



# ANALYSIS REPORT ON CURRENT STATUS OF PE MULCH FILM APPLICATION IN CHINA

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## Imprint

Commissioned by the Federal Ministry for Economy Cooperation and Development (BMZ) and under the framework of develoPPP.de Programme, Sino-German Project for Upgrading Plastics Management in Agriculture is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, together with Reifenhäuser GmbH & Co. KG Maschinenfabrik, Zhuhai Kinfa Biomaterial Co., Ltd and TÜV Rheinland (Shanghai) Co., Ltd. Commencing in 2020 September, the project aims at tackling “white pollution” caused by inappropriate plastic film management in China. The project will, for one thing, enhance the recycling efficiency of PE film by digitalized tracking system; for another, promote the utilization of biodegradable mulch film. Five pilots will be implemented in Gansu, Heilongjiang, Inner Mongolia, Hubei and Beijing, respectively. Against the project best practices, technical specifications and political suggestions will be generated to facilitate the upgrading of agricultural plastic management in China.



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## List of Acronyms

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Abbreviation	Full name
PE	Polyethylene
PVC	Polyvinyl chloride
EVE	Ethylene-Vinyl Acetate copolymer
HDPE	High-Density Polyethylene
LDPE	Low-Density Polyethylene
LLDPE	Linear Low Density Polyethylene



# Status Quo of Agricultural Film Application

## 🌱 Necessity of Agricultural Film Application

Agricultural plastic film mainly includes mulch film and greenhouse film. It has been widely used in modern agriculture and listed as the fourth important production material after seeds, fertilizers and pesticides. Taking mulch film as an example, it can improve the production environment and yield of crops, by increasing temperature and moisture, regulating growth cycle, resisting diseases and pests, and inhibiting weeds. The yields of cereal crop and industrial crop could increase by 20%-35% and 20%-60%, respectively. Agricultural film mulching technology has become the largest application technology for agricultural production in northern China, as well as the main technology for saving water and enhancing drought resistance in dry farming areas.

**Agricultural film mulching can greatly improve production conditions, particularly in terms of temperature increase and moisture retention.**

It effectively solves the production problems of insufficient soil moisture in the arid or semi-arid areas in northern areas and southwest mountainous areas of China, as well as low temperature and insufficient accumulated temperature in spring. Compared with conventional planting, mulch film covering increased the water use efficiency of corn by 30% to 70%.

**Agricultural film mulching could effectively expand the planting area of crops.**

Compared with conventional planting, film mulching could not only make crops stably produce and mature early, but also expand the planting area of crops by changing its growth microenvironment. Firstly, the cultivation boundary of some thermophilic crops can be moved northward by 2 to 5 latitudes, that is, more than 500 kilometers northward. Secondly, the elevation of crop planting can be raised by 500 m to 1000 m. For instance, film mulching in Southwest China can greatly increase the altitude of tobacco planting, and effectively solve the limitation of tobacco planting area in Yunnan, Guizhou, and Sichuan plateau.

**Agricultural film mulching can effectively shorten the growth cycle of crops.**

In the Huang-Huai-Hai plain, the Loess Plateau, the Yangtze River Basin and its south, film mulching can advance the marketing period by 5 days to 15 days for some vegetables, and by 7 days to 15 days for watermelon and muskmelon. In the northeast, northwest and other cold areas, the harvest time of main vegetables and melons can be advanced by 7 days to 20 days. As for vegetable production, film mulching could not only support vegetables' early maturity and yield increase but also improve vegetable quality, prolong supply period, and effectively improve as well as enhance its supply level.



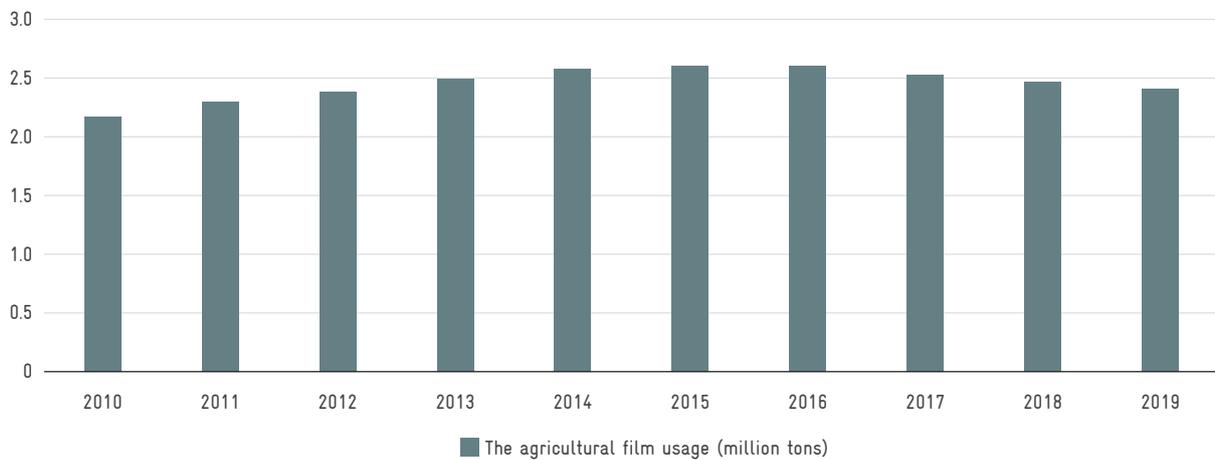
## 🌿 Total Amount of Agricultural Film Used

### The General Situation of Agricultural Film Usage

Agricultural film is one of the important production materials for China's agriculture. In recent ten years, agricultural film has been used above two million tons annually, ranking first around the world. According to "China Rural Statistical Yearbook 2020", the amount of agricultural film application in China increased from 2.1730 million tons to 2.6036 million tons between 2010 and 2015, counting for an average annual growth rate of 4.28%. Since 2016, with the promulgation

and implementation of the "Action plan for soil pollution prevention and control", the "Action plan for agricultural film recycling" and other policy documents, the usage of agricultural film in China decreased year by year. In 2019, the agricultural film usage was 2.4077 million tons, about 0.20 million tons less than that in 2015, with an average annual growth rate of -1.93%, as shown in Figure 1.

Figure 1 Use of agricultural film in China from 2010 to 2019



Data source: China Rural Statistical Yearbook

Affected by the cultivated land area, varieties of crops and the development of Facility Agriculture, the use of agricultural film in China has evident regional characteristics, mainly concentrated in three areas: central area including Shandong, Henan and other major agricultural provinces, northwest area including Gansu province, and southwest area including

Sichuan and Yunnan province. According to the "China Statistical Yearbook", the agricultural film usage in the central and northwest area are much higher than that in the others. Detailed use of agri-film in provinces in 2019 are shown in Table 1.

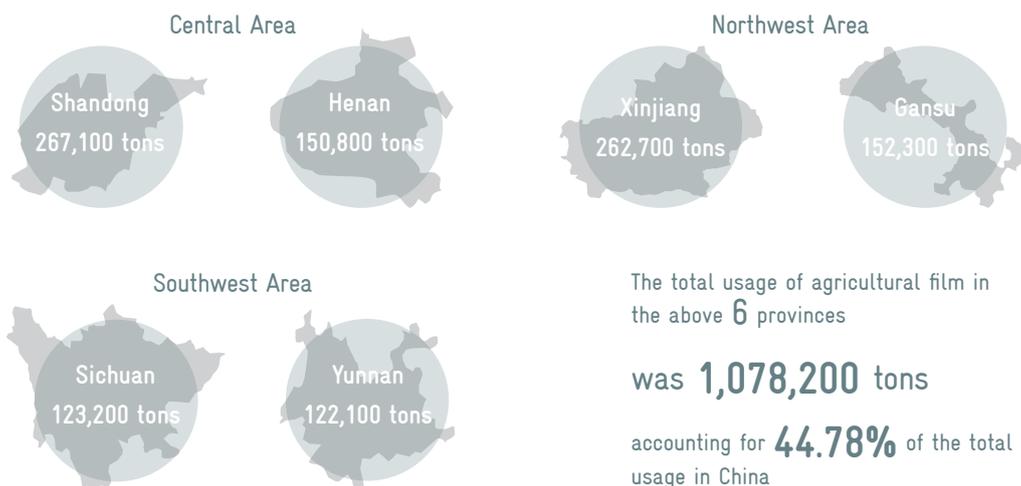


Table 1 The use of agricultural film in some provinces of China in 2019

Number	Province	The agricultural film usage (million tons)	Proportion
1	Shandong	0.2671	11.09%
2	Xinjiang	0.2627	10.91%
3	Gansu	0.1523	6.32%
4	Henan	0.1508	6.26%
5	Sichuan	0.1232	5.12%
6	Yunnan	0.1221	5.07%
7	Jiangsu	0.1142	4.74%
8	Liaoning	0.1135	4.71%
9	Anhui	0.1037	4.31%
10	Hebei	0.1032	4.29%

Data source: China Statistical Yearbook 2020

### The Utilization of Mulch Film

In the early 1970s, some areas of China have used wasted agricultural film to conduct small-scale cultivation experiments on vegetables, cotton and other crops. Certain effects were received but could not be promoted in practice due to economic and technical reasons. In 1978, a whole set of mulching technology was introduced from Japan, including operating methods, special mulching and covering machinery, through foreign scientific and technological exchanges. After several years of digestion and absorption, combined with traditional agronomic techniques, China has formed its specific mulching cultivation approach. In 1979, China successfully trial-produced a special film for ground cover, followed by a variety of new products such as colored mulch film, reflective film, weeding film, aging-resistant long-life film, and incision film. In 1980, the mulching machine were produced and trialed. In 1984, more than 60 kinds of mulching machines with different power traction have been generated. In the same year, the China Film Mulching Cultivation Research Association was established. In 1985, the area covered by mulch film in China ranked as the first globally. Since 1993, mulch products with stable quality, mature application model has been used for increased types of crops. Meanwhile, major breakthroughs have been made for the mulching equipment, which can be used for large-scale applications. At present, mulching has been put into use for more than 80 crops.

Similar as the agricultural film in general mentioned in the last chapter, in the past ten years, the application amount of mulch film in China has shown a trend of increasing at first, followed by decreasing. According to the data from the “China Rural Statistical Yearbook” and “China Statistical Yearbook on Environment”, the mulch film usage in China increased by about 0.2711 million tons from 2010 to 2016, with an average annual growth rate of 3.70%. In regard to the growing structure, it starts with a rapid growth, then slows down, and hits a plateau, reaching a peak of 1.4701 million tons in 2016. After that, with the promulgation and implementation of the “Action plan for soil pollution prevention and control”, the “Action plan for agricultural film recycling” and other policy documents, the agricultural film usage in China has gradually decreased, with negative growth for 3 consecutive years with -2.11% on average and dropped to 1.3792 million tons in 2019. The acreage changes of coverage stay consistent with changes of the mulch usage amount. In 2010, the total mulched area in China was 15.59 million hm<sup>2</sup>, peaked in 2017 (18.66 million hm<sup>2</sup>), accounting for 13.5% of the cultivated land area in China. The number decreased slightly in 2019 to 17.43 million hm<sup>2</sup>. The details are shown in Table 2.

Table 2 The use of mulch film in China from 2010 to 2019

Year	Total cultivated land area (million hm <sup>2</sup> )	Area covered by mulch film (million hm <sup>2</sup> )	The mulch film usage (million tons)	Growth rate of mulch film use (%)
2010	135.268	15.5956	1.1838	-
2011	135.239	19.7905	1.2448	5.16%
2012	135.158	17.5825	1.3108	5.30%
2013	135.163	17.6570	1.3618	3.89%
2014	135.057	18.1403	1.4415	5.85%
2015	134.999	18.3184	1.4548	0.93%
2016	134.921	18.4012	1.4701	1.05%
2017	137.881	18.6572	1.4366	-2.28%
2018	137.881	17.7647	1.4094	-1.89%
2019	137.881	17.6281	1.3792	-2.15%

Data source: China Rural Statistical Yearbook, China Statistical Yearbook on Environment.

The national average of intensity mulch film use<sup>1</sup> also shows the same trend, which increased from 8.75 kg/hm<sup>2</sup> and peaked at 10.90 kg/hm<sup>2</sup> between 2010 and 2016. Followed by decreasing and the intensity fell to 10.00 kg/hm<sup>2</sup> in 2019.

Affected by crop types, farming methods, and mulching products itself, the average amount of mulching used per unit area<sup>2</sup> changed slightly, but continuous in the range of 77-79.4 kg/hm<sup>2</sup>. Details are shown in Table 3.

Table 3 Use intensity and unit coverage of mulch film in China from 2010 to 2019

Number	Province	The agricultural film usage (million tons)	Proportion	单位面积地膜覆膜量增速 (%)
1	Shandong	26.71	11.09%	-
2	Xinjiang	26.27	10.91%	-17.13%
3	Gansu	15.23	6.32%	18.52%
4	Henan	15.08	6.26%	3.45%
5	Sichuan	12.32	5.12%	3.03%
6	Yunnan	12.21	5.07%	-0.05%
7	Jiangsu	11.42	4.74%	0.60%
8	Liaoning	11.35	4.71%	-3.62%
9	Anhui	10.37	4.31%	3.04%
10	Hebei	10.32	4.29%	-1.39%

Data source: China Statistical Yearbook 2020

1 The use intensity of mulch film refers to the ratio of the mulch film usage in a region to the total cultivated land area of the region, which is an index reflecting the mulch film usage in a region.  
2 The mulch film usage per unit area refers to the ratio of mulch film usage to mulch film area, which is an index reflecting the intensity of mulch film per unit area.

Along with the well-developed theory and production practice, the types of crops using mulch film increased rapidly. At the beginning, only vegetables and flowers with relatively high economic value are worthy with mulch covering, and now it has been expanded to a variety of cash crops, such as peanuts, watermelons, sugarcane, tobacco, cotton. In addition, in arid and low-temperature areas, in order to maintain

humidity and temperature, mulch film cultivation has been even used to grow corn, wheat and other staple food crops. In the cold, arid and semi-arid areas such as Shandong, Shanxi, Inner Mongolia, Shanxi and Gansu Province etc., mulch film technology has been applied to most kinds of crops, showing a continuous growth trend.



Figure 2 Film covered varieties of common crops

## Regional Distribution of Mulch Film

### The Application Amount of Mulch Film

According to the analysis of the mulch film use in the “China Statistical Yearbook” from 2010 to 2020, mulching area in China has gradually expanded from arid and semi-arid areas in the north to alpine and cold areas in the Southwest. By 2019, three regions were formed, namely: the facility vegetable film mulching areas mainly in East China, heat preservation and moisturizing film mulching areas mainly in Northwest, and industrial crops weeding film mulching areas mainly in Southwest.

In addition, affected by degrees of drought, altitude, temperature, and film mulching varieties, the mulch film usage in different regions also has its specific regional characteristics. Among them, the mulch film usage in arid and semi-arid areas is significantly higher than other regions.

Taking Xinjiang Uygur Autonomous Region, Inner Mongolia Autonomous Region and Gansu Province as examples, the mulch film usage in 2019 reached 242,700 tons, 80,800 tons and 116,000 tons respectively, accounting for 31.5% of total usage in China. In addition, mulch film was mainly used in these two provinces, accounting for 85.7% and 73.3% of the agricultural film, respectively. In the southern alpine and cold areas, the mulch film is mainly used for weeding and heat preservation. In this regard, the mulch film usage in Sichuan and Yunnan accounted for 12.9% of total usage. In provinces with large sowing areas such as vegetables, mulch film is also irreplaceable. For instance, mulch film usage in Shandong and Henan accounted for 12.2% of the total use. More details are shown in Table 4.

Table 4 The use of mulch film in some provinces of China in 2019

Number	Province	Mulch		The area covered by mulch film		Main varieties of mulched crops
		Usage (million tons)	Proportion	Cover areas (ten thousand mu)	Proportion	
1	Xinjiang	0.2427	17.6%	3.5480	20.1%	Cotton, vegetables, melon, corn, etc
2	Gansu	0.1116	8.1%	1.2986	7.4%	Corn, potato, watermelon, yam, broad bean, etc
3	Shandong	0.1016	7.4%	1.7678	10.0%	Vegetables, cotton, peanuts, potatoes
4	Yunnan	0.0968	7.0%	1.0774	6.1%	Vegetables, tea trees, potatoes, corn, rape, etc
5	Sichuan	0.0813	5.9%	0.9446	5.4%	Vegetables, rice seedling raising, broad bean, rice, watermelon, peanut, etc
6	Inner Mongolia	0.0808	5.9%	1.4159	8.0%	Corn, potato, etc
7	Henan	0.0661	4.8%	0.9953	5.6%	Vegetables, peanuts, cotton, etc
8	Hunan	0.0552	4.0%	0.6390	3.6%	Vegetables, potatoes, millet, tobacco, etc
9	Hebei	0.0503	3.6%	0.7738	4.4%	Vegetables, peanuts, cotton, etc
10	Anhui	0.0452	3.3%	0.4849	2.8%	Vegetables, rice, sweet potatoes, peanuts, etc

Data source: China Rural Statistical Yearbook, China Statistical Yearbook on Environment.

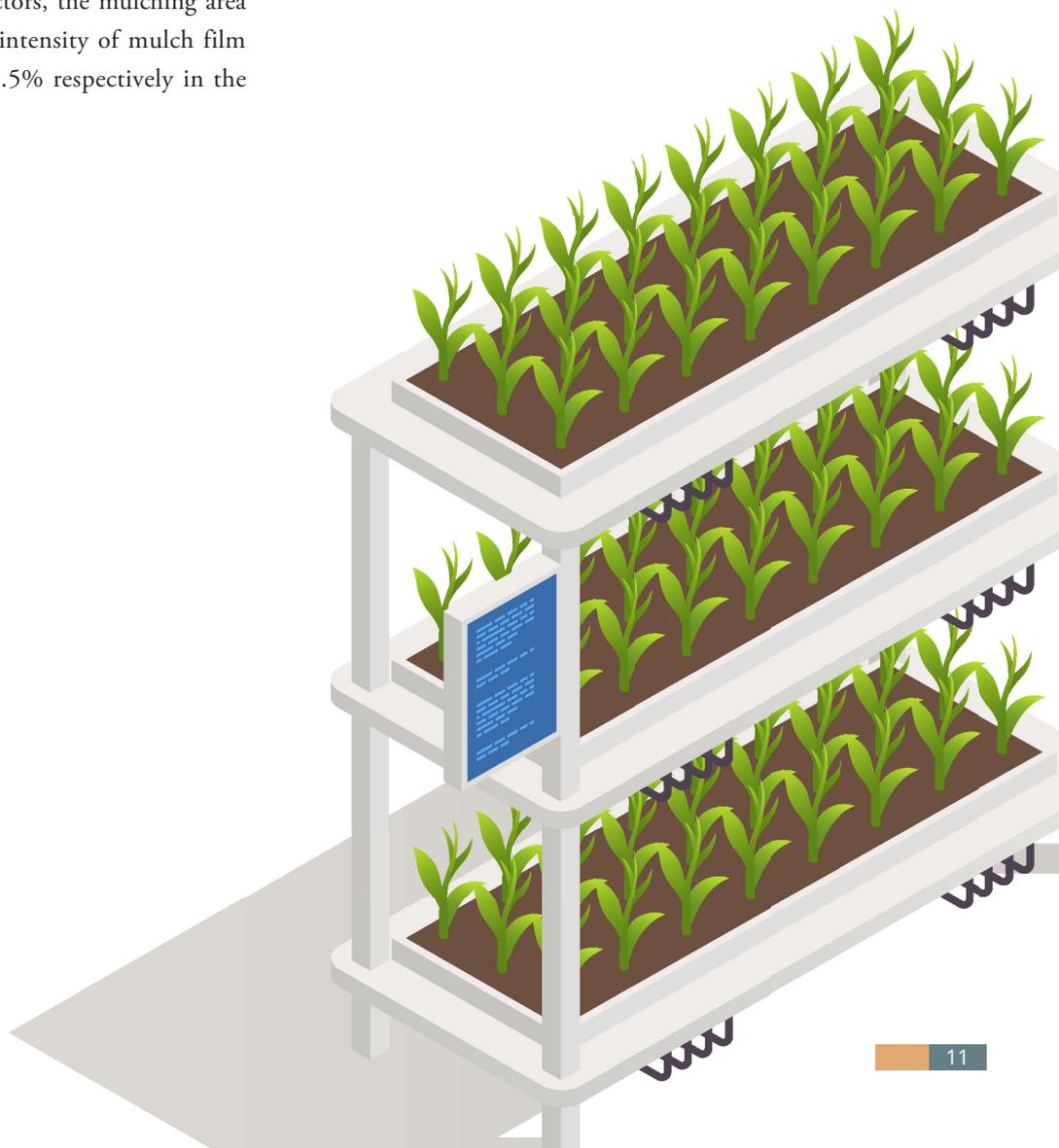
## The Application Intensity of Mulch Film

According to the 2010-2020 “China Statistical Yearbook”, “China Rural Statistical Yearbook”, and “China Statistical Yearbook on Environment”, both area and amount of mulch usage showed a consistent trend of increasing at first and gradually decreasing. Compared with 2010, the use intensity of mulch film in China increased in 2019. The situation in sub-regions varies from each other, among which 8 provinces (municipalities) including Shandong, Henan, Hubei, Heilongjiang, Beijing, Shanghai, Tianjin and Qinghai lower the intensity, while other provinces (cities and autonomous regions) show opposite signal.

Taking Beijing, Tianjin, and Shanghai as examples. Originally, these cities are dominated by industrial crops. In recent years, along with the municipal development, the area for agricultural production has gradually reduced, e.g. in Beijing from 21,200 hm<sup>2</sup> to 9,200 hm<sup>2</sup> from 2010 to 2019. Affected by the adjusted production structure, planting models production technology and other factors, the mulching area decreased significantly, and the use intensity of mulch film decreased by 57.6%, 46.3% and 53.5% respectively in the past ten years.

Decrease: Due to the adjustment of planting area and other factors, the planting area of cotton in Hubei Province decreased from 480,100 hm<sup>2</sup> in 2010 to 162,800 hm<sup>2</sup> in 2019, causing the decrease of mulch usage from 3.62 million tons to 2.17 million tons. The use intensity of mulch film decreased from 6.82 kg/hm<sup>2</sup> to 4.14 kg/hm<sup>2</sup> with a reduction of 39.2%.

Increase: Affected by factors such as the expanded production areas, the continuous improvement of mechanization and scale size, the mulching area in Gansu for maize has increased, likewise, the mulch use intensity has increased significantly from 13.70 kg/hm<sup>2</sup> in 2010 to 20.76 kg/hm<sup>2</sup> in 2019, by 51.5%.



## Materials and Standard Requirements for Mulch Film

### Mulch Film: Materials and Types

According to different application requirements, PE film is composed of 40% LDPE (low density polyethylene), 30% of LLDPE (linear low-density polyethylene), 15% of HDPE (high density polyethylene) and 15% of other additives. PE film has the advantages of being light and soft, easy to shape, good light transmission and non-toxic, but with poor weather resistance and insulation. Taking function as criteria, mulch film can be divided into ordinary transparent, colored, light conversion, weeding, heat preservation, biodegradable, aging resistance, immersion (including pore film, microporous film), etc.

On May 1, 2018, the standard “Polyethylene blown mulch film for agricultural uses” was officially implemented, which stipulates that the film thickness must above 0.010 mm, the deviation cannot be higher than 0.002 mm. In addition to that, other three kinds of thickness from 0.015 mm – 0.02 mm, 0.02 mm – 0.025 mm, 0.025 mm – 0.03 mm have been recommended compared with the last standard published in 1992. As mechanical recycling of mulch film residue will be the future direction, not only the thickness but also the strength should also be considered as a key factor. The use of high-strength mulch film can effectively improve its recyclability. However, in agricultural production, neither

ultra-thin nor ultra-thick plastic film is suitable. Most scholars suggested a thickness of 0.008 to 0.012 mm. However, more attention need to be paid and think the end-of-use treatment in advance. Specifically, the economic and ecological benefits of plastic film mulching should be taken into consideration. At present, in no-tillage farming and dry farming modes, mulching is mainly used for two seasons, or even film for three years, and full film mulching, etc. For such modes, the mulch must with extreme high quality and avoid the fake saving.

In recent years, with the rapid development of high crop yield, efficient and high-quality agriculture in China, various coloured agricultural films have been widely used in agricultural production. Advantages of coloured agricultural films vary from growth promotion, early maturity, yield increase, water retention, brightness enhancement, weed control, disease and insect resistance. However, different kinds of coloured film act diversely in light absorption, refraction and reflection, with that, its distinctive impact on crops leading to disparate economic benefits. For different crops, production and income increasing can only be achieved if the farmer selected the appropriate coloured film. Ten typical film colours and suitable crops are shown in Table 5.

Table 5 Characteristics of typical colored film and suitable crops

Number	Types	Characteristics and suitable crops
1	Red mulch film	Promote early maturity and increase production, and mainly suitable for rice, beet, leek, cucumber, tomato and other crops.
2	Blue mulch film	Commonly used for rice, cotton, potato, eggplant, sweet pepper, strawberry, etc. High light transmittance, high seedling rate and strong seedlings.
3	Dark mulch film	Effectively prevent water evaporation in soil and inhibit weed growth. Suitable for summer radish, cabbage, spinach, autumn cucumber, etc.
4	Purple mulch film	Used for eggplant fruits and green leafy vegetables in greenhouse or plastic greenhouse in winter and spring, which can improve quality and promote early ripening.
5	Green mulch film	Increase green light and inhibit weed growth. Widely used in eggplant, strawberry and melon crops.
6	Yellow mulch film	Fit for tea, celery, lettuce, dwarf beans, cucumber and other crops. It is conducive to vigorous growth, early maturity and yield increase.

Number	Types	Characteristics and suitable crops
7	Silver grey mulch film	The reflectivity of light can reach 40%, which can reflect ultraviolet rays, drive away aphids and whitefly, reduce diseases and pests, conserve water and soil and weed. Recommended for cucumber, watermelon, tomato, celery, spinach, cotton, flue-cured tobacco and other crops.
8	Black and white double-sided mulch film	White side for upward and black side downward. Mainly used for disease prevention and heat resistance cultivation of vegetables, melons and fruits in summer and autumn. Positive functions of cooling, water conservation, light enhancement, grass elimination and so on.
9	Silver and black double-sided mulch film	Silver side upward, and the black side downward. Film with multi-functions, such as driving away aphids through reflection, disease prevention, weeding and water conservation. It is mainly used for disease prevention and heat resistance cultivation of summer and autumn vegetables and melons. According to the production needs of facilities, some manufacturers currently provide reusable prefabricated perforated membranes.
10	Silver reflective mulch film	Advantages includes heat insulation, reflection and ground temperature reduction. The reflection rate is up to 80-100%. Mainly used for orchard coverage and brings positive effect for fruit trees, increase production significantly. In some cases, farmers hung it on the north side of the greenhouse cultivation border, it improves the light conditions in the greenhouse and lead to early maturity and yield increase.

### Mulch Film: Product Standard

The “Polyethylene blown mulch film for agricultural uses (GB13735-2017)” (revised in 2017) acts as the ongoing national standard for mulch film in China. The standard specifies the product classification, technical requirements, test methods, inspection rules and marks, packaging,

transportation, storage, etc. Compared with last version in 1992, the application scope, classification, product grade, thickness and deviation, tensile property, weather resistance and other indicators of plastic film have been revised. Detailed requirements are shown in Table 6.

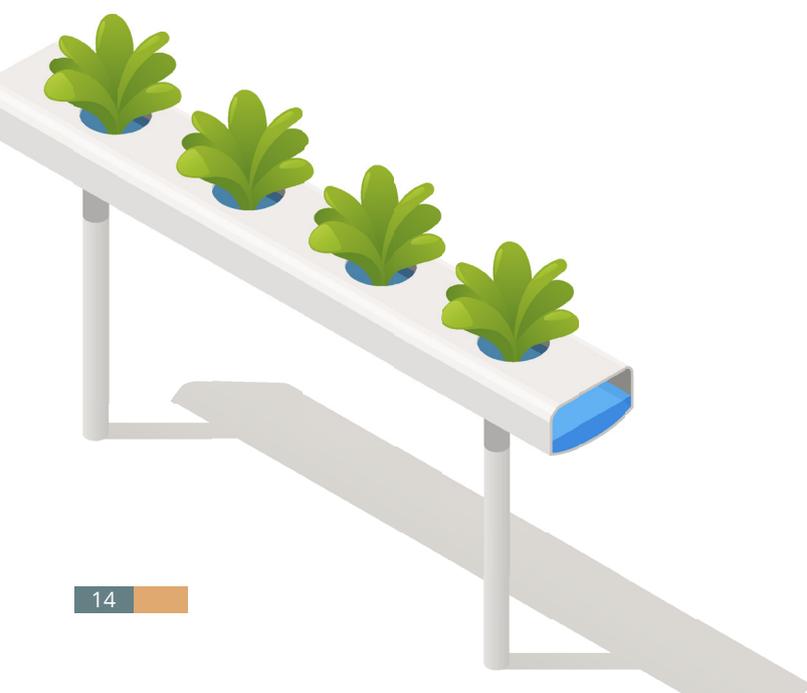
Table 6 Detailed index table of polyethylene blown mulch film standard

Index	The specific content
Classification	I (Aging resistant mulch film): thickness (mm): 0.010、0.012、0.014、0.015、0.016、0.018、0.020、0.025 II (Ordinary mulch film): thickness (mm): 0.010、0.012、0.014、0.015、0.016、0.018、0.020、0.025、0.030
Time	I: ≥180 days. II: ≥60 days
Thickness	thickness≥0.001mm
Limit deviation of thickness	Thickness (mm): 0.010 ≤ d0 < 0.015 Limit deviation (mm): [-0.002, +0.003] Thickness (mm): 0.015 ≤ d0 < 0.020 Limit deviation (mm): [-0.003, +0.004] Thickness (mm): 0.020 ≤ d0 < 0.025 Limit deviation (mm): [-0.004, +0.005] Thickness (mm): 0.025 ≤ d0 ≤ 0.030 Limit deviation (mm): [-0.005, +0.006] Mean thickness deviation: [-12%, 15%]

Index	The specific content
Physical and mechanical properties	Thickness (mm): $0.010 < d_0 < 0.015$ Tensile load (longitudinal and transverse)/N: $\geq 1.6$ Nominal strain at break (longitudinal, transverse) /%: $\geq 260$ Right angle tear load (longitudinal and transverse) /N: $\geq 0.8$  Thickness (mm): $0.015 < d_0 < 0.020$ Tensile load (longitudinal and transverse)/N: $\geq 2.2$ Nominal strain at break (longitudinal, transverse) /%: $\geq 300$ Right angle tear load (longitudinal and transverse) /N: $\geq 1.2$  Thickness (mm): $0.020 < d_0 < 0.030$ Tensile load (longitudinal and transverse)/N: $\geq 3.0$ Nominal strain at break (longitudinal, transverse) /%: $\geq 320$ Right angle tear load (longitudinal and transverse) /N: $\geq 1.5$
Weatherability	The nominal strain retention rate of longitudinal fracture after aging of type I mulch film shall not be less than 50%.

In addition, some provinces have also formulated corresponding local standards. For example, Gansu Province issued the local standard “Polyethylene blown mulch film for agricultural uses in Gansu Province (DB62/T2443-2019)”, which was promulgated in 2014 and revised in 2019. This is the first local standard for mulch film in China, and raised up stricter indicators compared with national one, such as the coverage time, physical and mechanical properties. Qinghai and Xinjiang have also issued local standards, namely, “Polyethylene blown mulch film for agricultural uses in Qinghai Province (DB63/T1468-2016)” and “Polyethylene blown mulch film

for agricultural uses in Xinjiang Uygur Autonomous Region (DB653189-2014)”. Among them, the local standard from Gansu has a complete and diverse classification of products, and higher requirement on covering time and nominal fracture strain comparing with other two local standards. However, its index of thickness limit deviation and average thickness deviation is slightly lower than Qinghai standard, while its requirement on tensile load and right-angle tearing load of some thickness specifications also slightly lower than the other two.





## Mulch Residue Pollution

## Mulch Residue: Status Quo

After the use for months, mulch film covered on crops without proper and effective recycling counts as residue pollution. Its leftover on the soil cannot be degraded and will gradually accumulate, destroy the soil as well as harm plants/animals as consequences. At present, the recycling rate of mulch film is below 2/3 in China, especially ultra-thin mulch film, which is brittle and difficult to be collected after use. Moreover, there are various impurities such as straw and soil contained in the film, making its following processing extreme expensive. Hence, plenty of waste mulch film cannot be collected nor recycled in time and result in residue pollution.

Residual mulch film not only destroys the soil structure and affects the growth of crops, but also has the potential of generating microplastics in the upcoming years. According to the recent survey results, mulched farmland has been exposed with different levels of residue pollution. In the farmland soil in China, up to 40% of the tested sites had plastic residue contamination up to 30 kg/ha, and 30.1% of the sites with above 90 kg/ha. The northwestern inland, the northern agricultural-pastoral transition zone, and the Yunnan-Guizhou Plateau are facing extreme tough challenges in this regard, as the level-three and level-four pollution sites mainly distributed in these areas. Southeast region is apparently with better situation with residue amount of up to 30 kg/ha. Figure 3 shows the mulch residue pollution in soil.<sup>3</sup>

Figure 3 Residual mulch film contamination



<sup>3</sup> Source: <https://caas.cn/xwzx/zjgd/300299.html>

Due to the unscientific use of mulch film and the lack of effective recycling process, in particular, as the mulch film is severely broken during the harvesting season with extreme poor strength, lead to the relative low collection rate. The spatial distribution of film residue in soil layer has been affected by various factors such as mulching duration, cultivation pattern and film thickness. Several typical characteristics can be found as follow:

### Accumulative

Mulch residue remains in soil for 200-400 years and accumulate continuously. According to the research on the features of residual film in mulched cotton field, the inefficient collection contributes to steady adding up of residue amount. The longer the field has been mulched, the more plastic will contaminate the soil.

### Distribution in different soil layers

According to the research, the residual film in soil concentrated mainly at the depth of 0-30 cm, featured by a layered spatial distribution. There were 3-layer distributions according to the tillage structure, namely the surface, 0-12 cm under surface, and 12-30 cm under surface. Among them, limited mulch residue left on the surface or in the deep soil, accounting for about 6%-8.33% of the total amount of film residue in tillage layer. 53.99%-68% of the plastic will stay in soil depth of 0-12 cm, and about 26%-37.68% exist in soil depth of 12-30 cm<sup>4</sup>. Mulching year won't make a difference on the distribution characteristics. The cultivation pattern, such as deep ploughing or rotary tillage, will increase the polymer accumulation in plough layer of farmland soil in the wake of non-stopping mulching. Moreover, a dynamic analysis on the distribution of plastic debris in soil indicates that the longer mulch has been used, the deeper the residual film will move to.

### Migration of micro-plastic degraded from mulch film

Mulch residue may break to micro-plastic and absorbed by organisms. Consequently, microplastic might enter the food chain, accumulate and transfer to different crops. Plastic pieces can be transferred over long distances by wind or waterways, through inland water bodies and finally end up in the ocean. In addition to that, microplastics, in small particles and large specific surface area, with strong hydrophobicity and microbial affinity, obtains higher ability to become pollutant carriers for persistent organic pollutants and heavy metals. Once attached to the microplastic, contaminants could migrate for a long distance under the action of ocean currents and get spread globally.



4 Current Status of Residual Film Pollution in Xinjiang Farmland and Prevention and Control Strategies [J], Transactions of the Chinese Society of Agricultural Engineering, 2019

## Mulch Residue: The Major Hazards

Mulch film residue (also known as farmland “white pollution”) exert an enormous influence on sowing and fertilization operations as well as the crop growth. Moreover, it would damage soil structure, reduce the quality of cultivated land, affect livestock production, and impact rural landscape. With the continuous increase of mulching area and dosage, residue pollution will exist permanently and becomes one of the hidden risks hindering the sustainable agricultural development. Major hazards of as follows:

### Affecting physical properties as well as air and water permeability of soil, reducing soil fertility

The mulch rest in soil would lead to changes in bulk density and porosity of soil. Along with the growing residual amount, soil bulk density increases while its porosity decreases gradually. Mulch film debris would block the normal movement of water and air, resulting in reduced soil moisture content. Furthermore, it would reduce air and water permeability of soil, unbalance the nutrient distribution, slow down the activity of soil microorganisms and destroy the normal soil structure. These results would inhibit the mineralization release of soil nutrients, retard and lower the soil fertility ultimately.

### Affecting agricultural operations and reducing cultivation quality

The large number of film residue in the tillage layer wrapped around the farm machinery, blocking the sowing hole of seeding machines during a variety of agricultural activities such as soil preparation, arable land and sowing. As consequences, the sowing and event seedlings will be influenced.

### Causing contamination of plants and crops

The white pollution also affects the sprouting, growing of plants and crops, and causes even inner accumulation of pollutants in plants. The toxic and harmful substances decomposed from film and remain in soil could have chance to enter into crops along with water and nutrients, and thus affect the growing as well the quality of the agricultural products.

### Causing plastic and microplastic contamination

After use, mulch film would break into large plastic pieces and microplastic alongside weathering and fragmentation, enter into the atmosphere and water as final destination. Studies have shown that soil is the main storage place of microplastic on land and the key contamination carrier for groundwater.

### Other negative effects

On agricultural production and agricultural environment. The rest plastic scattered in lakes, ponds, rivers and streams would float in the forest treetops, cables, causing “visual pollution” on the field, canals and forests, thereby contaminate the rural environment. Burning residual film would generate harmful gas emissions and pollute the atmosphere. If cattle, sheep or other livestock accidentally eat crop straw and grass mixed with residual film, their gastrointestinal dysfunction might be induced, resulting in severe anorexia and even death. The secondary soil contamination could occur as well, such as phthalate contamination and increased pesticide and heavy metal leaving in field.



Collection and  
Recycling of End-of-  
Life Mulch Film

## Collection and Recycling of End-of-Life Mulches: Status Quo

In recent years, due to the increased amount and period of using mulches, “white pollution” on farmland as a result has become a prominent problem hindering the green development of agriculture. The national government and society have attached great attention on this problem. Results of the second national survey on pollution sources have illustrated that over the past 30 years, the mulched area in China has exceeded 20 million hm<sup>2</sup>. Nearly 1.2 million tons of mulch film remained in the soil, accounting for 25% to 33% of the total usage, while the collection rate of mulch film was less than 70%. As the end-of-life mulch film has high impurity rate after use and the impurities are difficult to be cleaned or removed, the recycling rate thus is less than 50%.<sup>5</sup> Due to long-term extensive usage and oversimplified recycling, film residue pollution has become a serious challenge in some areas of China. The recycling and pollution control of waste mulch cannot be handled only if people treat it systematically and consider/balance a set of influencing factors. With no double, accelerating the collection and promoting its recycling has been seen as necessary measures to prevent and control mulch film pollution and transit to agricultural green development.

In this regard, the Ministry of Agricultural and Rural Affairs (MARA) in collaboration with other ministries developed relevant policies and measures on mulch film collection and recycling, e.g. implement pilot projects, explore technologies and practice on recycling, as well as constantly construct the systematic approaches. Since 2012, a total of RMB 2.4 billion has been invested by the national central finance department to implement projects including demonstration of cleaner agricultural production, demonstration counties for mulch film collection and recycling, as well as promotion of dryland farming technology. In order to tackling mulch residue issue, nearly 300 demonstration counties for cleaner production, 100 demonstration counties for pollution treatment, and above 700 sites for residue monitoring have been built. In addition to that, the national government supported in the construction of more than 400 recycling and processing enterprises and more

than 3,000 collection points.<sup>6</sup> At present, the collection rate of end-of-life mulch film in demonstration counties and pilot areas has reached about 80%.<sup>7</sup>

Agricultural departments throughout the country also actively promote the issue. In 2011, Gansu Province took the lead in China to set up the special fund, aiming at to support the recycling enterprises and collection stations in major mulching areas within the province. Up to now, above 200 recycling enterprises and more than 2,000 collection locations have been built, which basically established a network system for collection, transportation and, with above 81% of collection rate as result. Inner Mongolia Autonomous Region supported and cultivated a total of 21 recycling enterprises and cooperatives, set up 225 collection points in counties, achieving the collection rate of 72% in 2019, and 15 demonstration counties of 80%. In Hebei province, 24 counties (cities, districts) have been selected as cleaner agricultural production pilots, as consequences, 24 recycling enterprises and a number of collection locations have been built up, key areas realized the collection rate of above 80%. Shaanxi province set up 288 film collection points in five pilot counties, build up 326 transport stations and “exchange banks”, recycled 10,209.18 tons of mulch film and reflective film. Zhejiang province has immensely contributed against the white pollution issue by clearing the responsibilities, constructing the collection and recycling system, trialing the innovative models, monitoring and evaluation as well carrying out pilots, which in the end reached 80% collection rate. Ningxia Hui Autonomous Region actively seek to establish one-stop service of film mulching and collection, reward for film collection, start the mechanism for “exchanging wasted film for new” and other approaches. A total of 220 collection points were built and 28 recycling enterprises were supported. As conclusion, all provinces and autonomous regions in China have continuously carried out relevant activities, and would like to actively and effectively promote the collection and recycling of mulch residue.

5 Source: <https://caas.cn/xwzx/zjgd/300299.html>

6 Source: <https://caas.cn/xwzx/zjgd/300299.html>

7 Source: <http://country.people.com.cn/n1/2020/1110/c419842-31925424.html>

## Collection and Recycling of End-of-Life Mulch Film: Policies and Regulations

In recent years, in order to strengthen pollution prevention and control, Chinese government has formulated, promulgated and implemented a series of laws and regulations, policy documents, local regulations, and standards, in order to promote the collection and recycling of end-of-life mulch film.

### National Laws, Regulations and Policy Measures

#### (1) Laws and Regulations

Topics including the application, pollution prevention and control, collection and recycling, as well as scientific disposal. Key regulations as follows:

Article 58 of “Agriculture Law of the People’s Republic of China” stipulates that farmers and organizations for agricultural production and operation should maintain cultivated land, rationally use chemical fertilizers, pesticides and agricultural films, increase the usage of organic fertilizers, adopt advanced technology to protect and improve the fertility of the land and prevent the contamination, destruction and deterioration of the land.

Article 49 of “Environmental Protection Law of the People’s Republic of China” stipulates that the people’s governments at various levels and agricultural departments and institutions should guide agricultural production operators in scientifically planting and breeding, scientific and reasonable application of agricultural inputs such as pesticides and fertilizers, and scientific disposal of agricultural waste such as agricultural films, crop straw and other agricultural waste, to prevent agricultural non-point source contamination.

Article 19 of the “Agricultural Product Quality and Safety Law of the People’s Republic of China” stipulates that agricultural producers ought to reasonably use chemical products such as chemical fertilizer, pesticide, veterinary medicine and agri-film to prevent environmental pollution.

Article 22 of the “Cleaner Production Promotion Law of the People’s Republic of China” stipulates that agricultural producers should use chemical fertilizers, pesticides, agricultural film and feed additives in a scientific way. This is aimed to improve planting and breeding techniques, achieve high-quality and harmless agricultural products and

recycle agricultural wastes, in order to prevent agricultural environmental contamination.

Article 34 of the “Circular Economy Promotion Law of the People’s Republic of China” stipulates that the State encourages and supports agricultural producers and enterprises to adopt advanced and applicable technologies to comprehensively utilize crop straws, livestock and poultry excrement, by-products of agricultural processing industry, end-of-life agricultural film, etc.

Article 65 of Chapter 5 of the “Law of the People’s Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste” stipulates that entities, including producers or other operators, who generate solid waste such as crop straw, end-of-life film, pesticide packaging, should take measures to recycle and prevent environmental pollution. Similarly, the State encourages related research, development, production, sale and application of biodegradable agricultural films.

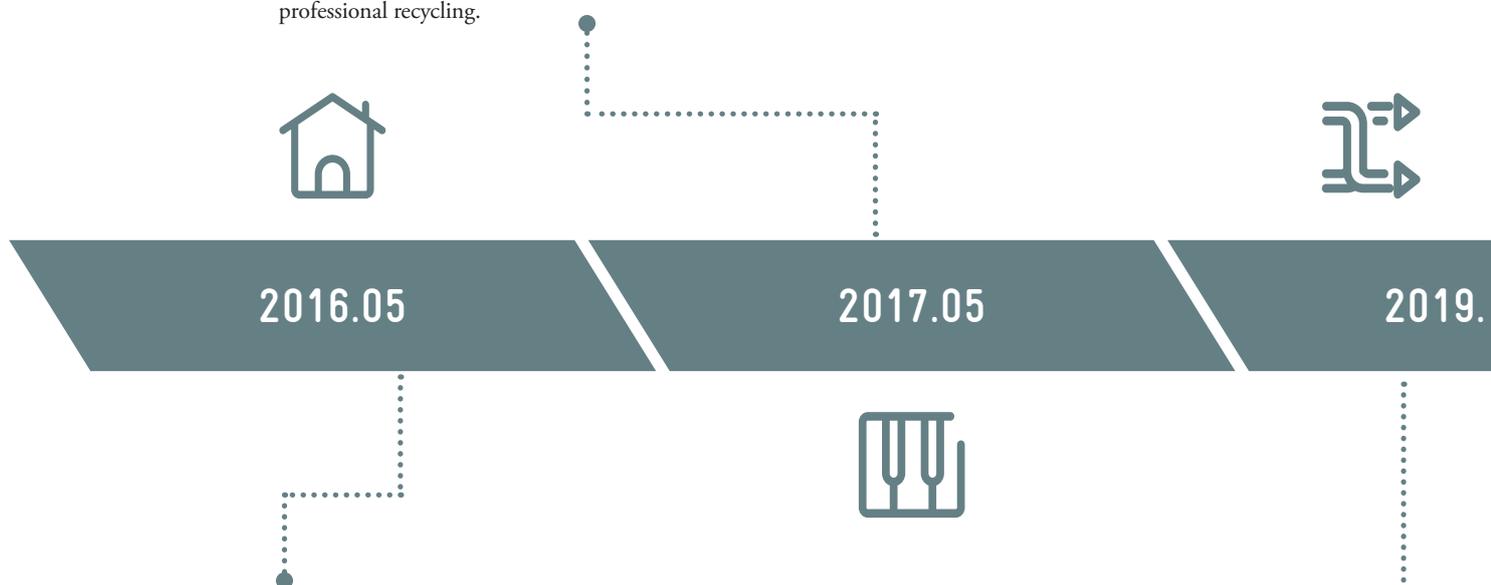
On January 1, 2019, the “Soil Pollution Prevention and Control Law of the People’s Republic of China” came into force. It requires tighter control on the end-of-life agricultural film, all stakeholders should be aware of and take over their own legal responsibility to facilitate the film recycling. Against the uncollected end-of-life agri-film, for the first time, penalty can be imposed.

## (2) Policy Measures

Mulch film pollution control gains great attention in the recent years, thus the related authorities have issued a series of policy documents to improve the mulch film management.

the former Ministry of Agriculture issued the “Action Plan of Agricultural Film Collection”

Along with the plan, 100 demonstration counties in Gansu, Xinjiang and Inner Mongolia Autonomous Region (Province) have been built up. Within 2 to 3 years, the demonstration counties should pilot thick mulch film, establish fundamental recycling capacity and achieving a collection rate of above 80% , acting as the leading areas realizing the resource utilization of plastic film. By 2020, the national network for mulch film recycling should be constructed with optimized resource utilization potential, while the collection and recycling rate of mulch film would reach 80% or above. Northwest China with cotton, corn, potato as key crops, has been seen as a key region for this action, mainly through approaches including application of thick film, mechanical collection and professional recycling.



The State Council issued the “Action Plan for The Prevention and Control of Soil Contamination”

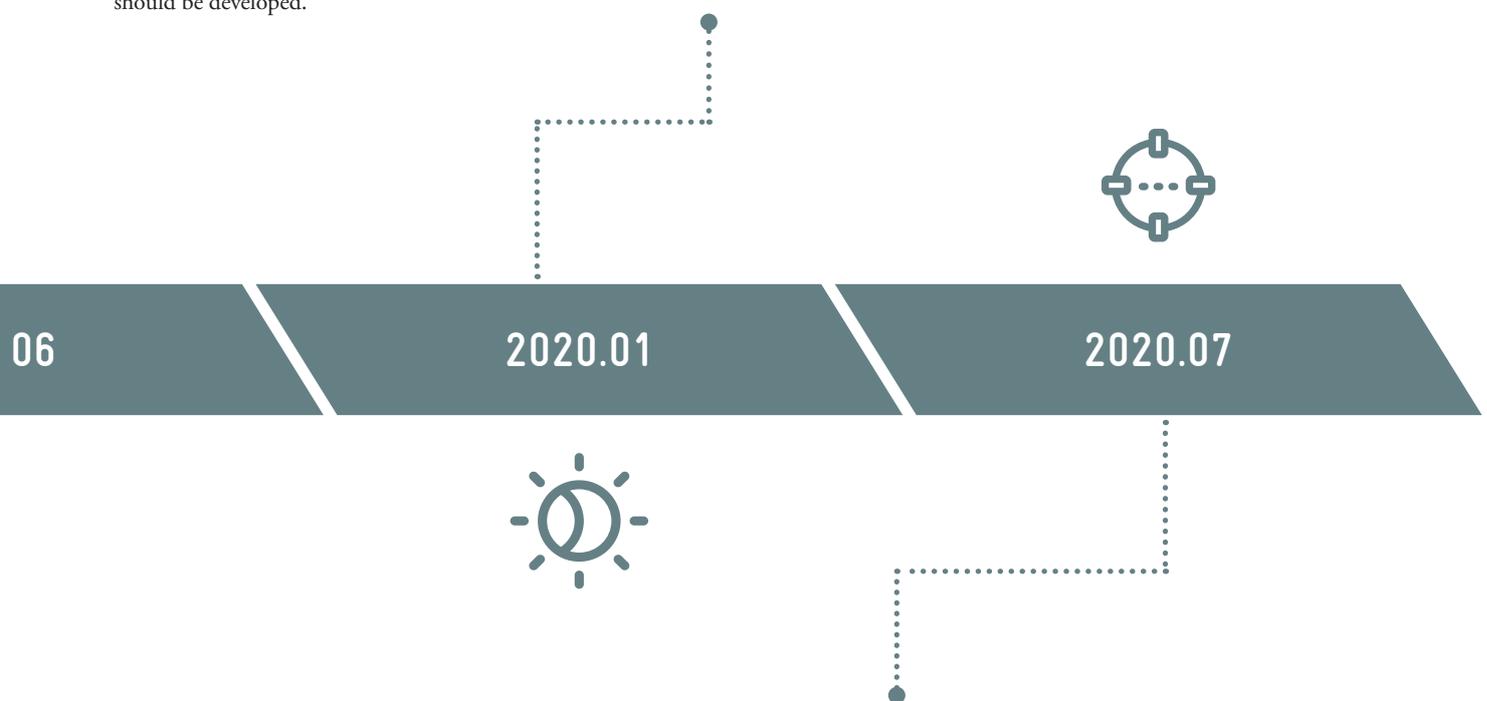
requiring the issuance of corresponding regulations to facilitate the collection and recycling of mulch film as soon as possible. The Action also required the standard revision of mulch product, raising the minimum film thickness, researching and developing standards of biodegradable mulch film. Following objectives have been stipulated: to strengthen the collection and recycling of agricultural waste, to crack down on illegal production and sales of unqualified films, to establish and improve the network for collection / transport / recycling waste film. Provinces consumed huge amount of mulch film, such as Hebei, Liaoning, Shandong, Henan, Gansu and Xinjiang, should strive to achieve full collection of waste films by 2020.

The Ministry of Agriculture and Rural Affairs in collaboration with the National Development and Reform Commission and other four departments issued the “Opinions on Accelerating Agricultural Mulch Contamination Prevention”

The Opinions put forward the establishment of a smooth working mechanism with clear responsibility, basically building up the recycling system and reach 80% collection rate, and realize zero growth in mulching area by 2020. By 2025, agricultural film would be completely collected, the residue amount of mulch film in China should achieve negative growth, and “white pollution” in farmland would be effectively prevented and controlled. The overall requirements, institutional measures, key tasks and policy guarantee were clarified in this document.

The National Development and Reform Commission, along with the Ministry of Ecology and Environment issued "Opinions on Further Strengthening plastic Contamination Control"

It has a number of clear requirements for farmland mulching, such as banning the production and sale of polyethylene mulching with a thickness of less than 0.01 mm. In key areas covered with mulch film, biodegradable mulch should be promoted on a large scale combined with agronomic measures. In addition, collection and recycling network for end-of-life film should be established and improved. The cleaning and remediation of film residue in farmland should be optimized to reduce the residue accumulation in farmland gradually. Pilot demonstration should be further carried out. In regard to biodegradable mulch film, more focus should be given on the safety, controllability of degradation and the economic aspect while using it for large-scale, corresponding technical verification and product selection should be developed.



The Ministry of Agriculture and Rural Affairs, the Ministry of Industry and Information Technology and other two departments jointly issued "Measures for the Mulch Film Management"

To prevent and control film residue, strengthen the supervision and management, protect and improve the agricultural ecological environment. The production, sales, use, collection and recycling of mulch film and its supervision have been prescribed. The Measures point out that local governments at all levels should be responsible for the prevention and control of the mulch pollution in their respective administrative areas. In accordance with the law, local governments should organize, coordinate and urge relevant departments to perform their duties of supervision and management. The competent agricultural and rural departments of the governments at or above the county level should be responsible for the supervision and administration of the use and collection of mulch film, as well as guide the construction of the collection/recycling system. It is forbidden to produce, sell or use mulch films that are explicitly prohibited by the State or do not conform to compulsory national standards. The production and use of fully biodegradable mulch film is encouraged and supported. In terms of collection and recycling of mulch film, government should provide support and mobilize multi-party participation, enterprise as well as individuals are encouraged to take actions. Users are prohibited to discard, bury or burn non-biodegradable mulch film residue in the field. Instead of that, they are obliged to collect and hand the end-of-life film to corresponding recyclers after use. Mulch film producers, sellers, users, collectors, and recyclers, as well as other stakeholder if possible, should cooperate and adopt various measures to establish and optimize the mulch management system, and promote its collection, recycling and treatment.

### (3) Standards

Up to now, China has formulated a total of 18 standards related to mulch film collection/recycling, including 4 national standards, 3 industrial standards (1 of which has been abolished), and 11 local standards (1 of which has been abolished). These standards and specifications vary from standards for mulch product, collection machine, quality and procedure of collection, recycling quality, investigation on film residue and its limit, as well as processing procedure etc., which basically formed a complete set of standard system for the mulch film industrial chain.

“Polyethylene blown mulch film for agricultural uses (GB 13735-2017)” is a mandatory national standard and has been implemented since May 1, 2018, replacing GB 13735-1992. Targeting at environment protection and resource saving, this new standard revised the application scope, classification, product grade, thickness and deviation, tensile properties, weather resistance and other indicators of mulch film. A set of requirements on film product have been improved, especially the minimum film thickness, should be above 0.010 mm, which is beneficial to machine sowing and end-of-life collection.

The national standard “Mulch Film Residue Collecting Machine (GB/T 25412-2010)” stipulates the product requirements, test methods, test rules. It also put forward several performance indicators and testing methods including “cleaning rate on surface”, “cleaning rate underground”, “seedling injury rate”, “film tangling rate”, etc.

The national standard “Limit and test method for mulch residue (GB/T 25413-2010)” stipulates the limit value of residue amount in farmland soil and the determination method, which is suitable for testing the soil to be sown.

The national standard “Biodegradable mulching film for agricultural uses (GB/T35795-2017)” specifies several important technical requirements on the product performance, including appearance, mechanical properties, water vapor transmission, heavy metal content, biodegradation performance, artificial weathering performance.

In addition, in terms of mulch film collection and recycling process, various provinces and cities have also formulated corresponding local standards, including two investigation specifications, two operation specifications, two on recycling quality, and five on collection or recycling techniques. Formulation of these standards has enriched the system and provided corresponding support for the formulation of national standards.

## Local Ordinances and Regulations

In recent years, domestically, especially the areas with national demonstration counties, have formulated and issued policies and regulations on provincial level based on the local conditions.

Gansu Province has attached great importance to the mulch film issue. The “Notice on Strengthening the Collection and Recycling of Used Mulch film and Promoting the Control of Agricultural Non-point Source Pollution”, “Notice on Centralized Treatment of Used Mulch Film”, and “Action Plan of Collection and Recycling of End-of-Life Mulch Film and Tail Vegetables in Gansu Province” have been issued one after another. In 2021, the “Regulations of Gansu Province on Collection and Recycling of End-of-Life Mulch Film” was revised. The regulations stipulated that government at or above the county level are responsible for the film pollution control in their respective administrative areas, which has been set as the target and with clear responsible person. Funds required will be allocated from the provincial budget plan.

In 2019, Zhejiang Province formulated and issued “the Opinions on Accelerating the Recycling and Treatment of Used Agricultural film”. The opinions clarified, that users are responsible for collecting and recycling waste film. Taking the advantages of the marketing network of agricultural materials, collection stations have been set up at reasonable locations. Waste film lack of value to recycling should be incinerated together with other rural waste.

In 2019, Chongqing Municipality developed “Management Measures for Collection and Recycling End-of-Life Mulch Film of Chongqing Municipality (Trial)”. The measures proposed construction of a network system on district and county level and strengthen the data collection on mulch film application and its residue contamination. Providing guidance to the farmers and cooperatives on scientific application and collection. Disposing, burying or burning waste film are totally forbidden. Supervision and performance evaluation on the progress should be organized.

In 2021, Ulanqab City of Inner Mongolia issued the municipal regulations on the prevention and control of mulch film pollution, namely “Regulations on Pollution Prevention and Control of Mulch Film in Ulanqab City”. The regulations stipulated the scope of application, funding guarantee, roles and responsibilities, prevention and control measures, recycling mechanism, legal liability and other aspects, which could solve the mulch film contamination from the root.

## Collection and Recycling Patterns

According to the regional characteristics and the urgency of the challenge, all localities actively carry out activities. After years of exploration, the following typical patterns have been formed.

### Pattern 1: Recycling Enterprises + Collection Stations + Farmers + Subsidies

Relying on recycling enterprises, fixed and mobile collection stations will be established according to local conditions. Fixed collection stations can provide service to wider area. Counties will design and conduct overall plan and choose convenient collection stations on village level, which should be equipped with certain storage space and personnel, who can either be the farmers, professional cooperatives, specialized recycling organizations, sellers of agricultural materials, etc. Farmers would sell wasted mulch films to these stations, which are responsible for checking the impurities, store safely and transfer timely to recycling enterprises. Counties that adopt the mobile collection stations need to set up corresponding transportation facilities, which directly collect end-of-life films in the fields and then transport to the processing enterprises with high efficiency.



#### Case 1:

Ningxiang city of Hunan province promoted the recycling of tobacco mulch film to produce tobacco seedling tray. The farmers would collect the waste mulch film and send it to the nearest collection point designated by the cooperative according to the specified time. Each mu (15 mu equal to 1 ha) of tobacco field needs about 5.5 kg of mulch film on average, the tobacco farmers could get CNY 13.2 as a subsidy for collection. There are 240 tobacco farmers in the Golden Leaf Tobacco Cooperative in Hengshi, each farmer owns 31.3 mu on average, and earn a subsidy of CNY 413. The cooperative set up three collection points in Tiechong, Hengshi and Huangcai respectively, and could also get CNY 4 per mu for collecting and loading, as their additional service business besides acting as the professional tobacco cooperative. Ningxiang city adopts the mode of "tobacco subsidy + pick-up by tobacco farmers + collection and transportation by cooperative + enterprise recycling". The city planted 32,000 mu of flue-cured tobacco and sun-cured tobacco, owning above 170 tons of end-of-life mulch film. The municipal tobacco company would directly subsidize above CNY 400,000 to tobacco farmers, and CNY 120,000 to tobacco cooperative. After the consolidated process, the municipal tobacco company would gather and sell waste mulches to the Nanxiang Jinye mulch film company for recycling, such as producing recycled film, reprocessing into tobacco seedling tray or other products and bring significant social benefits.

## Pattern 2: Producer Recycles: Extended Producers' Responsibility (EPR) schem

In order to encourage the mulch producers engaging into recycling works, the local government has taken the recycling task as an important criterion during the bidding procurement for mulch film. Mulch film with high strength, long weather resistance period, easy to be recycled, will be prioritized during the procurement procedure. The producers, as consequences, are forced to improve the quality of film products, considering

its end-of-life management, as well as guide to the “producer recycles” mechanism. After several years of implementation, at present, large mulch film producers have basically carried out businesses in waste mulch film collection and recycling. In addition, some regions have built mulch film recycling enterprises with advanced technology equipment supported by political funds, which played a positive demonstration role.

### Case 2:

Considering local condition, Heshui county in Gansu Province has implemented film producers' responsibility scheme, starting with publishing “Guidelines on implementing the extended producers' responsibility system for mulch film in Heshui county”, “Registration and filing system for film producers and distributors in Heshui county”. The producers participating in the bidding for film purchasing, issued by the local government, must have the corresponding collection and recycling capacity to processing the used plastic film. The government has signed the EPR agreement with producers, requiring the bid-winner to collect and recycle all the used mulching film with the same amount of the government purchased, and promoted the enterprise to take over their social responsibility of protecting the environment. In 2017, the responsible producers in the county sold 650 tons of mulch film in line with the local standards of Gansu Province, and collected 530 tons of waste mulch film, reaching the collection rate of 80% as the goal set by the season.

## Pattern 3: Rewards Instead of Subsidies

Mulch film recycling confronts with a variety of difficulties, as it's time-consuming and with low profit. The government have set the recycling enterprise and farmers as key players for the collection and recycling. Thus, thinking of the measure of

“rewards instead of subsidies”, the government grant certain reward in form of money to recycling companies and farmers based on their collection/recycling performance, in order to arouse their enthusiasm for the task.

### Case 3:

According to mulch film usage and covered area, and following the selection process of enterprise self-declaration, recommendation by counties, plus publishing for checking, the agricultural environmental protection agencies in Gansu Province have assigned the recycling work to selected recycling enterprise, who should sign a letter of responsibility with the government, with the assigned working area, minimum protective price, and total recycling target determined. At the end of the year, based on the quantity of pellets, ledger and the electricity consumption, etc., the recycling enterprise will be paid with RMB 100 for one ton of polyethylene pellets produced. In 2018, Gansu province reward RMB 20 million to 78 recycling using their agricultural ecological and environmental protection funds. Moreover, farmers who are able to work and willing to pick up mulch film are engaged in collecting and selling waste mulch film. The recycling enterprise shall record and retain the transaction account, sales voucher and other data in detail. By end of the year, farmers will be given a one-time subsidy of CNY 20 /m<sup>3</sup> or an collection cart after the verification process. In the meantime, a one-time reward will be given to 30% of the intermediary collect

#### Pattern 4: Old for New + Film for Others

Exchange supermarkets should be set up for waste mulch film to explore the Old for New + Film for Others. However, this model requires detailed exchanging methodology based on actual condition. According to the quantity of handed film, farmers could exchange for new mulch film, chemical fertilizer,

organic fertilizer, and goods for daily-use such as washing powder, soap, and salt. In this model, goods in exchanging market are not limited to mulch film that only for production, which can better arouse the enthusiasm of peasants.

##### Case 4:

In Qin Zhou District, Gansu Province, amounts of small groceries can be found in rural areas. Thus, individual operators are encouraged to open the first Exchange Market in the village supported by the provincial subsidy. In order to ensure the long-term stable operation, the environmental protection agency of Qin Zhou district has signed agreement with the market owner, setting corresponding rules on personnel arrangement, exchange standard, registration book, etc. RMB 10,000 has been allocated for purchasing goods. Based on the quantity of collected end-of-life mulch, the farmers can exchange products in accordance with the exchanging standard. In 2018, two exchanging markets have collected 16 tons of mulch film costing RMB 13,000.

#### Pattern 5: Polluter Takes Actions

Farmers in China only owns the right to cultivate the farmland but without ownership. In order to efficient curb the phenomenon, that farmers only use the farmland without caring about it, in some areas, local authorities have started

the model of “Polluter takes actions”. The farmers renting the farmland, while signing the renting contract, need to pay deposit in advance and guarantee that they will collect the mulch residue after use.

##### Case 5:

Linze county in Gansu province has piloted the polluter pays scheme to promote the collection of used mulch film and crop straw. While the county government signing renting contract with farmers, RMB 1,500 per hectare would be charged in advance as deposit. Inspection will be organized with farmland, road, riverway, trees etc. as key areas. The planting cooperative, who have successfully passed the check will get the deposit returned with additional reward. For whom didn't take their responsibility, the deposit will be reallocated to other mulch agent or collectors as third party and conducting corresponding cleaning activities. In 2018, 15 tons of used mulch film were collected in the end using this scheme.

## ♻️ Recycling Technology used for Agri-Plastics

Agricultural plastic types vary from each other. Including PE mainly used for mulch film, the recycling of all kinds agri-plastics face enormous challenges. The short of relevant recycling technology can be seen as one of the key bottlenecks. At present, the collected end-of-life agri-plastics have been mainly sent to recycling or energy recovery, main approaches as follows.

### Recycling

#### (1) Pelleting

The basic principle of regenerative granulation is to obtain secondary masterbatch via melting, extrusion, and molding for reprocessing through physical change, without changing the physical properties of plastic, producing goods including safety helmet, suitcases, etc. The processing procedure can be divided to wet granulation and dry granulation. Wet granulation mainly includes crushing, cleaning, dehydration, melt granulation etc., which can effectively remove impurities. Dry granulation is generally used to produce low-value plastic products which have lower requirement on product quality as dry granulation doesn't include the process of repeatedly cleaning nor dehydration.

#### (2) Dissolution

Although plastics can remain stable for a long time in the natural environment, it would dissolve in the suitable medium, such as xylene, the mixture of alcohol and water, organic solvents, etc. Using this characteristic, plastic can be made to various architectural coatings by adding a variety of pigments. Polystyrene can be dissolved in organic solvents containing benzene and made into resin adhesive. However, the strict classification of end-of-life plastics counts as the essential step, and a certain amount of impurities would directly affect the performance of the coating and adhesive.

#### (3) Plastic alloying

Collected waste plastics mixed with other plastics or additives during the recycling process, the original physical properties can be strengthened thanks to the improved bond between different polymers. The compatibility of various blends plays an essential role here, so that poor mechanical properties can be optimized.

#### (4) Modification and regeneration

Physical as well as chemical properties of the end-of-life polyethylene can be greatly improved during the recycling process by crosslinking via high energy radiation, silane coupling agent, and ultraviolet methods. After modification, the optimized resistance contributes to extreme low possibility of stress cracking, the temperature grade can be increased to 90°C, short circuit temperature with 130°C -250°C, and the products can be widely used in wire tubes, water heaters, heat shrinkable tubes, etc.

## Energy Recovery

Energy recovery refers to gaining high-value fuel or electricity through thermal decomposition or catalytic decomposition, or realizing energy recovery through incineration via rural waste treatment system, etc.

### (1) Oilification

Plastic is polymer compounds mainly synthesized by petroleum. In theory, some chemical bonds and radicals in polymers can be removed or cut off, and regenerating compounds with similar to physical and chemical properties as oil molecules does. Relevant experiments have proved, that this kind of products can be used as fuel, especially as oil for boilers and realize energy recovery. The conversion rate can reach 75%-80%. At present, the technology has not been widely applied due to the challenges of difficult processing, strict technical requirements, high investment, and limited profit.

### (2) Chemical Recycling

Chemical Recycling refers to the process of dissembling the polymer structure to obtain the original monomer or other valuable chemicals through depolymerization (methanolysis, glycolysis and hydrolysis), partial oxidation (gasification), and pyrolysis processes. Pyrolysis (thermal catalytic) can also be used for recycling polyolefin and other polymer. After the pyrolysis of polymer, liquid and gas products can be developed and used as fuel, or even via reprocessing to get plastic monomer with similar quality of raw material. However, the operational cost is commonly too high, and 30% will remain as solid residue without value, which may even cause serious harm to the environment if improperly treated.

Overall, bottlenecks and challenges can be found in China's agri-plastic recycling and treatment technologies and equipment, which indicates, that further research are eagerly needed. In regard to the end-of-life mulch film, this entails the development of feasible mechanical collection and clean technology with corresponding equipment, recycling technology and equipment with low-cost and high-efficiency, in order to improve its collection and recycling rate and reduce the white pollution especially in farmland, achieving agricultural sustainable development in the end.



## Main Bottlenecks and Difficulties

Although the collection and recycling end-of-life mulch film has received great attention worldwide as a measure of saving resources and protecting the environment. At present, a chain of challenges can be found ahead:

### Low Product Standard Leads to Difficulty in Collection

Compared with international regions, such as Europe, the requirement on mulch film thickness in China is relatively low. Mulch film in China is mainly made from polyethylene (PE). The oversimplified production process and ordinary quality of the mulch film in China works with low tensile capacity, poor mechanical performance, easy to fragile, aging, and break to residue in soil, which are extremely difficult to be removed or collected by manual or mechanical methods. In addition to that, film producers can easily enter the industry and may produce ultra-thin mulch films. These make the collection/recycling much more tougher from the source and the new product standard cannot be put into practice.

### Complexity in Collection

Due to the differences in operation methods, natural conditions and crop types, planting patterns are diverse. Diversified mulching methods and planting modes requires much more efforts on the design and development of film collection machines and tools, and costly, which also increases the difficulty while collection in general. At the same time, farmland in China is normally in large-scale and planted with extreme high-density, which brings extra challenge to the collection, as most of the existing machines are shown with low efficiency and poor stability.

### Incomplete Recycling System and Low Participation of Farmers

In China, the short of mulch film residue collection station in general as well as the unbalanced distribution brings a set of difficulties to the farmers. They are either relatively away from the collection points, or even don't have the access in their village. In addition to that, rural area in China is lack of labor force and farmers don't have enthusiasm to conduct

the collection activity. While picking-up the film, farmers are usually doing manually with a high amount of impurities, which enlarge the operational costs for the recycling companies, as they are obliged to pay extreme high price for sorting and cleaning but with relative low earnings as benefits, which as consequences, also would like to quit from the business.

### Inefficient Supervision Mechanism

In China, mulch film production, sales, use, pollution, collection and its recycling are managed by various departments in China. Its production and sales is managed by the Ministry of Industry and Information Technology and the State Administration for Market Regulation. The Ministry of Agriculture and Rural Affairs is in charge of application, while the pollution is task of the Ministry of Ecology and Environment. However, in terms of mulch film collection and recycling, there is no clear regulatory and leading department, and lack of sufficient policies or standards. Therefore, the shortage on effective supervision must be improved timely to strengthen management measures.

## International Experience

Due to the cheap price and convenience, plastic mulch film is still irreplaceable and counted as the mainstream product on the global market. Japan, the United States (US), and European countries have issued relatively high requirements on product itself as well as following collection and recycling process. The relevant production standards, laws, and policies can be taken as good references for China.

In order to prevent the “white pollution” from the very beginning, the United States, Europe, Japan, and other developed countries have promulgated their own production standards and made clear requirements on indicators such as thickness. In the United States, the mulch film is divided into 10 grades based on thickness, range from 0.025 mm to 0.25 mm, and the deviation rate is  $\pm 20\%$ , which means the thinnest thickness of the mulch film in the US is 0.02 mm. Similarly, thickness has been also taken as the classification index in European standard, according to that, five categories have been set between 0.025 mm to 0.2 mm with an allowable deviation of  $\pm 5\%$ . The Japanese standard stipulates the material, quality, size, thickness, and allowable deviation range ( $\pm 15\%$ ) of five kinds of mulch films with thickness of 0.02 mm as the lowest and 0.1 mm as the highest. Comparing to that, the thickness of standardized mulch film in China is much lower with the range of 0.01-0.03 mm. As most of the producers will choose the lowest requirement, with no doubt that the mulch film used in China is normally only half thick as the one required in developed countries and causes chain challenges in collection.

In developed region/country, such as Europe, America, and Japan, waste mulch film has always been treated as industrial waste, and relevant collection, recycling and treatment system has been established through the governmental guidance, together with the EPR scheme, according to that, producers, manufacturers, distributors, and consumers along the value chain should jointly share the responsibilities for the life end of the mulch film. Moreover, policy, economic and other institutional measures have been put into force to promote the recycling or energy recovery, in order to maximize the resource efficiency and economic value. A specific producer responsibility organization has been built up, including stakeholders from government, producers, recyclers, and representatives from scientific research institutes, such as Agricultural Association in Japan, A.D.I.VALOR in France, Cicloagro in Spain, ERDE and RIGK in Germany, IFFPG in Ireland, Sveg Retur in Switzerland, GRANT PUNKT in Norway, Cleanfarms in Canada, Plastic Recycling Association APR in USA, etc. In addition, unified collection measures and machines, well-coordinated cross-departments procedures as well as strengthened supervision actions have been put into effect.

### USA

The United States counted as the first country in world to enact the legislation on waste mulch film recycling. In 1970, the Resource Recycling Act was promulgated, which made detailed provisions on the key entities responsible for end-of-life mulch film recycling and their respective duties, as well as collection and recycling methods. The plan proposed that the farmers are obliged to collect mulch film and transfer to collection center or treatment plants. Mulch film manufacturers and importers also have the responsibility on collection and treatment. All state governments have approved

and listed the qualified recycling enterprises on their website. At present, 30 states have introduced agricultural plastics regulations and many states have established corresponding management association by charging additional recycling fee while selling the product as a common way. Besides, encouragement and discount policies have been published in many states. Based on that, farmers can pay cheaper price for treatment, while using the fee given by the farmers, the associations can further allocate for other recycling activities.

## Europe

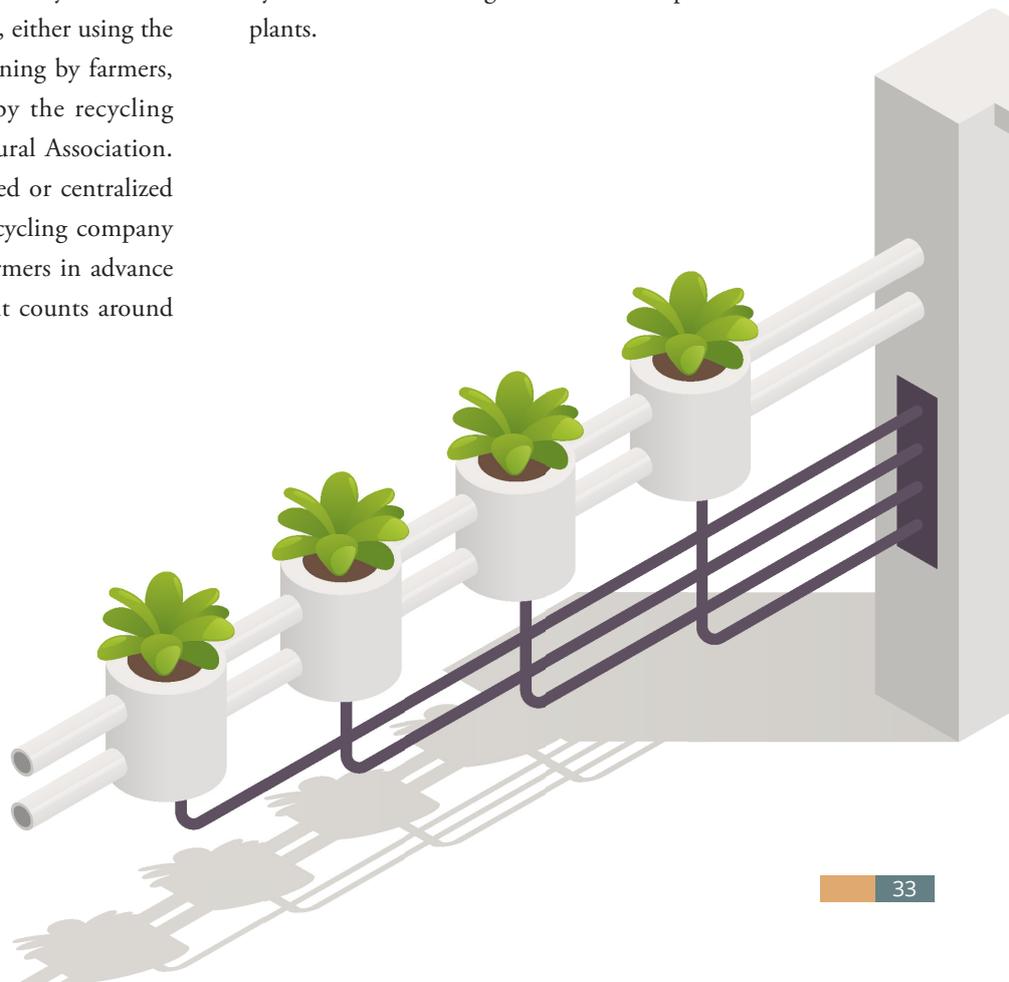
Many European countries, such as France, Germany and Italy, have promulgated relevant agricultural waste disposal laws, such as Waste Framework Directive (2008/98/EC), Landfill Directive (1999/31/EC), and Directive on Packaging and Packaging Waste (94/62/EC). The European Union has established the LabelAgriWaste program, in order to enhance the recycling and/or recovery rate of the collected agri-plastic waste, mainly piloted in Spain, Italy, and Greece etc., countries with agricultural industry as focus. At first, the agricultural plastic waste will be collected, sorted, cleaned and bundled in a specific collection area. According to the standardized rules on

the cleanliness, material and performance, the qualified waste plastics will be labeled with a special mark, and will be able to transported or traded on the European market, maximizing its economic benefits. Using the labelling management, not only the quality but also the destination of the end-of-life agri-plastics will be monitored transparently. Moreover, farmers and SMEs will be trained on the efficient collection and sorting, which facilitate the standardized industrialization of the waste plastic market, empowered to achieving 100% collection rate as well as cleaner environment.

## Japan

In Japan, the recycling of end-of-life mulch film has been merged into the treatment of agricultural plastic in general. Japanese Agricultural Association plays a leading role in applying the cover technology but also its material recycling. Agricultural Cooperatives in Japan organize the collection, recycling and treatment of plastic mulch film after use, in accordance with the relevant provisions of the “Waste Treatment and Cleaning Law”. The collection of the film from the farmland will be carried out by farmers directly thanks to the high-strength and easy-to-collect mulches, either using the small rolling machine or by hand. After cleaning by farmers, the film will be transferred and recycled by the recycling company affiliated to the Japanese Agricultural Association. In Japan, the mulch film will be decentralized or centralized collected in villages and towns. The film recycling company will issue leaflets for 2-3 times to inform farmers in advance every year. The cost for recycling / treatment counts around

YEN 30-35 per kg, and plus other administrative fee with about YEN 40-50 per kg. Most of the cost is borne by farmers, in some areas, village governments, Japanese Agricultural Association, and farmers can independently undertake one-third of the cost. In general, Japanese Agricultural Association tend to take more responsibility than village governments. As the Mainichi Shimbun reported, new policy from Japanese government aims to achieve 100% recycling of new plastics by 2035, and encourages the use of bioplastics derived from plants.





Future Trend and  
Suggestions for Mulch  
Film Application

China is the largest country in production and use of agricultural plastic mulch film. The wide usage of mulch film plays an essential supporting role in increasing crop yields production and protecting the vegetable basket. However, it brought ecological environmental risks such as “white pollution” in soil.

## Future Trends

Since 2015, China has formulated and promulgated a series of policies and measures for promoting the green and sustainable development of the mulch film industry. In order to encourage enterprises to develop mulch film with high-quality and technology innovation, establish and improve collection and recycling system for the used mulch film, as well as promote the application of biodegradable mulch film, etc., the National Development and Reform Commission with other departments promulgated a series of policy documents. These include “Opinions on Further Strengthening the Treatment of Plastic Pollution”, “Agricultural Film Management Measures”, “Resolutely Banning the Two Types of Ultra-Thin Plastic Products” (Ultra-thin plastic shopping bags with a thickness less than 0.025 mm and ultra-thin polyethylene agricultural film with a thickness of less than 0.01 mm) and other policy documents in 2020. In the next step, reduction and treatment at source, new alternative, collection and recycling would become the future of mulch film development in China.

### Reduction and Treatment at Source

As the problem of mulch film pollution getting serious, China would further strengthen the measures, especially in the reduction at source. Measure as following: Providing guiding policy documents to the areas, where the mulch film is not necessary, in order to prevent the overuse. Promoting the crop rotation, e.g. growing grain, cotton, rape, etc. in a row, to reduce the average coverage of unit area and the amount of mulch film. To tighten the governance by strengthening the supervision and management of mulch film product, that enterprises must meet the national mandatory standards, as well as standardize the supply of raw materials and quality inspection process. In addition, using laws and regulations, plus punishment measure to limit the production and sales of ultra-thin mulch film.

### New Alternative

From the development trend of mulch film products, degradable mulch film gains rapid development under the governmental promotion, and gradually replaces the non-degradable film, e.g. biodegradable film, paper film etc. Amount of studies have been carried out in Germany, the United States, Japan, and other developed countries, as well as relevant scientific research from China. Besides, the market has been filled by low-quality film but lack of high-grade products. Professional and customized development of mulch film for specific crop types can be foreseen in the future.

### Collection and Recycling

From the perspective of mulch film collection and recycling, in addition to the ability of degradation, proper technology and machine for collection and recycling are highly relevant. For example, the covering period of the mulch film can be shortened by 20-30 days, while the film still retains reliable quality, its collection can become easier, although large labor and capital investment is required. Research on a series of special equipment for mulch film picking-up will be supported to further lower the operational costs and facilitate the process.

## Recommendations for Further Development

### Improve Laws and Regulations, Clarify Rights

At present, China is lack of the laws and regulations on the collection and recycling of end-of-life mulch film, as well as safety monitoring and evaluation on the recycled products. The legal system should be further improved with a comprehensive legislation for the whole process of mulch film residue management, including its collection, transportation, storage, recycling and treatment, etc. According to comprehensive utilization mode and process of used mulch film. The responsibilities and obligations of different practitioners must be defined and clarified by governmental authorities, including mulch film producers, sellers, users/collectors, recyclers etc. Enhanced supervision of the mulch film market and the strict prohibition of selling and using ultra-thin, low-strength, and easy-aging mulch film can efficiently enable the operability and feasibility of plastic mulch film collection at the source. According to the quality standards towards mulch film thickness, strength, composition, and anti-aging from the adjusted National Standard, relevant technical standards should also put the recycling process and quality into consideration, in addition to that, a set of standards on film storage, transportation, and recycling should be developed, which can contribute efficient and safe management of the end-of-life mulch film.

### Optimize the Management System and Mobilize Stakeholders' Enthusiasm

At present, the missing collection station and recycling enterprises lead to the broken value chain of the end-of-life mulch film in a lot of areas. As consequences, collected film can only get piled up, burned, or buried in soil. More researches/efforts should be made to figure out other innovative solutions, such as other financial tools, set and assess indicators etc., to provide political support in a broader area and involve all stakeholders on the chain. Moreover, infrastructure for collection-transportation-recycling should be built up and enable sustainable and long-term management. The successful models, e.g. specific subsidy for the mulch film recycling, clear guidance and impurity requirements on the collected film, old for new (5 kg end-of-life mulch

for 1 kg new), exchanging markets etc., have raised up the interest of farmers and mobilized their engagement. However, the "Polluter Pays Principle" is hard to be introduced to the farmers in China, as this target group is with extreme low income in the Business-as-Usual status, which means direct additional costs would be infeasible.

### Technology and Equipment Development

Manuel collection has been widely chosen in most areas in China with time consuming and high cost. Although the research and design of collection machine has started, the current equipment has been still marked as low efficient and over simplified, such as the crop straw and plastic film cannot be separated effectively. Extra supports will be given on the equipment and technology development, with special focus on: the purification while collection to lower the impurity; anhydrous cleaning during recycling process; recycling mulch film to building materials, such as road filling and wall; composite material using end-of-life mulch film plus straw fiber; secondary pollution potentials while recycling; energy recovery process and equipment, including melting compression extrusion as fuel, reprocessing as fuel for power plant, as well as the feasibility of pyrolysis. Moreover, enterprises are encouraged to further trial the application of biodegradable mulch film, while research institutes should give more efforts on the monitoring and assurance of the soil safety. In addition to that, industrialization and scale development of the technologies / equipment can be seen as one of the key measures to facilitate the rapid, standardized green development in agriculture and will be boosted for the upcoming transition.



# SINO-EUROPEAN SUSTAINABLE TRANSITION TOWARDS CIRCULAR ECONOMY

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