FASE FRONTIERS OF AGRICULTURAL SCIENCE AND ENGINEERING

Engineering Transactions of CAE

REVIEW

2026 / Volume 13 / Issue 2 / 25654

Agricultural methane emission reduction in China: policy evolution, practical challenges and policy recommendations

Xiangyang ZHANG[1,2], Yumei ZHANG (✉)[1,2], Shenggen FAN[1,2]

1 College of Economics and Management, China Agricultural University, Beijing 100083, China.
2 Academy of Global Food Economics and Policy, China Agricultural University, Beijing 100083, China.

KEYWORDS

Agriculture, challenges, methane, policy

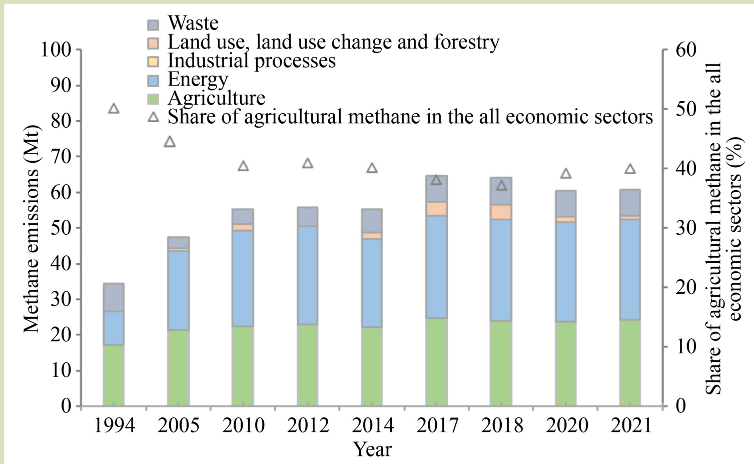
HIGHLIGHTS

- Agricultural methane emissions in China remain high being 40% of total methane emissions in 2021.
- The Chinese government is promoting agricultural methane reduction through the integrated implementation of climate change policies and green agriculture development policies.
- Agricultural methane reduction creates multiple challenges, including growing pressure from increasing food demand, low adoption of mitigation technologies, an underdeveloped measurement, reporting and verification system and insufficient policy support and economic incentives.
- Greater emphasis should be placed on technological innovation, enhanced policy support and strengthened economic incentives.

Received April 12, 2025;
Accepted August 1, 2025.

Correspondence: zhangyumei@cau.edu.cn

GRAPHICAL ABSTRACT



ABSTRACT

China has made considerable effort to address methane emissions in the agricultural sector. This paper analyzes the trends in China's agricultural methane emissions using national greenhouse gas inventory data from 1994 to 2021, identifies key emission sources and reviews relevant policies, while summarizing the practical challenges currently faced in mitigation efforts. The findings reveal that China's agricultural methane emissions remain high. Although a turning point emerged in 2017, emissions rebounded slightly in 2021 with the recovery of pork production. Rice production, enteric fermentation and manure management are the key agricultural methane emission sources. China has made progress in reducing agricultural methane emissions by integrating climate change policies with green agricultural development initiatives. However, the implementation of these policies must overcome several challenges. The growing food demand will further intensify the pressure on methane reduction. Low adoption rates of existing technologies and limited development of innovative solutions hinder progress toward emission reduction targets. The measurement, reporting and verification (MRV) system remains inadequately developed. Inadequate policy support and financial incentives compromise the sustainability of current efforts. This paper proposes several pathways to promote agricultural methane reduction and support the transition to low-carbon agricultural development. These include strengthening the MRV system, enhancing policy and financial support for emission reduction, advancing research and development, establishing compensation mechanisms for emission reduction, encouraging low-carbon and healthy dietary habits among consumers and strengthening international cooperation.

1 Introduction

As the second-most important greenhouse gas, methane has a shorter atmospheric lifetime compared to other greenhouse gases. Controlling methane emissions can directly reduce its concentration in the air. Therefore, reducing methane emissions is considered an effective way to slow global warming and mitigate the impacts of climate change in the short and medium term[1,2]. As the largest methane emitter globally, accounting for one-fifth of global methane emissions[3], China has attached great importance to methane mitigation efforts. The country released the Methane Emission Control Action Plan in 2023, its first dedicated policy targeting methane reduction. Methane reduction has become a fundamental strategy in China's long-term response to climate change[4]. Also, Chinese goverment emphasized China would announce its 2035 Nationally Determined Contributions (NDCs) target covering all economic sectors and all greenhouse gases before the United Nations Climate Change Conference in Belém in April 2025 at the Leaders Meeting on Climate and the Just Transition.

The agricultural sector, as the second-largest emitter of methane, is crucial for methane reduction and should not be ignored[5]. China is a major agricultural producer, with agricultural methane emissions ranking third globally, only behind India and Brazil. Methane is the predominant greenhouse gas emitted by China's agricultural sector, accounting for 73% of its total agricultural greenhouse gas emissions[6]. Consequently, reducing agricultural greenhouse gas emissions primarily means lowering methane emissions. Methane emissions from China's agricultural production activities mainly come from rice production, enteric fermentation and manure management. The Chinese government has repeatedly emphasized the adoption of mitigation technologies to curb emissions from these key sources in various policies. Nevertheless, agricultural methane emissions remain high and overall progress has been limited.

In fact, mitigating methane emissions in the agricultural sector is not only a technical issue, it is fundamentally a matter of policy and economics given its implications for food security, dietary consumption and government policy[7]. Therefore, this paper first analyzes the trends of methane emissions and identifies major emission sources based on methane emission data from all economic sectors and the agricultural sector in China. Secondly, this paper systematically reviews China's policies on agricultural methane reduction, analyzes the evolution of these policies and highlights the new characteristics reflected in recent policy documents. Finally, this paper identifies the key challenges hindering methane mitigation in agriculture and proposes targeted policy recommendations to better promote methane reduction in agriculture.

2 Trends of agricultural methane emissions in China

To better understand the trends and characteristics of agricultural methane emissions, this paper uses detailed national greenhouse gas inventories from successive National Communication on Climate Change of the People's Republic of China and the latest the First Biennial Transparency Report on Climate Change of the People's Republic of China issued by the National Development and Reform Commission and the

Ministry of Ecology and Environment[6,8–15]. In addition to analyzing total emissions, the paper incorporates activity-level data to calculate and assess emission intensity, offering a more comprehensive evaluation of emission dynamics in the agricultural sector. The data covers 1994, 2005, 2010, 2012, 2014, 2017, 2018, 2020 and 2021, and provides a detailed classification of methane emission sources across all economic sectors and within the agricultural sector. Agricultural methane emission sources are categorized into enteric fermentation, rice production, manure management and burning of crop residues. These data can effectively capture the trends in both all sectors and agricultural methane emissions in China over the past three decades, which is helpful to analyze the structure of methane emissions in the agricultural sector, identify major emission sources and provide a basis for targeted methane reduction efforts in agriculture.

China's total methane emissions across all economic sectors remain high. Total methane emissions increased from 34.3 Mt in 1994 to 64.7 Mt in 2017, an increase of 88.8% (Fig. 1). Since 2018, total methane emissions have had a slight downward trend, falling to 60.7 Mt by 2021, a 6.3% decrease from the 2017 level. As the second-largest source of methane emissions, the agricultural sector exhibited a similar trend. China's agricultural methane emissions also increased from 17.2 Mt in 1994 to 24.7 Mt in 2017, an increase of 43.7%, which was much lower than the growth rate of total methane emissions across all economic sectors during the same period. Agricultural methane emissions have also declined since 2017. However, the extent of the reduction has remained limited. By 2021, emissions had decreased to 24.3 Mt, being only a 1.7% reduction compared to 2017. Agriculture remains the second-largest source of emissions after energy sector. In 2021, methane emissions from energy and agriculture accounted for 46.4% and 40.0% of the total methane emissions, respectively. The share of agricultural methane emissions in total methane emissions declined from 50.2% in 1994 to 40.0% in 2021. This decline was primarily driven by the rapid increase in methane emissions from energy activities, which significantly raised total methane emissions and thereby squeezed the share of agricultural methane emissions.

Enteric fermentation and rice production are the primary sources of agricultural methane emissions. In 2021, the two accounted for 47.4% and 36.5% of agricultural methane emissions, respectively. This is mainly because China is one of the global leaders in livestock and rice production. The high productivity of ruminant animals, such as cattle and sheep, contributes significantly to methane emissions through enteric fermentation. Also, a large amount of methane is produced during rice production. Additionally, the rapid development of the livestock industry has led to methane emissions from manure management to rise, accounting for 15.5% of agricultural methane emissions, which must not be ignored.

There are notable differences in methane emission trends between the crop and livestock sectors. Methane emissions

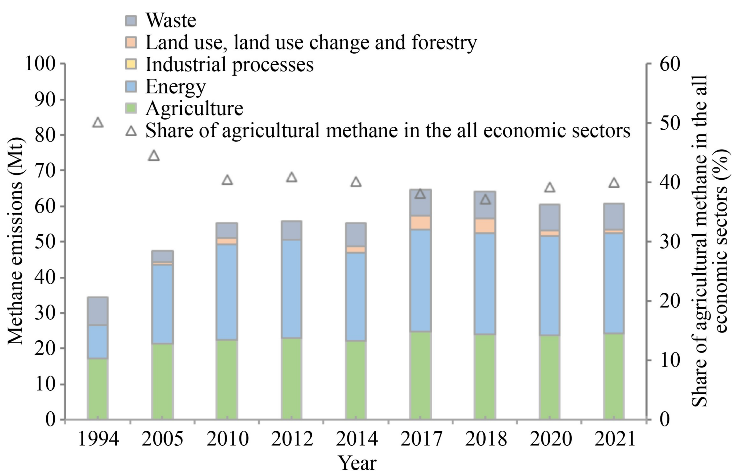


Fig. 1 Trends of China's methane emissions and agricultural share from 1994 to 2021.

from crop production have shown a downward trend after 2017 (Fig. 2). For example, methane emissions from rice production declined from 9.63 Mt in 2017 to 8.85 Mt in 2021. In contrast, methane emissions from livestock sector began to decline after 2017, primarily due to the outbreak of African swine fever in 2018, which caused a sharp reduction in pork production. As a result, methane emissions from both enteric fermentation and manure management experienced a slight decline in 2018. However, with the gradual recovery of pork production in 2020 and 2021, emissions from enteric fermentation and manure management began to rise again, and by 2021, total methane emissions from the livestock sector had surpassed the 2017 level. Similarly, this is also the reason why agricultural methane emissions rebounded in 2021.

With the implementation of methane mitigation measures, the emission intensity of enteric fermentation in the livestock sector has shown a downward trend. Similarly, the emission intensity of rice production has also declined when measured per unit of yield.

Due to data limitations, emission intensity is only available for 2005, 2020 and 2021. Nevertheless, the trend indicates a decrease in enteric methane emission intensity from 2020 to 2021. Specifically, for ruminants, methane emissions intensity dropped from 75.2 to 74.5 kg CH_4 per head for cattle and from 11.7 kg to 11.6 kg CH_4 per head for sheep (Fig. 3). In contrast, methane emission intensity of rice production per unit of area increased from 243 to 281 kg·ha^{-1} CH_4. However, when measured per unit of yield, the intensity declined, from 41.8 to 41.6 kg·t^{-1} CH_4 of rice (Fig. 4). This trend is consistent with previous research[16], indicating that the adoption of mitigation technologies can reduce emissions while maintaining agricultural productivity.

3 China's agricultural methane emission reduction policy

3.1 Policy review

China attaches great importance to the issue of climate change[17], and has implemented a range of policies to address agricultural methane emissions, including both climate change policies with direct impacts and green agricultural development policies with indirect impacts. Collectively, these types of policies contribute to reducing methane emissions from the agricultural sector.

The Chinese government issued its first policy document on addressing climate change in 2007, the National Climate Change Program, which already examined strategies for mitigating methane emissions in agriculture[18]. The document proposed measures such as cultivating high-yield, low-emission rice cultivars, adopting scientific irrigation techniques, advancing ruminant breeding technologies and improving animal manure management. In subsequent policy documents (Table 1), agricultural methane mitigation has continued to be addressed, particularly in three key areas: rice

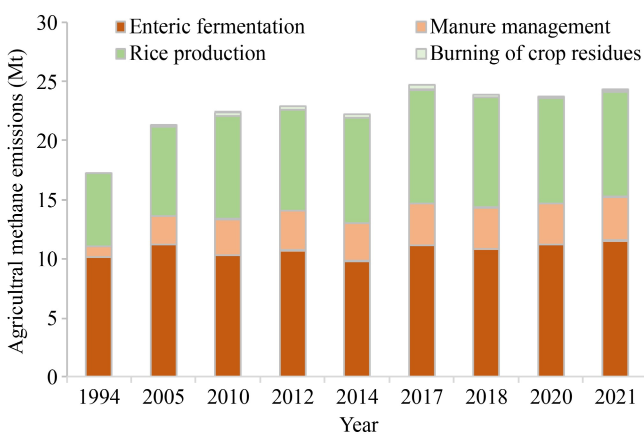


Fig. 2 Agricultural methane emissions by source in China from 1994 to 2021.

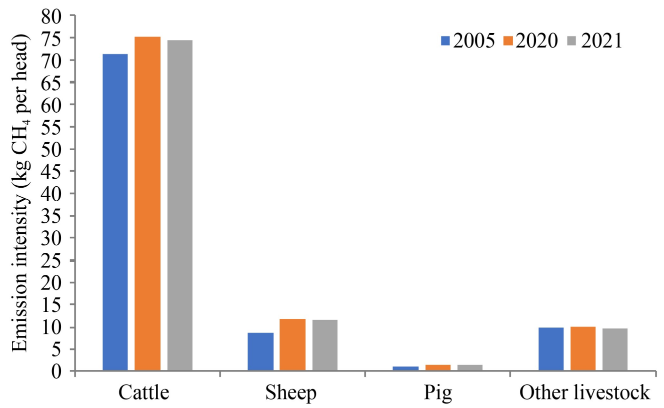


Fig. 3 Methane emission intensity of livestock in 2005, 2020 and 2021.

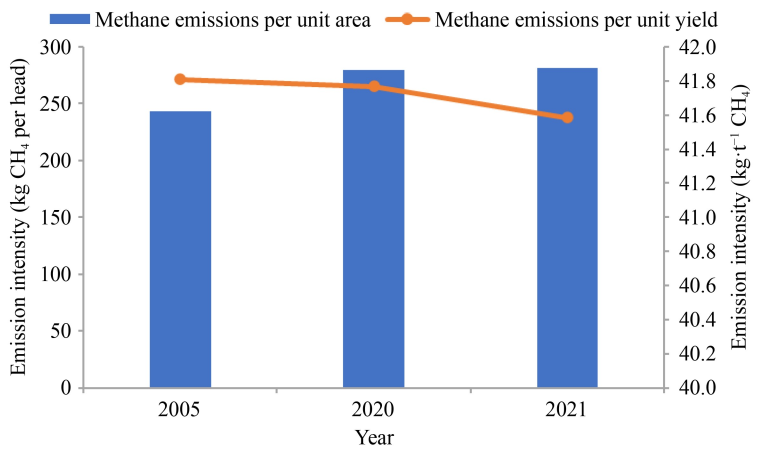


Fig. 4 Methane emission intensity of rice in 2005, 2020 and 2021 measured by area and yield.

production, enteric fermentation and manure management. For example, the Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions released in 2015 proposed continuing efforts to control methane emissions from paddies and to promote the comprehensive utilization of livestock manure.

Since China announced its dual-carbon goals in 2020, agricultural methane reduction has received increasing attention. The Implementation Plan for Agricultural and Rural Emission Reduction and Carbon Sequestration, jointly released by the Ministry of Agriculture and Rural Affairs and the National Development and Reform Commission in 2022, listed six key tasks, three of which explicitly mentioned methane reduction. These included three key initiatives: (1) reducing methane emissions from paddies, (2) lowering enteric methane emission intensity through improved digestive management and enhancing the resource utilization of livestock manure to reduce emissions from manure management, and (3) developing ecological fisheries to reduce methane emissions in the fishery sector[19–24]. This shows that reducing methane is a key focus area in the agricultural sector. Although China has not yet joined the Global Methane Pledge, it has actively pursued domestic methane reduction initiatives. In 2023, the Methane Emission Control Action Plan was jointly issued by the Ministry of Ecology and Environment and ten other

Table 1 China's climate change policies related to agricultural methane

Policy name	Issuing agency of China	Issue year	Rice production		Livestock production			Fisheries
			Variety breeding	Water management	High-quality ruminant breeds	Feeding management	Manure management	Ecological fisheries
National Climate Change Program	NDRC	2007	+	+	+	+	+	
Plan on Greenhouse Gas Emission Control During the 12th Five-year Plan Period	State Council	2011	+		+	+	+	
National Plan for Response to Climate Change (2014-2020)	NDRC	2014	+			+	+	
Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions	NDRC	2015	+	+			+	
Plan on Greenhouse Gas Emission Control During the 13th Five-year Plan Period	State Council	2016	+	+			+	
The Implementation Plan for Agricultural and Rural Emission Reduction and Carbon Sequestration	MARA and NDRC	2022		+	+	+	+	+
Methane Emission Control Action Plan	MEE, MFA, MARA and other agencies	2023		+		+		

Note: MARA, Ministry of Agriculture and Rural Affairs; MEE, Ministry of Ecology and Environment; MFA, Ministry of Foreign Affairs; NDRC, National Development and Reform Commission; + indicates the relevant agricultural methane reduction measures mentioned in the documents.

departments, highlighting the need to control methane emission in the agricultural sector[24]. This is China's initial action plan dedicated to methane reduction, marking the beginning of targeted measures to reduce non-CO_2 greenhouse gases.

China's green agriculture policies are also key in methane reduction, particularly through improved livestock manure management and water conservation in agriculture[25–33]. For example, policies on manure management set a target of achieving a comprehensive utilization rate of over 85% for livestock waste by 2030. While these policies are primarily designed to improve waste utilization and reduce environmental pollution, they also contribute indirectly to methane mitigation (Table 2). Overall, green agricultural policies and climate change policies are complementary, working together to advance methane mitigation in the agricultural sector. Therefore, the contribution of green agricultural policies to methane reduction should not be underestimated.

Over the last two decades of work in this area, China's agricultural methane reduction policies have shown three key characteristics.

First, the scope of policy coverage has become increasingly comprehensive. The existing policies focus not only on major methane emission sources such as rice production, ruminant enteric fermentation and manure management, but have also gradually expanded to include the fisheries sector. In terms of rice production, policy documents promote methane reduction through the adoption of high-yield, low-emission crop cultivars and improved water irrigation practices. In the livestock sector, mitigation measures include advancing ruminant breeding technologies, encouraging precision feeding to control enteric fermentation and enhancing the comprehensive utilization of livestock manure. Also, the Implementation Plan for Agricultural and Rural Emission Reduction and Carbon Sequestration released in 2022 broadened the scope of emission reduction efforts by proposing the development of ecological and sustainable aquaculture systems, such as rice-fish integrated farming and large-scale ecological fisheries, to reduce methane emissions from the fishery sector.

Table 2 China's agricultural green development policies related to agricultural methane

Policy name	Issuing agency of China	Issue year	Main content
Opinions of the CPC Central Committee and the State Council on Accelerating the Ecological Civilization Construction	CPC Central Committee and the State Council	2015	Promote the utilization of crop straw and other agricultural and forestry waste. Effectively control emissions of carbon dioxide, methane, and other greenhouse gases.
Opinions on Promoting the High-Quality Development of Animal Husbandry	State Council	2020	Promote the utilization of livestock manure.
The 14th Five-year National Plan for Green Agricultural Development	MARA, MEE, MNR, MST, NFGA and NRDC	2021	Promote the utilization of livestock manure, aiming to achieve a comprehensive utilization rate of over 80% by 2025. Advance agricultural carbon sequestration and emission reduction by enhancing the carbon sequestration capacity of forests, grasslands, farmland, and soils. Promote the adoption of water-saving technologies.
14th Five-year Plan Comprehensive work plan for energy conservation and emission reduction	State Council	2021	Further advance pollution control in large-scale livestock farms and promote county-wide resource utilization of livestock manure. By 2025, achieve a comprehensive utilization rate of over 80% for livestock manure.
Guiding Opinions of the State Council on Accelerating the Establishment of a Sound Economic System with Green, Low-carbon and Circular Development	State Council	2021	Promote the development of eco-agriculture by enhancing the resource utilization of livestock manure and advancing the comprehensive use of crop straw. Promote agricultural water conservation through the adoption of efficient water-saving technologies.
Guiding Opinions on Promoting the Development of Ecological Farms	MARA	2022	Explore low-carbon compensation policies focused on reducing emissions from paddy field methane, agricultural land nitrous oxide, enteric methane from animals, and methane and nitrous oxide from livestock manure management.
Guiding Opinions of the Ministry of Agriculture and Rural Affairs on Accelerating the Comprehensive Green Transformation of Agricultural Development and Promoting Rural Ecological Revitalization	MARA	2024	Strengthen the use of livestock manure as fertilizer by returning it to the fields. By 2030, achieve a comprehensive utilization rate of over 85% for livestock manure. Optimize feed formulations.
Opinions of the Ministry of Agriculture and Rural Affairs on Implementing the Feed Saving Action in Animal Husbandry	MARA	2024	Promote low-protein diversified feed formulation technology to improve feed conversion efficiency.

Note: MARA, Ministry of Agriculture and Rural Affairs; MEE, Ministry of Ecology and Environment; MNR, Ministry of Natural Resources; MST, Ministry of Science and Technology; NDRC, National Development and Reform Commission; NFGA, National Forestry and Grassland Administration.

Second, the range of governance actors has become more diversified. In the face of the complex challenges posed by climate change, the common single-agency governance models are increasingly inadequate for addressing modern environmental issues. Cross-department collaboration and multistakeholder participation have become more prevalent[34]. Agricultural methane reduction is no longer solely an issue for the agricultural sector, it also involves natural resource management, technological innovation and broader socioeconomic development. For example, although the Implementation Plan for Agricultural and Rural Emission Reduction and Carbon Sequestration released in 2022 targeted greenhouse gas emissions in the agricultural and rural sectors, it was jointly issued by six departments. While the Ministry of Agriculture and Rural Affairs is leading this initiative, other departments contribute significantly to the collaborative governance process.

Third, emission reduction targets have become increasingly ambitious. After nearly two decades of methane control efforts, policy objectives have evolved from the initial aim of merely controlling the growth of methane emissions to a more proactive goal of reducing and lowering emissions. This shift reflects a significant change in policy orientation and growing confidence among policymakers. Nevertheless, the setting of agricultural methane reduction targets cannot be separated from the specific historical period and social context. When agricultural methane emission targets were first established in 2007, agriculture was in a period of rapid development and the agricultural policy at that time prioritized increasing production. However, as agricultural productivity has improved, the goals of agricultural policy have gradually evolved into a dual-objective system that balances both productivity and environmental sustainability[35]. Consequently, driven by China's dual-carbon goals, the agricultural sector is now expected to adopt more ambitious methane mitigation targets to effectively contribute to overall emissions reduction.

3.2 Policy effect

China has implemented a series of measures targeting agricultural methane emissions since 2007, and these efforts have made some progress, with a turning point observed in 2017. First, the growth rate of agricultural methane emissions has slowed. Between 2005 and 2017, the average annual growth rate of agricultural methane emissions was 1.2%, substantially lower than the 2.6% growth rate for total national methane emissions during the same period. Also, the average annual growth rate of the sector declined from 2.0% in 1994–2005 to a lower level in 2005–2017, effectively meeting the target outlined in the 2007 China's National Climate Change Program to strive to control the growth rate of methane emissions. Agricultural methane emissions had entered negative growth since 2017, indicating initial progress toward the more ambitious goal of reducing methane emissions. Second, methane emission intensity has been gradually decreasing. With the gradual implementation of relevant policies, there has been continuous innovation and promotion of methane mitigation technologies in agriculture. The broader adoption of these technologies has led to a reduction in methane emissions per unit of agricultural output, reflecting improvements in both efficiency and sustainability.

However, it is important to recognize that agricultural methane mitigation in China is still in an early stage. Agricultural methane emissions remain high, reaching 24.3 Mt being 40% of the overall national methane emissions. Despite the turning point in 2017, the overall decline in emissions was limited, with only a 1.7% decline observed by 2021 compared to 2017 levels. Also, with the recovery of pork production in 2020 and 2021, agricultural methane emissions experienced a slight rebound in 2021 compared to 2020.

4 Challenges of reducing agricultural methane emissions in China

Despite China's efforts to reduce methane emissions, agricultural methane emissions remain persistently high. Although a turning point occurred in 2017, the reduction in emissions by 2021 has been modest. In light of this, this section summarizes the challenges facing agricultural methane reduction action.

First, the growing demand for food consumption intensifies the conflict between methane reduction and food security goals[36]. Rice, as a staple food of nearly 60% of China's population, is expected to maintain a stable growth in production over the medium to long-term. These trends make it difficult to reduce agricultural methane emissions from rice production. Given that both the rice production area and output are unlikely to decline significantly, mitigating emissions from paddies remains a considerable challenge[37]. As resident income rises, the demand for livestock products is projected to continue increasing[38,39], which is likely to drive continued growth in methane emissions from the livestock sector[40]. Efforts to reduce emissions may risk undermining food security goal[41,42]. How to reduce methane emissions from enteric fermentation and livestock manure while meeting rising demand for meat poses an even greater challenge[43].

Second, the low adoption rate of existing methane mitigation technologies coexists with inadequately developed innovation in emerging technologies. Although, agricultural methane reduction technologies have been proven to have enormous emission reduction potential[44–47], the adoption rate remains relatively low. For instance, the adoption rate of rice methane emission reduction technologies by farmers is less than 35%[48]. This is mainly because these technologies often require the integration of multiple practices to achieve maximum mitigation, increasing labor demands and implementation costs. Similar challenges are evident in the livestock sector, where many mitigation strategies are viable only for large-scale operations. Smallholder farms frequently lack the financial and technical capacity to adopt low-carbon practices. On the other hand, the cutting-edge technologies for methane emission reduction are still in the exploration stage. For example, breeding ruminants for low methane emissions is still at the experimental stage, and feed additives designed to suppress methane emissions lack systematic field testing and large-scale application[49,50]. These areas represent critical frontiers for future innovation in livestock methane reduction.

Third, the MRV system for agricultural methane has not yet been fully established, limiting the availability of reliable data to support mitigation policies. The dominance of smallholder farming leads to highly fragmented and spatially heterogeneous agricultural activities[51], which poses significant challenges for data collection and monitoring. Additionally, methane emissions in agriculture stem from diverse sources and involve complex mechanisms. For example, methane emissions from enteric fermentation in ruminants are influenced by factors such as animal species, feeding practices, and the development stage of the rumen. Similarly, methane emissions from rice production vary with cultivar type, water management practices, soil characteristics and fertilization regimes[52,53]. These complexities further complicate accurate emissions accounting and hinder the establishment of a robust MRV framework.

Fourth, economic incentives for agricultural methane reduction remain insufficient. Mitigating methane emissions aims to reduce the negative externalities of agricultural production. Since the benefits of emission reductions are shared by whole society, if the increased cost of adopting mitigation technologies is borne by farmers alone, it will be difficult to establish sustainable emission reduction behavior. Currently, subsidy schemes for methane reduction in ruminant livestock and rice production are still in the exploratory phase. There is no well-established ecological compensation or incentive mechanism specifically targeting farmers. Also, China has yet to establish a carbon trading market for agricultural methane[54]. Although the livestock industry is highly industrialized and many large-scale farming enterprises have adopted low-carbon practices, these efforts are not rewarded through any market-based incentives. As a result, the lack of economic return undermines the long-term sustainability of such mitigation efforts. If all costs are borne by farmers adopting emission reduction technologies, rational farmers, constrained by high costs and shrinking profit margins, will give up or scale back on adoption. This would significantly hinder the widespread implementation of mitigation measures and prevent the theoretical emission reduction potential convert into actual emission reduction results[55].

5 Policy recommendations

Mitigating agricultural methane emissions is a key measure for the agricultural sector to address climate change in the medium and long-term. Through this review of China's agricultural methane emission reduction policies, it is evident that although China has initially established a policy system for agricultural methane emission reduction, which is characterized by broad sectoral coverage, diversified governance and increasingly ambitious mitigation targets are needed. However, in the specific implementation process, due to the trade-off between emission reduction and food security goals, low technology adoption rate, an inadequately developed MRV system, and insufficient economic incentives, it is difficult to convert theoretical methane emission reductions to actual reductions, resulting in China's agricultural methane emissions remaining high. Therefore, this paper offers the following recommendations.

First, it is essential to accelerate the development of MRV system for agricultural methane. Scientific measurement and accounting of emissions are critical for identifying emission trends, informing policy decisions and supporting participation in carbon trading market. Key efforts should include establishing MRV systems in major emitting regions and sectors, refining methane accounting methodologies, regularly updating baseline data sets and emission factors, and building a standardized, transparent and authoritative agricultural methane inventory framework. These improvements will provide a strong data foundation for emission mitigation, facilitate the design of low-carbon compensation mechanisms and lay the groundwork for integrating agriculture into national carbon trading systems.

Second, the policy framework should be refined through the development of a detailed action plan specifically targeting agricultural methane reduction. The reasonable emission reduction targets and timelines must be established to guide orderly and effective implementation. As a major methane-emitting sector, agriculture will inevitably face increased pressure to align with the new NDCs targets. Future agricultural development must therefore go beyond the long-established objective of increasing production to also prioritize greenhouse gas mitigation, particularly of methane and nitrous oxide, while maintaining or enhancing productivity. For major livestock-producing provinces and rice-growing regions, achieving NDCs targets will require the rapid deployment and scaling of methane mitigation technologies aimed at reducing emissions from enteric fermentation, manure management and rice production.

Third, greater emphasis should be placed on the research, development and promotion of methane reduction technologies. Compared to adjustments in agricultural production scale, technological innovation remains the most critical driver for effective emission reductions. It provides a viable pathway to reconcile the potential trade-offs between methane mitigation and food security by leveraging technological synergies. Focus should be placed on key methane emission sources. Existing mitigation technologies must be more widely adopted, particularly among smallholders. Fiscal incentives should be strengthened to reduce the financial burden associated with technology uptake. Concurrently, investments should be increased in the development of cutting-edge innovations. In the context of rice production, this includes breeding high-yield, low-emission cultivars and improving water-saving irrigation technologies to lower methane intensity. In the livestock sector, priorities should include optimizing feed composition, promoting digital precision feeding systems, applying methane-reducing feed additives and enhancing the efficient resource utilization of livestock manure.

Fourth, a compensation mechanism for agricultural methane reduction should be established. To offset the increased costs associated with the adoption of emission reduction technologies and to incentivize stakeholder participation, it is essential to provide economic compensation. Government subsidies can be offered to support farmers and enterprises that implement methane mitigation technologies. Additionally, market mechanisms should be leveraged to incentivize farmers to reduce emissions by incorporating agricultural methane reduction into the carbon trading market[56]. This would encourage stakeholders to adopt emission reduction measures during agricultural production and earn economic benefits by trading their reduction results in the carbon market, thereby promoting sustainable methane reduction through economic incentives.

Fifth, dietary diversification among consumers should be actively encouraged. Since rice and livestock products are the main sources of methane emissions in agriculture, and current dietary patterns in China show excessive consumption of grains and red meat[57], it is crucial to guide residents to adjust their dietary structure based on sustainable and healthy dietary guidelines. Consumers should be encouraged to reduce rice consumption as a staple, choose more sustainable alternatives such as whole grains, and replace red meat with lower-emission protein sources such as poultry or plant-based options such as soy products[58]. Such shifts in consumption patterns can gradually lead to a reduction in demand for ruminant livestock, thereby helping to curb methane emissions from the livestock sector.

Sixth, international cooperation on agricultural methane reduction should be strengthened. As climate change is a global challenge, China should not only increase its domestic mitigation efforts but also actively engage in international collaboration through bilateral and multilateral climate initiatives. Although China has not yet joined the Global Methane Pledge, it has shown great ambition in methane mitigation. In 2021, China and the USA released the US-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s, which recognized the critical role of methane in climate change and committed both nations to taking action to reduce methane emissions from the agricultural sector. Also, China should continue to exchange experiences with other countries and strengthen capacity-building related to agricultural methane mitigation[59].

Acknowledgements

This research was supported by the National Social Science Foundation of China (22&ZD085).

Compliance with ethics guidelines

Xiangyang Zhang, Yumei Zhang, and Shenggen Fan declare that they have no conflicts of interest or financial conflicts to disclose. This article does not contain any studies with human or animal subjects performed by any of the authors.

REFERENCES

1. Ocko I B, Sun T Y, Shindell D, Oppenheimer M, Hristov A N, Pacala S W, Mauzerall D L, Xu Y Y, Hamburg S P. Acting rapidly to deploy readily available methane mitigation measures by sector can immediately slow global warming. *Environmental Research Letters*, 2021, **16**(5): 054042
2. Fesenfeld L P, Schmidt T S, Schrode A. Climate policy for short- and long-lived pollutants. *Nature Climate Change*, 2018, **8**(11): 933–936
3. Khanna N, Lin J, Liu X, Wang W J. An assessment of China's methane mitigation potential and costs and uncertainties through 2060. *Nature Communications*, 2024, **15**(1): 9694
4. He C M, Chi Y Y, Xiang P P, Xu Y M, Wu Y Z, Jiao Y J, Hu Y, Jiang K J. CH_4 emission scenario analysis for China: IPAC results. *Transactions of Atmospheric Sciences*, 2022, **45**(3): 414–427 (in Chinese)
5. Liu S H, Liu K Y, Wang K, Chen X C, Wu K. Fossil-fuel and food systems equally dominate anthropogenic methane emissions in China. *Environmental Science & Technology*, 2023, **57**(6): 2495–2505
6. Ministry of Ecology and Environment (MEE). First Biennial Transparency Report on Climate Change of the People's Republic of China. Beijing: *MEE*, 2024. Available at MEE website on March 30, 2025 (in Chinese)
7. Rosa L, Gabrielli P. Achieving net-zero emissions in agriculture: a review. *Environmental Research Letters*, 2023, **18**(6): 063002
8. National Development and Reform Commission (NDRC). The People's Republic of China Initial National Communication on Climate Change. Beijing: *NDRC*, 2004. Available at NDRC website on April 1, 2025 (in Chinese)
9. National Development and Reform Commission (NDRC). The Second National Communication on Climate Change of the People's Republic of China. Beijing: *NDRC*, 2013. Available at NDRC website on April 1, 2025 (in Chinese)
10. National Development and Reform Commission (NDRC). The First Biennial Update Report on Climate Change of the People's Republic of China. Beijing: *NDRC*, 2016. Available at NDRC website on April 1, 2025 (in Chinese)
11. Ministry of Ecology and Environment (MEE). The Third National Communication on Climate Change of the People's Republic of China. Beijing: *MEE*, 2018. Available at MEE website on April 1, 2025 (in Chinese)
12. Ministry of Ecology and Environment (MEE). The Second Biennial Update Report on Climate Change of the People's Republic of China. Beijing: *MEE*, 2018. Available at MEE website on April 1, 2025 (in Chinese)
13. Ministry of Ecology and Environment (MEE). The Fourth National Communication on Climate Change of the People's Republic of China. Beijing: *MEE*, 2023. Available at MEE website on April 1, 2025 (in Chinese)
14. Ministry of Ecology and Environment (MEE). The Third Biennial Update Report on Climate Change of the People's Republic of China. Beijing: *MEE*, 2023. Available at MEE website on April 1, 2025 (in Chinese)
15. Ministry of Ecology and Environment (MEE). The Fourth Biennial Update Report on Climate Change of the People's Republic of China. Beijing: *MEE*, 2024. Available at MEE website on April 1, 2025 (in Chinese)
16. Zhen W, Tang Y J, Wang H Y, Qin Q D. Crop-specific embodied greenhouse gas emissions inventory for 28 staple crops in China from 2007 to 2017. *Scientific Data*, 2025, **12**(1): 421
17. Wu S. A systematic review of climate policies in China: evolution, effectiveness, and challenges. *Environmental Impact Assessment Review*, 2023, **99**: 107030
18. National Development and Reform Commission (NDRC). National Climate Change Program. Beijing: *NDRC*, 2007. Available at NDRC website on April 1, 2025 (in Chinese)
19. The State Council of the People's Republic of China. Plan on Greenhouse Gas Emission Control During the 12th Five-year Plan Period. Beijing: *The State Council of the People's Republic of China*, 2011. Available at The State Council of the People's Republic of China website on April 1, 2025 (in Chinese)
20. National Development and Reform Commission (NDRC). National Plan for Response to Climate Change (2014–2020). Beijing: *NDRC*, 2014. Available at NDRC website on April 1, 2025 (in Chinese)
21. National Development and Reform Commission (NDRC). Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions. Beijing: *NDRC*, 2015. Available at NDRC website on April 1, 2025 (in Chinese)
22. The State Council of the People's Republic of China. Plan on Greenhouse Gas Emission Control During the 13th Five-year Plan Period. Beijing: *The State Council of the People's Republic of China*, 2016. Available at The State Council of the People's Republic of China website on April 1, 2025 (in Chinese)
23. Ministry of Agriculture and Rural Affairs (MARA) and National Development and Reform Commission (NDRC). The Implementation Plan for Agricultural and Rural Emission Reduction and Carbon Sequestration. Beijing: *MARA, NDRC*, 2022. Available at MARA website on April 1, 2025 (in Chinese)
24. Ministry of Ecology and Environment (MEE), Ministry of Agriculture and Rural Affairs (MARA), National Development and Reform Commission (NDRC), Ministry of Foreign Affairs (MFA), Ministry of Science and Technology (MST), Ministry of Industry and Information Technology (MIIT), Ministry of

Finance (MF), Ministry of Natural Resources (MNR), Ministry of Housing and Urban-Rural Development (MHURD), Ministry of Emergency Management (MEM), National Energy Administration (NEA). Methane Emission Control Action Plan. Beijing: *MEE, MARA, NDRC, MFA, MST, MIIT, MF, MNR, MHURD, MEM, NEA*, 2023. Available at MEE website on April 1, 2025 (in Chinese)
25. Wei S, Fan J M, Tian Y F, Dong H M. Low-carbon development policies and achievements in the context of the livestock sector in China. *Frontiers of Agricultural Science and Engineering*, 2024, **11**(3): 367–380
26. General Office of the CPC Central Committee and General Office of the State Council. Opinions of the CPC Central Committee and the State Council on Accelerating the Ecological Civilization Construction. Beijing: *The State Council of the People's Republic of China*, 2015. Available at The State Council of the People's Republic of China website on April 1, 2025 (in Chinese)
27. The State Council of the People's Republic of China. Opinions on Promoting the High-Quality Development of Animal Husbandry. Beijing: *The State Council of the People's Republic of China*, 2020. Available at The State Council of the People's Republic of China website on April 1, 2025 (in Chinese)
28. Ministry of Agriculture and Rural Affairs (MARA), Ministry of Ecology and Environment (MEE), Ministry of Natural Resources (MNR), Ministry of Science and Technology (MST), National Forestry and Grassland Administration (NFGA), and National Development and Reform Commission (NDRC). The 14th Five-year National Plan for Green Agricultural Development. Beijing: *MARA, MEE, MNR, MST, NFGA, NDRC*, 2021. Available at MARA website on April 1, 2025 (in Chinese)
29. The State Council of the People's Republic of China. 14th Five-year Plan Comprehensive Work Plan for Energy Conservation and Emission Reduction. Beijing: *The State Council of the People's Republic of China*, 2021. Available at The State Council of the People's Republic of China website on April 1, 2025 (in Chinese)
30. The State Council of the People's Republic of China. Guiding Opinions of the State Council on Accelerating the Establishment of a Sound Economic System with Green, Low-carbon and Circular Development. Beijing: *The State Council of the People's Republic of China*, 2021. Available at The State Council of the People's Republic of China website on April 1, 2025 (in Chinese)
31. Ministry of Agriculture and Rural Affairs (MARA). Guiding Opinions on Promoting the Development of Ecological Farms. Beijing: *MARA*, 2022. Available at MARA website on April 1, 2025 (in Chinese)
32. Ministry of Agriculture and Rural Affairs (MARA). Guiding Opinions of the Ministry of Agriculture and Rural Affairs on Accelerating the Comprehensive Green Transformation of Agricultural Development and Promoting Rural Ecological Revitalization. Beijing: *MARA*, 2024. Available at MARA website on April 1, 2025 (in Chinese)
33. Ministry of Agriculture and Rural Affairs (MARA). Opinions of the Ministry of Agriculture and Rural Affairs on Implementing the Feed Saving Action in Animal Husbandry. Beijing: *MARA*, 2024. Available at MARA website on April 1, 2025 (in Chinese)
34. Wagner P M, Torney D, Ylä-Anttila T. Governing a multilevel and cross-sectoral climate policy implementation network. *Environmental Policy and Governance*, 2021, **31**(5): 417–431
35. Zhang X Y, Zhang Y M, Fan S G. The multiple roles of crop structural change in productivity, nutrition and environment in China: a decomposition analysis. *Journal of Integrative Agriculture*, 2024, **23**(5): 1763–1773
36. Zhao M J, Shi R, Du R R, Yao L Y. The pathway to China's carbon−neutral agriculture: measures, potential and future strategies. *Chinese Political Science Review*, 2023, **8**(2): 304–324
37. Jiang Y, Zhu X C, Qian H Y, Zhang N, Ding Y F. Higher rice yields and lower methane emissions can be reconciled for rice cultivation: a review. *Journal of Nanjing Agricultural University*, 2022, **45**(5): 839-847 (in Chinese)
38. Horton P, Long S P, Smith P, Banwart S A, Beerling D J. Technologies to deliver food and climate security through agriculture. *Nature Plants*, 2021, **7**(3): 250–255
39. Fan S G, Zhang Y M. Strategic thinking on the low-carbon transformation of agrifood systems in China. *Issues in Agricultural Economy*, 2024, **45**(12): 15–23 (in Chinese)
40. Wei Y Q, Long F, Yue X R. Carbon emission changing and reduction strategy of agriculture and rural areas under the background of rural vitalization. *Issues in Agricultural Economy*, 2022, **43**(9): 62–73 (in Chinese)
41. Xu Z W, Zheng Y, Wu Y Q. Paving the way for sustainable agriculture: an analysis of evolution and driving forces of methane emissions reduction in China. *Resources, Conservation and Recycling*, 2024, **202**: 107392
42. Yuan S, Peng S B. Food-energy-emission nexus of rice production in China. *Crop and Environment*, 2022, **1**(1): 59–67
43. Cheng P, Tang H T, Lin F F, Kong X S. Bibliometrics of the nexus between food security and carbon emissions: hotspots and trends. *Environmental Science and Pollution Research International*, 2023, **30**(10): 25981–25998
44. Duan Y, Gao Y M, Zhao J, Xue Y L, Zhang W, Wu W J, Jiang H Q, Cao D. Agricultural methane emissions in China: inventories, driving forces and mitigation strategies. *Environmental Science & Technology*, 2023, **57**(36): 13292–13303
45. Tian Z, Fan Y D, Wang K, Zhong H L, Sun L X, Fan D L, Tubiello F N, Liu J G. Searching for "Win-Win" solutions for food-water-GHG emissions tradeoffs across irrigation regimes

of paddy rice in China. *Resources, Conservation and Recycling*, 2021, **166**: 105360

46. Sun J, Zhao G Y, Li M M. Using nutritional strategies to mitigate ruminal methane emissions from ruminants. *Frontiers of Agricultural Science and Engineering*, 2023, **10**(3): 390–402
47. Zhu Z P, Wang Y, Yan T, Zhang Z R, Wang S L, Dong H M. Greenhouse gas emissions from livestock in China and mitigation options within the context of carbon neutrality. *Frontiers of Agricultural Science and Engineering*, 2023, **10**(2): 226–233
48. Jiang L L, Tian Y, Chen N, Luo Y. An empirical exploration into the determinants of rice farmers' decisions to adopt low-carbon agricultural technologies in Hubei Province, China. *Mitigation and Adaptation Strategies for Global Change*, 2023, **28**(4): 15
49. Hosseiniyan Khatibi S M, Adviento-Borbe M A, Dimaano N G, Radanielson A M, Ali J. Advanced technologies for reducing greenhouse gas emissions from rice fields: is hybrid rice the game changer. *Plant Communications*, 2025, **6**(2): 101224
50. Kelly L, Kebreab E. Recent advances in feed additives with the potential to mitigate enteric methane emissions from ruminant livestock. *Journal of Soil and Water Conservation*, 2023, **78**(2): 111–123
51. Wang G F, Liu P, Hu J M, Zhang F. Spatiotemporal patterns and influencing factors of agriculture methane emissions in China. *Agriculture*, 2022, **12**(10): 1573
52. Gu X Y, Weng S M, Li Y E, Zhou X Q. Effects of water and fertilizer management practices on methane emissions from paddy soils: synthesis and perspective. *International Journal of Environmental Research and Public Health*, 2022, **19**(12): 7324
53. Ma N, Liu X J, Wang L, Liu G. A meta-analysis on the mitigation measures of methane emissions in Chinese rice paddy. *Resources, Conservation and Recycling*, 2024, **202**: 107379
54. Lin B Q, Huang C C. Analysis of emission reduction effects of carbon trading: market mechanism or government intervention. *Sustainable Production and Consumption*, 2022, **33**: 28–37
55. Zhang G B, Ma J, Xu H, Yan X Y. Status quo of research and suggestions on reduction of non-CO_2 greenhouse gas emission from Chinese farmland. *Bulletin of Chinese Academy of Sciences*, 2023, **38**(3): 504–517 (in Chinese)
56. Luo C J, Chen M P. Theoretical and pathway analysis of utilizing carbon trading to promote agricultural emission reductions: international experience and its implications for China. *Advances in Climate Change Research*, 2023, **19**(6): 761–770 (in Chinese)
57. Academy of Global Food Economics and Policy (AGFEP). China and Global Food Policy Report: Reforming Agricultural Support Policy for Transforming Agrifood systems. Beijing: *AGFEP*, 2022
58. Ou Y, Iyer G, Fawcett A, Hultman N, McJeon H, Ragnauth S, Smith S J, Edmonds J. Role of non-CO_2 greenhouse gas emissions in limiting global warming. *One Earth*, 2022, **5**(12): 1312–1315
59. Li X, Zhang Y M, Fan S G, Ouedraogo I. Agrifood system carbon emissions and reduction policy: insights from China and Africa. *Frontiers of Agricultural Science and Engineering*, 2025, **12**(4): 656–669