Problem Chosen	2022	Team Control Number
D	ShuWei Cup Summary Sheet	2022103113305

Research on the loss evaluation and coping strategies of extreme climate disasters under the Triple La Niña Event

According to meteorological data, we are going through the first triple La Nina event of this century. Some in-depth study of the triple La Nina event is meaningful and important.

In Question 1, in order to comprehensively show the impact of La Nina on the world, we selected the five countries more severely affected by the disaster and the six major meteorological indicators for statistical analysis to study the impact of the triple La Nina event on these countries. We then performed a descriptive statistical analysis of the collected data. From the statistical figure, we can intuitively see that the triple La Nina event brings different degrees of influence to different countries in different aspects. To accurately calculate the impact of the triple La Nina event, we performed a regression analysis on the different metrics to obtain the significant effect of the triple La Nina event on the different countries.

Next we need to predict the probability of a future triple La Nina event. After establishing the Markov prediction model, we made statistics for 66 years from 1957-2022. The number of transitions between El Nino events, neutral year, and La Nina events and each state was calculated, and the state transition matrix was constructed combined with the statistics. The effects of the future annual triple La Nina events were finally calculated and presented in tabular form. The probability of triple La Nina events in 2032 and later stabilized at 3.22%.

In Question 2, we choose China as the research country. First, the evaluation model of high temperature and drought disaster loss caused by triple La Nina event in China was established. Three first and secondary indicators and seven secondary indicators were selected to evaluate disaster loss. Then, two different loss assessment models were established for different indicators. For the indicators of market value, the loss caused by the disaster is calculated by using the market value assessment method. For indicators not calculating market value, we calculate losses using the opportunity cost assessment method. Then the magnitude of loss caused by triple La Nina compared to drought disaster in different aspects. Finally, we formulate an effective coping strategy based on the system dynamics model. After the four-point response strategy, the causal relationship diagram of the response strategy on each index is put forward. On this basis, the stock flow chart is constructed and used to calculate the loss caused by high temperature and drought under the response strategy of 10%, 20% and 30% loss cost respectively. It is most reasonable to find that 20% of the original loss value should be used to implement the coping strategy.

In question 3, our basic thinking is in line with question 2. First, three first indicators and eight second indicators were determined, and the flood loss evaluation model was established. Then we propose the governance cost evaluation method and calculate the loss value of each index in combination with the method of problem 2. Then analyze the size of the flood disaster caused by the triple La Nina event to different indicators. Finally, an effective response strategy is developed based on the system dynamics model, and it is found that 30% of the original loss value should be used to implement the response strategy.

In question 4, some effective policy suggestions were put forward to the Chinese government in view of a series of problems brought by La Nina phenomenon to agriculture and Marine aquaculture.

Keywords: Triple La Nina event, Markov prediction, Disaster assessment, System dynamics

Content

1. Introduction

La Nina event refers to the phenomenon of continuous abnormal cold on the surface of the central tropical and eastern Pacific seas. La Nina events can affect most parts of the world to varying degrees. Continuous high temperatures and dry weather can occur in some places, rare floods in some places, and unusual typhoons / hurricanes in others.

La Nina, which has been running for two years, will continue to extend until the end of the year or tomorrow. That means that we are going through the first triple La Nina event of this century. This is full of uncertainty for the world. Therefore, we need to dig deeper into the different effects of the triple La Nina event around the world. This will be very meaningful and important. Next, this paper will analyze the impact of triple La Nina events from different perspectives, including statistical analysis, prediction and assessment. Finally, we will develop effective coping strategies and make policy suggestions to relevant parts.

2. Problem analysis

2.1 Analysis of question one

The title asked us to perform a statistical analysis of the major countries and regions affected by the Triple La Nina event. In this step, we first need to consult relevant materials and read relevant literature, determine which countries are mainly affected by the triple La Nina event, and select representative countries for analysis. Then, according to the different impact of La Nina event on the climate, the analysis indicators were determined and the relevant data of the indicators was collected. Finally, statistical methods were used to make statistical analysis and compare the climate changes of different countries under the influence of La Nina.

This question also requires predicting the possibility of triple La Nina events in the future, so we need to make a reasonable prediction of the possible future La Nina events according to the causes and rules of La Nina formation.

2.2 Analysis of question two

Question 2 requires us to take a country more seriously affected by the triple La Nina event as an example, evaluate and analyze the various disaster losses caused by the high temperature and drought under the triple La Nina event, and propose targeted response strategies. First of all, we need to select countries, considering the availability of data and the impact caused by triple Lanina. After that, it is necessary to analyze which meteorological, agricultural, and economic and social indicators high temperature and drought will affect, and build a disaster loss evaluation index system. Then the evaluation method is selected to construct the disaster loss evaluation model and solve the model. Finally, we need to combine the model-seeking results to give targeted coping strategies to help the country cope with the triple La Nina event.

2.3 Analysis of question three

Problem 3 is consistent with the basic task of question 2, which requires us to take a certain country as an example to evaluate and analyze the disaster damage caused by the flood under the triple La Nina event, and to propose targeted response strategies. First, we need to choose the country. After that, it is necessary to analyze what disaster losses will be caused by flood disasters, and build a disaster loss evaluation index system. Then the evaluation method is selected to construct the disaster loss evaluation model and solve the model. Finally, we need to combine the model-seeking results to give targeted coping strategies to help the country cope with the triple La Nina event.

2.4 Analysis of question four

Question 4 requires us to combine the existing research results of the first three questions with the existing research literature to write a report for the relevant departments and propose some policy suggestions to help various countries deal with the potentially increasingly serious La Nina event and minimize the disaster loss caused by La Nina event to the world.

3. Symbol and Assumptions

3.1 Symbol Description

Symbol	Notation	Unit
P	state transition matrix	
E_i	event is in the state i	
$\pi_i(k)$	probability of a state i after k state transfer	
L_i	the i type of disaster loss	yuan
Q_i	production per unit area of the Type i product	kg/hm^2
M_j	the j degree of the affected area of the disaster	hm^2
S_g	Unit opportunity cost of type g environmental resource	yuan/hm^2

3.2 Fundamental assumptions

To simplify the given problems and modify it more appropriate for simulating reallife conditions, we make the following basic hypotheses.

(1) Historical data can more accurately describe the possibility of El Nino events, the neutral year and La Nina events occurring annually in the future.

(2) The representative areas selected can comprehensively reflect La Nina's different influences around the world.

(3) The selected evaluation indicators can fully reflect the loss caused by the triple La Nina event

(4) The loss estimation error for different indicators is within the allowable range.

4. Model establishment and solution of question one

4.1 Analysis and preparation before modeling

For the statistical analysis of the major countries and regions subject to the triple La Nina event. We need to combine the existing literature and the research results to find out which countries are being affected by the La Nina events, and which countries are being affected by them, respectively. Then we need to select some climate indicators and collect relevant data for statistical analysis. Comparing the climate indicators of different countries in the time of La Nina event, which shows the impact of La Nina on these countries.

Then, to predict the possibility of a triple La Nina event in the future. We can use the Markov Chain approach for the predictions. Markov chain prediction is a prediction method commonly used in the geographical environment field, which can predict the probability of each event according to the state transition matrix. The flowchart of question 1 is as shown below.

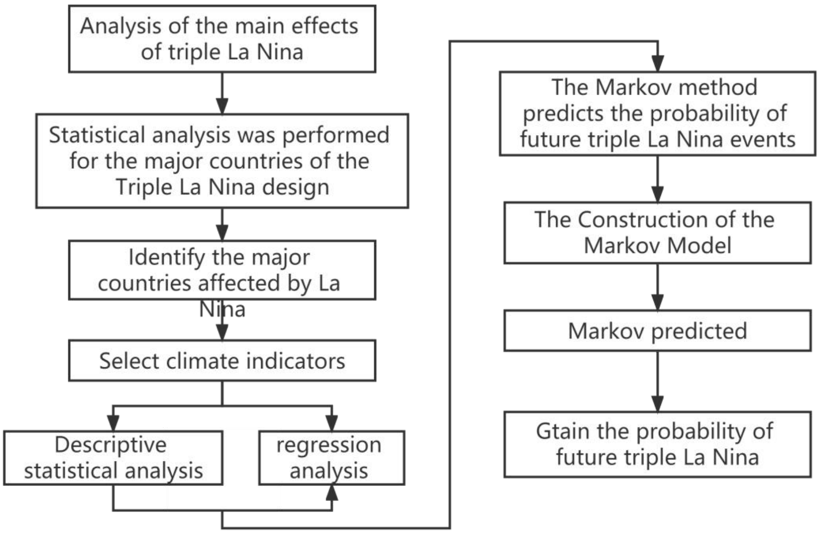


Figure4-1：Flow chart of question one

4.2 La Nina mainly affects the countries and climate indicators

la Nina event refers to the tropical middle and east Pacific sea surface wide continued abnormal cold phenomenon, the criteria also have certain differences in the international, the domestic general NINO3 area sea surface temperature level index for at least six consecutive months 0.5℃ defined as a la Nina event, the United States to NINO3.4 area sea surface temperature level 3 months sliding average 5 consecutive 0.5℃ is defined as a la Nina event.The following figure shows a schematic diagram of generating the main sea area division of the La Nina event:

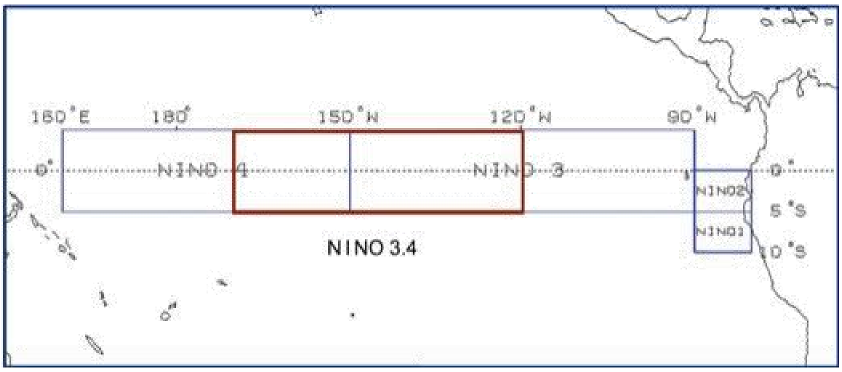


Figure 4-2：NINO:Distribution of each district

Based on the above analysis and combined with relevant references, we found that the Pacific coastal countries were the most severely affected by the La Nina event. Therefore, we selected five representative countries: China, US, Indonesia, Australia and Brazil to analyze the impact of the triple La Nina event on these five countries.

Next, we selected the specific indicators for the statistical analysis. According to the relevant literature, the impact of La Nina event on the climate around the world is extremely complex. Therefore, to comprehensively consider the various possible climate impacts of La Nina, we selected the following six indicators for statistical analysis:annual average rainfall, annual average temperature, annual high temperature days, annual drought days, annual rainstorm days, annual typhoon/hurricanes times. The selected national and statistical indicators are shown in the table below.

Table 4-1：Selected countries and statistical indicators

Country	Statistical indicator
China America Indonesia Australia Baxi	Annual average precipitation Annual average temperature High temperature days Drought days Rainstorm days Annual number of typhoons/hurricanes

In order to reduce the workload of data collection, some indicators are selected from the representative cities of each country for statistics.

4.3 Statistical analysis

First, the six indicators of the selected five countries were data collected, and the collected data was visually processed. The relationship between the Lanina phenomenon and the other six indicators was analyzed by bar chart comparison. In order to further obtain precise conclusions, the correlation analysis was conducted using SPSS.

4.3.1 Statistical analysis of China

- **Annual average precipitation**

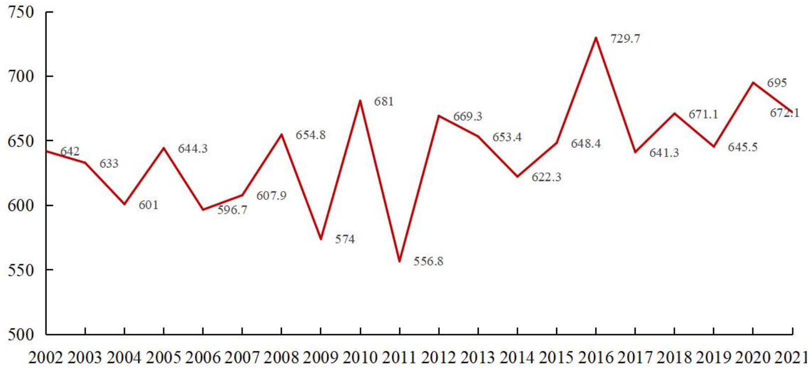


Figure 4-3：China chart of average precipitation in the past 20 years

- **Annual average temperature**

Figure 4-4：China chart of average temperature in the past 20 years

As can be seen from the above two chart, in 2004, 2006, 2009, 2011, 2014, 2017, 2019, 2021, precipitation in these years is at a lower point. Especially in 2006, 2009, 2011, the average annual precipitation was less than 600 mm. In terms of annual average temperatures, the average temperatures in the years 2004, 2008, 2011, 2011, 2012, 2018 were lower. According to the literature search, in 2006, 2008, 2009, 2011, 2012, 2021, the La Nina phenomenon appeared in the world, with a high degree of overlap with the abnormal climate years in China.

In addition to the annual average annual precipitation and temperature, through data collection, we also found Liaoning province affected by La Nina, collected the number of annual high temperature weather days, drought days, rain and snow days, and the number of typhoons in China in Liaoning Province, and made a line map.

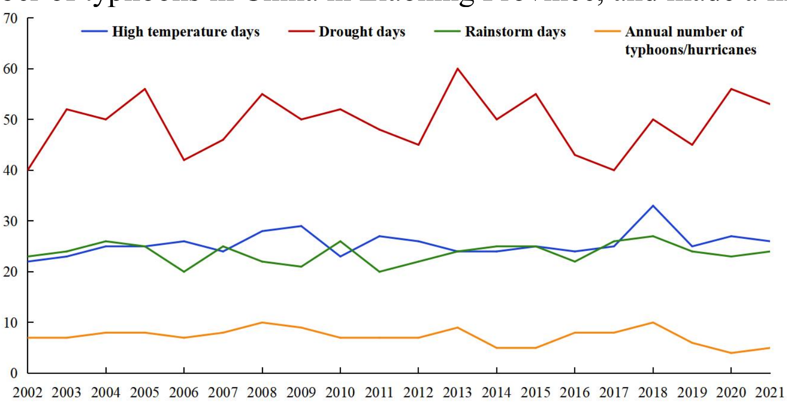


Figure 4-5：Statistical of high temperature, drought, thunderstorm and typhoon

The average value of these 6 metrics in La Nina years and in non-La Nina years was calculated and normalized to obtain the data and make the following figure.

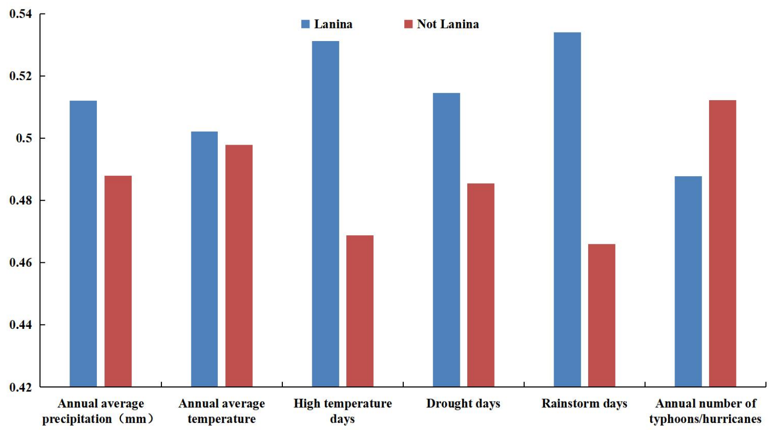


Figure 4-6: The difference brought by the La Nina

It can be seen that whether the occurrence of La Nina phenomenon affects these indicators, so, in order to get more accurate results, the correlation analysis is conducted. The year with La Nina is 1, and the year without La Nina is 0, and the regression analysis is conducted with the other 6 variables, and the results are shown in the following table.

Table 4-2：Correlation analysis of La Nina phenomenon in China

coefficient[a]

model		Unstandardized coefficients		Standardization coefficient		
		B	Standard error	Beta	t	Sig.
1	(constant)	-3.798	1.258		-3.018	.010
	Annual average precipitation	-.004	.002	-.270	-2.299	.039
	Annual average temperature	.523	.087	.540	6.012	.000
	High temperature days	.057	.025	.281	2.220	.045
	Rainstorm days	.007	.019	.031	.374	.714
	Annual number of typhoons	.002	.016	.006	.102	.920
	Drought days	-.003	.004	-.036	-.726	.480

a. dependent variable: La Nina

As can be seen from the figure above, there is a significant correlation between La Nina phenomenon and the average annual precipitation and the average annual temperature, and a negative correlation with the average annual precipitation, and a positive correlation with the average annual temperature. This shows that when La Nina phenomenon appeared, China is prone to cold winter and hot summer, the number of tropical cyclones landing in China is more than all the year round, the phenomenon of "south drought and north flood" has appeared, the annual precipitation has decreased significantly, and the annual average temperature has increased significantly.

4.3.2 Statistical analysis of America

Through data collection, we have compiled various climate data from the United States, then conducte correlation analysis.The results are shown in the following table.

Table 4-3：Correlation analysis of La Nina phenomenon in America

coefficient[a]

model	Unstandardized coefficients	Standardization coefficient	t	Sig.

		B	Standard error	Beta		
1	(constant)	3.724	2.300		1.619	.129
	Annual average precipitation	-.005	.002	-.417	-2.452	.029
	Annual average temperature	-.279	.171	-.126	-1.634	.126
	High temperature days	.047	.023	.237	2.076	.058
	Rainstorm days	-.023	.027	-.067	-.881	.394
	Annual number of typhoons	.024	.022	.085	1.123	.282
	Drought days	.022	.013	.396	1.782	.098

a. dependent variable: La Nina

Unlike the situation in China, the correlation of La Nina phenomenon is not significant with the average annual temperature in the United States, but has a significant correlation with the average annual precipitation, the number of annual high temperature days, and the number of annual drought days. Moreover, it showed a negative correlation with annual average precipitation, and with annual high temperature weather and annual dry weather.

4.3.3 Statistical analysis of Indonesia

We also collected the data of Indonesia, and made the correlation analysis, and the results are shown in the following table below.

Table 4-4: Correlation analysis of La Nina phenomenon in Indonesia

coefficient[a]

		Unstandardized coefficients		Standardization coefficient		
model		B	Standard error	Beta	t	Sig.
1	(constant)	0.781	.085		9.060	.001
	Annual average precipitation	.007	.001	.854	11.716	.000
	Annual average temperature	.079	.053	.089	1.489	.160
	High temperature days	-.069	.029	-.174	-2.403	.032
	Rainstorm days	.046	.026	.128	1.792	.096
	Annual number of typhoons	-.011	.018	-.039	-.608	.554
	Drought days	-.002	.006	-.021	-.303	.767

b. dependent variable: La Nina

Whether the La Nina phenomenon occurs is significantly correlated with the average annual precipitation and the average annual rain and snow days in Indonesia, and both are positively correlated with it.

4.3.4 Statistical analysis of Australia

Consistent with the above countries, we also collected several meteorological data from Australia and analyzed its correlation with La Nina phenomenon, and the results are shown in the table below.

Table 4-5: Correlation analysis of La Nina phenomenon in Australia

coefficient[a]

		Unstandardized coefficients		Standardization coefficient		
model		B	Standard error	Beta	t	Sig.
1	(constant)	-2.591	.540		-4.797	.000
	Annual average precipitation	.006	.001	1.002	9.766	.000

	Annual average temperature	.044	.049	.049	.894	.388
	High temperature days	.020	.029	.073	.685	.056
	Rainstorm days	.037	.023	.103	1.640	.125
	Annual number of typhoons	-.012	.016	-.042	-.759	.462
	Drought days	.003	.005	.031	.530	.605

c. dependent variable: La Nina

Similar to Indonesia, whether the La Nina phenomenon appeared showed a significant positive correlation with the average annual precipitation in Australia, but also with the average annual number of days with high temperature. Australia in Great.

4.3.5 Statistical analysis of Baxi

The correlation analysis in Brazil yielded the results shown in the following table.

Table 4-6: Correlation analysis of La Nina phenomenon in Baxi

coefficient[a]

model		Unstandardized coefficients		Standardization coefficient	t	Sig.
		B	Standard error	Beta		
1	(constant)	1.839	.836		2.201	.046
	Annual average precipitation	-.006	.001	-.623	-6.220	.000
	Annual average temperature	-.098	.050	-.109	-1.948	.073
	High temperature days	.101	.021	.370	4.777	.100
	Rainstorm days	-.001	.028	-.003	-.036	.972
	Annual number of typhoons	.028	.017	.097	1.618	.130
	Drought days	.009	.004	.152	2.241	.043

d. dependent variable: La Nina

Different from the situation in Australia, the occurrence of La Nina phenomenon has a significant correlation with the average annual precipitation and the number of annual drought days in Brazil, and has a negative correlation with the average annual precipitation, and a positive correlation with the annual dry weather.

4.4 Markov method predicts the probability of future triple La Nina

4.4.1Construction of the Markov prediction models

In order to predict the probability of the triple La Nina events in the future, we need to find a suitable mathematical model for the prediction. Commonly used prediction models such as time-series prediction and machine learning-based prediction methods usually can only give definite predictions, but not the probability of a predicted event. The Markov prediction rule is different. It is a probabilistic prediction method about events. It is a prediction method to predict the change situation of the future moment (or period) according to the current situation of the event.

- The State, the state transfer process, and the Markov process

(1) State: In Markov predictions, "state" is an important term. A state refers to the outcome of an event at a certain time (or time). For the problem in this topic, can be

divided into three states, respectively, "La Nina", "El Nino" and "neutral year".

(2) State transfer process: In the development of an event, the transition from one state to another is called a state transfer. When changed from La Nina year to neutral year to El Nino year is a state shift.

◆ State transition probability and state transition probability matrix

(1) State transition probability: In the process of the development and change of the event, the possibility of moving from a certain state to the next moment to the other state is called the state transition probability. According to the definition of the conditional probability, the state transition probability $P(E_i \to E_j)$ from state E_i to state E_j is the conditional probability $P(E_j/E_i)$, namely:

$$P(E_i \to E_j) = P(E_j/E_i) = Pij \tag{1}$$

(2) State transition probability matrix: Assume that some of the predicted events have, E_1、E_2、$\cdots E_i$、$\cdots E_n$, a total of n possible states. Note P_{ij} as the state transition probability from state E_i to state E_j, as a matrix

$$P = \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} \end{bmatrix} \tag{2}$$

Then P is called a state transition probability matrix.

If a predicted event is currently in a state E_i, so at the next moment, It may shift from a state E_i to any state in the E_1、E_2、$\cdots E_i$、$\cdots E_n$. So the meets the P_{ij} conditions:

$$\begin{cases} 0 \leqslant P_{ij} \leqslant 1, \ (i,j = 1, 2, \cdots, n) \\ \sum\limits_{j=1}^{n} P_{ij} = 1, \ (i = 1, 2, \cdots, n) \end{cases} \tag{3}$$

In general, we refer to any matrix satisfying the above conditions as a random matrix, or a probability matrix. It is not difficult to prove that, if P is a probability matrix, the matrix P_m is a probability matrix for any number $m > 0$.

If P is a probability matrix, and there is an integer $m > 0$, so that all the elements in the probability matrix P_m are not zero, P is called a standard probability matrix. It can be shown that, if P is a standard probability matrix, there is a non-zero vector $a = [x_1, x_2, \cdots, x_n]$, and meet $\left| 0 \leqslant x_i \leqslant land\ \Sigma\, x_i = 1 \right|$ so that:

$$a \cdot P = a \tag{4}$$

Such a vector a is called the equilibrium vector, or the ultimate vector.

(3) Calculation of the state-transition probability matrix: To find each P_{ij}, we adopt the idea of frequency approximate probability to calculate it.In this question, we can calculate the transition probability of each state using past historical data, and then construct the state transition matrix.

◆ Markov predicted

In order to predict the probability of the state in the process of event development, another noun needs to introduce: state probability $\pi_j(k)$. $\pi_j(k)$ indicates that the event occurs when the initial state $(k = 0)$ is known, after k times of state transfer, the probability that moment k (period) is in state E_j.

$$\sum_{j=1}^{N} \pi_j(k) = 1 \tag{6}$$

Starting from the initial state, the state transfer process of reaching state E_j after k state transfer can be regarded as reaching state $E_i(i=1,2,\cdots,n)$ first after $(k-1)$ state transfer, and then reaching state E_j after a state transfer by E_i. According to the effectiveness of Markov process and Bayes conditional probability formula, there are:

$$\pi_j(k) = \sum_{i=1}^{n} \pi_i(k-1)P_{ij},\ (j=1,2,\cdots,n) \tag{7}$$

If the line vector $\pi(k) = [\pi_1(k),\pi_2(k),\cdots,\pi_n(k)]$ is remembered, the recursive formula(7) of the state probability can be calculated by the formula:

$$\begin{cases} \pi(1) = \pi(0)P \\ \pi(2) = \pi(1)P = \pi(0)P^2 \\ \vdots \\ \pi(k) = \pi(k-1)P = \pi(0)P^k \end{cases} \tag{8}$$

In formula (8), $\pi(0) = [\pi_1(0),\pi_2(0),\cdots,\pi_n(0)]$ is the initial state probability vector.

From the above analysis, if the initial state of an event at the 0th moment (or period) is known (namely $\pi(0)$ is known), then the recurrence formula (8), it can obtain after k state transfer, various possible state probability ($\pi(k)$) in the k time (period), so as to get the event at the k moment (period) state probability prediction.

4.4.2 Markov Prediction Process

For the problems studied in this paper, we can divide the annual states into three categories: El Nino year, neutral year, and La Nina year.

We selected a total of 66 years from 1957-2022 for statistics. First, in the observed data, the El Nino and La Nina events will need to be selected from between 1957 and 2022. The outliers of this study were obtained by removing the 19572022 climate mean and annual cycle. When an event has an average standardized Nino3.4 index over 0.5 in the winter months, it calls the event an El Nino event. Following this rule, 21 El Nino events were selected. When an event had the average standardized Nino3.4 index below 0.5 in the winter, calling the event a La Nina event, from which 22 La Nina events were selected. We show the standardized Nino3.4 index over the calendar year in Figure 4.x and annotate the different states. The El Nino/La Nina years occurring in 1957 in 2022 are also listed in Figure 4-7.

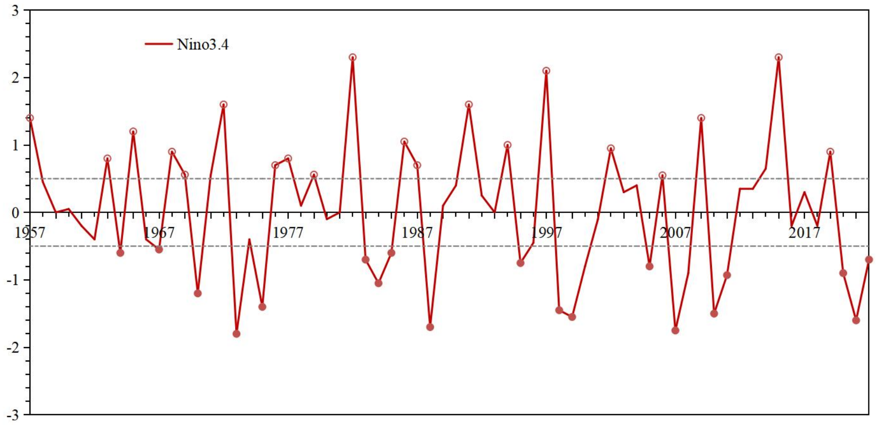


Figure 4-7: 1957－2023Standardized Nino3.4 index time series（Hollow circle mark El Nino year, and solid circle mark La Nina year）

Table 4-7：The El Nino / La Nina Incidents in 1957－2022 年

State	El Nino years	Lanina year
Year	1957/1958，1963/1964，1965/1966，1968/1969，1969/1970，1972/1973，1976/1977，1977/1978，1979/1980，1982/1983，1986/1987，1987/1988，1991/1992，1994/1995，1997/1998，2002/2003，2006/2007，2009/2010，2014/2015，2015/2016，2019/2020	1964/1965，1967/1968，1970/1971，1971/1972，1973/1974，1975/1976，1983/1984，1984/1985，1985/1986，1988/1989，1995/1996，1998/1999，1999/2000，2000/2001，2005/2006，2007/2008，2008/2009，2010/2011，2011/2012，2020/2021，2021/2022，2022/2023

We set the El Nino year as state 1 E_1, the neutral year as state 2 E_2, and the La Nina year as state 3 E_3. Based on the state statistics of the above historical years, we can obtain each state transition probability. The specific calculation is as follows:

$$\begin{cases} P_{11}=P(E_1 \to E_1)=P(E_1|E_2)=\dfrac{4}{20}=0.2000 \\ P_{12}=P(E_1 \to E_2)=P(E_2|E_1)=\dfrac{7}{20}=0.3500 \\ P_{13}=P(E_1 \to E_3)=P(E_3|E_1)=\dfrac{9}{20}=0.4500 \\ P_{21}=P(E_2 \to E_1)=P(E_1|E_2)=\dfrac{9}{24}=0.3750 \\ P_{22}=P(E_2 \to E_2)=P(E_2|E_2)=\dfrac{12}{24}=0.5000 \\ P_{23}=P(E_2 \to E_3)=P(E_3|E_2)=\dfrac{3}{24}=0.1250 \\ P_{31}=P(E_3 \to E_1)=P(E_1|E_3)=\dfrac{8}{22}=0.3636 \\ P_{32}=P(E_3 \to E_2)=P(E_2|E_3)=\dfrac{5}{22}=0.2273 \\ P_{33}=P(E_3 \to E_3)=P(E_3|E_3)=\dfrac{9}{22}=0.4091 \end{cases} \tag{9}$$

The state transition matrix is obtained as follows:

$$P=\begin{bmatrix} 0.2000 & 0.3500 & 0.4500 \\ 0.3750 & 0.5000 & 0.1250 \\ 0.3636 & 0.2273 & 0.4091 \end{bmatrix} \tag{10}$$

We set the 2022-2023 state to the initial state, namely:

$$\pi(0)=[0,0,1] \tag{11}$$

The probability of various states in the future year can be calculated by using MATLAB according to equation (8), (10), and (11). The specific results are shown in the following table:

Table 4-8: 2023-2032 predicts the probability of the various states

Year	2023/2024			2024/2025			2025/2026		
State	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
probability	0.3636	0.2273	0.4091	0.3067	0.3339	0.3594	0.3172	0.3560	0.3268
Year	2026/2027			2027/2028			2028/2029		
State	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
probability	0.3158	0.3633	0.3209	0.3161	0.3651	0.3188	0.3161	0.3657	0.3183
Year	2029/2030			2030/2031			2031/2032		
State	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
probability	0.3161	0.3658	0.3181	0.3161	0.3658	0.3181	0.3161	0.3658	0.3181

From the above table, we can clearly see the probability of various states in the future, and the equilibrium state probability $\pi = [0.3161, 0.3658, 0.3181]$ can be found after a certain number of times, namely:

$$\lim \pi_i(k) = \lim \pi_i(k+1) = \pi \tag{12}$$

Therefore, the probability of El Nino event is 0.3161, neutral year is 0.3658, and 0.3181 is 0.3181.

We assume that the state in the time period in 2023-2024 is unknown, and we do not consider the state in the time time before 2023. Accordingly, the probability of future triple La Nina events can be shown in the following table:

Table 4-9: Probabilities of a future triple La Nina

Year	**Probabilities of a future triple La Nina**
2025/2026	0.0480
2026/2027	0.0380
2027/2028	0.0334
2028/2029	0.0326
2029/2030	0.3228
2030/2031	0.0322
2032 and beyond	0.0322

5. Model establishment and solution of question two

5.1 Analysis and preparation before modeling

Question 2 requires us to take a country more seriously affected by the triple La Nina event as an example, evaluate and analyze the various disaster losses caused by the high temperature and drought under the triple La Nina event, and propose targeted response strategies. First of all, we need to select countries, considering the availability of data and the disaster impact caused by the triple Lanina. After that, it is necessary to analyze which meteorological, agricultural, and economic and social indicators high temperature and drought will affect, and build a disaster loss evaluation index system. Then the evaluation method is selected to build the disaster loss evaluation model, and the model is solved after determining the index weight.

Finally, we can evaluate the impact of a variety of feasible coping strategies, and select the highly effective coping strategies to help the country cope with the triple La Nina event. Problem 2 flow chart is as follows:

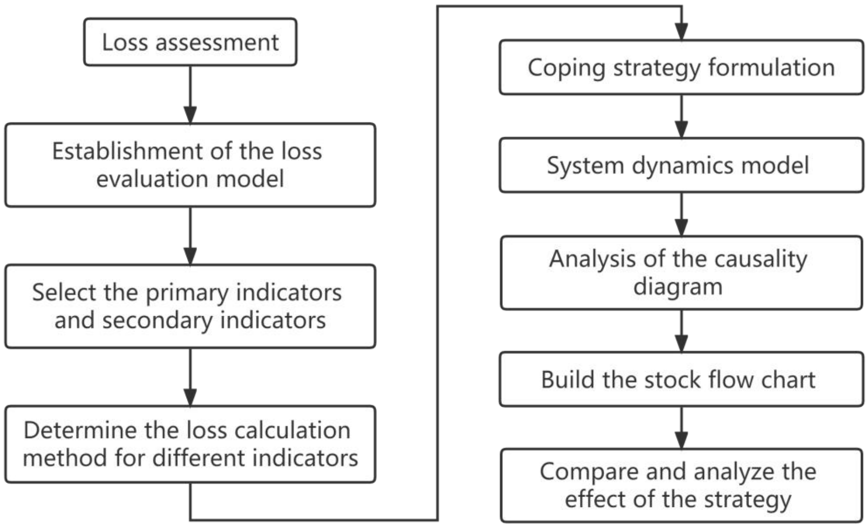


Figure 5-1: Flow chart of question two

5.2 Triple La Nina disaster assessment of high heat and drought damage

5.2.1 Construction of Evaluation Model of High Temperature and Drought Disaster Loss

In order to evaluate the loss caused by the high temperature and drought disaster caused by the triple La Nina event, we need to select the evaluation indicators to construct the evaluation model. In order to comprehensively assess all the losses caused by disasters, and by comprehensively considering all aspects of agriculture and the economy and society, we have selected three first-level indicators. They are agricultural losses, direct economic losses and indirect losses. Next, we discuss the second-level indicator below each first-level indicator.

◆ **Agricultural loss**

Continued high temperature and drought weather will inevitably affect the growth of crops and vegetation. For crops, higher temperatures are not conducive to normal crop growth, and sustained drought does not provide enough water for crop growth. All of this will lead to a crop production cut. Therefore, we chose the decline value of crop output value as one of the indicators. In the later model solution, we selected several crops with the widest planting area in China for calculation.

High temperatures and dry weather can not only cause crop production, but also affect pasture grass growth. A decline in pasture yield can further lead to a decline in livestock production. Therefore, the decline value of animal husbandry output value was selected as one of the indicators.

◆ **Direct economic loss**

Persied heat and drought can cause forest fires, damage to power stations and some infrastructure. These are the loss of public property, so the public property loss can be included.

At the same time, high temperatures and drought weather can also cause the loss of personal property. Examples are the cost of heatstroke, the extra cost of cooling down, and the cost of remedial measures taken by farmers to prevent excessive crop losses. We therefore take personal property losses into account. But due to the difficulty of data acquisition. Here is the heat allowance as a personal property loss.

Finally, in order to help the disaster areas through the difficulties, the government will inevitably allocate special funds to help the disaster areas. So the government's disaster relief costs are also taken into account.

◆ **Consequential loss**

For the introduction loss part, we mainly consider the harm to the environment. Continuous high temperature and drought weather will cause farmland salinization and land desertification. There is no direct economic loss, but additional costs to repair the environment. Therefore, the environmental harm caused by the disaster is regarded as an indirect loss.

The following figure shows in detail the various indicators of the high temperature and drought disaster loss evaluation model.

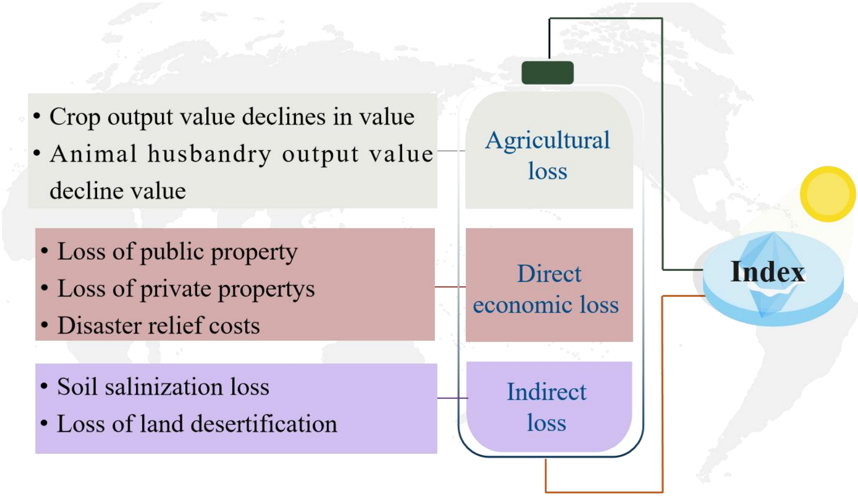


Figure 5-2: High temperature and drought disaster loss evaluation model

5.2.2 Construction of Evaluation

For the above models, we identified two different loss assessment methods by combining different metrics.

(1) Market value evaluation method

The two indicators of crop output value and livestock output value can be estimated by using the loss of the product multiplied by the market value of the product. The specific formula is as follows:

$$L_1 = \sum_{i=1}^{n} \sum_{j=1}^{3} Q_i \cdot p_i \cdot A_j \cdot M_j \tag{13}$$

In the formula L_1: Value of products (crops/livestock) (yuan);

Q_i: Production per unit area of the Type i product (kg/hm^2);

p_i: The Average market value of the i product (yuan/kg);

A_j: Production reduction rate caused by the type j degree of disaster (%);

M_j: Impact area of the type j degree of disaster (hm^2);

$i = 1, 2, \cdots, n$, represents the product (crop / livestock) type;

$j = 1, 2, 3$,Degree of disaster, respectively: mild, moderate, and severe severity.

(2) Opportunity cost assessment method

Market value is not used to estimate such indirect losses as soil salinization loss and land desertification loss. But the loss of this environmental damage can be estimated by opportunity cost.

$$L_2 = \sum_{g=1}^{n} \sum_{j=1}^{3} S_g \cdot V_j \cdot M_j \tag{14}$$

In the formula L_2 : The opportunity cost value of environmental resource loss caused by disasters (yuan);

S_g : Unit opportunity cost of type g environmental resource (yuan/hm^2);

V_j : Loss rate due to the type j degree of disaster (%);

$g = 1, 2, \cdots, n$, type g environmental resource.

The remaining symbols are the same as those mentioned above.

The above two methods can calculate each indicator of agricultural loss and indirect loss, respectively. For the direct economic losses, the data can be collected directly. When calculating, we took the average of the three non-La Nina indicators in 2017-2020 as the reference standard, and calculated the loss caused by the high temperature and drought disaster caused by the triple La Nina event. The calculation results are shown in the following table:

Table 5-1: Loss caused by high temperature and drought disasters

Index	Loss value (billion)	Share of GDP: (%)
Agricultural loss	205866	0.18
crop output value declines in value	164692.8	
animal husbandry output value decline value	41173.2	
Direct economic loss	68622	0.06
loss of public property	19214.16	
loss of private property	8234.64	
disaster relief costs	41173.2	
Indirect loss	148681	0.13
soil salinization loss	47577.92	
loss of land desertification	101103.08	
Total	423169	0.37

In order to show the impact of disasters in different aspects in more detail, we made the following statistical map for intuitive display.

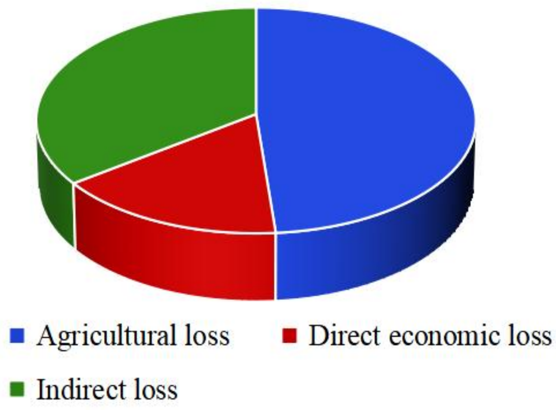


Figure 5-3: Three losses caused by high temperature and drought disasters under the influence of triple La Nina

In terms of the economic loss value of the three primary indicators, agricultural loss accounted for the largest proportion of 48.65%, followed by indirect loss of 35.14%; and the smallest economic loss was direct economic loss, accounting for 16.22%.

More detailed losses are shown in the figure below. According to the value of economic loss, the influence of high temperature and drought and the influence ranged from large to small: the decline value of crop output value, the loss of land desertification, the loss of soil salinization, disaster relief costs, the decline value of animal husbandry output value, the loss of public property, and the loss of private property.

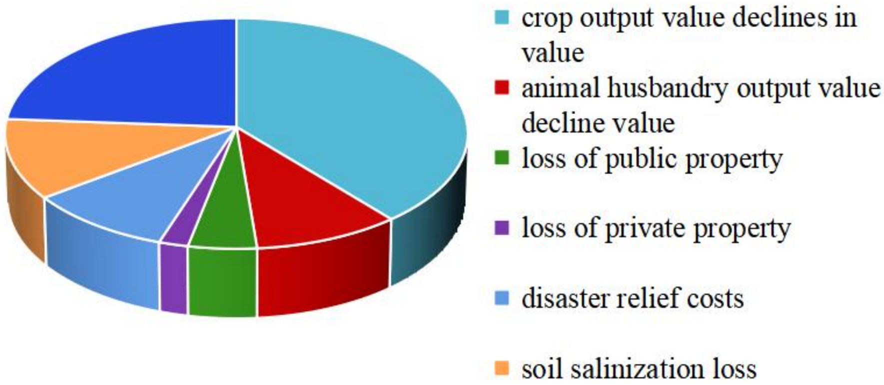


Figure 5-4: Detailed losses caused by high temperature and drought disasters under the influence of triple La Nina

5.3 Coping strategy formulation based on system dynamics

In order to develop effective response strategies to help the government cope with the heat and drought disasters that may continue in the future, we need to consider the effectiveness of different policies. To this end, we can consider developing strategies to address disasters based on system dynamics.

System dynamics is a subject of analyzing and studying information feedback systems. The unique feature of its problem solving lies in that system dynamics is based on the view of causality and structure determining behavior, starting from the microstructure inside the system. With the differential equation as the analysis tool, with the help of computer simulation technology to analyze the internal relationship between the system structure and function and the dynamic behavior, so as to find out the solution to the problem.

In view of high temperature and drought disasters, we propose four points and four response strategies:

(1) Strengthen efforts to cultivate crop varieties with better drought tolerance.

(2) Build water conservancy facilities to minimize the impact of drought.

(3) Afforestation, to reduce the impact of high temperature and drought through the regulation of forest on the environment.

(4) To ensure energy security, the demand for electricity continues to rise in high temperature and dry weather, and energy security needs to be guaranteed in advance.

The system dynamics model is developed below to evaluate the effectiveness of the strategy. The system dynamics model is shown in the figure below:

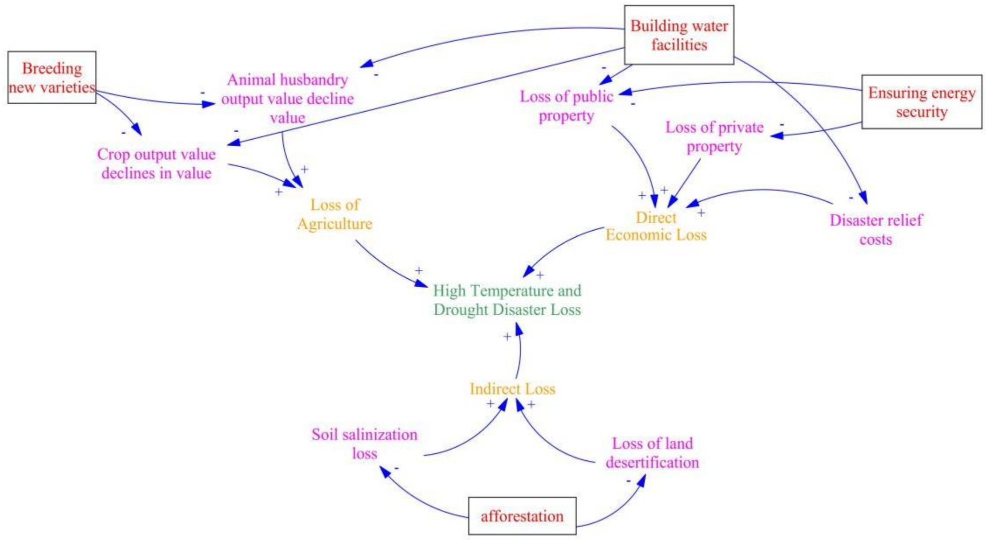


Figure 5-5: Causal Diagram of System Dynamics Model

Then, the stock flow diagram is constructed according to the causality diagram.

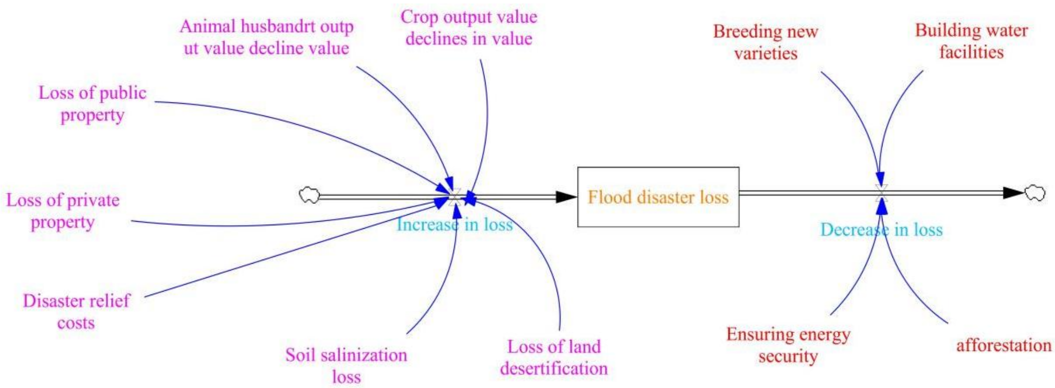


Figure 5-6: Stock Flow Diagram of System Dynamics Model

In combination with our proposed response policy, we spent 10%, 20% and 30% of the disaster losses, respectively, to implement the response measures. All the comparison results are shown in the following figure.

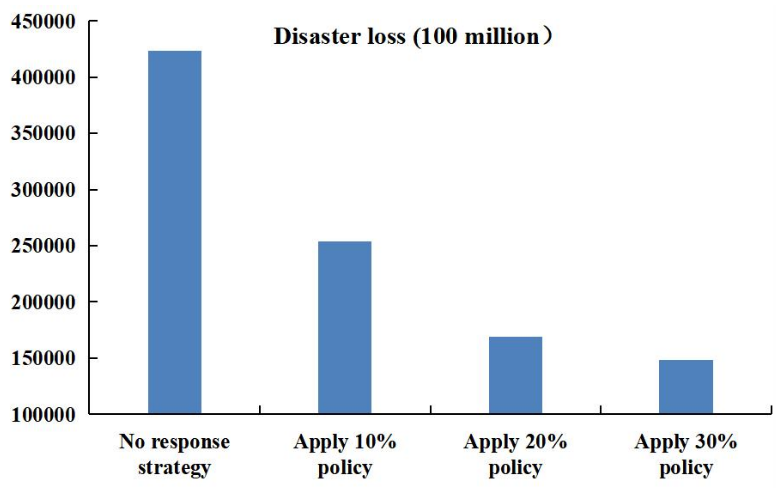


Figure 5-7: Implementation effect of high temperature and drought disaster response strategy

As shown from the figure above, 10% of the disaster loss is reduced by about 60% of the disaster loss, and about 65% when 30% of the disaster loss is spent. Therefore, we should spend about 20% of the estimated disaster losses in advance to implement the response strategy to resist the possible losses of high temperature and drought disasters in advance.

6. Model establishment and solution of question three

6.1 Analysis and preparation before modeling

Problem 3 is the same as the basic task of problem 2, which requires us to take a country more seriously affected by the triple La Nina event as an example, evaluate and analyze the flood losses caused by the triple La Nina event, and put forward targeted response strategies. First of all, we need to select the country, combined with the existing research on question 2, we will continue to select China as the research object. After that, it is necessary to analyze what agricultural and economic and social indicators the flood disaster will affect, and build a disaster loss evaluation index system. Then the evaluation method is selected to build the disaster loss evaluation model, and the model is solved after determining the index weight.

Finally, we can evaluate the impact of a variety of feasible coping strategies, and select the highly effective coping strategies to help the country cope with the triple La Nina event. Problem 3 is basically the same as the idea flow chart of problem 2, which will not be shown here.

6.2 Triple La Nina disaster assessment of floods damage

6.2.1 Construction of flood disaster loss evaluation model

In order to evaluate the loss caused by the flood disaster caused by the triple La Nina event, we need to select the evaluation indicators to construct the evaluation model. In order to comprehensively evaluate all the losses caused by disasters, and comprehensively considering all aspects of agriculture and economy and society, three first-level indicators are selected. They are agricultural losses, direct economic losses and indirect losses. Next, we discuss the second-level indicators below each first-level indicator.

In the flood disaster loss assessment model, five of the two primary indicators of agricultural loss and direct economic loss are still retained. In terms of indirect losses, they can cause different forms of environmental damage due to floods and drought. Therefore, the secondary index are changed as follows.

When the flood disaster occurs, the flood will take away a large amount of soil, causing serious soil erosion problems. At the same time, floods can pollute clean water, leading to a lot of money spent to restore water. Finally, the occurrence of floods will lead to social paralysis for a period of time, causing high loss of work costs. Therefore, the indirect loss index in this model includes three secondary indicators, namely, water erosion loss, water pollution loss and lost work cost.

The following figure shows in detail the various indicators of the high temperature and drought disaster loss evaluation model.

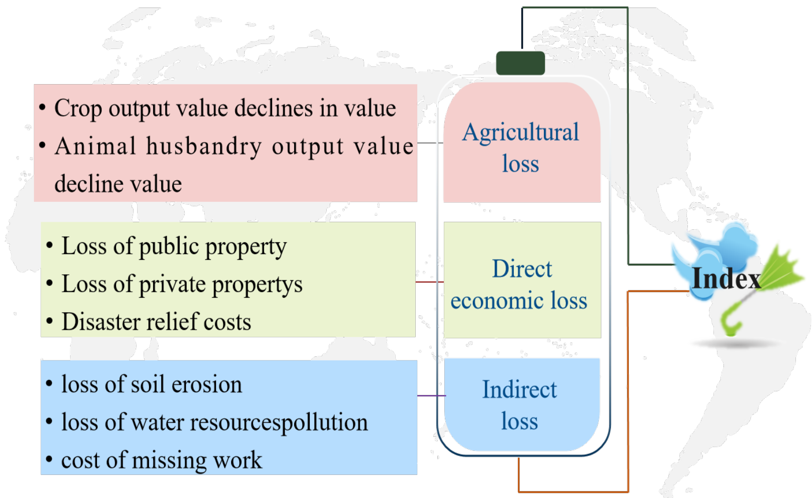


Figure 6-1: Evaluation model of flood disaster loss

6.2.2 Evaluate the solution of the model

For the agricultural losses and direct economic losses in the flood disaster loss assessment model, use the problem 2 formulas (13) and (14) for calculation. In the calculation of indirect losses, we use the governance cost assessment method to calculate the indirect losses. The specific method is as follows.

Governance cost assessment method

$$L_3 = \sum_{e=1}^{2} \sum_{j=1}^{3} W_e \cdot \mu_j \cdot M_j \tag{15}$$

In the formula L_3 : The cost of recovery and treatment of environmental damage caused by disasters (yuan);

W_e : Unit governance cost of type e of environmental damage (yuan/hm^2);

μ_j : Conversion coefficient of the type j degree of disaster(%);

$$e = \begin{cases} 1, & \textit{Soil and water loss} \\ 2, & \textit{Water pollution} \end{cases};$$

The remaining symbols are the same as those mentioned above.

Combined, the above three loss assessment methods can calculate each index of agricultural loss and indirect loss respectively. For the direct economic losses, the data can be collected directly. In the calculation, we took the average of the three non-La Nina indicators in 2017-2020 as the reference standard to calculate the flood damage caused by the triple La Nina event. The calculation results are shown in the following table:

Table 6-1: Loss caused by flood disaster

Index	Loss value (billion)	Share of GDP: (%)
Agricultural loss	182992	0.16
crop output value declines in value	150053.44	
animal husbandry output value decline value	32938.56	
Direct economic loss	217303	0.19
loss of public property	60844.84	
loss of private property	69536.96	
disaster relief costs	86921.2	
Indirect loss	102933	0.09
loss of soil erosion	30879.9	
loss of water resources pollution	51466.5	
cost of missing work	20586.6	
Total	503228	0.44

In order to show the impact of disasters in different aspects in more detail, we made the following statistical map for intuitive display.

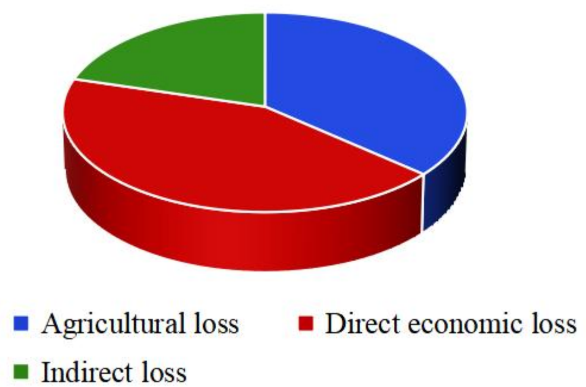


Figure 6-2: Three losses caused by the flood disaster under the influence of triple La Nina

In terms of the economic loss value of the three primary indicators, agricultural loss accounted for the largest proportion of 48.65%, followed by indirect loss, consisting of 35.14%; the smallest loss was direct economic loss, accounting for 16.22%.

More detailed losses are shown in the figure below. According to the value of economic loss, the impact of flood disaster on each index is judged. The influence is from large to small is: the decline value of crop output value, disaster relief cost, loss of private property, loss of water resource pollution, the decline value of animal husbandry, soil erosion loss and cost of lost work loss.

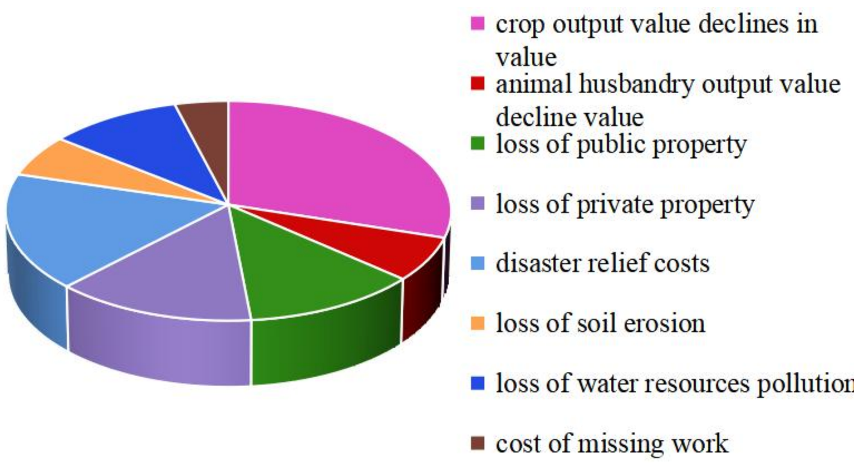


Figure 6-3: Detailed damage caused by floods under the influence of Triple La Nina

6.3 Development of coping strategies based on system dynamics

In view of the flood disaster, we propose the following five response strategies:

(1) Step up efforts to cultivate better crop varieties.

(2) Build water conservancy facilities to minimize the impact of flooding.

(3) Do a good job before the disaster forecast work, and make defense deployment in advance.

(4) Reinforcement the mountains prone to debris flow and other geological disasters to reduce the occurrence of disasters.

(5) Dredge the river course before the flood season to strengthen the dredging role of the rivers.

The system dynamics model is developed below to evaluate the effectiveness of the strategy. Firstly, the causal relationship diagram of each part is analyzed, which is shown in the following figure:

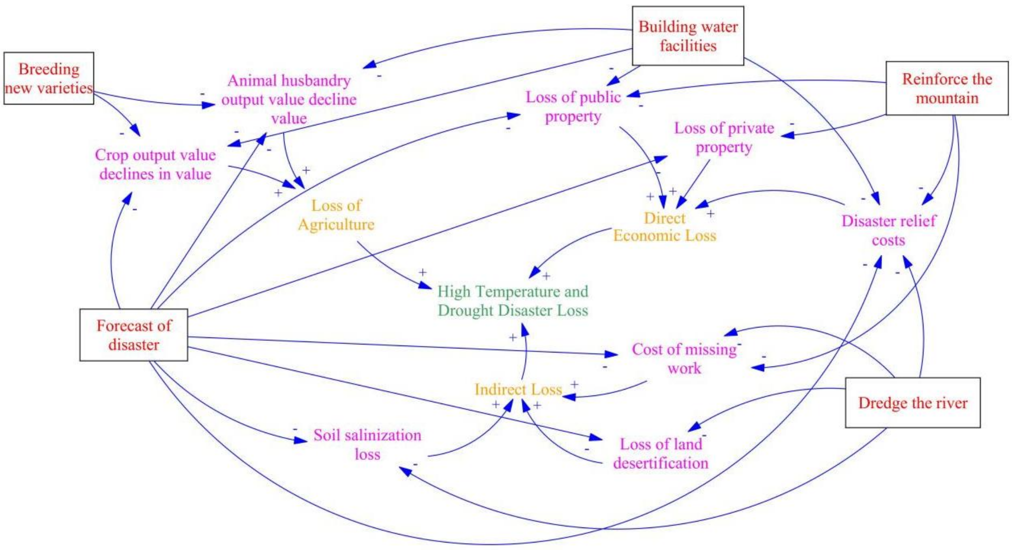


Figure 6-4: Causal Diagram of System Dynamics Model

Then, the stock flow diagram is constructed according to the causality diagram.

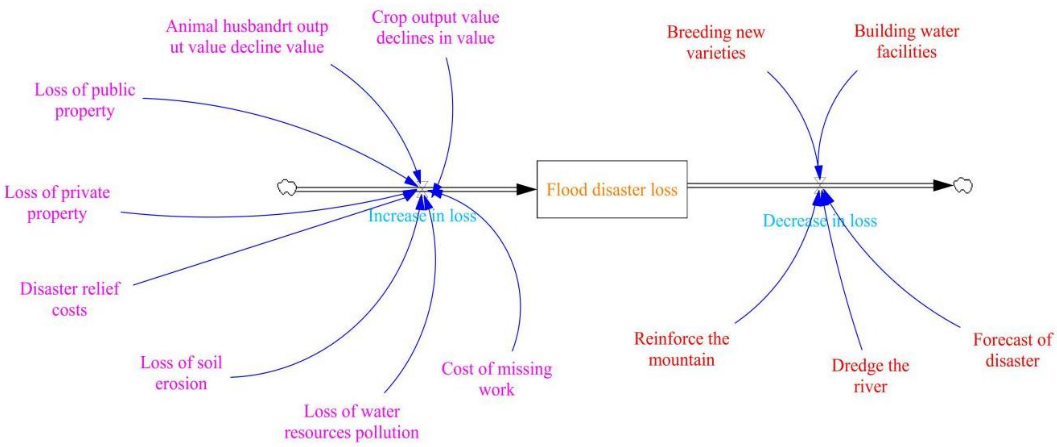


Figure 6-5: Stock Flow Diagram of System Dynamics Model

In combination with our proposed response policy, we spent 10%, 20% and 30% of the disaster losses, respectively, to implement the response measures. All the comparison results are shown in the following figure.

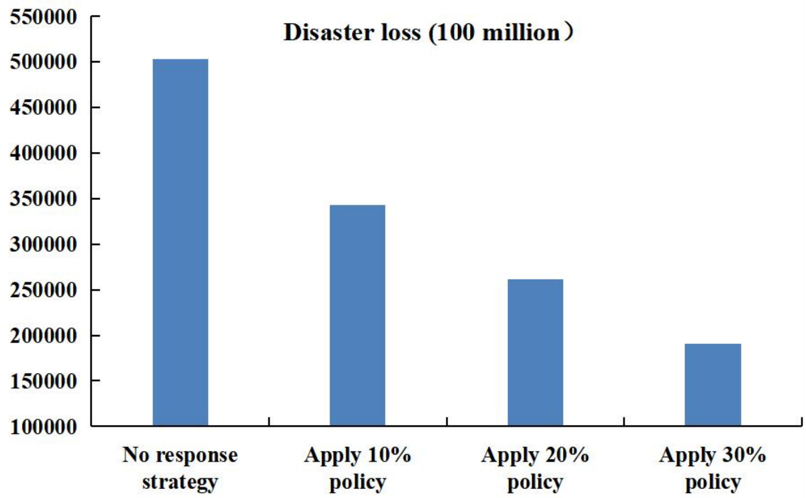


Figure 6-6: Implementation effect of flood disaster response strategy

From the figure above, spending 10% of the disaster loss, about 48% of the disaster loss, and 30% of the disaster loss by about 60%. Therefore, we should spend about 30% of the disaster of the estimated loss in advance to implement the response strategy to resist the possible loss of high temperature and drought disasters in advance.

7. Deal with La Nina

——Report to the Chinese government on response to La Nina

The harm caused by La Nina

La Nina mainly refers to the abnormal cooling of the seawater in the central and eastern part of the Pacific Ocean, which can lead to large freezing of the offshore water surface, resulting in long-term harsh environmental conditions such as low temperature, hypoxia, large proliferation of harmful bacteria and reduced pH conditions. Not only shorten the growth cycle, but also can cause serious production reduction or even lost production.

In recent years, due to the worldwide climate change and Marine ecological environment deterioration, coastal areas continue high temperature, heavy rainfall, ice and other extreme weather occurs, margin outbreak of green tide and other harmful algae China frequently occur, to our country thorn land-based breeding and shallow sea proliferation production and product quality have caused a serious impact, annual losses up to 10 billion yuan of above, induced secondary disasters more breeding industry once showed a negative growth.

At the same time, under the influence of La Nina, the frequency of agricultural meteorological disasters in China has increased significantly in recent years, with many disasters occurring and occurring. In particular, in 2021, the climate was significantly abnormal. In January, many places saw extreme low temperature, frequent severe convection weather in spring, rare heavy rainfall and flood disaster in northern China in flood season, and continuous continuous rain in autumn, which brought great adverse effects on grain and agricultural production. It is expected that the heavy occurrence of disasters in the future, combined with various factors such as production costs and the epidemic, will bring greater challenges to the security of food and important non-staple food supply.

Relevant policy recommendations

In view of the above problems, we put forward the following systematic countermeasures and prevention strategies for Marine aquaculture and agricultural agriculture, in order to provide reference for enhancing the industry's ability to resist risks, reduce production losses, and ensure the sustainable, efficient and healthy development of the industry.

◆ *Marine aquaculture*

(1) Strengthen infrastructure construction, improve the ability to resist and respond to risks

Standard breeding pond construction standard, improve the construction of water well, oxygen, light, shade, etc facilities, while increasing investment in disaster prevention and resistance facilities construction, for different regions in flood season and high temperature pond, water supply difficulties, advocate interval cooperation, financial support and local funds, build emergency water channel or large reservoir, set up large block sluice between pond aquaculture area and sea area, abnormal lock water storage, to prevent offshore pests into the pool and extreme weather supply pond, water supply.

(2) Accelerate the process of breeding of superior varieties, and consolidate the foundation of thorn ginseng germplasm

In view of the breeding and production needs of different environmental conditions such as summer high temperature and low salt in flood season, make full use of the excellent production traits of thorn ginseng, increase the breeding of superior varieties with high stress resistance and salt resistance and compound dominant traits, select new varieties (lines) and carry out large-scale propagation, demonstration and promotion. Strengthen the combination of industry, university and research, advocate scientific research institutes and leading enterprises to jointly build a research and development platform, build a modern seed industry enterprise integrating "breeding, breeding and promotion", gradually establish the industrial parent supply system, provide excellent germplasm guarantee for the increased breeding and production from the source, and improve the industrial coverage rate of improved varieties and good products.

◆ Agriculture

(1) Prevent the spring drought in the northern winter wheat area

One is to water up the wall. Overhaul irrigation facilities in advance and strengthen drought monitoring. Second, agronomy to protect the environment. Early spring vigorously promote sugar rake hoe suppression and other measures to reduce the evaporation of soil, increase soil water storage.

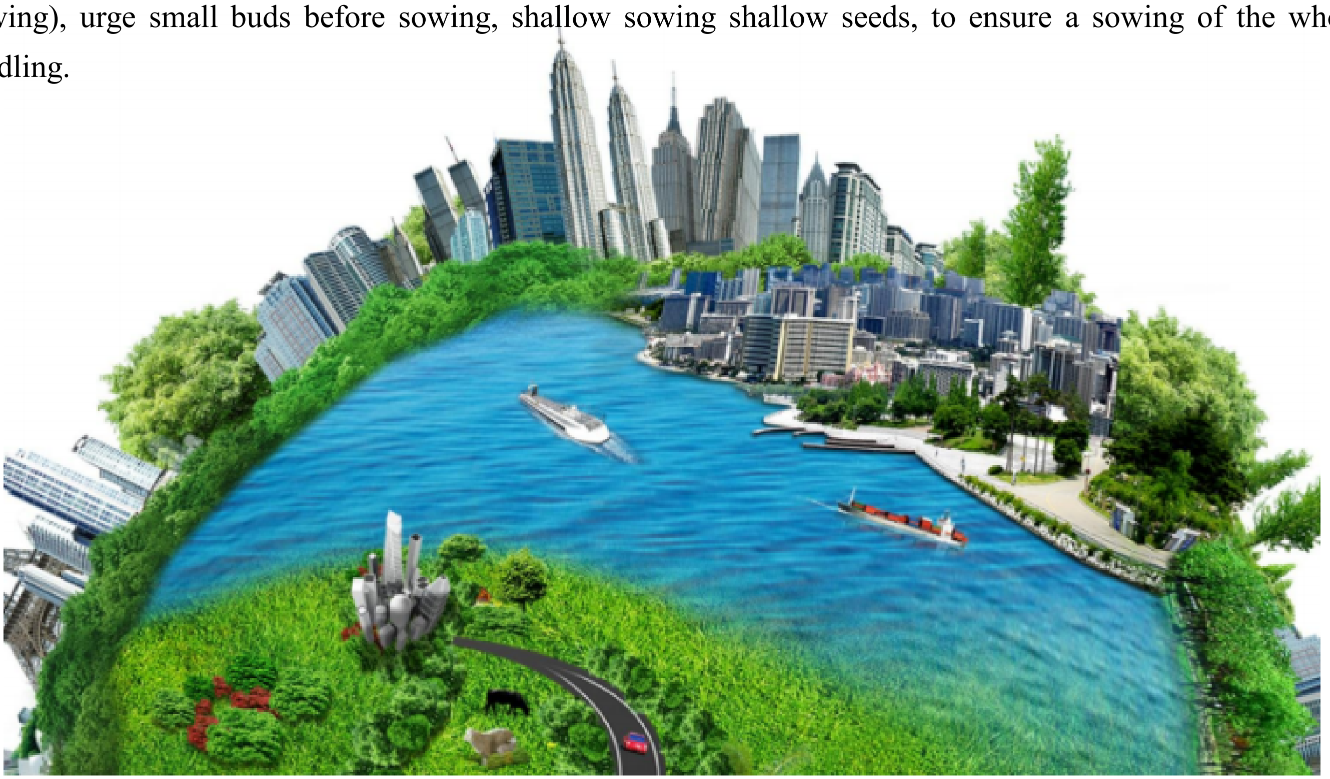
Third, chemical control and humidification. Leaf surface spray with drought resistance and water protection agent to increase the drought resistance of plants, cool down and damp, and provide necessary water and nutrients for leaves.

(2) Prevent the spring drought in the western northeast China

First, rationally adjust structural structure to avoid disasters. To guide the old arid area in western northeast China to conform to the weather and combine the adjustment of planting structure. Reserve the required seeds in advance to meet the production needs. Second, to promote drought-resistant sowing technology. In the field block with irrigated conditions, timely irrigation, build a wall sowing. Vigorously promote drought-resistant technologies such as plastic film mulching and drip irrigation under film, and organize cross-regional machine tillage and machine sowing operations. Third, the scientific determination of crop varieties. According to the climatic conditions such as accumulated temperature and the needs of structural adjustment, the main varieties should be scientifically determined and transferred as soon as possible.

(3) Prevent spring waterlogging in the central and eastern parts of Heilongjiang Province

Speed up drainage and stains. Taking advantage of the favorable conditions of spring temperature rise and large wind force, ploughing and drying the wall. Soil moisture saturated areas make full use of large machinery to rake land as soon as possible to speed up snow melting and farmland freezing. We will implement deep loosening of land preparation, and promote scientific and standardized land preparation. Timely suitable for the wall sowing. Determine suitable ripe varieties early and prepare seeds. Once the sowing period is postponed, timely select appropriate and early maturity varieties (or 1~2 days before sowing), urge small buds before sowing, shallow sowing shallow seeds, to ensure a sowing of the whole seedling.



Appendix

-Notes

-The actual length of the article is 25 pages, which fullfills the requirements of the competition.
-See attachment(D2022103113305fj.rar) for core code details.

-Strengths & Weakness

Strengths:

(1) Using the Markov prediction method, combined with historical data from 1957-2022, the probability of accurate counting is 1957-2022.

(2) In the establishment of the disaster loss assessment model, the various effects are comprehensively considered, which makes the model evaluation effect better.

(3) System dynamics-based methods are used to make the strategy more effective, and the implementation effect can be calculated.

Weakness:

(1) When collecting the data, the data in some areas is difficult to obtain, so the fuzzy data is used in some places, which may have some impact on the model accuracy.

(2) Multiple methods are not used to predict the possibility of future triple La Nina events, and the accuracy of the prediction cannot be verified.

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