[CCNT・Agricultural Sector]

Reducing Fertilizer Usage for Increased Efficiency and Nitrous Oxide Emission Reduction: Observations and Prospects

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With the introduction of the “dual carbon” goals and other related measures, China has started to focus on reducing greenhouse gases other than carbon dioxide (CO_2). “China’s Achievements, New Goals and New Measures for Nationally Determined Contributions,” for example, submitted to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat, proposes researching and implementing action plans for controlling and reducing non-CO_2 greenhouse gas emissions. China is also gradual establishing a comprehensive system for statistical accounting, policies, and management of non-CO_2 greenhouse gas emissions. “Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy,” another key policy guidance document, also emphasizes the need to strengthen the control of non-CO_2 greenhouse gases. This article focuses on the current emissions and reduction progress of nitrous oxide (N_2O), the third-largest greenhouse gas after CO_2 and methane, and proposes recommendations for addressing reduction challenges.

1. Agriculture is the largest contributor to global nitrous oxide emissions.

Nitrous oxide is the third-largest greenhouse gas globally, following only carbon dioxide CO_2 and methane (CH_4). In 2019, N_2O emissions amounted to approximately 3.1 billion metric tons of CO_2 equivalent, accounting for approximately 6% of total global greenhouse gas emissions. N_2O is also a greenhouse gas with a strong warming potential, with its global warming potential over a 100-year period being roughly 300 times that of CO_2. Additionally, it has a relatively long atmospheric lifetime, estimated to be around 120 years.

While global N_2O emissions include contributions from natural sources such as soil, oceans, and the atmosphere, the ability of the atmosphere and biosphere to adjust to these natural emissions over time has prevented significant accumulation of N_2O in the atmosphere. However, human activities have led to a 20% increase in atmospheric N_2O concentration compared to the pre-industrial era. [1]

When global N_2O emissions are categorized by specific sectors, the agricultural sector accounts for the highest share, at 74%. The remaining 23% is divided among energy-related activities (10%), industrial production processes (9%), and waste management (5%).

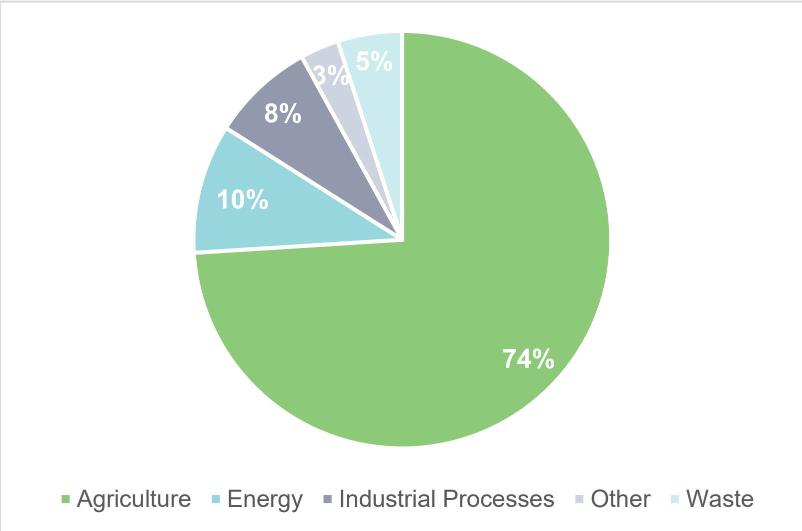

Figure 1: Global N_2O Emissions by Sector (2019, %)

Source：ClimateWatch database

[1] Bouwman, L., Daniel, J. S., Davidson, E. A., de Klein, C., Holland, E., Ju, X., Kanter, D., Oenema, O., Ravishankara, A. R., & Skiba, U. M. (2013). *Drawing down N2O to protect climate and the ozone layer. A UNEP Synthesis Report*. United Nations Environment Programme (UNEP).

2. In the world's major N_2O-emitting countries, agricultural fertilizer application is the primary source of emissions.

In the global distribution of N_2O emissions, as shown in Figure 2, the major emitting countries and regions are China, the United States, India, and the EU. In all four of these major emitting areas, over half of N_2O emissions come from the agricultural sector. In the EU and India, 80% of their N_2O emissions originate from agricultural activities.

In China's N_2O emission distribution, approximately 62% of emissions come from agricultural production. As illustrated in Figure 3, within the agricultural sector, the largest source of N_2O emissions is attributed to fertilizer application, accounting for around 44%. The second-largest sources are emissions from livestock and poultry manure management and emissions resulting from the practice of returning crop residues to the field, comprising approximately 32%. Other minor sources of emissions include those from agricultural waste management and incomplete combustion of fuels used in agriculture.

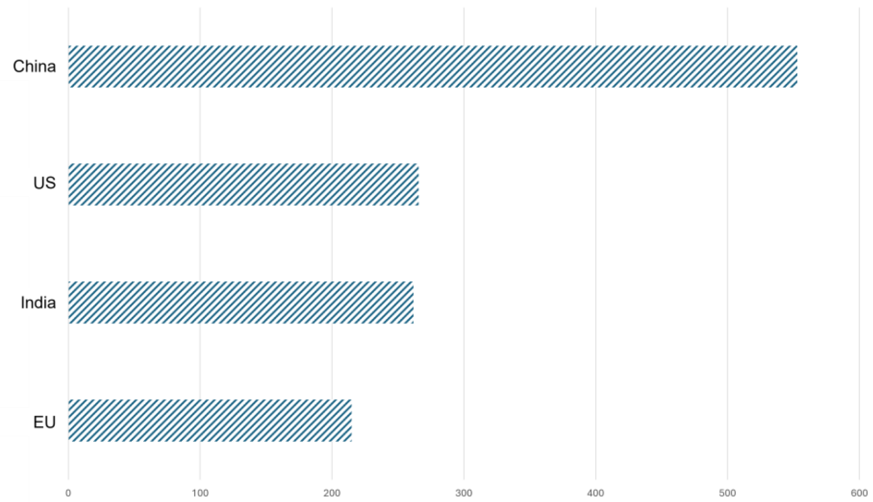

Figure 2: Major N_2O Emission Countries and Regions Worldwide (2019, million tons of CO2e)

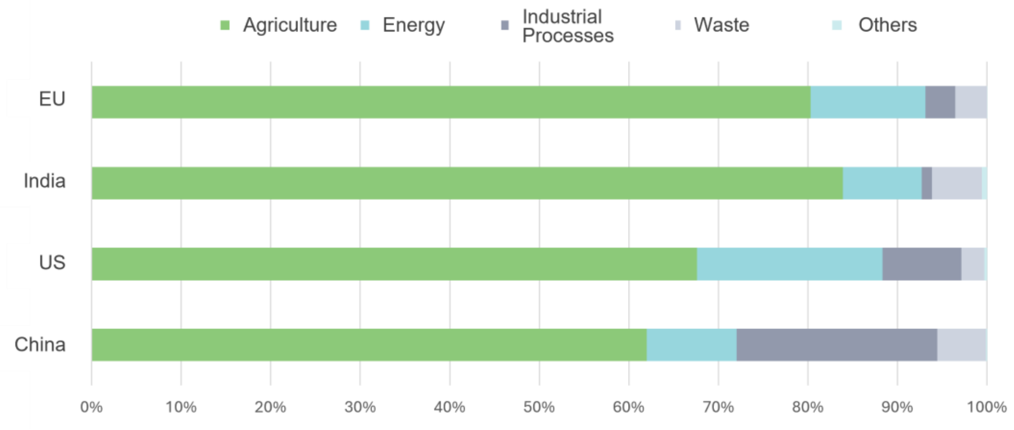

Figure 3: Sectoral N_2O Emissions Breakdown by Major Emitting Countries and Regions (2019)

Source: ClimateWatch database

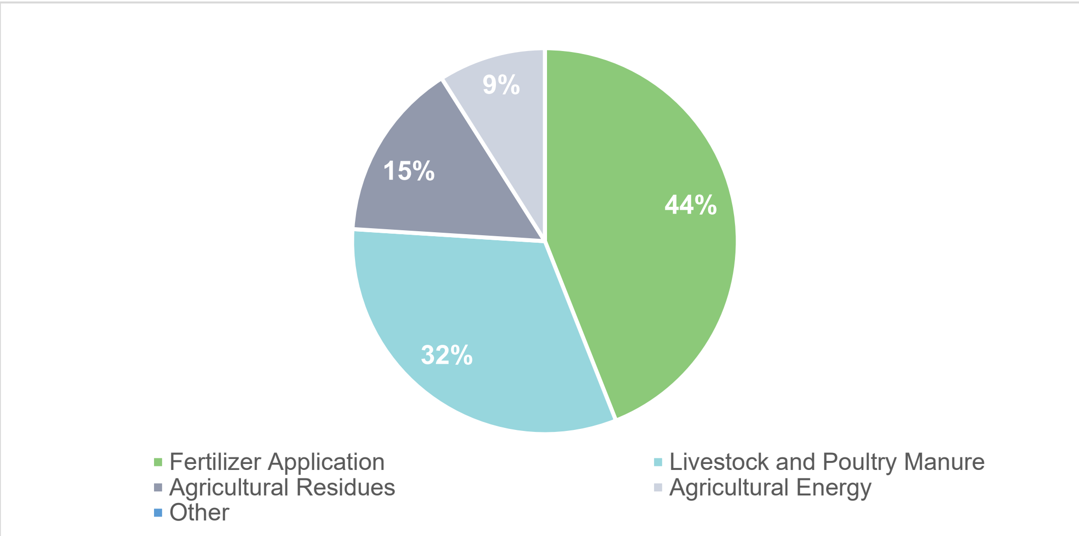

Figure 4: Breakdown of N_2O Emissions from Agricultural Production in China by Sector (2019, %)

Data source: FAO

3. Progress Has Been Made in Reducing Fertilizer and Promoting Efficient Fertilizer Use in China.

Excessive use of chemical fertilizers not only increases N_2O emissions but also leads to water and air pollution. It also results in soil acidification, compaction, and reduced fertility. Therefore, China has taken a series of actions to promote the reduction and efficiency enhancement of chemical fertilizers.

China has established the objectives of zero growth in fertilizer usage and peaking of nitrous oxide emissions in the agricultural sector. These objectives are outlined in China's central policy document, known as the "Number 1 Central Document," which guides agricultural policies. This document has consistently addressed the issue of agricultural fertilizer pollution for nine consecutive years, from 2013 to 2017.2 For example, the 2017 "Number 1 Central Document" emphasized the need to "deepen the promotion of the zero-growth action for chemical fertilizers and pesticides, initiate pilot projects for replacing chemical fertilizers with organic fertilizers and promote cost-effective and efficient agricultural practices." [3] Furthermore, "The Work Plan for Controlling Greenhouse Gas Emission During the 13^{th} Five-Year Plan Period (2016-2020)," includes the target of reaching the peak of nitrous oxide emissions from agricultural fields by the year 2020.

Secondly, China has eliminated preferential policies related to electricity and tax incentives for fertilizer production. In 2015, under the unified directive of the National Development and Reform Commission (NDRC), China began phasing out preferential electricity prices for fertilizer production nationwide. After April 20, 2016, there were no longer preferential electricity prices for medium and small-sized fertilizer producers in the categorized electricity pricing. This marked the end of China's preferential electricity pricing policy for fertilizer production that had been in place since 2003. China also discontinued the value-added tax (VAT) subsidy policy for fertilizer production in 2015, which had been in effect since 1994.[4]

Furthermore, China has been actively promoting optimized fertilizer application methods such as soil testing and formula fertilization and integrated water and fertilizer management. To balance soil nutrients and improve fertilizer efficiency, China introduced soil testing and formula fertilization technology in 2005, which involves applying fertilizers based on the results of soil analysis. Specific targets for the coverage of soil testing and formula fertilization technology were set. In 2019, the national coverage of this technology reached 89.3%.[5] At the same time, China is also promoting water and fertilizer integration through drip irrigation technology in water-scarce regions such as North China and Northwest China. This method involves evenly delivering nutrients to the root zone of crops through drip irrigation,

[2] Zheng L., Zhang X., Wang B. The Evolution of Fertilizer and Organic Fertilizer Subsidy Policies and an Initial Exploration of Supporting Technologies[J]. World Environment, 2018, 4.

[3] http://www.moa.gov.cn/ztzl/yhwj2017/zywj/201702/t20170206_5468587.htm

[4] Zheng L., Zhang X., Wang B. *The Evolution of Fertilizer and Organic Fertilizer Subsidy Policies and an Initial Exploration of Supporting Technologies*[J]. World Environment, 2018, 4.

[5] https://www.gov.cn/xinwen/2019-12/19/content_5462243.htm

reducing the nitrification and denitrification processes in the soil that contribute to N_2O emissions. In 2016, China released the "The Implementation Plan for Promoting Water and Fertilizer Integration (2016-2020)." Additionally, digital agriculture and rural development plans were established to develop smart control technologies and equipment for precise application of water, fertilizers, and pesticides.

In addition, China provides policy support for the development and promotion of organic fertilizer substitutes and new types of fertilizers. For example, since 2017, China has selected 175 key counties (cities, districts) in regions with prominent advantages in fruit, vegetable, and tea cultivation, assured resources of organic fertilizer, mature organic fertilizer application techniques, and a certain industrial foundation to conduct pilot projects for substituting organic fertilizers for chemical fertilizers. Provinces and cities like Beijing, Jiangsu, Shanghai, and Zhejiang have also introduced subsidies for farmers using commercial organic fertilizers, with subsidy amounts ranging from 150 ($20) to 480 yuan ($65.7)per ton.[6] Additionally, China provides favorable railway freight rates for new types of fertilizers like slow-release fertilizers and water-soluble fertilizers.

Table 1: Key Policies in China Promoting Reduced and Efficient Use of Agricultural Fertilizers

Year	Policy	Main Content
2008	Notice on Exemption from Value Added Tax on Organic Fertilizer Products	Exemption of value-added tax for taxpayers producing, selling, wholesaling, and retailing organic fertilizers, organic-inorganic compound fertilizers, and biological organic fertilizers.
2015	Notice by the National Development and Reform Commission on Lowering On-grid Electricity Prices for Coal-fired Power Generation and Industrial and Commercial Electricity Prices	Cancellation of preferential electricity prices for fertilizer production.
2015	Action Plan for the Growth of Fertilizer Use by 2020	Aims for zero growth in the use of chemical fertilizers in major crops by 2020.
2015	Notice on Resuming Value-Added Tax Policy for Fertilizers	Ends the preferential value-added tax policy for fertilizers. Imposes a unified 13% tax rate on taxpayers selling and importing fertilizers.
2015	National Sustainable Agriculture Development Plan (2015-2030)	Aims for a nationwide promotion coverage of soil testing and formula fertilization technology of over 90% by 2020, an increase in fertilizer use efficiency to 40%, and strives for zero growth in fertilizer application.

[6] http://www.moa.gov.cn/govpublic/ZZYGLS/201909/t20190917_6328090.htm

2016	Notice on Promoting the Market-Oriented Reform of Natural Gas Prices for Fertilizer Production	Cancels preferential policies on natural gas for fertilizer production and fully liberalizes gas prices for fertilizer production.
2016	The Work Plan for Controlling Greenhouse Gas Emission During the 13th Five-Year Plan Period (2016-2020)	Aims to reach the peak of nitrous oxide emissions from farmland by 2020.
2016	Implementation Plan for Promoting Water-Fertilizer Integration (2016-2020)	Aims to promote water-fertilizer integration technology, covering 150 million hectares by 2020, with an additional 80 million hectares. It aims to increase grain production by 45 billion catties, save 15 billion cubic meters of water, reduce fertilizer usage by 300,000 tons, and achieve an additional 50 billion yuan ($6.84 billion) in efficiency.
2017	Action Plan for Promoting the Substitution of Organic Fertilizer for Chemical Fertilizer in Fruit, Vegetable, and Tea Production	Selects 100 key counties (cities, districts) for pilot programs substituting organic fertilizers for chemical fertilizers in fruit, vegetable, and tea production, building a long-term mechanism for organic fertilizer substitution.
2019	Development Plan for Digital Agriculture and Rural Areas (2019-2025)	Aims to create digital farmland and promote the integrated application of intelligent sensing, analysis, and control technologies and equipment in large-scale crop planting and facility horticulture. The plan includes systems for environmental control, precise water, fertilizer, and pesticide application, precision planting, smart agricultural machinery operation, and monitoring and decision-making. It promotes intelligent "workshop agriculture" and advances smart management in crop production and operations.
2021	14th Five-Year National Plan for Green Agricultural Development	Integrates and promotes scientific fertilization techniques, demonstrates and promotes new types of fertilizers like slow-release fertilizers and water-soluble fertilizers, and improves fertilizer application methods. It encourages local investments for wider adoption of organic fertilizer substitutes for chemical fertilizers.
2021	Notice by the NDRC on Implementing Railway Preferential Freight Rates for Slow-Release Fertilizers and Other Farm Chemicals	Increases railway preferential freight rates for eight new types of fertilizers, including slow-release fertilizers and water-soluble fertilizers.
2022	Implementation Plan for Agricultural Rural Carbon Reduction and Carbon Sequestration	Focuses on nitrogen fertilizer reduction and efficiency improvement in major grain-producing areas, fruit, vegetable, and tea production areas, and leading regions of green agricultural development. It aims to develop and promote new high-efficiency fertilizer products with high crop absorption and utilization rates and to promote efficient fertilization techniques, such as integrated water and fertilizer management, thereby improving fertilizer utilization. The plan also advocates combining organic fertilizers with chemical

		fertilizers, increasing organic fertilizer input, and substituting some chemical fertilizers.
2022	Implementation Plan for Building National Agricultural Green Development Pilot Zones to Promote Comprehensive Green Transformation of Agricultural Modernization Demonstration Zones	Promotes soil testing and formula fertilization, demonstrates, and promotes new types of fertilizers like slow-release fertilizers and water-soluble fertilizers. It establishes a green planting and breeding circular agriculture model, promotes the transformation of livestock and poultry manure from “treatment” to “utilization.”

Source: CCNT

With the issuance of multiple policies aimed at reducing and improving fertilizer use, China’s fertilizer application has been slowly decreasing since 2016. This marks the first time that China has achieved negative growth in fertilizer use since 1974.[7] In 2017, the goal of zero fertilizer growth was reached three years ahead of schedule.[8] As shown in Figure 5, China’s fertilizer application was 59.84 million tons in 2016, a decrease of 380,000 tons compared to 2015, and it further declined to 54.03 million tons in 2019. Meanwhile, N_2O emissions resulting from fertilizer use have also been on the decline.

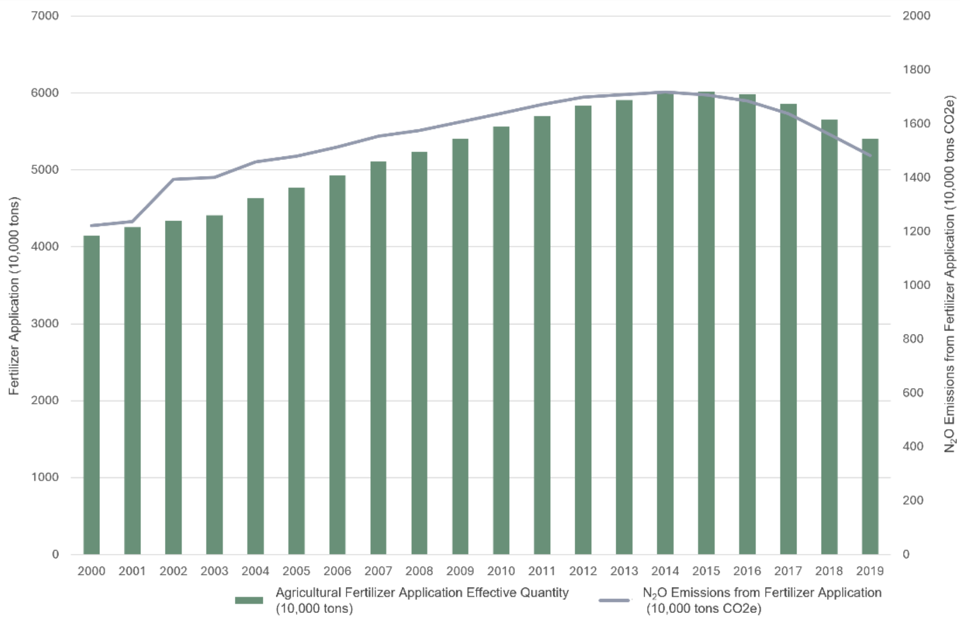

Figure 5: Agricultural Fertilizer Application in China from 2000 to 2019 (in 10,000 tons) and N_2O Emissions from Fertilizer Application (in 10,000 tons of CO2e)

Source: Agricultural fertilizer application data is from the National Statistical Yearbook, and fertilizer N_2O emission data is from FAO.

[7] https://www.gov.cn/xinwen/2017-12/28/content_5251080.htm

[8] http://www.xinhuanet.com/politics/2018-04/25/c_1122739925.htm

Case Study: Technology Facilitates Soil Testing and Precision Fertilization

Sinofert Holding Limited (Sinofert), with support from the Ministry of Agriculture, has been rolling out smart fertilization service centers across the country since 2014. These centers are equipped with intelligent fertilization machines that enable precise soil testing and fertilization.[9] Both large-scale and small-scale farmers can use the corresponding application software linked to the smart fertilization terminals on the Internet. Farmers input their planting information and provide soil samples, allowing the fertilization machines to perform rapid soil testing and transmit the results to the cloud. The cloud server calculates a planting plan, the required fertilizer formula, and its cost based on the soil test results. This information is then used to generate a fertilization order that is sent to the farmer's smartphone.[10] The direct-to-farmer distribution of fertilizers through this smart fertilization process reduces the costs associated with middlemen in the distribution chain. According to estimates, the smart fertilization system can directly reduce fertilizer usage and costs by 10% to 30%, while increasing crop yields by over 5%. This, in turn, boosts farmers' income by more than 10%.[11]

Another example of smart fertilization comes from the application of intelligent agricultural equipment by XAG, a leading agricultural technology company, in the high-standard farmland unmanned planting demonstration farm in Bufeng Town, Yancheng, Jiangsu.[12] The farm covers 5,000 acres and is managed by a team of just three people.

Before planting, a remote sensing drone is used to survey the farmland and obtain high-resolution maps. Based on these maps, field profiles are established in the system for precise land management. During the growth period of rice, the remote sensing drone, in combination with AI models, is used to analyze the growth status of rice, identify seedlings, and monitor diseases and pests. Additionally, when it’s time to apply pesticides and fertilizers to the rice fields, drones take over instead of manual labor for precise fertilization and pesticide spraying.[13] Under the management of smart agriculture, compared to traditional production methods, the amount of pesticide and

[9] http://www.sinofert.com/s/4368-12223-56364.html
[10] https://www.yicai.com/news/5003423.html
[11] http://www.sinochem.com.cn/s/1375-5662-19811.html
[12] https://m.thepaper.cn/newsDetail_forward_19944206
[13] Ibid.

fertilizer used per unit of farmland has decreased by approximately 10%, and crop yields have increased by around 10%.[14]

4. Challenges Remain in Achieving Fertilizer Reduction and Efficiency Improvement

Despite the declining trend in the application of chemical fertilizers in agriculture, there is still room for adjusting the intensity of fertilizer use. As shown in the figure below, in 2021, China's fertilizer application intensity was around 307 kilograms per hectare, still significantly exceeding the internationally recognized safe upper limit of 225 kilograms per hectare. Furthermore, China has been promoting soil testing and formula fertilization technology since 2005, but there is still a gap between the extent of technology promotion and the actual application area.[15]

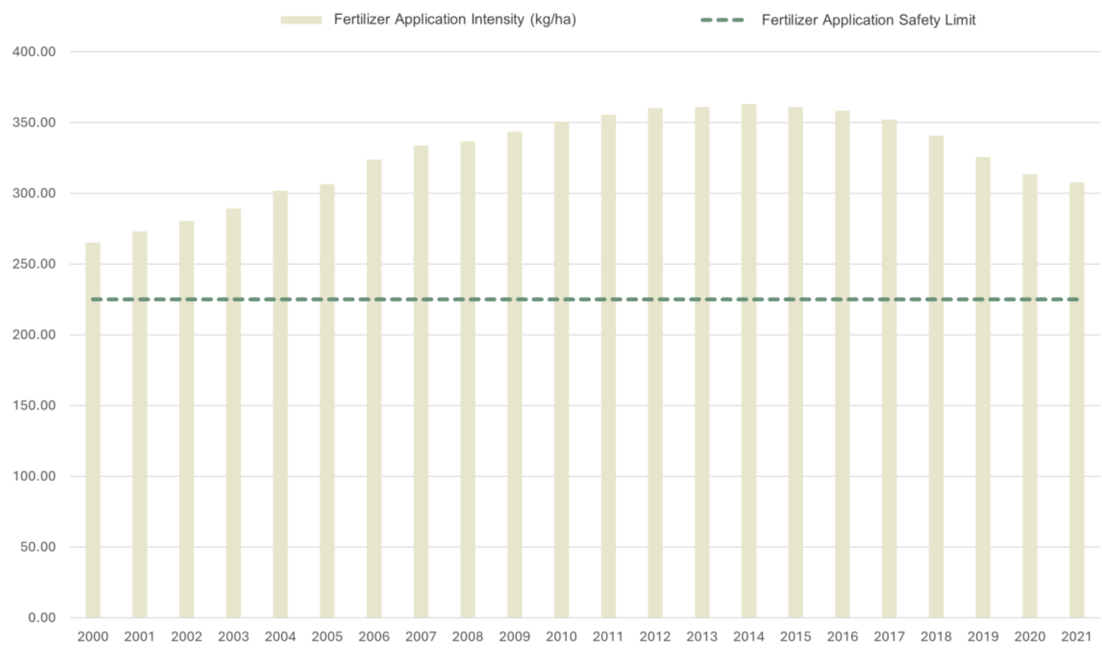

Figure 6: Fertilizer Application Intensity in China (Kilograms per Hectare, 2000-2021)

Source: National Statistical Yearbook

The promotion of organic fertilizers faces challenges related to high costs, limited immediate benefits, and the risk of heavy metal pollution, among others. From the demand side, the use of organic fertilizers faces challenges due to its higher cost compared

[14] XAG 2022 Corporate Social Responsibility Report

[15] Zheng L., Zhang X., Wang B. The Evolution of Subsidy Policies for Chemical and Organic Fertilizers and Preliminary Exploration of Supporting Technologies[J]. World Environment, 2018, 4.

to chemical fertilizers, with limited short-term yield benefits. Calculations from Zhejiang Province indicate that, despite subsidies, the cost of organic fertilizers per ton is lower than chemical fertilizers. However, the significantly higher application rate of organic fertilizers per acre results in a per-acre cost for farmers that is about four times that of chemical fertilizers (see Table 2). Furthermore, organic fertilizer application in China is primarily done manually, which increases labor costs.[16] Subsidies for organic fertilizers are generally directed toward large-scale producers.[17] Another challenge is the slow release of nutrients by organic fertilizers, as they decompose and become available to plants over a longer period, which may not meet the quick demands of high-yield crops.[18] On the production side, the technology for manufacturing organic fertilizers is relatively underdeveloped, lacking proper testing equipment and quality control. Consequently, the market sometimes sees substandard organic fertilizer products, including issues with excessive heavy metals content.[19] The primary raw material for organic fertilizers is livestock manure, and if antibiotics and heavy metals are not effectively removed during the manufacturing process, they can lead to soil pollution. Additionally, lax standards for some heavy metals can lead to their accumulation in soil due to prolonged and excessive use of organic fertilizers, eventually entering the food chain and posing food safety concerns.[20]

Table 2: Comparison of Input Costs for Organic and Chemical Fertilizers

	Organic Fertilizer	Chemical Fertilizer
Market Price (CNY/ton)	448 (subsidized)	650
Unit Application Rate (ton/acre)	1.5	0.25
Unit Input Cost (CNY/acre)	672	162.5

Source: Zheng L., Wang B. Research on the Development Bottleneck and Strategies of Commercial Organic Fertilizers in China[J]. Environmental and Sustainable Development, 2017, 42(3): 38-41.

The promotion and application of new fertilizers, including slow-release fertilizers and stabilized fertilizers, are still constrained by cost factors, and their mechanisms of action require further clarification. Slow-release fertilizers are costly to manufacture, have high

[16] Du W., Tang S., Wang H. Solving the Difficulties in Promoting Organic Fertilizers Requires Comprehensive Solutions[J]. China Agri-Production News, 2021.

[17] Zheng L., Zhang X., Wang B. The Evolution of Subsidy Policies for Chemical and Organic Fertilizers and Preliminary Exploration of Supporting Technologies[J], World Environment, 2018, 4.

[18] http://www.ce.cn/cysc/sp/info/202010/13/t20201013_35881440.shtml

[19] Du W., Tang S., Wang H. Solving the Difficulties in Promoting Organic Fertilizers Requires Comprehensive Solutions[J], China Agri-Production News, 2021.

[20] Xie, W., Wu, T., Shi, Y., & Zhu, Y. Comparison of Domestic and International Organic Fertilizer Standards and Risk Assessment. Chinese Journal of Eco-Agriculture (Chinese-English), 2020,28(12), 1958-1968.

technological barriers, and are typically priced at 3-8 times that of regular fertilizers. They are primarily used for high-value crops like landscaping and flowers and are less suitable for field crops like grains.[21] On the other hand, stabilized fertilizers, which extend nutrient release by incorporating urease and nitrification inhibitors through certain processes, are affected by various environmental factors, leading to inconsistent effectiveness in inhibiting nutrient loss. Furthermore, their nutrient retention duration can be unstable, and these fertilizers are relatively expensive.[22]

The predominance of small-scale farming in China's agricultural production poses challenges for the widespread adoption of smart precision fertilization. Compared to developed countries, China's agriculture is still dominated by small-scale farming. Nearly 70% of China's farmland is managed on plots of 2 hectares or less, while in most regions worldwide, farmland is typically managed on plots of 5 hectares or more.[23] Additionally, based on estimates from 2017 statistical data, China has approximately 220 million farming households, with an average landholding size of only 0.5 hectares per household. Even when accounting for land transfers, the average landholding size remains at only 0.7 hectares per household.[24] Due to small land sizes, and with cost-benefit considerations in mind, many farmers may not be highly motivated to adopt and manage precision fertilization technologies.[25] Furthermore, rural agricultural labor is decreasing among younger populations, and there is a trend of aging in the workforce. Additionally, the general level of education among rural workers tends to be low. These factors collectively hinder the adoption and diffusion of new agricultural production technologies and concepts.[26]

[21] Farmer's Daily, 2022, Developing Controlled-release Fertilizers is an Important Direction for Achieving Fertilizer Reduction and Efficiency Improvement.

[22] Li, S., Liu, R., Liu, J., et al. Development and Prospects of the Stabilized Fertilizer Industry[J], Modern Chemical Industry, 2022, 42(11), 1-8.

[23] Wu, Y., Xi, X., Tang, X., Luo, D., Gu, B., Lam, S. K., Vitousek, P. M., & Chen, D. (2018). Policy distortions, farm size, and the overuse of agricultural chemicals in China. Proceedings of the National Academy of Sciences, 115(27), 7010–7015.

[24] Du, Y. (2018). Small-scale Farming and Agricultural Modernization. China Rural Economy, 10, 2–6.

[25] Ju, X., Gu, B., Wu, Y., & Galloway, J. N. (2016). Reducing China's fertilizer use by increasing farm size. Global Environmental Change, 41, 26–32.

[26] Hu, Y., Zhang, R. Operational Model Issues and Strategic Countermeasures for Smart Agriculture in China. Economic System Reform, 2017(4), 70-76.

5. Policy Recommendations

Fertilizers, as essential inputs in agricultural production, play a significant role in crop cultivation and yield improvement. However, the excessive and prolonged use of fertilizers has made them a major source of N_2O emissions in our country. Therefore, the key to reducing N_2O emissions lies in promoting the more efficient and judicious use of fertilizers. Below are some recommendations based on the discussions mentioned above:

Continuing to advance soil testing and formula fertilization practices, along with providing effective training and services to farmers, is crucial. Existing practices have demonstrated that technical training and management programs tailored to farmers can yield better emission reduction results. For example, between 2005 and 2015, a program involving over 20 million farmers in China, focused on enhancing agricultural management and technical training, led to the development of locally adapted land improvement plans. This not only reduced fertilizer usage and increased yields but also decreased greenhouse gas emissions.[27]

Strengthening policy support for organic fertilizers, their research and development, and widespread adoption is essential. This includes raising the subsidy standards for organic fertilizers to reduce the cost for farmers using them. Additionally, expanding the scope of organic fertilizer subsidies to encompass small-scale production enterprises and smallholders is important. Moreover, improving organic fertilizer production standards and product quality is necessary to minimize the presence of substandard products. The current standard for organic fertilizers is the "Organic Fertilizer (NY525-2012)" industry standard. However, it currently focuses mainly on total nutrient requirements, with less attention to other components.[28] Furthermore, promoting integrated farming approaches that connect animal husbandry and crop cultivation not only facilitates the resourceful utilization of livestock and poultry manure but also enhances the use of organic fertilizers in the agricultural sector.

Promoting land transfer and land leasing, while ensuring the interests of small-scale farmers, is essential to encourage large-scale land management and the widespread adoption of precision fertilization techniques. The predominant small-scale farming system in China poses challenges for the widespread adoption of precision fertilization

[27] Cui, Z., Zhang, H., Chen, X., Zhang, C., Ma, W., Huang, C., Zhang, W., Mi, G., Miao, Y., & Li, X. (2018). Pursuing Sustainable Productivity with Millions of Smallholder Farmers. Nature, 555(7696), 363–366.

[28] Jin, S., Tang, J., Yang, X., et al. EU Organic Fertilizer Product Standards, Management Mechanisms, and Their Implications, Chinese Journal of Eco-Agriculture (Chinese-English), 2021, 29(7): 1236-1242.

techniques. Accelerating land transfer is advantageous for agricultural machinery operations and large-scale farming, improving land utilization efficiency, and reducing the cost of implementing new technologies. Research indicates that in China, 86% of farmland can be consolidated into large farms with an average size exceeding 16 hectares. This type of consolidation can significantly enhance the level of agricultural mechanization, increase farmers' income, reduce nitrogen fertilizer input by 24%, raise nitrogen fertilizer efficiency by 18%, and cut agricultural labor costs by 39%.[29]

In the long term, improving soil quality and enhancing soil health are essential for achieving reduced fertilizer use and substitutions, while also promoting sustainable agricultural production. For instance, in agricultural practices, adopting conservation tillage methods such as reduced tillage and no-till, as well as straw mulching, helps reduce soil disturbance and aids in restoring soil fertility. These measures are gradually being promoted in regions such as Northeast China and the Huang River-Huai River-Hai River region. Furthermore, in addition to traditional green manure planting and returning crop residues to the fields, strengthening the research and development of green production methods and planting techniques has shown significant effects in increasing soil organic matter and reducing chemical fertilizer application.[30] Research and monitoring results demonstrate that using green manure in rice cultivation in the southern regions can reduce nitrogen and potassium fertilizer application by 40%, while dryland farming can reduce it by approximately 20-30%.[31]

[29] Duan, J., Ren, C., Wang, S., Zhang, X., Reis, S., Xu, J., & Gu, B. (2021). Consolidation of Agricultural Land can Contribute to Agricultural Sustainability in China. Nature Food, 2(12), 1014–1022.

[30] Cao W., Bao X., Xu C., Nie J., Gao Y., Geng M. A Review and Future Prospects of 60 Years of Green Manure Research in China. Journal of Plant Nutrition and Fertilizer, 2017, 23(6): 1450-1461.

[31] http://www.news.cn/globe/2022-07/18/c_1310640187.htm

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