Evaluation of Plastic Waste based on Logistic Model

Zixuan Pan[1], Xueqi Wang[2], Chenyang Sun[2], Yong Xu[3*]
[1]School of Finance, Anhui University of Finance and Economics, Bengbu, 233000, China
[2]School of Statistics and Applied Mathematics, Anhui University of Finance and Economics, Bengbu, 233000, China
[3]School of Management Science & Engineering, Anhui University of Finance and Economics, Bengbu, 233000, China

Abstract: Since the 20th century, plastic has become an indispensable material, but its non-decomposable plastic properties have also caused terrible damage to the earth. Taking China as an example, the clustering algorithm is first used to classify the amount of plastic used, followed by the establishment of a model for evaluating the amount of waste plastics, introducing constraints to establish a logistic model, and finally combining policy intervention to reclassify and optimize the model. The study concluded that without further environmental damage, the maximum amount of plastic waste will reach 22,107.35 million tons by 2050; after national policy intervention, it will reach 11,960.78 million tons, a reduction of 10,146.57 million tons. Finally, relevant suggestions are put forward to achieve the overall goal of plastic reduction.

Keywords: Plastic waste; Cluster analysis; Index model; Logistic model; SPSS; MATLAB

1. Introduction

1.1. Reasons for the sharp increase in plastic waste

Since the 1950s, due to the impact of economic globalization, the economic environment has become increasingly prosperous. In the process of commercial trade, the diversity of plastics use has also been gradually tapped. The rise of the catering industry, medical service industry, agriculture, and packaging industry has led to the development of plastic manufacturing industry into an exponential growth.

1.2. Call for control of plastic growth to protect the environment

The 21st century advocates energy conservation and emission reduction, saving resources and environmental protection. However, the negative impact of the growth of the plastics industry is worrying. According to scientific research, humans have produced about 8.7 billion tons of plastic products, of which 6.6 billion tons have been discarded, and only 9% of them have been recycled. Process [1], the rest becomes garbage. In addition, more research indicates that 60% to 80% of marine debris is from land activities, and 80% of these debris are plastic [2], and there are up to 4-12 million tons of plastic waste each year Entering the ocean has caused inestimable damage to the marine environment. What is more frightening is that plastic pollution has gradually entered the food chain.

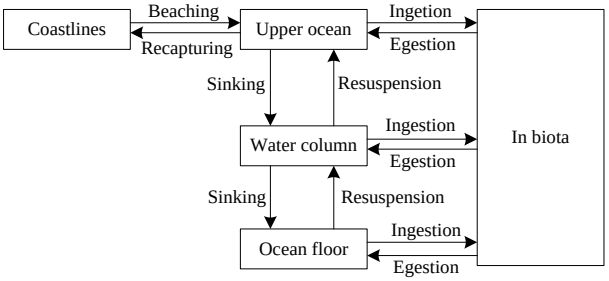

Figure 1. Transmission mechanism of plastic garbage into organisms

It is predicted that if our current trend continues, there will be more plastic in the ocean than fish by 2050, and the useful time of this product will be much shorter than the time required to properly reduce plastic waste [3-4]. Therefore, in order to solve the problem of plastic waste, we need to slow down the speed of plastic production and improve our management of plastic waste.

2. Glossary and Symbols

2.1. Glossary

Disposable Plastic Products: plastic materials or products that are not recyclable and become trash.
Mitigate: To make less severe, to moderate, to alleviate.
Plastic Waste: plastic objects that have not been recycled properly or cannot be recycled; debris made of plastic.
Single-Use Plastic Products: products made of plastic intended for one time use before being discarded.

2.2. Varible

Table 1. Notations

Variable	Definition
t	Symbol symbol description
x	Time (year)
$r_i\left(i=1,2,3,4\right)$	Clearance of plastic
$r_i'\left(i=1,2,3,4\right)$	China Four District Index Model Growth Rate
$r_i''\left(i=1,2,3,4\right)$	Growth rate of China's four regions
$r_i'''\left(i=1,2,3,4,5\right)$	Improved growth rate of China's four regions
$x_{0_i}'\left(i=1,2,3,4\right)$	China's four-zone index model initial plastic clearance
$x_{0_i}''\left(i=1,2,3,4\right)$	China's Initial Plastic Clearance Volume in Four Districts
$x_0'''\left(i=1,2,3,4,5\right)$	Improved initial plastic clearance in China's four districts
$x_m'\left(i=1,2,3,4\right)$	The largest plastic clearance in China's four districts
$x_{m_i}''\left(i=1,2,3,4\right)$	The largest plastic clearance in China's four regions after improvement
$x_m'\left(i=1,2,3,4\right)$	China's largest plastic clearance
$x_m''\left(i=1,2,3,4\right)$	Improved China's Largest Plastic Clearance

3. Prediction Model of Plastic Waste Quantity based on Cluster Analysis

3.1. Data collection

Based on the source of disposable plastics, we selected all the plastic manufacturing-related indicators in all provinces in China, and collected data for these indicators to use for a constant amount of plastic waste. And due to lack of data, Hong Kong, Macao and Taiwan regions are not in the scope of study.

Plastic Waste Clearance: As the amount of plastic waste generated is not easy to obtain, this article uses the amount of cleaning and transportation instead.

GDP data for various provinces in China: Since 1993, the United Nations has used GDP as an indicator to measure the economic development of various countries. Now many countries and places have adopted GDP as an indicator to measure the economic development of that country or locality, which has high authority and comparability [5]. This article also uses GDP as an indicator to measure the economic development of our province. Economic development is closely related to the development of the plastic manufacturing industry. As the best indicator of economic development, GDP can represent the change in plastic output to a certain extent.

Data related to catering and tourism: To a large extent, plastic products are imported into these two industries and play an indispensable role in them. Therefore, the prosperity of these two industries can also better reflect the generation of plastic waste.

3.2. Cluster analysis

We conducted a systematic cluster analysis on 33 provinces and autonomous regions in the country, and brought together similar fruit and plastic pollution. The cluster analysis chart is shown in Figure 2:

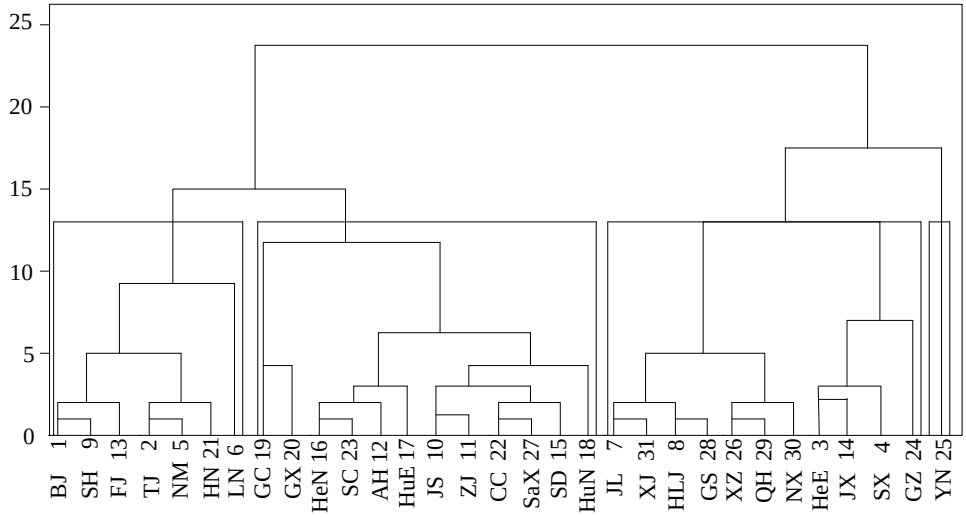

Figure 2. Clustering of plastic use areas in China

The abscissa represents the abbreviations of Chinese provinces and cities. According to the graphic results, when the square Euclidean distance is between 10 and 15, we can divide 31 plastic use provinces and cities across the country into 4 categories. The regions with the most plastic waste production per unit of GDP in the indicator system indicate that the amount of plastic waste produced is not compatible with economic development and has

exceeded the growth rate of GDP by a large margin. By analogy, the lower the level, the closer the growth level of the two is, and the amount of plastic produced is within the acceptable range.

Table 2. Improved classification of China's plastic usage zones

Grade	Main division basis	Included provinces and cities
Level 1	Largest plastic removals per unit of GDP	Beijing, Shanghai,Fujian, Tianjin, Inner Mongolia Valley, Hainan, Liaoning
Level 2	Large amount of plastic removals per unit of GDP	Guangdong,Guangxi,Henan,Sichuan,Anhui, Hubei,Jiangsu,Zhejiang,Chongqing,Shaanxi, Shandong, Hunan
Level 3	Clearance of plastics per unit of GDP	Jilin,Xinjiang, Heilongjiang, Gansu, Tiet, Qinghai, Ningxia, Hebei, Jiangxi, Shanxi, Guizhou
Level 4	Minimal clearance volume per unit of GDP	Yunnan

It is easy to see from the table that there are 7 middle-level plastic use areas, 12 second-level plastic use areas, 11 third-level plastic use areas, and 4 fourth-level plastic use areas in mainland China. It can be seen from the map that the regions with the most plastic waste generation are the central region and the central region. Compared to the western region and the northeast region, plastic waste is better. However, as far as China is concerned, plastic Pollution is still relatively serious. Therefore, reducing plastic waste is urgent.

3.3. Exponential model

The rapid development of the plastic manufacturing industry has led to an exponential increase in the amount of plastic waste [6], so this article attempts to establish an exponential growth model to predict the maximum amount of plastic waste that may be reached in the future.

$$\begin{cases} \dfrac{dx}{dt} = rx \\ x(0) = x_0 \end{cases} \tag{1}$$

Simplified:

$$x(t) = x_0 e^{(r_i)} \tag{2}$$

We perform parameter estimation based on the least squares operation, and the index model parameters suitable for the four regions are as follows:

Table 3. Index model parameters

	Type 1	Type 2	Type 3	Type 4
x_0	4451.4	2380.1	2085.8	6352.9
r_i	0.0553	0.0560	0.0362	0.0429

The value of the growth rate with the abscissa is as follows:

Table 4. Changes in the growth rate of the region of the index model

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Clearance	4625	4733	4994	5073	5219	5910	6266	6573	7118
growth rate	5.26	2.34	5.51	1.59	2.87	13.24	6.02	4.91	8.29

Table 5. Changes in the growth rate of the regional model of the index model

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Clearance	2449	2534	2709	2718	2902	3076	3234	3491	3937
growth rate	-1.36	3.5	6.9	0.32	6.77	6	5.11	7.97	12.76

Table 6. Changes in the three regional growth rates of the index model

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Clearance	2174	2202	2254	2286	2253	2380	2545	2800	2911
growth rate	-0.71	1.28	2.35	1.41	-1.42	5.64	6.91	10.02	3.98

Table 7. Changes in the four regional growth rates of the index model

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Clearance	6050	6924	7122	7160	7484	7773	8316	8654	8833
growth rate	-9.24	14.45	2.86	0.53	4.53	3.86	6.98	4.07	2.07

Then use the programming software to get the fitted exponential graph as follows:

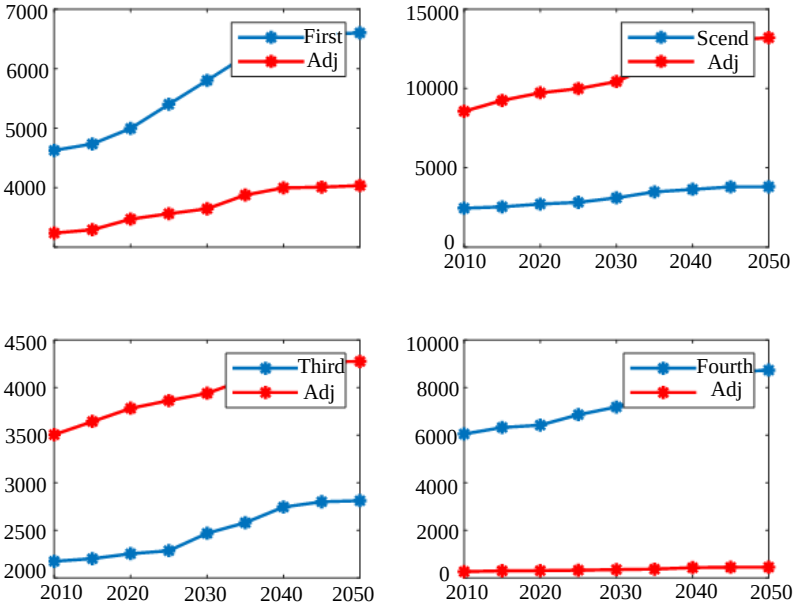

Figure 3. Four types of plastic use area index model diagram

It can be seen from the figure that without considering any limiting factors, China's plastic waste production has grown exponentially in all regions, and the growth has become increasingly fierce.

3.4. Logistic regression model

Because resources and the environment have a certain retarding effect on the plastic manufacturing industry, as the economy continues to grow, people can extract less and less natural resources, and the retarding effect becomes larger as the amount of plastic waste increases. Considering only natural factors, we established a logistic model.Logistic growth model, also called retarded growth model, has been widely used in population, economy, agriculture, industry and other fields.

Model building:

Using the differential equation model, two equations are established simultaneously, as follows:

$$\begin{cases} \dfrac{dx}{dt} = r'x\left(1-\dfrac{x}{x'_{m_i}}\right) \\ x(0) = x'_0 \end{cases} \tag{3}$$

Simplified:

$$x(t) = \frac{x'_{m_i}}{1+\left(\dfrac{x'_{m_i}}{x'_0}-1\right)e^{-r't}} \tag{4}$$

Model solving:

According to the total amount of clearing and transportation in the fourth-level plastic use area, Logistic regression analysis is performed on it using Matlab, as shown in the Figure 4.

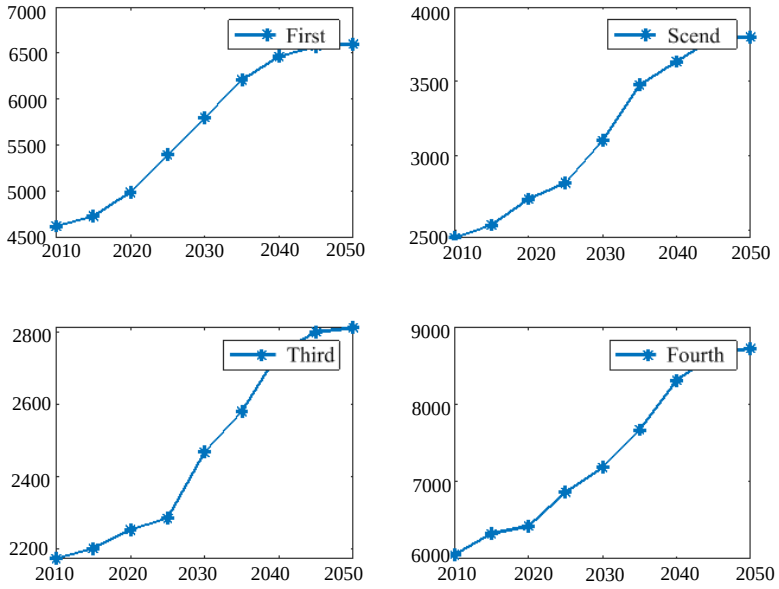

Figure 4. Logistic model of four types of plastic use area

Calculated by the programming software as shown in the following Table 8.

Table 8. Logistic model running results

level	First level	Secondary	Third grade	Fourth grade
x_{m_i}	6750.434	3811.641	2811.494	8733.785
avg	750.048	952.910	937.165	582.250

Therefore, without causing further environmental damage, the maximum amount of disposable plastics used in China is:

$$x_{m'} = \sum_{i=1}^{n=4} x_{m_i'} \tag{5}$$

Results and conclusions: Cluster analysis of the source of disposable plastic waste, the severity of the waste problem, and the availability of resources were used to divide 31 provinces in China into four types of plastic use zones, and logistic regression was used for the total amount of disposable plastic waste at each level It is predicted that the maximum amount of disposable plastics will be obtained when the growth rate of the amount of disposable plastics is 0, and then the maximum total amount of use in China will be obtained. It is expected that after 2050, the maximum amount will be 22107.35 million tons.

4. Optimized Plastic Waste Quantity Prediction Model

As the country attaches great importance to environmental protection issues and has promulgated various policies such as the "plastic limit order", plastic pollution has been brought under some control. However, due to the different enforcement efforts in each region, the degree of cleaning up of plastics is also very different. Different regions can achieve different levels of environmental safety [7]. Taking into account the impact of national policies, we comprehensively consider the amount of plastic waste produced in all provinces and cities, and implement an optimized logistic model for the implementation of national policies.

4.1. Data collection

The harmless treatment rate represents the intensity of policies on plastics production in different provinces of China. The higher the treatment rate, the greater the intensity of policy control. The calculation formula is

$$\text{Harmless treatment rate of plastic waste} = \frac{\text{Harmless treatment of plastic waste}}{\text{Quantity of plastic waste}} \times 100\%$$

4.2. Cluster analysis

We analyzed the indicators and data selected after the improvement, and the resulting cluster analysis chart is as follows:

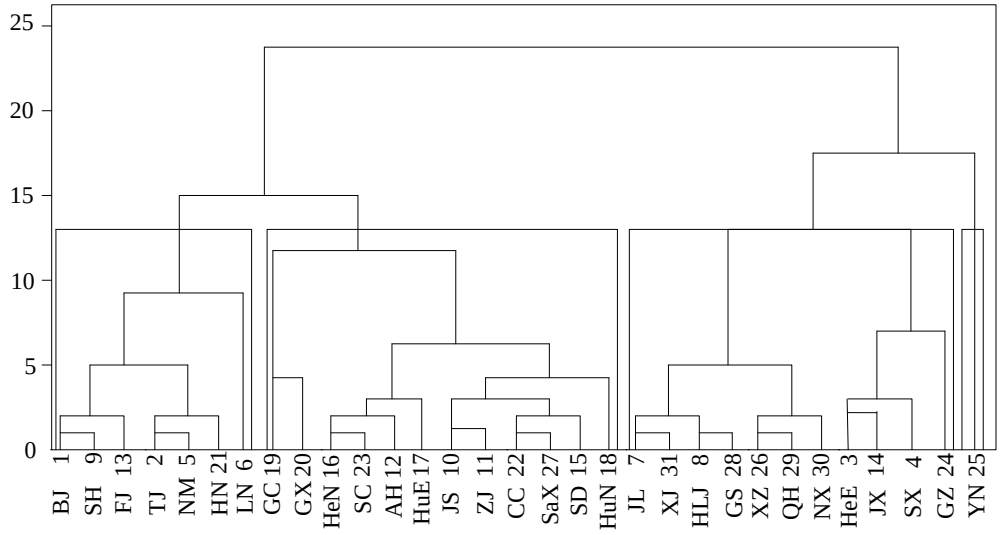

Figure 5. Improved clustering of plastics usage areas in China

The abscissa represents the abbreviations of China's provinces and cities. We have added data on the intensity of plastics cleaning policies in different provinces and cities. When the square Euclidean distance is between 10 and 15, based on the improved results, 31 plastics can be used nationwide. Provinces and cities re-divided into four categories.

Table 9. Classification of China's plastic use zones

Grade	Main division basis	Included provinces and cities
Level 1	Largest plastic removals per unit of GDP	Inner Mongolia, Qinghai, Ningxia, Tianjin, Fujian, Beijing, Tibet, Hainan, Shanghai
Level 2	Large amount of plastic removals per unit of GDP	Liaoning, Heilongjiang, Xinjiang, Jilin
Level 3	Clearance of plastics per unit of GDP	Guangdong, Guangxi, Yunnan
Level 4	Minimal clearance volume per unit of GDP	Jiangsu, Zhejiang, Shandong, Henan, Shanxi, Hebei, Hubei, Guizhou, Sichuan, Gansu, Hunan, Jiangxi, Anhui, Shaanxi, Chongqing

According to the table, there are 9 middle-level plastic use areas, 4 second-level plastic use areas, 3 third-level plastic use areas, and 4 fourth-level plastic use areas in mainland China. It can be seen from the map that the areas with the most plastic waste production are the western and northeastern regions, and the plastic waste production in the central and eastern regions has greatly improved. This may benefit from the implementation of national policies and the provinces and cities' Better policy enforcement.

4.3. Improved logistic regression model

Model establishment, Similarly, using equations:

$$x(t)=\frac{x''_{m_i}}{1+\left(\frac{x''_{m_i}}{x''_0}-1\right)e^{-r''t}} \tag{6}$$

Model solving:

In order that plastic waste can be reduced to an environmentally safe level, taking into account the factors that affect the level of plastic waste, based on the source of disposable plastic waste, the severity of the waste problem, and the availability of resources, and regional policies, And the availability of plastic alternatives, logistic regression analysis using matlab again, compared with before implementing the policy.

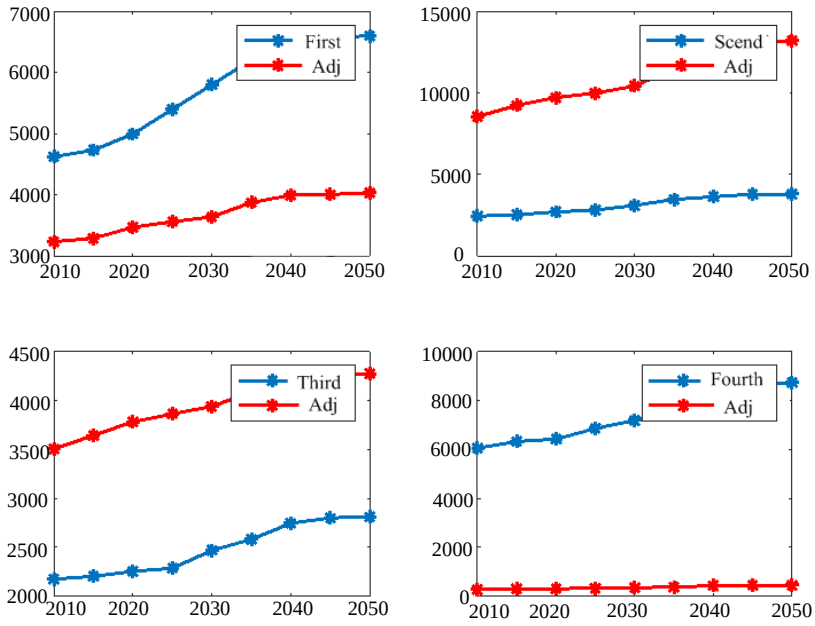

Figure 6. Improved Logistic model of four types of plastic use area

Calculated by the programming software as shown in Table 10.

Table 10. Improved logistic model results

Level	First level	Secondary	Third grade	Fourth grade
x_{m_i}	6750.431	3811.64	2811.494	8733.785
Adj	4033.434	3200.151	4275.443	451.812
Avg	576.260	266.700	388.670	451.812

Therefore, without causing further environmental damage, the maximum amount of disposable plastics used in China is:

$$x_{m'} = \sum_{i=1}^{n=4} x_{m_i'} \tag{7}$$

Results and conclusions: Based on the source of disposable plastic waste, the severity of the waste problem, and the availability of resources, taking into account regional policies and the availability of plastic alternatives, the 31 provinces nationwide were again clustered and still divided into 4 categories Based on Logistic regression prediction of the total amount of disposable plastic used at each level, the maximum use amount when the growth rate of the disposable plastic amount is 0 is obtained, and then the maximum total use amount in China after the implementation of the policy is reached, that is, environmental safety The level of the level, the maximum total use, is expected to reach the maximum amount of 11960.78 million tons after 2050.

Taking into account policies and the availability of plastic alternatives, the maximum amount of disposable plastic used to reach the level of environmental safety has been reduced by 10146.57 million tons. It can be seen that the policies adopted and the methods implemented in various regions have a certain effect on reducing the amount of disposable plastics.

4.4. Model comparison

Table 11. Comparison before and after policy implementation

Grade	Adjust	Original	Variation
Level 1	9	7	2
Level 2	4	12	-8
Level 3	3	11	-8
Level 4	15	1	14

It can be seen from the table that the pollution degree of plastic waste in China has improved significantly. The specific performance is that the number of provinces and cities in which the production of second- and third-level plastic waste is not compatible with GDP has decreased significantly, indicating that the plastic waste production has been effectively controlled , And the number of four-level plastic use areas, that is, the area with the least plastic pollution per unit of GDP, the number of provinces and cities has increased significantly, all thanks to the implementation of national policies and the improvement of people's environmental awareness.

5. Conclusions

Firstly, cluster analysis was used to classify most areas of plastic pollution areas in China with different degrees. Secondly, the waste plastic quantity evaluation index

model was established. Constraints were used to establish the Logistic model. Finally, policy intervention was used to reclassify and optimize the model. The study concluded that without further environmental damage, the maximum amount of plastic waste will reach 22,107.35 million tons by 2050; after national policy interve-ntion, it will reach 11,960.78 million tons, a reduction of 10,146.57 million tons.

Plastic pollution is not only a problem in China, it is also a problem in the world. Therefore, in order to reduce more plastic waste and better protect the environment, the following suggestions are put forward: attach great importance to personnel training, increase support for the research and development team of plastic substitutes, and restrict large plastic countries Only export green plastic products, strengthen pollution monitoring, and strictly control illegal emissions; do a good job in building the lifestyle of the people, strengthen publicity and guidance, supervision and education of citizens' environmental protection, establish an environmental protection system, form related plastic environmental protection industries, and make environmental protecti on Enter a virtuous circle; do not blindly pursue speed, but combine the actual situation of the country and region. From "restricting plastics" to consciously abandoning plastic products is a long process that requires everyone to consciously implement, but as long as you persist, there will always be a day to resolve white pollution.

6. Acknowledgments

The Teaching Research Foundation of Anhui Education Department of China under Grant No. 2018jyxm0086; the "six excellence, one top" talent training innovation project of Anhui Education Department of China under Grant No. 2018zygc005.

References

[1] Li Guo, Zhang Tianfeng, Sun Celebrity. Empirical research on the Impact of China's sports industry on national economic development. Journal of Shenyang Institute of Physical Education. 2019, 38(02), 36-42.

[2] Yang Yu. Analysis of the impact of the "plastic limit order" on plastic bag production industry, business operators and consumers. Cai Zhi. 2008, (13), 233-234.

[3] Feng Shuzheng, Li Ruinan, Zhang Fan. Regarding marine plastic waste, what will happen at the g20 summit. China Ship Inspection. 2019, (12), 78-83.

[4] Wang Changlian. To curb white pollution, it is necessary to grow teeth with "plastic restriction order". People's Court. 2019, (002).

[5] Ingemar Nåsell. Approximations of cumulants of the stochastic power law logistic model. Bulletin of Mathematical Biology. 2020, 82(2).

[6] Yang Meiling, Che Shiyou, Zhang Yunxiu, Song Wenqin, Yan Guorong, Yu Weiwei. Malus niedzwetzkyana (Dieck Langenf transcriptome comparison and phylogenetic analysis with Malus sieversii) Ledeb Roem. Genetic Resources and Crop Evolution. 2020, 67(2).

[7] Mo Xiaoliang, Zeng Yachang. The relationship between ovarian endometriosis and clinical pregnancy and abortion rate based on logistic regression model. Saudi Journal of Biological Sciences. 2020, 27(1).