

# Dual role of agricultural plastic in China's food security and green transition: policy progress and prospects

Chengtao WEN<sup>1</sup>, Ji MA (✉)<sup>1</sup>, Xin'er SHI<sup>1</sup>, Xuejun LIU<sup>2</sup>, Changrong YAN<sup>3</sup>, Kai WANG<sup>2</sup>, Jingwen CHENG<sup>2</sup>

1 College of Economics and Management, China Agricultural University, Beijing 100083, China.

2 College of Resources and Environmental Sciences, China Agricultural University, Beijing 100193, China.

3 Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences, Beijing 100081, China.

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Correspondence: [maji@cau.edu.cn](mailto:maji@cau.edu.cn)

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## SUPPLEMENTARY MATERIALS

**Table S1** Review of policy documents for the first phase of agricultural plastics management (1982–1997)

Date of publication	Policy document	Document content
Popularization of agricultural plastics stage (1982–1990)		
1982	Sixth Five-Year Plan for National Economic and Social Development of the People's Republic of China (1981–1985)	Agricultural film production should be increased, new agricultural technologies should be vigorously promoted and developed, and plastic film technology should be systematically promoted
1985	Circular of the State Council Approving the Report of the State Planning Commission on the Technical Policy and Technological Reform of Industry in the Seventh Five-Year Plan	In polyethylene products, it adopts closed mixing equipment, improves the production process of mulch film and masters the technology of ultra-thin production

1988	Decision of the State Council on the Implementation of Specialized Management of Chemical Fertilizers, Pesticides and Agricultural Films	Fertilizers, pesticides, and agricultural films are essential components of agricultural production. In a scenario where demand exceeds supply, the State Council decided to specialize in these products to prevent multiple buyers and sellers from engaging in transactions, which aims to eliminate market and price confusion, protect farmer interests, and promote the development of the rural commodity economy
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Emergence of awareness of agricultural plastic waste pollution stage (1990–1997)

1990	Decision of the State Council on Further Strengthening Environmental Protection	For the first time, residual film pollution has been included in the scope of agricultural environmental management. This emphasizes the need for the agricultural sector to improve the protection and management of the agricultural environment while controlling environmental pollution caused by fertilizers, pesticides and agricultural films
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1991	Ten-Year Plan for National Economic and Social Development and the Outline of the Eighth Five-Year Plan of the People’s Republic of China	Efforts should be made to increase the supply of mineral fertilizers, pesticides, agricultural films, agricultural machinery and other essential inputs, while ensuring that their prices are reasonably controlled. In addition, it is important to promote widely applicable technologies that have a significant impact on increasing crop yields
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1993	Agricultural Law of the People’s Republic of China	The State promotes the development of the agricultural input industry through measures such as taxation and credit, and ensures the supply of essential inputs such as fertilizers, pesticides, veterinary medicines, agricultural films and machinery to meet the needs of agricultural production
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1995	Law of the People’s Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste	The State encourages research institutions and production units to develop agricultural films that are recyclable, biodegradable or easily disposable. Users of agricultural films shall take measures, such as recycling, to minimize the environmental pollution caused by their use
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1996	Decision of the State Council on Several Issues Concerning Environmental Protection	To promote organic farming and reduce pollution of farmland and water sources from fertilizers, pesticides and agricultural film
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1996	Outline of the Ninth Five-Year Plan and the 2010 Vision for the National Economic and Social Development of the People’s Republic of China	Increase the production of raw materials for agricultural films, adjust the structure of materials used for agricultural films and mulch films, and develop new varieties
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1997	Circular of the General Office of the State Council on the Effective Implementation of Drought Relief and Double-Protection Work	Water-saving and dry farming techniques should be actively promoted, especially in water-scarce areas, using methods such as fine land preparation, deep plowing, soil compaction, mulching, and transplanting seedlings
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**Table S2** Review of policy documents for the second phase of agricultural plastics management (1997–2017)

Date of publication	Policy document	Document content
Awareness-raising of agricultural plastic waste pollution stage (1997–2011)		
1997	Opinions of the former State Environmental Protection Administration on Strengthening Environmental Protection Work	In order to promote the coordinated development of the rural economy and the environment, environmental protection departments at all levels should establish a target responsibility system for rural ecological protection and a quantitative assessment of the improvement of the rural ecological environment. In areas with severe surface pollution and in the Three Lakes area, the relevant provincial and municipal environmental protection departments should actively organize and carry out demonstrations of integrated pollution prevention and control of fertilizers, pesticides agricultural film, animal manure and aquaculture
1998	Decision of the Central Committee of the Communist Party of China on Several Major Issues of Agriculture and Rural Work	Control of the pollution of land and water resources caused by the irrational use of fertilizers, pesticides and agricultural films in industry, life and agriculture
1999	Circular of the State Development Planning Commission and the Ministry of Science and Technology on the Issuance of the Guide to the Priority Areas of High-Tech Industrialization for Current Development (1999)	The guide identifies 138 key areas of high-tech industrialization that should be prioritized for development, including biodegradable agricultural film masterbatches and new materials for agricultural use
1999	Opinions of the State Environmental Protection Administration on Strengthening Rural Ecological Environmental Protection Work	Actively examine effective ways to prevent and control pollution from fertilizers, pesticides and agricultural films, and promote the rational use of agrochemicals
2002	Law of the People's Republic of China on Promoting Clean Production	Agricultural producers should use fertilizers, pesticides, agricultural films and feed additives in a scientific manner, improve planting and breeding techniques, achieve high quality and harmless agricultural products and utilization

		of agricultural production wastes, and prevent pollution of the agricultural environment
2002	Agriculture Law of the People's Republic of China (2002 Revision)	Farmers and agricultural production and management organizations should cultivate arable land, make rational use of mineral fertilizers, pesticides and agricultural films, increase the use of organic fertilizers, apply advanced technologies, protect and improve the strength of the soil, and prevent the pollution, destruction and deterioration of the strength of agricultural land
2004	Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Wastes (2004 Revision)	The State encourages scientific research and production units to research and produce film coverings and commodity packages that are easy to recycle and utilize, easy to dispose of or degradable in the environment. Units and individuals using agricultural films should take measures such as recycling to prevent or reduce the pollution of the environment caused by agricultural films
2007	Circular of the National Development and Reform Commission on the Issuance of the Eleventh Five-Year Plan for the Nationwide Economic and Social Development of Rural Areas	Scientific use of mineral fertilizers, pesticides and agricultural films and prevention of soil pollution caused by irrational use of mineral fertilizers, pesticides and agricultural films. Strengthen the research and development of biodegradable agricultural films and their production
2007	Circular of the National Development and Reform Commission, the Ministry of Finance and the Ministry of Agriculture on Strengthening the Management of Agricultural Film Production and Operation	Strict industrial policy, the development and release of agricultural film industry access conditions. At the same time, to strengthen the promotion and use of agricultural film guidance to enhance farmers' awareness of their rights
2008	Circular Economy Promotion Law of the People's Republic of China	The State encourages and supports agricultural producers and relevant enterprises to adopt advanced or applicable technologies to comprehensively utilize crop residues, livestock and poultry manure, by-products of the agricultural product processing industry, agricultural film waste, and to develop and utilize biomass energy sources such as biogas
2010	Bulletin of the First National Census of Pollution Sources	The amount of film residue in the planting industry is 121 kt, and the film recycling rate is 80%

Initial control of the agricultural plastic waste pollution stage (2011–2017)

2011	Opinions of the State Council on Strengthening Major Environmental Protection Work	The development of ecological and organic agriculture, the scientific application of mineral fertilizers, pesticides, and agricultural films, and the effective reduction of surface pollution
2011	Opinions of the Ministry of Agriculture on Further Strengthening Energy Conservation and Emission Reduction in Agriculture and Rural Areas	Promote the use of agricultural films with a thickness of no less than 8 $\mu\text{m}$ while strictly restricting ultra-thin films. Accelerate the adoption of technologies and equipment for used film collection, and provide subsidies to farmers for recycling efforts. Encourage and guide farmers to participate in film recycling, support the establishment of recycling and processing facilities, and develop a comprehensive network for used film collection and reuse. Gradually implement a mechanism linking the use, recycling, and reuse of agricultural films. Additionally, secure financial support and collaborate with relevant departments to establish systems for recycling and processing pesticide waste packaging
2012	Notice of the General Office of the Ministry of Agriculture on the Issuance of Technical Guidelines for Mulching	Strengthen the promotion of water-saving technology for mulching, while strengthening the recycling and reuse of film waste, and increase efforts to recycle and reuse film waste
2012-2015	National Development and Reform Commission, Ministry of Finance and former Ministry of Agriculture demonstration projects on cleaner agricultural production for four consecutive years	A cumulative investment of more than 900 million yuan has been made to support the development of film recycling projects and capacity building in counties and cities, with pilot projects covering 229 counties and cities in 11 regions and the Corps, such as Gansu, Xinjiang and Inner Mongolia
2014	National Conference on Agricultural Work (2014)	For the first time, a clear target has been set for the management of agricultural surface pollution, requiring that the recycling rate of agricultural film should in principle exceed 80% by 2020
2015	Circular of the Ministry of Agriculture, the National Development and Reform Commission and the Ministry of Science and Technology on the Issuance of the National Plan for Sustainable Agricultural Development (2015–2030)	To comprehensively manage film pollution, promote film thickening, carry out mechanized collection demonstration and promotion of film waste and recycling, accelerate research and development of biodegradable film, and achieve basic recycling of agricultural film waste in major agricultural production areas by 2030

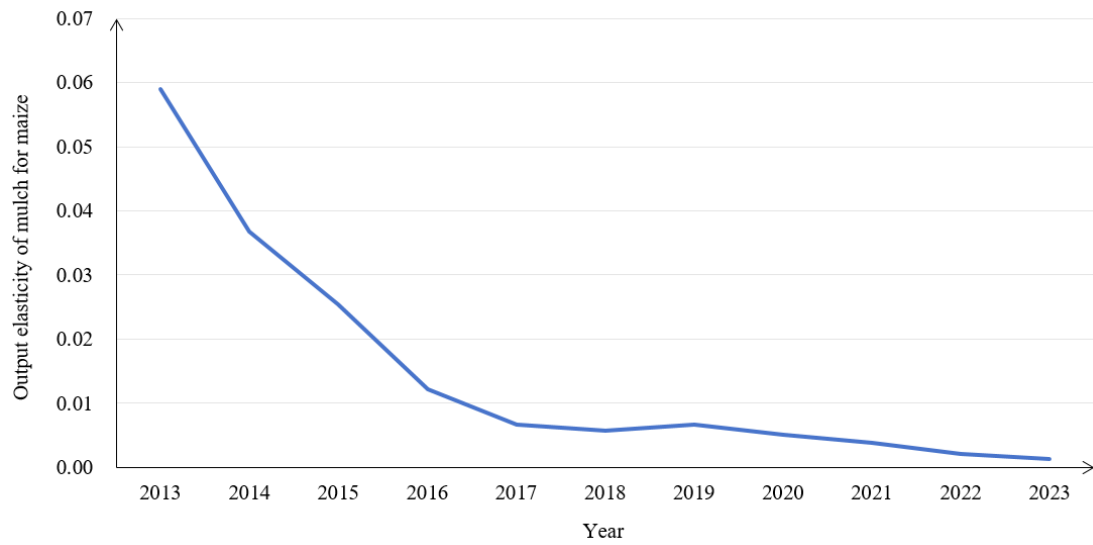
2016	Notice of the State Council on Issuing Soil Pollution Prevention and Control Action Plan	Revise standards for agricultural films, increase thickness requirements, and study and formulate standards for biodegradable agricultural films. Increase recycling of pesticide packaging waste and recycling of discarded agricultural films
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**Table S3** Review of policy documents for the third phase of agricultural plastics management (2017 onwards)

Date of publication	Policy document	Document content
2017	Circular of Ministry of Agriculture on the Issuance of the Action Program on Agricultural Film Recycling	The agricultural film recycling initiative prioritizes the Northwest region and focuses on key crops such as cotton, corn and potatoes. It emphasizes the use of thicker films, mechanized collection, professional recycling and resource utilization. Key measures include improving support policies, strengthening pilot demonstrations, enhancing scientific and technological support, innovating recycling mechanisms and promoting agricultural film recycling to increase resource utilization of waste film and prevent “white pollution”
2017	Polyethylene blown mulch film for agricultural uses (GB 13735-2017)	The thickness of the film should not be less than 10 $\mu\text{m}$ , while the tensile strength and weather resistance of the film should meet the requirements of the national standard
2018	Soil Pollution Prevention and Control Law of the People’s Republic of China	The State has implemented measures to encourage and support the recycling of agricultural input packaging waste and agricultural film by both organizations and individuals. It also encourages the use of biodegradable film. Organizations or individuals who violate these laws are subject to fines
2019	Opinions of Ministry of Agriculture and Rural Development, National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Finance, Ministry of Ecology and Environment, and State Administration for Market Supervision and Administration on Accelerating the Prevention and Control of Pollution from Farmland Films	The general requirements, institutional measures, key tasks and policy guarantees for the prevention and control of soil pollution have been further clarified, and strengthening the management of agricultural soil pollution has become an important initiative to promote the green development of agriculture

2020	Bulletin of the Second National Census of Pollution Sources	In 2017, 1.42 Mt of mulch was used and 1.18 Mt of residue accumulated over the years.
2020	Measures for the Administration of Agricultural Film	Specific requirements have been set for the production, sale and use of agricultural films. It has vigorously promoted the use of standardized films, promoted the implementation of the recycling responsibility of agricultural films by relevant key organizations, participated in the construction of the recycling system, and continuously improved the level of recycling and utilization
2020	Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Wastes (2020 Revision)	Units and other producers and business operators that produce agricultural solid waste such as straw, waste agricultural films and pesticide packaging waste shall take recycling and other measures to prevent environmental pollution
2022	Circular of the General Office of Ministry of Agriculture and Rural Affairs and the General Office of Ministry of Finance on the Pilot Work of Scientific Use and Recycling of Film	Focus on key film using areas, select districts (cities, counties, and regiments) with large film use, high motivation, good working conditions, and strong policy support for pilot projects, and focus on supporting the promotion of thickened and high-strength films and fully biodegradable films
2023	Circular of the General Office of Ministry of Agriculture and Rural Affairs, the General Office of General Administration for Market Supervision, the General Office of Ministry of Industry and Information Technology and the General Office of Ministry of Ecology and Environment on Further Strengthening the Supervision and Enforcement of Agricultural Films	Effectively strengthen the supervision of agricultural film throughout its entire lifecycle, targeting the production and sale of non-compliant film and illegal practices such as the improper recycling of used film.

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**Fig. S1** Output elasticity of mulch for maize in 2013–2023. Calculated based on data published by the National Bureau of Statistics of China (2013–2023)<sup>[1]</sup>.

#### REFERENCE

1. National Bureau of Statistics, People's Republic of China. China Statistical Yearbook 2014–2024. Beijing: China Statistics Press, 2014–2024 (in Chinese)