$ is the N_2O emissions from species i animal manure management (million tons of N_2O/year); $EF_{N2O,\,manure,\,i}$ is the N_2O emission factor for manure management of animal i (kg/year); AP_i is the number of animals of species i.

$$E_{N_2O} = \sum E_{N_2O,manure,i} \tag{6}$$

where E_{N2O} is total N_2O emissions from animal manure management (million tons of N_2O/year); E_{N2O} is the N_2O emissions from animal species i (tones of N_2O/year).

3 GHG emission equivalence and intensity of emissions from the livestock and poultry sector

3.1 Spatial and temporal distribution of CH4 emission equivalents

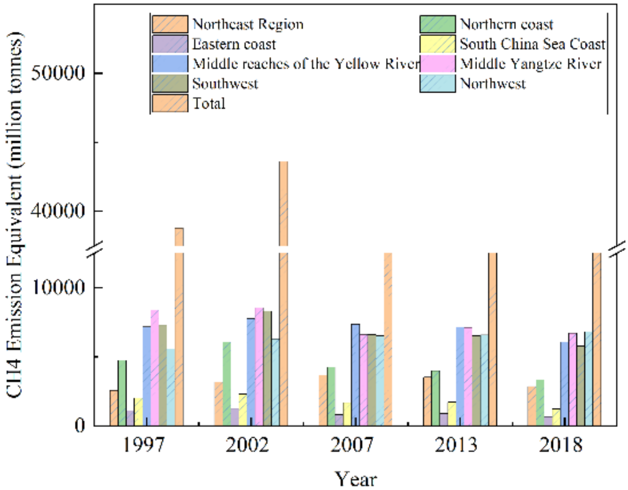

Fig. 5. Spatial and temporal distribution of CH_4 equivalent emissions from livestock and poultry farming in China (data come from the National Bureau of Statistics)

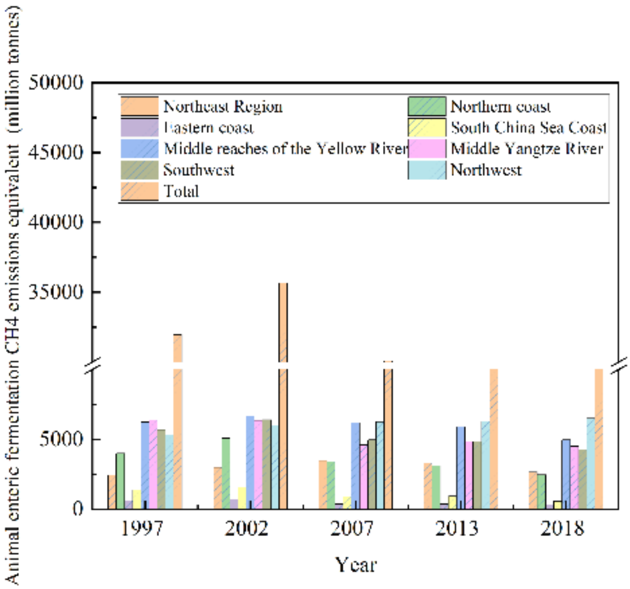

Fig. 6. Spatial and temporal distribution of CH_4 emission equivalents from animal enteric fermentation during livestock and poultry farming in China (data come from the National Bureau of Statistics)

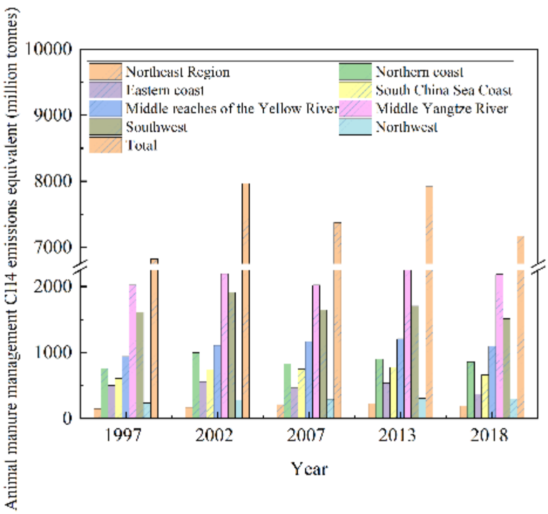

Fig. 7. Spatial and temporal distribution of CH_4 emission equivalents from animal manure management for livestock and poultry farming processes in China (data come from the National Bureau of Statistics)

During the period from 1997 to 2018, CH_4 emission equivalent from livestock and poultry farming showed a trend of increasing and then decreasing, from 387,844,700 tonnes to 333,275,100 tonnes (Figure 5). In terms of the geographical distribution of emissions, there was a small increase in livestock farming CH_4 emission equivalents on the northeast and northwest regions, 11.5% and 22.4% respectively, while there were significant decreases in CH_4 emissions in the northern coast, the eastern coast, the middle reaches of the Yellow River and the middle reaches of the Yangtze River. This indicates that the restructuring of the livestock breeding industry and the introduction of advanced technologies in each region have had a positive impact on GHG emission reduction. In terms of the composition structure of emissions, the share of enteric fermentation in CH_4 emissions from livestock and poultry farming in China has always remained around 80% during the period from 1997 to 2018, but with the restructuring of feeding, the share has gradually decreased from 82.4% in 1997 to 78.5% in 2018, while the share of manure management has gradually increased from 17.6% to 21.5% (Figure 6). In terms of the composition of emissions in terms of geographical distribution, the proportion of CH_4 emissions from manure management is relatively high in coastal areas, while the proportion of CH_4 emissions from enteric fermentation is relatively high in inland areas, which is closely related to their different feeding patterns and the structure of feeding stocks (Figure 7).

3.2 Spatial and temporal distribution of CH_4 emission equivalents

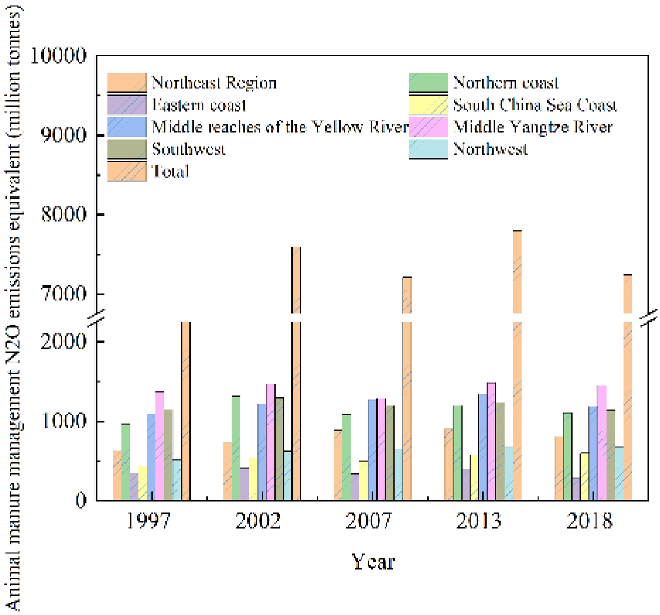

Fig. 8. Spatial and temporal distribution of N_2O emission equivalents from animal manure management for livestock and poultry farming processes in China (data come from the National Bureau of Statistics)

During the period from 1997 to 2018, the trend of N_2O equivalent emissions from animal manure management in China's livestock farming process and its CH_4 emission equivalent was generally consistent, increasing slightly from 64,872,500 tonnes in 1997 to 72,446,600 tonnes in 2018 (Figure 8). Since N_2O emissions from livestock farming processes are only calculated for N_2O emissions from animal manure management, this animal manure management N_2O emission equivalent is the N_2O emission equivalent from livestock farming in China. Total N_2O emissions from livestock and poultry farming in China were basically stable at 65-73 million tonnes over the 20-year period, with a small increase in N_2O emissions in inland areas but a small decrease in coastal areas, with the most significant decrease of about 16.9% in the eastern coast.

3.3 Spatial and temporal distribution of CH_4 emission equivalents

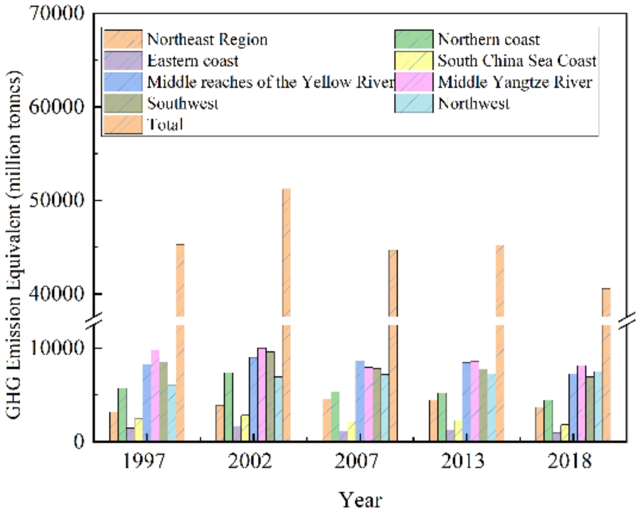

Fig. 9. Spatial and temporal distribution of GHG equivalent emissions from livestock and poultry farming in China (data come from the National Bureau of Statistics)

During the period from 1997 to 2018, the GHG equivalent emissions from livestock and poultry farming in China showed a trend of rising and then falling (Figure 9) due to a catastrophic clinical disease known as "unnamed hyperthermia" that struck large and small pig farms in June 2006, resulting in a large number of pig deaths. After the epidemic was alleviated, China's pig industry was able to recover and the GHG equivalent emissions from livestock and poultry farming slowly rose.

4 Conclusion and Carbon reduction measures

The results of various total carbon emission accounting and forecasting show that the situation of emission reduction in China's livestock and poultry farming industry is serious. If no carbon reduction measures are taken, the growth rate of carbon emissions from livestock and poultry farming will continue to rise with the continuous development of the industry [24]. At present, researchers mainly provide emission reduction measures for carbon emissions from livestock and poultry farming by controlling emissions at source, controlling emission factors through scenario analysis, and terminal carbon neutral [25, 26, 27, 28]. Comprehensive livestock and poultry farming carbon emission sources, influencing factors and control techniques, etc., the future emission reduction measures can be carried out in the following three aspects: (1) Source control. The focus is to adjust the animal's diet, including adding anti-methanogenic bacteria to inhibit CH_4 production and changing the feed structure to improve the digestibility of the diet. (2) Differentiated abatement factors. Manure management practices can affect CH_4 and N_2O emissions and the Intergovernmental Panel on Climate Change (IPCC) guidelines provide formulae for calculating emission factors involving different manure management practices and the proportion of them used. Emission factors can be altered by changing manure management practices. (3) Terminal carbon neutral. To achieve the double carbon target, in addition to emission reduction, carbon sequestration is also needed, and carbon sequestration and conversion have become the future trend in carbon reduction [29]. (1) Physical carbon sequestration is the long-term sequestration of carbon dioxide in exploited oil, and gas wells, coal seams and the deep sea [30]; (2) Biological carbon sequestration is the conversion of carbon dioxide into carbohydrates in the form of organic carbon through photosynthesis in plants [31]. Although a single emission reduction scheme can achieve a certain level of reduction, it can be found in previous studies that a combination of different emission control strategies can reduce carbon emissions from animal husbandry to a greater extent.

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