

Perspective

Open Access



Zoning management for agricultural non-point source pollution: a national-scale perspective in China

Xuran Li, Bin Xi, Lei Huang

Rural Energy and Environment Agency, Ministry of Agriculture and Rural Affairs, Beijing 100125, China.

Correspondence to: Dr. Xuran Li, Rural Energy and Environment Agency, Ministry of Agriculture and Rural Affairs, No. 24, Maizidian Street, Chaoyang District, Beijing 100125, China. E-mail: lixuran16@mails.ucas.ac.cn

How to cite this article: Li, X.; Xi, B.; Huang, L. Zoning management for agricultural non-point source pollution: a national-scale perspective in China. *Emerg. Contam. Environ. Health* 2025, 1, 2. <https://dx.doi.org/10.20517/eceh.2025.26>

Received: 30 Jun 2025 **First Decision:** 24 Jul 2025 **Revised:** 7 Aug 2025 **Accepted:** 12 Aug 2025 **Published:** 26 Aug 2025

Academic Editor: Joana C Prata **Copy Editor:** Pei-Yun Wang **Production Editor:** Pei-Yun Wang

Abstract

Agricultural non-point source pollution (ANPSP) poses significant challenges to global water security and ecosystem health. This study proposes a zoning management framework for ANPSP in China, integrating ecological sensitivity, pollution load intensity, and agricultural production structures. Seven distinct governance zones are delineated, each with tailored strategies and measures. Supported by technological innovation, policy incentives, and participatory governance, this framework aims to achieve precise pollution control and water quality improvement.

Keywords: Agricultural non-point source pollution, zoning management, integrated governance, precision control

INTRODUCTION

Agricultural non-point source pollution (ANPSP), driven by the irrational use of agricultural chemicals such as fertilizers and pesticides, as well as the improper treatment of livestock and aquaculture wastes, remains a major barrier to global water quality improvement^[1,2]. According to the Second National Pollution Source Census Bulletin released in 2020, total nitrogen and total phosphorus emissions from



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, sharing, adaptation, distribution and reproduction in any medium or format, for any purpose, even commercially, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.



agricultural sources in China reached 1.41 million tons and 0.21 million tons, respectively, accounting for 46.5% and 67.2% of the country's total water pollutant emissions. Over the past decade, the Chinese government has made great efforts to strengthen the institutional system for ANPSP prevention and control, and many regional agricultural cleaner production models have gradually emerged^[3]. Nevertheless, the persistent tight constraint on cultivated land and freshwater resources in China^[4,5] remains a major challenge to ensuring food security. This highlights the urgent need to balance sustainable agriculture with environmental protection, emphasizing the necessity of precise ANPSP control.

Ecological and environmental zoning is a policy tool that has been pioneered in developed countries since the 1980s and is based on the assessment of single or multiple ecological and environmental elements^[6]. For example, in the field of water environment management, the European Union formulated the European Water Framework Directive in 2000, breaking the administrative boundary restrictions by dividing territories into watershed control units and implementing integrated watershed management across Europe^[7,8]. European experience has proved that zoning is an effective approach to water environment management. Over the past 30 years, China has also implemented ecological space control measures, including the demarcation of ecological zones, the establishment of resource utilization upper limits, and the definition of eco-environmental regulation units^[9,10]. However, to date, China lacks a national-scale zoning strategy specifically for ANPSP control. Given the country's vast territory and diverse agricultural production modes, the characteristics of ANPSP differ greatly across regions, making zoning management more effective and cost-efficient than a uniform nationwide approach. Based on this analysis, this study aims to propose a national-scale ANPSP zoning strategy that harmonizes agricultural productivity with pollution mitigation, highlighting the main factors worthy of consideration across seven major units.

PRINCIPLES FOR DELINEATING ANPSP ZONING

1. Natural geography and ecological function. ANPSP zoning should prioritize natural geographic boundaries and ecosystem service values (e.g., major river basins, climate, topography, and soil properties). River basins and climatic zones affect hydrological connectivity and pollutant migration pathways. For instance, the alluvial plains of the Yangtze Delta are highly susceptible to nitrogen and phosphorus losses due to frequent precipitation and dense river networks^[11-13], whereas surface runoff in the Yellow River Basin exhibits significantly lower nitrogen and phosphorus losses^[14,15]. Soil erosion is more severe on cultivated land with slope gradients greater than 15°^[16,17] and in specific soil types (e.g., loessial soil).

2. Agricultural production structure and pollution load. Agricultural activities directly determine the amount and characteristics of ANPSP pollutants. It is essential to compile an ANPSP investigation dataset detailing the pillar agricultural industries, including types, amounts, timing, and methods of field inputs^[18-21], as well as the quantity and utilization efficiency of livestock and poultry manure. Priority should be given to areas with high pollution loads and significant environmental risks. For example, in regions dominated by plantation agriculture, the management of field water and nutrients is a critical focus.

3. Ecological sensitivity and water environment governance goals. Regions with higher ecological sensitivity require greater attention. For example, the national Environmental Quality Standards for Surface Water (GB 3838-2002) specify limits for key indicators, including ammonia nitrogen and total phosphorus. Notably, total phosphorus limits for lakes and reservoirs are stricter than for ordinary surface waters (e.g., rivers, canals, channels), reflecting more rigorous governance requirements. Specifically, the Grade V total phosphorus limit for lakes and reservoirs is 0.2 mg/L, equivalent to the Grade III limit for other surface waters.

4. Management Feasibility. Effective zoning should consider policy alignment, technical capacity, and economic feasibility. ANPSP zoning should integrate with existing national or regional regulations (e.g., the 2035 goals of the Beautiful China initiative, the “Three Lines One Permit” scheme, and targets for fertilizer utilization rates) to avoid overlaps or conflicts. Regions with advanced infrastructure could adopt technology-intensive solutions and establish systems for evaluating pollution loads, allowing dynamic adjustment of governance measures^[22]. Conversely, areas with limited infrastructure and economic resources should focus on governance priorities and implement cost-effective and practical measures first.

Based on these principles, seven preliminary zones have been delineated for precise ANPSP control [Figure 1].

The middle and lower reaches of the Yangtze River. As China’s primary region for grain, oil, livestock, and aquatic production, this area features dense river networks and a high risk of lake eutrophication (e.g., Taihu Lake and Dongting Lake). Key drivers of ANPSP include high nitrogen/phosphorus runoff from paddy fields and chemical-intensive farming, as well as discharges of untreated livestock manure and aquaculture tailwater. Cumulative pollution converges in lakes, triggering algal blooms. The core management strategy emphasizes source reduction, process retention, nutrient reuse, and water restoration (the 4R approach) [Figure 2], a concept that has been proposed for several years and widely implemented to reduce algal blooms in Taihu Lake^[23,24]. Notably, the principles of source reduction and nutrient recycling are also applicable to the livestock and aquaculture sectors, including the rational use of feed, additives, and veterinary drugs, the conversion of manure into biogas/organic fertilizer, and the recycling of nutrients in farmland^[25-27].

Hilly areas in the south. In the southern hilly regions, decentralized plantations and courtyard-based livestock production generally show low resource use efficiency. Therefore, the core ANPSP management strategy focuses on runoff retention and utilization, integration of planting and breeding, and endpoint treatment [Figure 3]. Runoff retention and utilization involves practices such as converting slopes to terraced fields, cross-slope planting, and establishing vegetation buffer strips^[28-30]. Integration of planting and breeding mainly includes matching the scale of crop and livestock operations, promoting solid-liquid separation and rainproof collection of livestock waste, and recycling manure on nearby farmland. Endpoint treatment technologies, such as constructed wetlands and biological wastewater treatment, aim to enable nutrient recycling or ensure standard-compliant discharge of water resources.

Huang-Huai-Hai region. This region has a long history of farming and serves as an important production base for grain, cotton, oil crops, meat, and fruits in China. However, intensive fertilization in farmland and the direct discharge of agricultural waste pose significant risks of nitrate contamination in groundwater and other environmental problems^[31]. The main goal of ANPSP control here is to protect groundwater resources, reduce the risk of water pollution, and ensure the sustainable productivity of cultivated soil^[32]. Key strategies include the rational management of nitrogen inputs in farmland (e.g., integrated water and fertilizer management, diversification of chemical fertilizer alternatives), the recycling of agricultural and livestock waste, and the provision of professional services in agricultural machinery and plant protection [Figure 4].

Northwest arid and semi-arid zone. This zone is characterized by vast land area, sparse population, and limited precipitation. Water scarcity and inefficient utilization are the major constraints on the sustainable development of regional agriculture^[33]. Thus, ANPSP control efforts should prioritize water conservation, ecological recycling, and waste reuse [Figure 5]. It is crucial to strictly regulate the total amount of



Figure 1. Overall diagram of ANPSP zoning management. This map is based on the map downloaded from the Standard Map Service System of the Ministry of Natural Resources, People's Republic of China, map number GS(2024)0650. The base map has not been modified. ANPSP: Agricultural non-point source pollution.

agricultural water use, optimize cropping structures, and promote water-saving technologies (e.g., integrated water and fertilizer management, efficient irrigation systems) tailored to local conditions. Livestock breeding layouts and scales should be scientifically planned based on resource and environmental carrying capacity. The proper treatment and resource utilization of manure are also encouraged to promote recycling and reduce greenhouse gas emissions such as methane and nitrous oxide. In addition, the collection and recycling of obsolete agricultural films are critical to mitigating the risk of plastic (including nanoplastic) pollution in farmland and water bodies^[34,35].

Northeast Plain. Characterized by fertile black soil and large-scale mechanized farming, this region contributes over 20% of the nation's total grain output but faces challenges such as nutrient leaching, livestock manure discharge, and plastic film residue from mulching^[36-39]. Conservation tillage practices (e.g., deep loosening and straw incorporation) and clean production approaches (e.g., soil test-based fertilizer

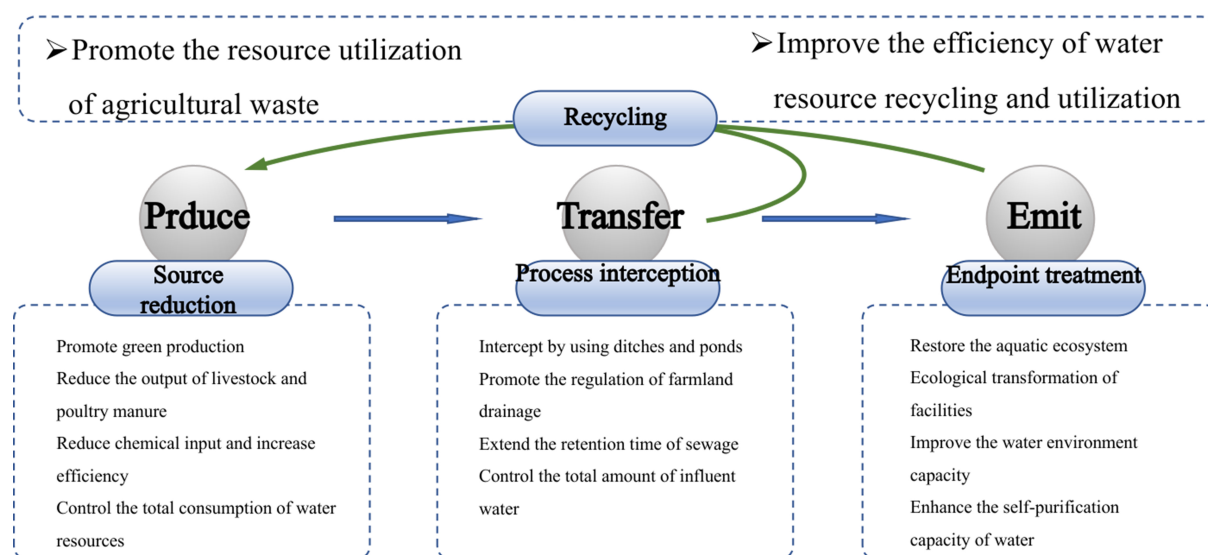


Figure 2. Strategy schematic for the middle and lower reaches of the Yangtze River.

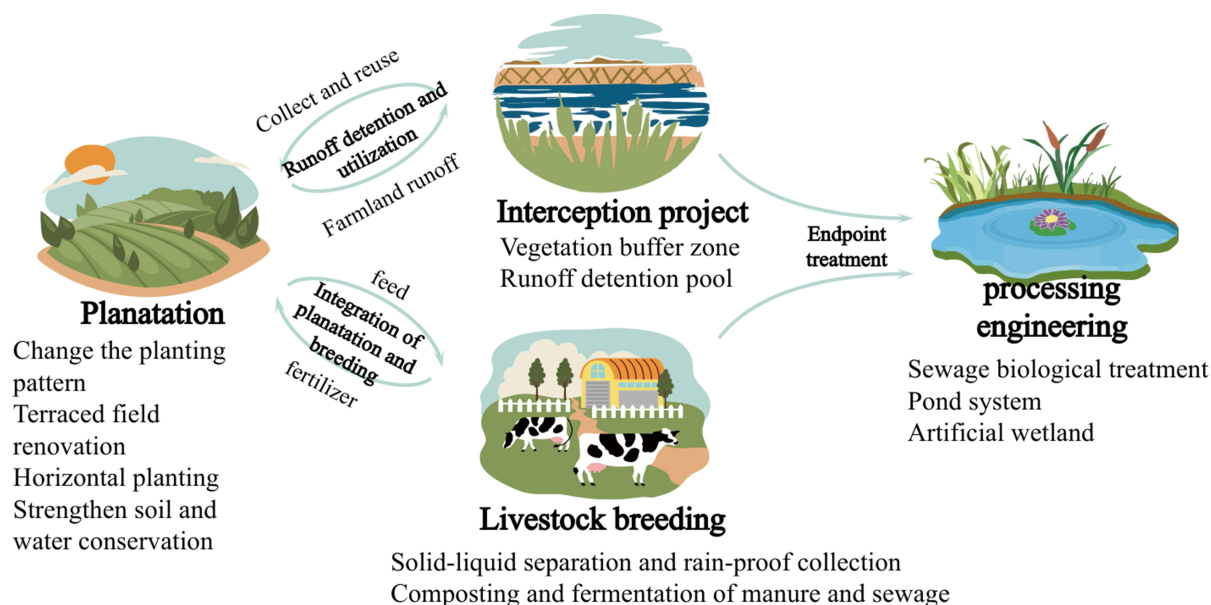


Figure 3. Strategy schematic for hilly areas in the south.

application, use of slow-release fertilizers) are recommended to improve soil quality and reduce nutrient losses [Figure 6]. In livestock breeding, promoting the harmless treatment of manure and integrated crop–livestock systems is particularly important. To mitigate the environmental impact of plastic film, the most effective measure is to reduce its use - especially films thinner than 0.01 mm - while strengthening recycling programs and promoting the adoption of biodegradable alternatives^[37].

South China tropical zone. This zone, marked by high temperatures, monsoons, and a year-round growing season, is a major production base for tropical cash crops and intensive aquaculture. However, it faces rapid nutrient loss due to high-density farming and climatic conditions. Typhoon-driven runoff also transports

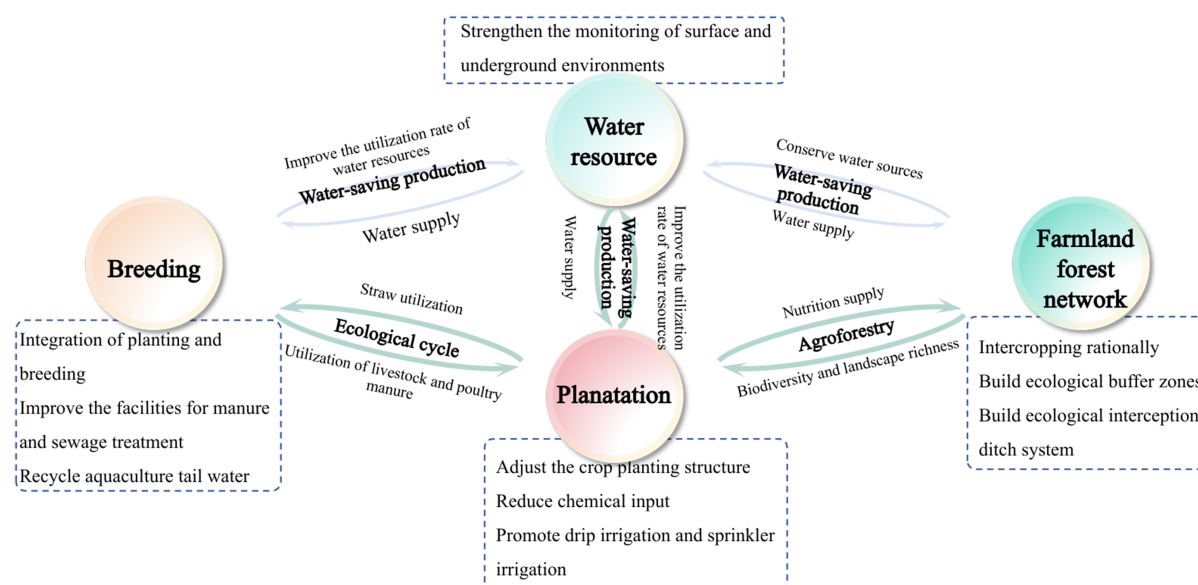


Figure 4. Strategy schematic for the Huang-Huai-Hai region.

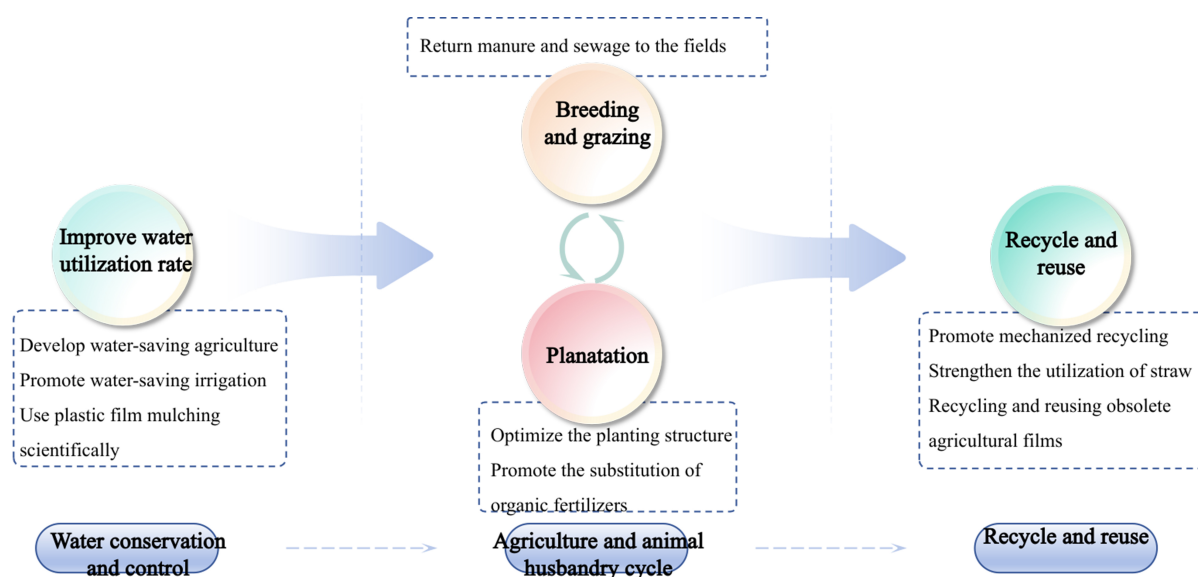


Figure 5. Strategy schematic for the northwest arid and semi-arid zone.

pollutants into the sea, threatening coastal ecosystems^[40]. To tackle these issues, strategies should focus on source control, process retention, and enhanced climate resilience. The 4R strategy could be applied^[41] by promoting precise, integrated water-fertilizer management and establishing riparian vegetation buffer strips. Additionally, developing pre-typhoon manure and water management protocols (e.g., draining low-concentration field water and regulating surface water levels) is crucial to minimizing runoff during typhoon seasons.

Qinghai-Tibet area. Known as China's "Water Tower", this region features high altitudes, sparse populations, and fragile ecosystems, with agriculture mainly confined to river valleys. The key challenge lies

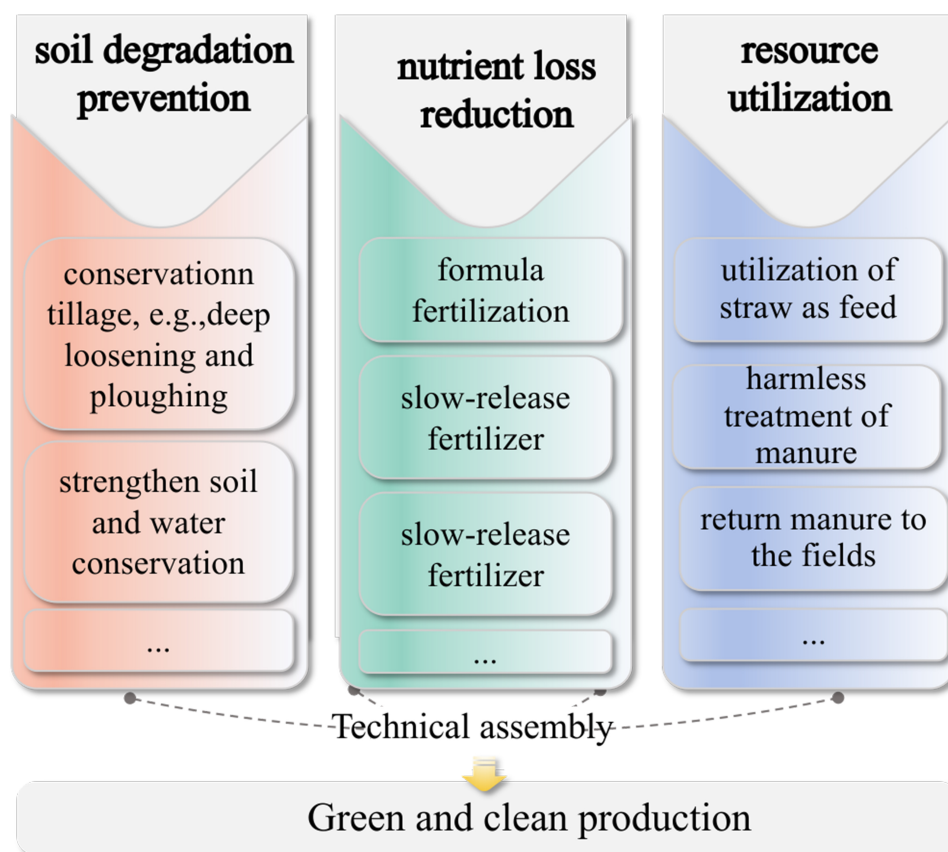


Figure 6. Strategy schematic for the Northeast Plain.

in balancing limited farming/pastoralism with the protection of headwater areas and biodiversity hotspots^[42,43]. Recommended measures include restricting agricultural expansion within ecological carrying capacity, promoting rotational grazing to prevent grassland degradation, and developing organic production systems such as highland barley cultivation and Tibetan medicinal plants without chemical pesticides.

A robust support system that integrates technological innovation, policy incentives, regulatory frameworks, and stakeholder engagement is essential for effective regional governance. Emerging technologies such as machine learning and artificial intelligence offer new opportunities for pollution control. Policy instruments should combine incentives with constraints. On the one hand, incentives - such as watershed eco-compensation schemes (e.g., Zhejiang's cross-regional "ecological compensation") and "green credit" programs for farms adopting clean production technologies (e.g., manure recycling subsidies for cooperatives) - can foster resource integration across regions and sectors. On the other hand, regulatory measures - such as mandatory effluent standards for aquaculture - are needed to shape societal norms around protecting agricultural ecosystems. Public participation is also indispensable given the public welfare nature of ANPSP management. This includes supporting service organizations that promote resource utilization of agricultural wastes (e.g., manure and straw), establishing transparent channels for public supervision, and strengthening social engagement.

To achieve precise ANPSP zoning management, smaller-scale governance strategies and goals (based on watersheds or administrative boundaries) should be developed, with priority given to key areas such as major lakes, reservoirs, and drinking water sources.

CONCLUSIONS AND OUTLOOK

Zoning management is essential for the precision control of ANPSP and for improving environmental quality. Spatially differentiated governance - tailored to regional variations in pollution drivers, ecological sensitivity, and socioeconomic contexts - enables targeted resource allocation and evidence-based interventions. Additionally, simplified yet representative indicators are critical for ensuring the practicality of zoning frameworks. Focusing on core factors enhances feasibility while maintaining regional distinctiveness, and avoids overly complex metrics that may hinder implementation. Furthermore, integrated technical measures should be prioritized over isolated solutions. Although extensive research exists on individual best practices (e.g., constructed wetlands, precision irrigation), cohesive, place-based strategies (spanning water conservation, resource recycling, and soil health) are more effective for achieving holistic improvements in water quality and soil resilience.

In the long term, zoning management of ANPSP holds broad prospects. Governance will benefit significantly from emerging technologies such as intelligent equipment, artificial intelligence-driven simulation systems, and blockchain applications. Meanwhile, zoning-based approaches will propel region-specific sustainable practices, accelerating the transition toward low-carbon, high-efficiency agriculture.

DECLARATIONS

Authors' contributions

Drafted the manuscript and prepared the figures: Li, X.

Contributed to the study conception: Xi, B.; Huang, L.

Availability of data and materials

Not applicable.

Financial support and sponsorship

This work was supported by the National Key Research and Development Program [2024YFD1701205].

Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Copyright

© The Author(s) 2025.

REFERENCES

1. Gu, B.; Zhang, X.; Lam, S. K.; et al. Cost-effective mitigation of nitrogen pollution from global croplands. *Nature* **2023**, *613*, 77-84. DOI PubMed PMC
2. Zou, L.; Liu, Y.; Wang, Y.; Hu, X. Assessment and analysis of agricultural non-point source pollution loads in China: 1978-2017. *J.*

- Environ. Manage.* **2020**, *263*, 110400. DOI PubMed
3. Lu, Y.; Wang, C.; Yang, R.; et al. Research on the progress of agricultural non-point source pollution management in China: a review. *Sustainability* **2023**, *15*, 13308. DOI
 4. Springmann, M.; Clark, M.; Mason-D'Croz, D.; et al. Options for keeping the food system within environmental limits. *Nature* **2018**, *562*, 519-25. DOI PubMed
 5. Schulte-Uebbing, L. F.; Beusen, A. H. W.; Bouwman, A. F.; de Vries, W. From planetary to regional boundaries for agricultural nitrogen pollution. *Nature* **2022**, *610*, 507-12. DOI PubMed
 6. Qin, C.; Yu, L.; Zhang, N.; et al. Building the technical standard system for ecological & environmental zoning-based regulation: current status, challenges and suggestions. *Chin. J. Environ. Manage.* **2024**, *15*, 7-14. DOI
 7. Arle, J.; Mohaupt, V.; Kirst, I. Monitoring of surface waters in Germany under the Water Framework Directive - a review of approaches, methods and results. *Water* **2016**, *8*, 217. DOI
 8. Copetti, D.; Erba, S. A bibliometric review on the Water Framework Directive twenty years after its birth. *Ambio* **2024**, *53*, 95-108. DOI PubMed PMC
 9. Wang, F.; Zheng, S.; Yang, H.; Yu, J.; Wang, Y.; Wang, Z. Regionalization and classification of water eco-environment in Zhejiang Province based on ecosystem service. *Acta. Ecol. Sin.* **2022**, *42*, 539-48. DOI
 10. Xue, Q.; Yu, L.; Li, M.; et al. Pilot practical exploration of coordinated pollution reduction and carbon reduction based on ecological environment zoning control: a case study in Zengcheng District, Guangzhou City. *J. Environ. Eng. Technol.* **2025**, *15*, 59-70. DOI
 11. He, S.; Li, F.; Liang, X.; et al. Window phase analysis of nutrient losses from a typical rice-planting area in the Yangtze river delta region of China. *Environ. Sci. Eur.* **2020**, *32*, 291. DOI
 12. Wang, Y.; Cai, Z.; Lang, X.; Yan, X.; Xu, K. Nitrogen cascade in the agriculture-food-environment system of the Yangtze Delta, 1998-2018. *Sci. Total. Environ.* **2021**, *787*, 147442. DOI PubMed
 13. Wang, R.; Zhang, J.; Cai, C.; Lei, G. Effects of different land uses on nitrogen & phosphorus losses of water source areas in Yangtze River Delta. *Res. Soil. Water. Conserv.* **2023**, *30*, 128-33. DOI
 14. Li, C.; Feng, H.; Luo, X.; et al. Limited irrigation and fertilization in sand-layered soil increases nitrogen use efficiency and economic benefits under film mulched ridge-furrow irrigation in arid areas. *Agr. Water. Manag.* **2022**, *262*, 107406. DOI
 15. Pan, Y.; She, D.; Ding, J.; et al. Coping with groundwater pollution in high-nitrate leaching areas: the efficacy of denitrification. *Environ. Res.* **2024**, *250*, 118484. DOI PubMed
 16. Feng, Q.; Zhao, W.; Hu, X.; Liu, Y.; Daryanto, S.; Cherubini, F. Trading-off ecosystem services for better ecological restoration: a case study in the Loess Plateau of China. *J. Clean. Prod.* **2020**, *257*, 120469. DOI
 17. Liu, Y.; Liu, Y.; Shi, Z.; López-Vicente, M.; Wu, G. Effectiveness of re-vegetated forest and grassland on soil erosion control in the semi-arid Loess Plateau. *CATENA*. **2020**, *195*, 104787. DOI
 18. Liu, M.; Wu, Y.; Huang, S.; et al. Effects of organic fertilization rates on surface water nitrogen and phosphorus concentrations in paddy fields. *Agriculture* **2022**, *12*, 1466. DOI
 19. Elrys, A. S.; Wang, J.; Meng, L.; et al. Integrative knowledge-based nitrogen management practices can provide positive effects on ecosystem nitrogen retention. *Nat. Food*. **2023**, *4*, 1075-89. DOI PubMed
 20. Meng, X.; Yu, H.; Zhang, X.; Li, Y.; Zamanien, K.; Yao, H. Fertilization regimes and the nitrification process in paddy soils: lessons for agricultural sustainability from a meta-analysis. *Appl. Soil. Ecol.* **2023**, *186*, 104844. DOI
 21. Li, T.; Zhang, G.; Li, Q.; et al. Response of runoff N and P concentrations, losses, and stoichiometry to rainfall amount category, multisource fertilization, and straw return in sloping croplands. *J. Hydrol.* **2024**, *640*, 131693. DOI
 22. Sishodia, R. P.; Ray, R. L.; Singh, S. K. Applications of remote sensing in precision agriculture: a review. *Remote. Sens.* **2020**, *12*, 3136. DOI
 23. Yang, L.; Shi, W.; Xue, L.; Song, X.; Wang, S.; Chang, Z. Reduce-retain-reuse-restore technology for the controlling the agricultural non-point source pollution in countryside in China: general countermeasures and technologies. *J. Agro. Environ. Sci.* **2013**, *32*, 1-8. DOI
 24. Xue, L.; Duan, J.; Hou, P.; et al. Full time-space governance strategy and technology for cropland non-point pollution control in China. *Front. Agr. Sci. Eng.* **2023**, *10*, 593-606. DOI
 25. Zhang, Z.; Hu, M.; Bian, B.; Yang, Z.; Yang, W.; Zhang, L. Full-scale thermophilic aerobic co-composting of blue-green algae sludge with livestock faeces and straw. *Sci. Total. Environ.* **2021**, *753*, 142079. DOI PubMed
 26. Ren, L.; Kong, X.; Su, J.; et al. Oriented conversion of agricultural bio-waste to value-added products - a schematic review towards key nutrient circulation. *Bioresour. Technol.* **2022**, *346*, 126578. DOI PubMed
 27. Sun, X.; Li, X.; Tang, S.; Lin, K.; Zhao, T.; Chen, X. A review on algal-bacterial symbiosis system for aquaculture tail water treatment. *Sci. Total. Environ.* **2022**, *847*, 157620. DOI PubMed
 28. Wang, X. H.; Yin, C. Q.; Shan, B. Q. The role of diversified landscape buffer structures for water quality improvement in an agricultural watershed, North China. *Agric. Ecosyst. Environ.* **2005**, *107*, 381-96. DOI
 29. Christen, B.; Dalgaard, T. Buffers for biomass production in temperate European agriculture: a review and synthesis on function, ecosystem services and implementation. *Biomass. Bioenerg.* **2013**, *55*, 53-67. DOI
 30. Wolka, K.; Mulder, J.; Biazin, B. Effects of soil and water conservation techniques on crop yield, runoff and soil loss in Sub-Saharan Africa: a review. *Agric. Water. Manag.* **2018**, *207*, 67-79. DOI
 31. Ma, L.; Wang, H.; Liu, G.; et al. Mitigation of nitrogen and phosphorus leaching from cropland in northern China. *Chin. J. Eco. Agric.*

- 2021, 29, 1-10. DOI
32. Du, J.; Laghari, Y.; Wei, Y.; et al. Groundwater depletion and degradation in the North China Plain: challenges and mitigation options. *Water* **2024**, *16*, 354. DOI
 33. Du, T.; Kang, S.; Zhang, X.; Zhang, J. China's food security is threatened by the unsustainable use of water resources in North and Northwest China. *Food. Energy. Secur.* **2014**, *3*, 7-18. DOI
 34. Gao, H.; Yan, C.; Liu, Q.; Ding, W.; Chen, B.; Li, Z. Effects of plastic mulching and plastic residue on agricultural production: a meta-analysis. *Sci. Total. Environ.* **2019**, *651*, 484-92. DOI PubMed
 35. Wang, T.; Wang, Z.; Guo, L.; et al. Experiences and challenges of agricultural development in an artificial oasis: a review. *Agric. Syst.* **2021**, *193*, 103220. DOI
 36. Zhao, Z.; Deng, X.; Zhang, F.; et al. Scenario analysis of livestock carrying capacity risk in farmland from the perspective of planting and breeding balance in Northeast China. *Land* **2022**, *11*, 362. DOI
 37. Ding, F.; Yan, C.; Wang, J. An overlooked issue in black soil protection: plastic film accumulation and pollution. *Chin. J. Soil. Sci.* **2022**, *53*, 234-40. DOI
 38. Gao, C.; Zhang, M.; Song, K.; Wei, Y.; Zhang, S. Spatiotemporal analysis of anthropogenic phosphorus fluxes in China. *Sci. Total. Environ.* **2020**, *721*, 137588. DOI PubMed
 39. Xu, X.; Xu, Y.; Chen, S.; Xu, S.; Zhang, H. Soil loss and conservation in the black soil region of Northeast China: a retrospective study. *Environ. Sci. Policy.* **2010**, *13*, 793-800. DOI
 40. Pradhan, U.; Wu, Y.; Wang, X.; Zhang, J.; Zhang, G. Signals of typhoon induced hydrologic alteration in particulate organic matter from largest tropical river system of Hainan Island, South China Sea. *J. Hydrol.* **2016**, *534*, 553-66. DOI
 41. Cha, Z. Z.; Lin, Z. M.; Luo, W.; Li, S. C.; Luo, X. H. Sustainable land management practices for rubber plantations in mountainous area of Hainan. *Pedosphere.* **2005**, *15*, 404-8. http://pedosphere.issas.ac.cn/trqcn/ch/reader/view_abstract.aspx?file_no=20050318&st=alljournals. (accessed 18 Aug 2025)
 42. Yang, Y.; Zhao, D.; Chen, H. Quantifying the ecological carrying capacity of alpine grasslands on the Qinghai-Tibet Plateau. *Ecol. Indic.* **2022**, *136*, 108634. DOI
 43. Fang, Y.; Zhu, F.; Yi, S.; Qiu, X.; Ding, Y. Ecological carrying capacity of alpine grassland in the Qinghai-Tibet Plateau based on the structural dynamics method. *Environ. Dev. Sustain.* **2021**, *23*, 12550-78. DOI