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T1 ________________	**87622**	F1 ________________
T2 ________________		F2 ________________
T3 ________________	Problem Chosen	F3 ________________
T4 ________________	**E**	F4 ________________

2018

MCM/ICM

Summary Sheet

How does climate change influence regional instability?

Summary

With the continuous development of human society, the climate problem has gradually become the focus of every state. This article discusses the impact of climate change on regional instability and conducts a multi-angle study and analysis.

For Task 1, the K-means algorithm is used to cluster the countries in the world based on the geographical location features. Calculate the distance between each cluster center and the climatic disaster zone, and then evaluate it as a value of climatic indicator. A comprehensive evaluation model of national vulnerability within this climatic factor index is established based on AHP to measure the vulnerability of the country and the impact of climate change. Through the sensitivity analysis of the vulnerability of the country to climate change, it is empirical that the countries with higher vulnerability are more vulnerable to climate change.

For Task 2, we first conduct the correlation analysis between the climate factor indicators and the other secondary indicators of the evaluation system. By the linear fitting, the relationship between the climate indicator and the relevant secondary indicators can be obtained. Based on that, the change of each secondary index can be obtained when the climate index changes. By substituting the results into the model in Task two, it can be found that when climate indicators are changing positively, Sudan's vulnerability increases. At the same time, when climate indicators are gradually dwindling to zero, Sudan's vulnerability diminishes gradually.

For Task 3, by using AHP, China's climate change index evaluation model is established. We deal the nine types of climate change, which common occur in China, with binarization processing. And then we figure out 512 cases of climate change that could occur in a year. Using the above model, we can figure out the evaluation index for all cases. The evaluation index is used to modify the climate indicators in task one to obtain the cases of climate change that could let China become a vulnerable country.

For Task 4, we establish a multi-objective programming model with two objectives, which are, the country's vulnerability score fluctuates within a given range and the total cost of the intervention is minimum. Adjust the value of China's climate indicator artificial, and figure out the best case by human intervention. Then solve out the change of each intervention factor and the total cost of intervention in this situation. Empirically, human intervention can mitigate the risks of climate change in China.

For Task 5, we expand the scope of the application object of national vulnerability comprehensive evaluation model. Correct the maximum distance parameters in the model and it will work on smaller “states”. Furthermore, the model can be optimized by detailing classification of the climate zone. For larger “states”, we focus on the contribution of each country to the vulnerability of the region where it is in and the vulnerability score of each country in order to get the vulnerability score of larger "states".

Finally, we evaluated scientifically for the three main models of this paper, and discuss the advantages and disadvantages of the model and the direction of the improvement.

Keywords：K-means, Climate change, AHP, country's vulnerability, MOP, Matlab

1.Introduction

1.1 Background

With the continuous development of human society, it has a great impact on the global environment. The environmental changes in the earth have gradually become the problems to be faced by human society. Statistics show that since the 1970s, the number of natural disasters in the world has been increasing year by year, and the number of disasters affected and disastrous losses have also risen. When the environment has unpredictable sudden changes such as tsunamis, earthquakes and volcanic eruptions, some countries, especially developing countries, will face great challenges in their state administration and will even make them change from a stable country to a fragile country. That is, The state where the state government is not able to, or chooses not to, provide the basic essentials to its people.

1.2 Statement of Problem

We are required to develop a model that can determine a country's fragility and simultaneously measures the impact of climate change. We should find the optimal index to show whether a state is fragile, vulnerable, or stable. In addition, our model should be able to identify how climate change increases fragility through direct means or indirectly as it influences other factors and indicators. Furthermore, we select one of the top 10 most fragile states, using our model to see if the state is tend to be stable without considering the climate effect.

After that, we select another state not in top 10 most fragile states, define an appropriate tipping point which the country turn to fragile and predict when a country may reach it. Besides, through our model, we figure out which state driven interventions could mitigate the risk of climate change and prevent a country from becoming a fragile state. And whether our model is work on smaller "states" or larger "states".

2. Problem analysis

2.1 Analysis of Task 1

In Task 1, in order to judge the country's vulnerability, we mainly completed the construction of a comprehensive national vulnerability assessment system. In the process of solving problem, we cluster the countries by geographical location features to improve the efficiency of the model operation. Then, in the process of building the comprehensive national vulnerability assessment system, we have introduced six first-level indicators and twelve second-level indicators to identify the country's vulnerability. At the same time, we will also build a comprehensive national vulnerability assessment model based on AHP to obtain more scientific weight values. At the end of the mission, we will also conduct a sensitivity analysis of climate change to national vulnerabilities and verify the relationship between sensitivity and national vulnerability.

2.2 Analysis of Task 2

In Task Two, we selected the Sudan, which has a more distinctive climate and geographical location, to discuss the impact of climate change on the country's vulnerability. Taking into account that the climate change has some impact on the secondary indicators, we first conduct a correlation analysis of the secondary indicators of climate change and evaluation system. Afterwards, the relationship between the CRI and each index value with correlation is obtained by the fitting method. We model the climate change by changing the global climate risk index by a positive Δy. The seven relevant index values obtained at this time were brought into the national comprehensive vulnerability assessment model established in Task 1, and the Sudan's vulnerability score was obtained. Based on this, we study the impact of climate change on Sudan's vulnerability. In the same way, we reduce the global climate risk index and find the corresponding vulnerability score. Based on this, we can research the changes in Sudan's vulnerability when ignoring climate change.

2.3 Analysis of Task 3

In Task 3, we chose China as the research object. First of all, we calculated the probability of different climate changes in each month and established an evaluation model of China's climate change index based on AHP. Furthermore, we do combination operation to the 9 major climate changes in China and use the evaluation model of China's climate change index to get the evaluation index of 2^9=512 results. After that, we use the evaluation index to revise the first-level climate indicator in Task1 and calculate the national vulnerability index again. Based on this, we can get climate change condition which may lead to the transformation of the country into a fragile country.

2.4 Analysis of Task 4

In task 4, we mainly completed the establishment of the multi-objective programming model based on the national vulnerability assessment index and brought into concrete countries for solution. First, we identify the indicators that external intervention can regulate by looking for information. After determining the variation range of national vulnerability score, the constraint conditions of each index are determined by the control variable method. And completed the establishment of multi-objective programming model. In the solution part of the model, we choose China as the research object. By querying the government financial report to determine the cost of various intervention methods, the results corresponding to the multi-objective programming model are multiplied and summed. Thus we can get the optimal external intervention cost and external intervention method.

2.5 Analysis of Task 5

In task 5, we mainly completed the expansion and improvement of national vulnerability comprehensive evaluation system in smaller "states" and larger "states". In the smaller "states" model, we reduce the interval between temperature bands so that we can divide more temperature zones. The vulnerability evaluation index which meets the requirements of smaller "states" can be obtained more precisely by clustering analysis of each temperature band. As for the larger "states", we focus on the contribution of each country to its vulnerability score, so as to calculate the weight of each country, and ultimately derive the vulnerability index applied to larger "states".

3.Definitions

Variable	Definition
C_j ($j = 1,2,\dots,94$)	Climate indicators for all types of countries
x_{ij} ($j = 1,2,\dots,94, i = 1,2,\dots,4$)	The shortest distance from the cluster center to each disaster zone
k_i	The weight coefficient of different disaster zones
W_{mni}	Weight code
C_{mni}	Value code
E_i ($i = 1,2,\dots,178$)	National vulnerability score
S	Sensitivity of E_i to C_j
X_i ($i = 1,2,\dots,12$)	Data for the i^{th} second-level indicator of Sudan
Y	Sudan's climate index
γ	Pearson correlation coefficient
y	the global climate risk index（CRI）
y_i(i=1,2,...,10)	Sudan's CRI for 2008 to 2017
D_j	Chinese climate change assessment index.
Q	the total cost of intervention
c_n	The cost of interfering with the corresponding index
q_n	The margin of intervention

4. Assumption

1. Assume that the data used is all true and valid.
2. Countries with the same clustering results have the same climate index values.
3. Assumed that the structure of judgment matrix is reasonable and universal.
4. Assumed that the selection of the coefficients in the model is reasonable and valid and representative.
5. Ignore the impact of climate change on indicators of low correlation in relevance analysis.
6. Assumed that the capital's latitude and longitude represented the national position.

5. The establishment and solution of the model

5.1 Task1

5.1.1 The selection of indicators and the construction of comprehensive evaluation system of national vulnerability.

A fragile state is a state where the state cannot or does not want to provide basic essentials to its people. It is obvious that unstable governments, potential racial and political differences can all contribute to national vulnerability. And we have to say that the impact of climate change on the country's vulnerability cannot be ignored either.

1. Clustering analysis of geographical location characteristics in various countries

In recent years, the impact of climate change on regional instability has become more pronounced, while climate change has the geographical feature of regionalization. Therefore, we selected 178 major countries in the world and checked their latitude and longitude. These countries are classified according to the northern, northern, tropical, southern, and southern frigid climates as shown in Figure 1.

On this basis, according to the countries included in each climatic, the clustering analysis with k-means clustering algorithm is used to obtain the results as shown in Figure2.

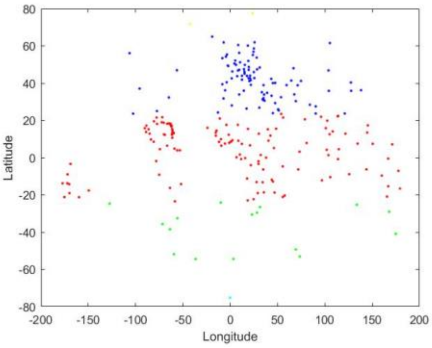


Figure 1

National location map classified by climate zone

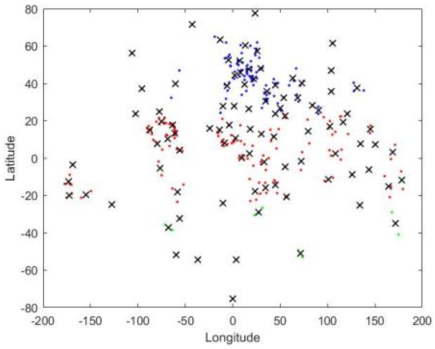


Figure 2

The climatic countries cluster map

K-means clustering algorithm flow chart shown in Figure 3. First of all, for the tropical countries that contain more countries, we randomly select the number of categories k in a certain range for simulation classification. Different values of k correspond to the degree of cohesion D_k between different countries, that is, the maximum distance between their location and their cluster centers. It is observed that when $k = 44$, the degree of agglomeration between the countries in each category and the cluster centers are reasonable as $D_k = 75.4855km$.

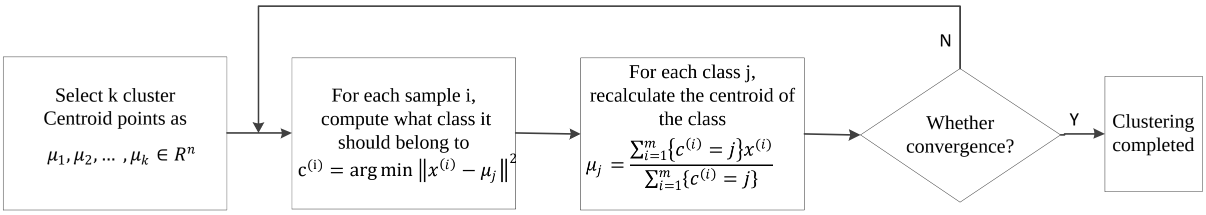


Figure 3 K-means clustering algorithm flow chart

Based on this, for other climatic zones, we draw up the classification number k for pre-division at first. If the maximum distance between countries in each cluster from its cluster center is greater than the critical value D_k, we can increase the classification number k until the maximum distance is less than the critical value D_k. We consider the clustering result at this time is scientific and reasonable.

2. The Composition and Construction Basis of National Vulnerability Assessment System

Build the comprehensive evaluation system of national vulnerability.As shown in Figure 4, in the comprehensive national vulnerability assessment model, we use climate change as a first-level indicator and directly affect the assessment of national vulnerability. In this model, climate change also indirectly affects the assessment of national vulnerability through secondary indicators.

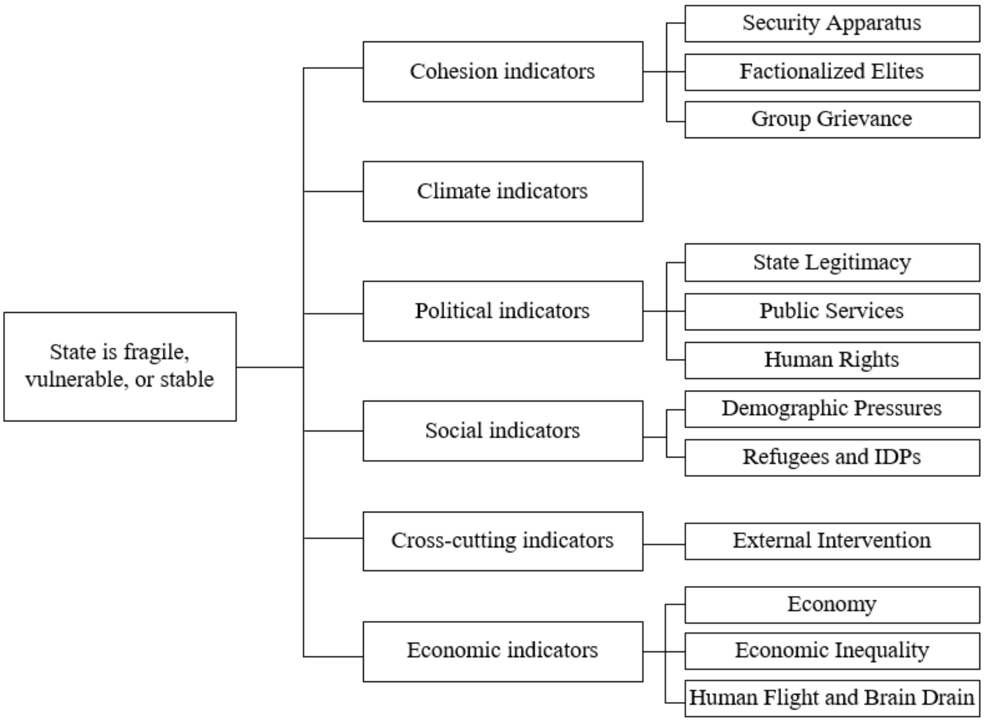


Figure 4 Schematic diagram of the comprehensive evaluation system of national vulnerability.

3. Definition and data processing of climate first-level indicators

The above problem is given by the geographical coordinates (longitude and latitude), and we need to calculate the actual distance between two points. If the geographical coordinates of point A and point B are(x_1, y_1) and(x_2, y_2), respectively, then the Cartesian coordinates of point A and point B are

A$(\mathrm{R}\cos x_1 \cos y_1, \mathrm{R}\sin x_1 \cos y_1, \mathrm{R}\sin y_1)$ $(Rcos x_2 cos\ y_2, Rsin x_2 cos\ y_2, Rsin y_2)$

Where $\mathrm{R} = 6370$ is the radius of the earth.

The actual distance between point A and point B is

$$d = Rarccos\left(\frac{OA \cdot OB}{|OA| \cdot |OB|}\right) \tag{1}$$

Simplify, and we have

$$d = Rarccos[cos(x_1 - x_2)\, cos y_1 cos\ y_2 + sin y_1 sin y_2] \tag{2}$$

As mentioned above, we have obtained the clustering centers of the countries in each climatic zone, then we transfer the disastrous line to segment for directly expression. So that we can get the shortest distance between each cluster center and each disaster zone. Obviously, the shortest distance from the disaster zone is inversely proportional to the climatic index value, and the shorter distance from the disaster zone, the faster the climate vulnerability should rise. Therefore, the shortest distance between the above and the climatic index value should be a convex monotonically decreasing function. Based on this, we choose the exponential function shown in the following formula to obtain the climate index values of various countries.

$$C_j = \sum_{i=1}^{4} k_i e^{-a x_{ij}}\ , j = 1,2, \dots, 94 \tag{3}$$

In this formula, C_j is the climatic index value of all kinds of countries after clustering, x_{ij} is the shortest distance between each cluster center and each disaster zone, $j = 1,2, \dots, 94$ indicates 94 kinds of countries obtained by cluster analysis, $i = 1,2, \dots, 4$ represent four different disaster zones. k_i is the weight coefficient of different disaster zones.

We find lots of data and get the number of death toll in the four different disasters over the past 20 years. Based on this, we can measure the risk of each disaster zone and find the weight coefficient corresponding to different disaster zones. In addition, combined with the data characteristics of x_{ij} as mentioned above, we add a correction coefficient a before x_{ij}, taking $a = 0.001$, so as to make the finally calculated index value branch more reasonable.

5.1.2 National Vulnerability Assessment Model Based on Analytic Hierarchy Process

Based on the above-mentioned comprehensive national vulnerability assessment system, using AHP to analyzes each country separately from six aspects of economy, politics, society, cohesion, climate and cross indicators. Determine the corresponding indicator weights of indicators at all levels (The procedure of using Analytic Hierarchy Process is shown in Appendix I).

When assessing the importance of the first-level index, the judgment matrix of the first-level index on the comprehensive evaluation system of opportunity and risk is constructed. After referring to the relevant materials and thinking repeatedly, the judgment matrix of the first-level index as shown in Table 1 is finally obtained.

Table 1 first-level indicators to determine the matrix

	Cohesion	Climate	Political	Social	Cross-cutting	Economics
Cohesion	1	1/3	1/2	1/2	2	1/4
Climate	3	1	1	1/2	2	1/3
Political	2	1	1	1	3	1/2
Social	2	2	1	1	3	1/2
Cross-cutting	1/2	1/2	1/3	1/3	1	1/3
Economics	4	3	2	2	3	1

In the same way, we can construct the judgment matrix of the secondary index under each first-level index, so as to obtain the judgment matrix of the national vulnerability comprehensive evaluation system. The obtained judgment matrix is input to MATLAB software and solved by AHP, and the corresponding weights and the corresponding total weights of the first-level index and the secondary index in this comprehensive evaluation system are obtained, as shown in Table 2.

Table 2 weight table of comprehensive evaluation system.

	A level of indicators	Weights	Secondary indicators	Weights	The corresponding total weight	Weight code	Value code
National Vulnerability Assessment System	Cohesion Indicators	0.0866	Security Apparatus	0.2971	0.0257	W_{11}	C_{11}
			Factionalized Elites	0.1629	0.0141	W_{12}	C_{12}
			Group Grievance	0.5400	0.0468	W_{13}	C_{13}
	Climate Indicators	0.1488	Climate Indicators	0.1488	0.1488	W_{21}	C_{21}
	Political Indicators	0.1705	State Legitimacy	0.4000	0.0682	W_{31}	C_{31}
			Public Services	0.2000	0.0341	W_{32}	C_{32}
			Human Rights	0.4000	0.0682	W_{33}	C_{33}
	Social Indicators	0.1945	Demographic Pressures	0.6667	0.1297	W_{41}	C_{41}
			refugees and IDPs	0.3333	0.0648	W_{42}	C_{42}
	Cross-cutting Indicators	0.0671	External Intervention	0.0671	0.0671	W_{51}	C_{51}

	Economics Indicators	0.3325	Economy	0.5400	0.1796	W_{61}	C_{61}
			Economic Inequality	0.1629	0.0542	W_{62}	C_{62}
			Human Flight and Brain Drain	0.2971	0.0988	W_{63}	C_{63}

After getting the above data, we test the consistency of the judgment matrix. Here we set the measure of consistency test:

$$CR = CI/RI \tag{4}$$

In formula 4, CR represents the consistency ratio, when $CR \leq 0.1$, we consider that the consistency of the judgment matrix represents acceptable and consistency test is passed. CI represents the consistency index. Formula 5 is：

$$CI = (\lambda - n)/(n - 1) \tag{5}$$

In formula 9,λ represents the largest eigenvalue of the judgment matrix, n represents the number of indicators (elements) in the judgment matrix. When $CI = 0$, the judgment matrix has complete consistency. The higher CI growth, the more serious the matrix inconsistency. RI represents a random consistency indicator. We can know that Saaty derived RI data through a large number of experiments, as shown in Table 3.

We do consistency test to the judgment matrix of the first-level index in the comprehensive evaluation system of national vulnerability obtained $CR = 0.0298 < 0.1$ which means the judgment matrix passed the consistency test. By the same token, we can find that all secondary index pass the consistency test and has good consistency. Due to the limited space of this article, we will not repeat it.

Table 3 RI random consistency indicator

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.58	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.44

For each country, the final weighted value W_{mn} of each indicator and the corresponding indicator value C_{mn} are weighted to obtain the score $E_i(i = 1,2, \dots ,178)$ in order to get the vulnerability of different countries.

$$E_i = W_{11_i}C_{11_i} + W_{12_i}C_{12_i} + W_{13_i}C_{13_i} + W_{21_i}C_{21_i} + W_{31_i}C_{31_i} + W_{32_i}C_{32_i} + W_{33_i}C_{33_i} + W_{41_i}C_{41_i} + W_{42_i}C_{42_i} + W_{51_i}C_{51_i} + W_{61_i}C_{61_i} + W_{62_i}C_{62_i} + W_{63_i}C_{63_i} \tag{6}$$

The national vulnerability assessment system established in formula (6) scores the above 178 countries, which can reflect the vulnerability of the country. (Please refer to the appendix for details)

Figure 5 shows a comparison about the vulnerability scores of 178 countries considering if the climate changed. It can be seen from the figure that when climate changing is taken into account, most countries have a certain increase in vulnerability score. So climate change increases the vulnerability of countries.

By using Matlab, the vulnerability scores of 178 countries can be draw into curves shown in Fig 6. According to the change of the slope, we find when the national vulnerability score reach score 6.5, the slope of curve will increase sharply.

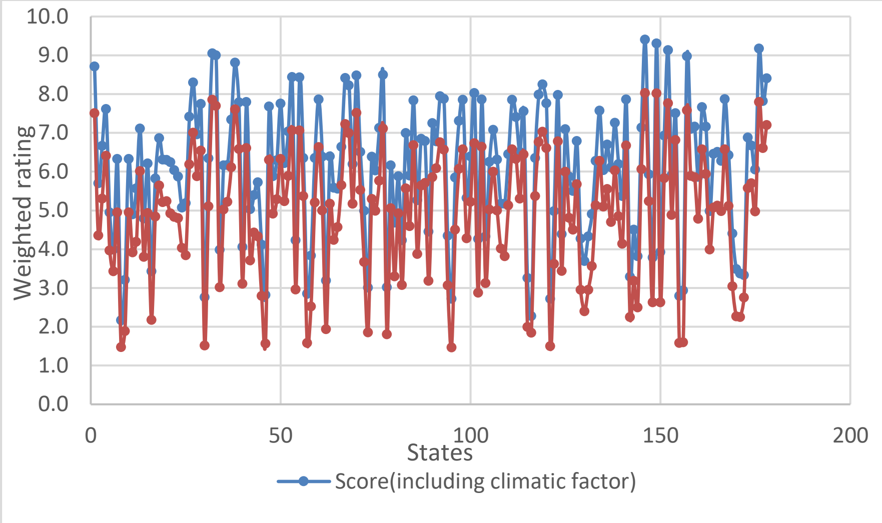


Figure 5 The score's variation after considering climate change

So we determined score 6.5 as boundary to show a country is stable or not. As shown in Figure 6.

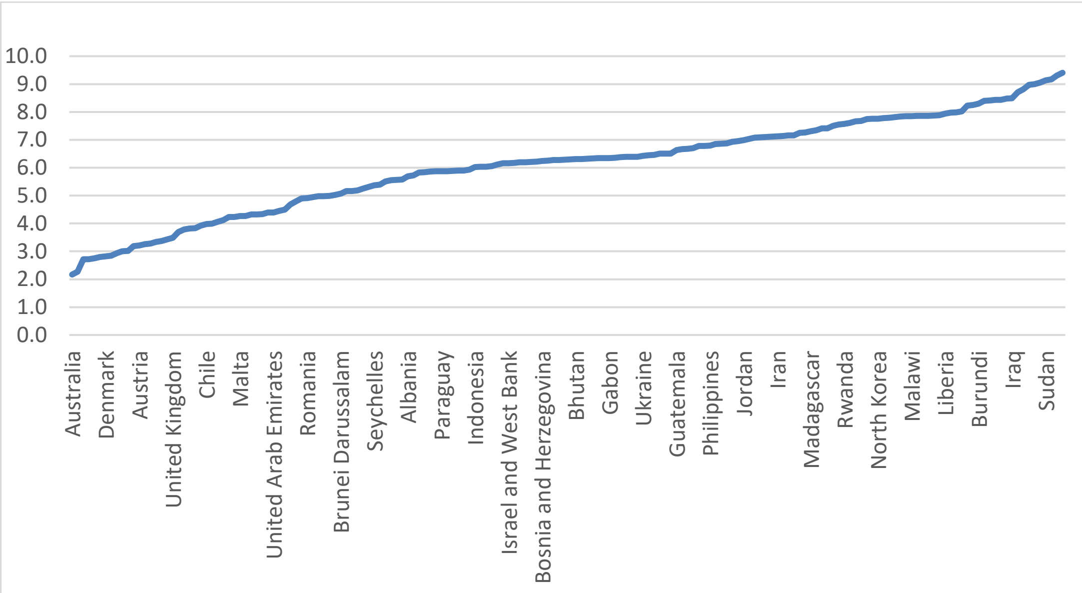


Figure 6 National Vulnerability Score Schematic

5.1.3 Sensitivity Analysis of Climate Change to National Vulnerability

This article will focus on the impact of a small change in climate change parameter C_j on national vulnerability E_i.

The relative degree of change is used to measure the sensitivity of the results to the parameters. The sensitivity of E_i to C_j is denoted as $S(E_i, C_j)$, which is defined as

$$S(E_i, C_j) = \frac{\Delta E_i / E_i}{\Delta C_j / C_j} \approx \frac{dE_i}{dC_j}\frac{C_j}{E_i} \tag{7}$$

Among them, the abscissa represents the national vulnerability ranking after considering the impact of climate factors, of which the higher the ranking, the more vulnerable the country. The ordinate represents the sensitivity of climate change to national vulnerability.

From the figure we can clearly see that a high ranking mainly suggest a high score of sensitivity. This shows that environmental change has a catalytic effect on fragile countries, while the more stable a country are, the more possibility a country will not effect by the climate change may take place.

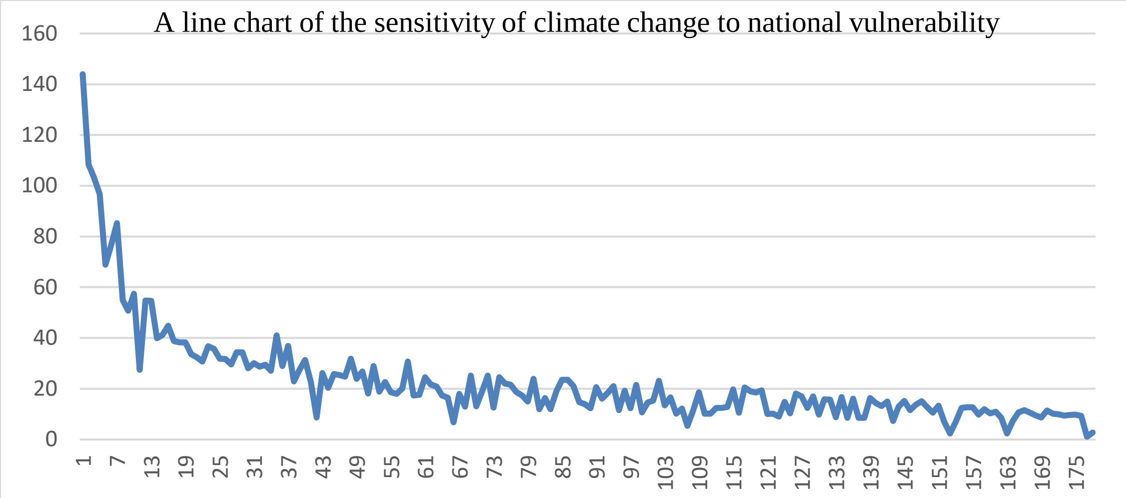


Figure 7 A line chart of the sensitivity of climate change to national vulnerability

5.2 Task 2

By looking for the background information on the ten most vulnerable countries, we selected the Sudan, which has a distinctive climate and geography. It is located in the northeast Africa, the Red Sea coast, the eastern of the Sahara Desert and is exposed to direct sunlight throughout the state. It is one of the hottest place in the world, arid and hot. In the following we will conduct an in-depth study and discussion on the impact of climate change on the country's vulnerability.

If the climate indicator is independent from the rest of the secondary indicators, the vulnerability of the country will also increase as the climate changes. However, in fact, some of the secondary indicators of the comprehensive evaluation system of national vulnerability are affected by climate change. We will discuss the situation when considering the impact of climate change on each of the second-level indicators as follow.

5.2.1 Correlation Analysis between Climate Change and Secondary Indicators

In the comprehensive national vulnerability assessment system, we have introduced 12 secondary Indicators. Taking into account that climate change will change the value of some of the secondary indicators, thus indirectly affecting the national vulnerability index. For the Sudan, we solve the correlation between its 12 secondary indicators and climate change parameters, and select the secondary indicators with higher relevance for analysis. The hypothetical indicators that affect national vulnerability are shown in Table 4.

Table 4 Supposed indicators affecting national vulnerability

	Index number	Index name
Cohesion indicators	X_1	Security Apparatus
	X_2	Factionalized Elites
	X_3	Group Grievance
Political indicators	X_4	State Legitimacy
	X_5	Public Services
	X_6	Human Rights
Social indicators	X_7	Demographic Pressures
	X_8	Refugees and IDPs
Cross-cutting indicators	X_9	External Intervention
Economic indicators	X_{10}	Economy
	X_{11}	Economic Inequality
	X_{12}	Human Flight and Brain Drain

The indicators in Table 4 are assumed indicators, and the specific correlation between each indicator and climate change can not be determined. Therefore, it is necessary to calculate the correlation between climate change and assumed indicators and select the high correlation indicators for analysis.

Pearson correlation coefficient is used to measure the linear relationship of distance variables, which is defined as follows:

$$\gamma = \frac{\sum(X_i - \bar{X})(Y - \bar{Y})}{\left(\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\right)\left(\sqrt{\sum_{j=1}^{n}(Y - \bar{Y})^2}\right)} \tag{8}$$

Where, γ represents Pearson correlation coefficient. Y represents the Sudan's climate index. X_i is the ith secondary indicator of Sudan. The value range of γ is [-1,1]. The greater the absolute value of the correlation coefficient, the higher the correlation, that is, the closer the correlation coefficient to ± 1, the higher the correlation between the two. On the contrary, the closer the correlation coefficient is to 0, the lower the correlation between them is.

The Pearson correlation coefficient was introduced to show the correlation between climate change and calculate the degree of correlation γ_i between each index and climate change. γ_i indicates the correlation between climate change and the ith indicator. Table 1 shows that i = 1,2, ..., 12.

Using SPSS analysis software to process the data, we can get the correlation of each index to climate change. According to the level of relevance of the indicators, we filter the indicator of low correlation. Select the higher correlation of indicators shown in Table 5.

Table 5 The name and the number of selected indicators

Index number	Index name	Index number	Index name
X_3	Group Grievance	X_{10}	Economy
X_5	Public Services	X_{11}	Economic Inequality
X_8	Refugees and IDPs	X_{12}	Human Flight and Brain Drain
X_9	External Intervention		

5.2.2 A model of the influence of climate change on the vulnerability of Sudan based on linear fitting

In order to further study the impact of climate change on these seven indicators, we find the seven index values of Sudan from 2008 to 2017. In addition, we find the global climate risk index (CRI) of the Sudan in ten years. The relationship between CRI and each indicator value is obtained by linear fitting method.

Using the fitting function in Matlab, the CRI value for the decade of Sudan is the ordinate. The indicators value for the decade of Sudan in Table 5 is the abscissa. Based on this, the relation curve between CRI and seven indicators with correlation is drawn. There is a certain randomness in the CRI value for each year. For the specific year, the difference between the actual value of CRI and the point on the fitting curve is the randomness of the CRI value of the year.

When the CRI changes Δy, correspondingly the x-coordinate changes the Δx, and add the Δx to the original value to obtain the corresponding index value when the CRI changes. Figure 8 shows the relationship between CRI and Group Grievance in 2017. In the same way, we can get the variation of the other six indicators when CRI make the same change in 2017.

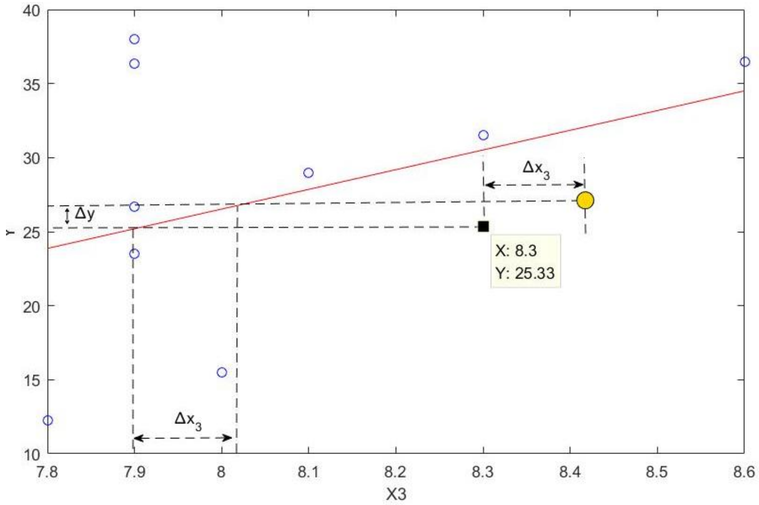


Figure8 The relationship of CRI and Group Grievance

In this way, we can figure out the value of the remaining six indices for each year when CRI changes the same value. Limited by the length of the article, we only take 2017 as an example to illustrate the impact of climate change on Sudan's vulnerability.

We simulated climate change by giving the global climate risk index a change in the positive Δy.At this time, Substitute the seven relevant index values into the model in task 1 to obtain the vulnerability score values of the Sudan, which as shown in Table 6. From the data, it can be found that, when the global climate risks index increases, the vulnerability score of Sudan also increases, that is, climate change increases the vulnerability of the country.

In the same way, we gradually reduce the global climate risk index, which is to give the global climate risk index a negative change in y. At this time, Substitute the seven relevant index values into the model in task 1 to obtain the vulnerability score values of the Sudan, which as shown in Table 6. From the data, it can be found that, when the global climate risk index is continuously reduced, the vulnerability score of Sudan has a decreasing trend. Thus, we can conclude that, when the global climate risk index is reduced to zero, that is, the impact of climate change will be completely ignored, and the vulnerability of Sudan will be reduced.

Table6 Climate change impacts simulation results

Δy	Δx_3	Δx_{10}	Δx_{11}	Δx_{12}	Δx_5	Δx_8	Δx_9	Score
0.50	0.04	4.67	-0.89	-0.15	-0.16	1.03	-2.09	10.00
0.10	0.01	0.93	-0.18	-0.03	-0.03	0.21	-0.42	10.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.10
-0.10	-0.01	-0.93	0.18	0.03	0.03	-0.21	0.42	8.72
-0.30	-0.03	-2.80	0.53	0.09	0.10	-0.62	-1.26	6.31
-0.50	0.04	4.67	-0.89	-0.15	-0.16	1.03	-2.09	3.11

Note: The gray part is the initial indicator value and score of Sudan.

5.3 Task 3

By searching for climate change data in countries other than the top 10 vulnerable countries, we decided to select China, which has a longitude latitude and longitude and a relatively diverse climate, as the research object. According to the results of Task 1, the comprehensive evaluation index of vulnerability in China is 6.2, which is in a steady state.

After checking the data, we find that it ignores the great influence of the seasons on climate change and the results are too gentle, which is not conducive to the solution of the problem by using the year as the data statistical period. Therefore, we shorten the statistical period of data to one month to increase the readability and accuracy of the results.

According to the basic situation of natural disasters in China released by the National Disaster Reduction Office of the Ministry of Civil Affairs, we screened out 9 major climate changes that have a great impact on China and calculated the frequency of occurrences of the 9 major climate changes in China in the recent 10 years by a monthly basis. As shown in Table7

Table7 Frequency of occurrence of climate change in China

	January	February	March	April	May	June
Snow Disaster	0.6	0.4	0.3	0.2	0.1	0.1
Earthquake	0.2	0.1	0.1	0.1	0.1	0.1
Flood	0.4	0.2	0.4	0.4	0.6	0.6
Freezing	0.7	0.7	0.5	0.2	0.1	0
Forest Fire	0.2	0.3	0.1	0.1	0.2	0
Geologic Hazard	0.3	0.6	0.4	0.7	0.5	0.6
Hailstorm	0.3	0.5	0.6	0.7	0.6	0.7
Typhoon	0.1	0.1	0	0	0.1	0.2
Drought	0.1	0	0.2	0.1	0	0
	July	August	September	October	November	December
Snow Disaster	0.1	0.1	0.1	0.2	0.5	0.5
Earthquake	0.1	0.1	0.1	0.1	0.3	0.2
Flood	0.9	0.6	0.5	0.4	0.2	0.2
Freezing	0.1	0	0	0.2	0.3	0.5
Forest Fire	0	0	0.1	0.2	0.4	0.4
Geologic Hazard	0.6	0.5	0.4	0.2	0.2	0.2
Hailstorm	0.4	0.3	0.2	0.1	0.1	0.2
Typhoon	0.3	0.4	0.5	0.4	0.1	0.1
Drought	0.1	0.2	0.1	0	0.1	0

Note: The highlight is the main period of climate change.

5.3.1 China Climate Change Index Evaluation Model Based on AHP

According to the basic situation of natural disasters in China released by the National Disaster Reduction Office of the Ministry of Civil Affairs, we have received the direct economic losses caused by all disasters. It will be used as the basis of AHP to establish the judgment matrix of climate change and China's climate change index. By querying the scale and related climate change data, we get the climate change judgment matrix shown in Table 8.

Table8 Climate change judgment matrix

	Snow Disaster	Earthquake	Flood	Freezing	Forest Fire	Geologic Hazard	Hailstorm	Typhoon	Drought
Snow Disaster	1	3	1/2	1/2	4	1/3	2	2	2
Earthquake	1/3	1	1/2	1	1	1/2	1	2	1
Flood	2	2	1	1	3	1	3	2	1
Freezing	2	1	1	1	2	1/2	1	1	3
Forest Fire	1/4	1	1/3	1/2	1	1/4	2	1	1/2

Geologic Hazard	3	2	1	2	4	1	2	3	4
Hailstorm	1/2	1	1/3	1	1/2	1/2	1	2	3
Typhoon	1/2	1/2	1/2	1	1	1/3	1/4	1	1
Drought	1/2	1	1	1/3	2	1/2	1/3	1	1

We use MATLAB, through the AHP, so as to get the corresponding weight of all kinds of climate change in China climate change index model. The results are shown in Table 9 where K_i $(i = 0,1, \dots, 9)$ is the weight coefficient of different climate change types.

Table9 The weight of various climate change in China in the evaluation index model

	Snow Disaster	Earthquake	Flood	Freezing	Forest Fire	Geologic Hazard	Hailstorm	Typhoon	Drought
Weight	0.1309	0.0797	0.1600	0.1254	0.0634	0.2123	0.0913	0.0612	0.0756
Weight Code	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9

After getting the weight data, we test the consistency of the judgment matrix. After calculating the $CR = 0.0759 < 0.1$, it passed the consistency test.

Use the equation

$$\mathrm{D}_j = \sum_{i=1}^{i=9} P_{ij} \times K_i \tag{6}$$

In the formula, i represents the type of climate change $i = 1,2, \dots, 9$, j represents the months $j = 1,2, \dots, 12$, $P_{i,j}$ represents the probability of representing the monthly climate change, K_i represents the weight coefficient of different climate change types, D_j represents China's monthly climate change assessment index.

We can calculate China's climate change assessment index, the data image as shown in Figure9.

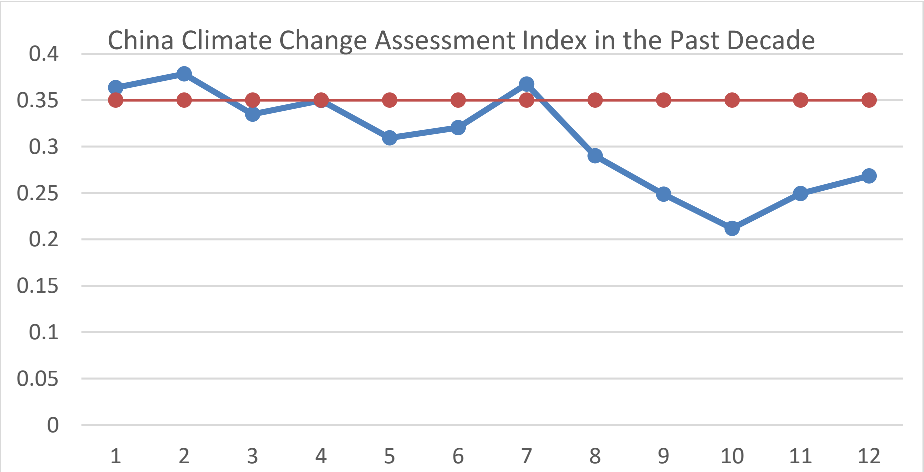


Figure9 China Climate Change Assessment Index in the Past Decade

The red line in the Figure is China's climate index calculated in Task1. We can see that China's climate change evaluation index has greatly improved in January, February and July. It directly and indirectly affects China's score in the comprehensive national vulnerability assessment system， thus make state more fragile.

From the Table 7 we can get that China's main climate change in January is now Disaster, Flood and Freezing, in February is Snow Disaster, Freezing, Geologic Hazard, Hailstorm and Drought and in July is Flood, Geologic Hazard and Typhoon. Therefore, these climate changes are the main reasons for the rising climatic index in China.

5.3.2 The Impact of Climate Change on China's National Vulnerability

Due to the variety of climate change in a year, the number of climate change will greatly affect the climate change evaluation index, thus affecting the national vulnerability assessment. In order to ensure the accuracy of the results, we conducted a combination of the nine major types of whether climate change occurring during the year. We obtain the $2^9 = 512$ kinds of situation evaluation index and denoted as $Z_j, j = 1,2, \ldots 512$ by using the calculation method of Formula 6 and get China Climate Change Assessment Index.

We use the following formula to correct the first-level climate indicator obtained in Task1 to get the climate change indicator more in line with China's specific conditions by using the evaluation index we obtained.

$$C'_j = C_0 + \alpha Z_j \tag{7}$$

In the formula, C'_j is the revised first-level climate index, C_0 is the uncorrected China's climate first-class index, and α is the direct impact of the correction factor. We think that the correction result is the best when $\alpha = 1.3$ after calculation and reflection.

It should be noted that in the process of revision, we should also consider the indirect impact of climate on the national vulnerability score. The process is similar to the process in Task2, and it will not repeat them here.

We obtain a national vulnerability score for all climate change scenarios by bringing the revised climate indicators into the national comprehensive vulnerability assessment system in Task 1. Some of the results are shown in the following Table10.

Table 10 China National Vulnerability Scores under Different Climate Changes

Code	National vulnerability score.	Code	National vulnerability score.	Code	National vulnerability score.	Code	National vulnerability score.
503	9.6	284	8.7	127	8.0	438	7.0
382	9.4	255	8.6	496	7.9	493	7.0
456	9.3	397	8.6	247	7.5	235	7.0
375	9.3	211	8.5	492	7.4	291	6.9
444	9.0	455	8.3	487	7.4	364	6.8
472	9.0	480	8.3	346	7.4	490	6.7
238	9.0	404	8.3	440	7.1	111	6.6
474	9.0	427	8.2	243	7.1	461	6.6
390	8.8	423	8.2	327	7.0	349	6.5
229	8.8	318	8.0	475	7.0		

Table 11 Numbers according to the following rules

Climate change									Code
Snow Disaster	Earthquake	Flood	Freezing	Forest Fire	Geologic Hazard	Hailstorm	Typhoon	Drought	
×	×	×	×	×	×	×	×	×	×

There × = 1 when climate change occurs, x = 0 when climate change does not occur, and 9 climate variables form a 9-digit binary number.

We think the country is vulnerable when the national vulnerability rating is above 6.5 by using the conclusions from Task1. Therefore, China will reach the tipping point with more obvious vulnerabilities in the case of a country with a Vulnerability Score greater than 6.5, namely Table 10 of the occurrence of climate change.

5.4 Task 4

5.4.1 The establishment of multi-objective programming model based on national vulnerability comprehensive evaluation system.

In order to find the best results from the interventions and find countries where the risk of climate change can be mitigated through interventions, we artificially adjust the climatic factors and choose the country's vulnerability score to fluctuate within a given range and minimize the total cost of intervention. And establish the multi-objective programming model.

Based on the report of the United Nations Conference on Trade and Development and combining with the relevant information, we think the indicators presented in table 12 are indicators that will be affected by the intervention.

Table12 Intervention index table

Index number	Index name	Index number	Index name
X_1	Security Apparatus	X_9	External Intervention
X_5	Public Services	X_{11}	Economic Inequality
X_6	Human Rights	X_{12}	Human Flight and Brain Drain

Based on this, the establishment of multi-objective programming model is as follows:

$$\begin{cases} \mathrm{Z}-\Delta\mathrm{Z} \le \mathrm{Z} \le \mathrm{Z}+\Delta\mathrm{Z} \\ \min Q = \sum c_n \Delta X_n \end{cases} \tag{7}$$

$$\mathrm{s.t.}\begin{cases} \Delta\mathrm{Z} \le 1 \\ 0 < Q \le 1000 \\ n = 1,5,6,9,11,12 \\ m = 2,3,4,7,8,10 \\ \Delta\mathrm{X_n} = |\mathrm{X_n} - \mathrm{X_{n0}}| \le q_n \\ Z = \mathrm{by} + \sum \mathrm{a_n X_n} + \sum \mathrm{a_m X_m} \end{cases} \tag{8}$$

Where Z represents the vulnerability score of the target country and Q represents the total cost of the intervention, in billions of yuan. Taking into account the actual national conditions, the total cost of intervention is no more than 10 billion yuan. $X_n(n = 1,5,6,9,11,12)$ represents the index value after the intervention of the six interposable indicators in Table 12, and c_n represents the cost of intervening the corresponding indicator. $X_m(m = 2,3,4,7,8,10)$ represents an index which shows the value of unintentional intervention. a_n,a_m represent the weight of each index in the national vulnerability evaluation system. y represents the index of climatic factors and b represents its weight.

For each indicators of intervention shown in Table 12, interventions should have some margin of intervention. Using the idea of a control variable, when only one indicator is intervened, the value of the indicator that makes Z change$\pm\Delta Z$ as the corresponding indicator's intervention margin is q_n.

5.4.2 Solution of the model

According to the flow shown in Figure 10, using the genetic algorithm toolbox in Matlab, the local optimal solution of the above multi-objective programming model can be solved.

We take the relevant fiscal expenditure of China as a reference and use the inverse relationship to convert the corresponding intervention cost as a reference. The model solution

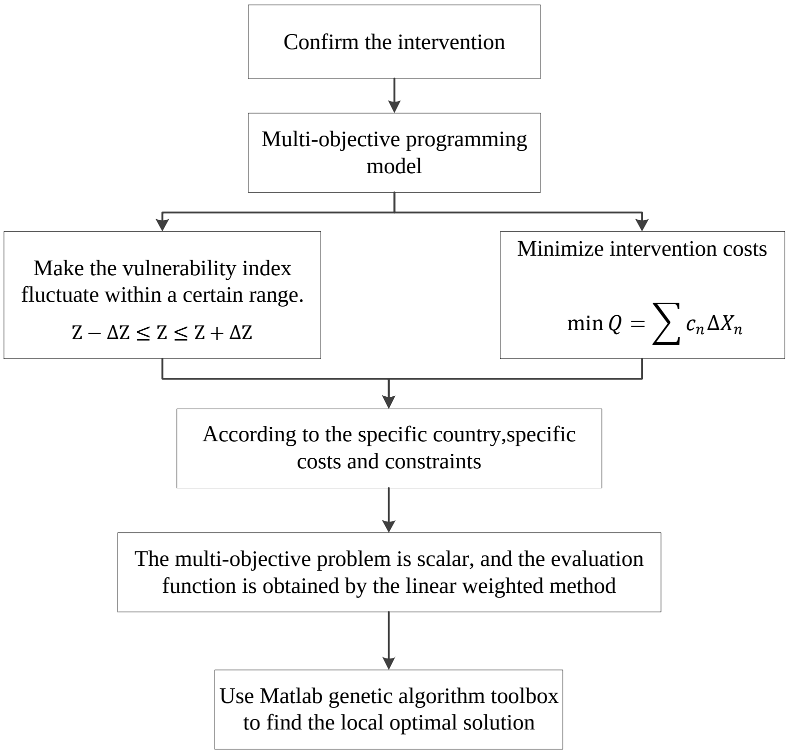


Figure10 Multi-objective programming problem solving flowchart

is shown in Table 13. Under this circumstances, the total cost of China's intervention is 67.44 billion yuan.

Table13 Result of the multi-objective programming model

	z	y	x_1	x_5	x_6	x_8	x_9	x_{12}
Initial score	6.2	7.7	5.9	7.3	4.9	5.7	8.5	2.7
No interventions	6.7	8.0	5.9	7.3	4.9	5.7	8.5	2.7
Have interventions	6.4	8.0	6.3	7.8	4.2	6.5	8.1	3.0
Increased score	0.2	0.3	0.4	0.5	-0.7	0.8	-0.4	0.3
Corresponding cost（bn¥）			51.85	38.67	26.49	40.26	31.09	87.14
Total cost（bn¥）	67.44							

On this basis, using the one-dimensional interpolation function interp1 in Matlab, we select the spline method of cubic spline interpolation, and draw the fluctuation curve of the initial value and the result value of each intervening index before and after the intervention, as shown in Fig11.

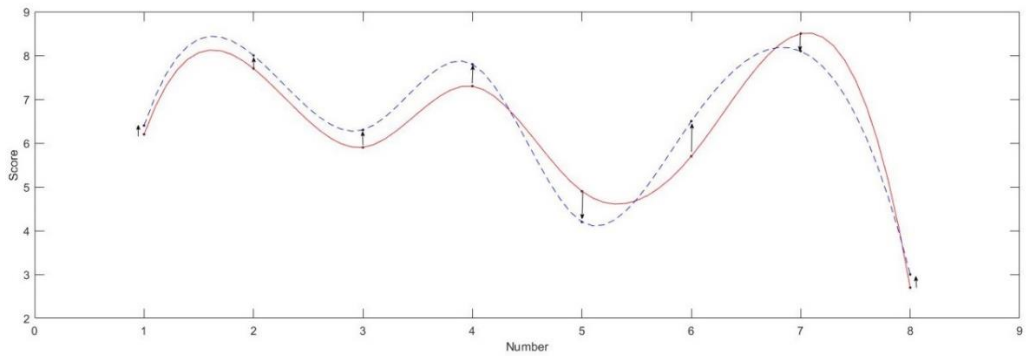


Figure11 Fluctuation trend of each indicator after human intervention

Therefore, given the volatility of a climatic indicator, the national vulnerability score is increased without intervention on other indicators; if the intervention is implemented, the national vulnerability score is higher than the original value but lower than the value at the time when the intervention was not implemented. So the intervention can reduce the risk of climate change.

5.5 Task 5

5.5.1 Improvement and Explanation of Vulnerability Comprehensive Evaluation Model for smaller "states"

In principle, the comprehensive national vulnerability assessment model we developed applies to smaller "states".

Here, City as the basic research unit. And we cluster all the cities in each climatic zone after classifying all the cities according to their own climatic zones. The difference is that at this point in the various types of points from its clustering center of the maximum distance D_k to be limited to a smaller number. Because the size of the smaller "states" is smaller relative to the country. If it have be done, the similarity of the smaller "states" across all classes will increase.

At this moment, the clustering center obtained can be directly treated as the clustering center in our Task1 model for the following processing, as shown in Figure12. Finally, we get the vulnerability score of the smaller "states."

However, we optimized the model in order to obtain a more accurate vulnerability score. In the cluster analysis of smaller "states", we need to consider the smaller area and detail the division of climate zone. For example, it is divided into 11 climatic zones such as tropical monsoon and Mediterranean sea by type. Then the same treatment and Task1 model. A more detailed division of the climate zone can get the clustering points more accurately and get more accurate smaller "states" vulnerability scores.

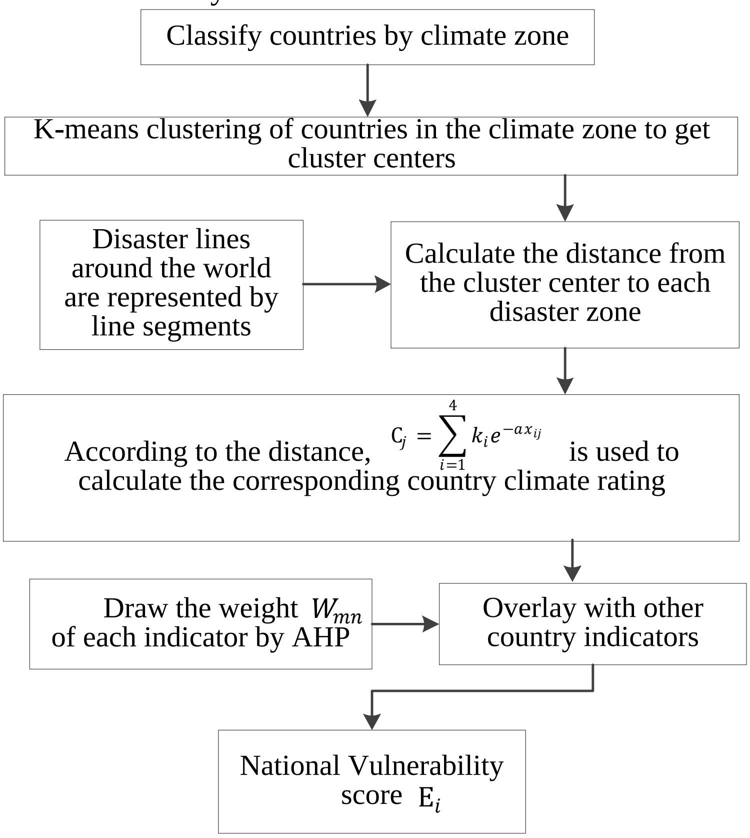


Figure12 Flow chart for vulnerability comprehensive evaluation model

5.5.2 Improvement and Explanation of Vulnerability Comprehensive Evaluation Model for larger "states"

We obtain the vulnerability scores of each country in the larger "states" from the Task1 model. Then it needs to research the degree of influence of these countries on the vulnerabilities of the larger "states". Finally, the vulnerability scores of the larger "states" are obtained.

Taking into account the economic strength of the countries in the region, land area and other aspects are different. It is clear that its impact on larger "states" is also different. We have chosen four indicators, respectively, DGP per capita, country area, PMI and Gini coefficient to measure the extent to which the countries within the larger "states" affect it. Determine the weights of the four indicators by AHP and by consulting the specific values of the four indicators. Then we take the above four indicators weighted sum 、get the measure of each country on the larger "states" score and finally get the weight coefficient of each country.

Taking South America as an example, we calculate the weight coefficients of 12 of these countries and use the country scores in Task1. Then the scores of 12 countries' impact on South America is calculated. And we finally got South America Vulnerability Assessment Index by adding these scores together. As shown in the Table 14.

Table14 South America Vulnerability Assessment Index Results Table

State	Weight	National Vulnerability Rating	National impact on the continent
Argentina	0.1234	4.0	0.5
Bolivia	0.0411	6.3	0.3
Brazil	0.0940	5.9	0.6
Chile	0.1315	4.0	0.5
Colombia	0.0823	6.2	0.5
Ecuador	0.0653	6.3	0.4
Guyana	0.0349	6.2	0.2
Paraguay	0.0367	5.9	0.2
Peru	0.0814	5.5	0.4
Suriname	0.0787	5.9	0.5
Uruguay	0.1127	3.3	0.4
Venezuela	0.1180	6.7	0.8
South America Vulnerability Total Score			5.3

From the table we can see that in South America, the score of vulnerability comprehensive evaluation model is 5.3, which is less than 6.5. South America is more stable.

Based on this, we make a thermodynamic assessment of South America's vulnerability score to more directly observe the vulnerability of the region. As shown in Figure 13.

Similarly, any other larger "states" can also be obtained by using the improved vulnerability assessment model, and it will not be repeated here.

Figure 13 South America Vulnerability Score Thermogram

6. Evaluation of the model

6.1 model 1

Model 1 is a comprehensive evaluation model of national vulnerability based on AHP.

6.1.1 Advantages

This model is based on the analytic hierarchy process, which combines with practical problems to establish a complete national vulnerability evaluation system. The method of clustering analysis is adopted in the process of obtaining the first-level index, which improves the practicability and efficiency of the model. The structure of this model is clear, which can balance the weight of influential factors scientifically, and obtain the persuasive national vulnerability assessment score.

6.1.2 Disadvantages

This model relies heavily on the experience of the modelers and the influence of subjective factors is great. It can only eliminate the serious inconsistency in the thought process, and cannot exclude the serious one-sidedness of the decision maker. Moreover, the comparison of this model is rough and cannot be applied to the problem of high precision.

6.2 model 2

Model 2 is a model of the influence of climate change on the vulnerability of Sudan based on correlation analysis.

6.2.1 Advantages

Firstly, this model uses the correlation analysis to select the secondary indicators related to Sudan and climate change without affecting the accuracy of the results. It greatly reduces the number of variables, simplifies the calculation process, and improves the readability of the model. To deal with data, we use the fitting function to find the relationship between each secondary index and the inner link of climate change. This process greatly simplified the relationship between the dependent variable and independent variable which promote the computational efficiency of the model.

6.2.2 Disadvantages

Some feature points are ignored in the fitting process. Moreover, due to the relatively small amount of data, this model adopts linear fitting. Its error is relatively large, and it cannot fully reflect the regular of the influence of climate change on vulnerability.

6.2.3 Optimization of the model

In the process of solving the model, due to the small amount of data collected, the model inevitably has some errors. When the amount of data is enough, the error of the model can be reduced to improve the accuracy of the model. In addition, when the data is sufficient, we can establish a regression equation model or a grey prediction model based on the correlation analysis results. This will give a more accurate picture of the relationship between climate change and national vulnerability.

6.3 model 3

Model 3 is a multi-objective programming model based on the national vulnerability comprehensive evaluation system.

6.3.1 Advantages

We translate the requirements of the national vulnerability index and the total cost of interventions into a multi-objective programming problem, which further translate into a single goal programming. The idea of this model is very clear. When looking for the impact of external intervention on national vulnerability, we first set up a national vulnerability comprehensive evaluation system to grade the vulnerability of the country, and use this score as a constraint. The application of this model can scientifically and accurately determine the impact of intervention on national vulnerability.

6.3.2 Disadvantages

The result of this model is the local optimal solution, which cannot get the optimal solution of the problem. Moreover, the calculation is increasing rapidly when the number of variables and the number of constraint equations of Multi-objective programming problem are increased to a certain number. Therefore, the model cannot apply to large-scale multi-objective programming problems.

6.3.3 Optimization of the model

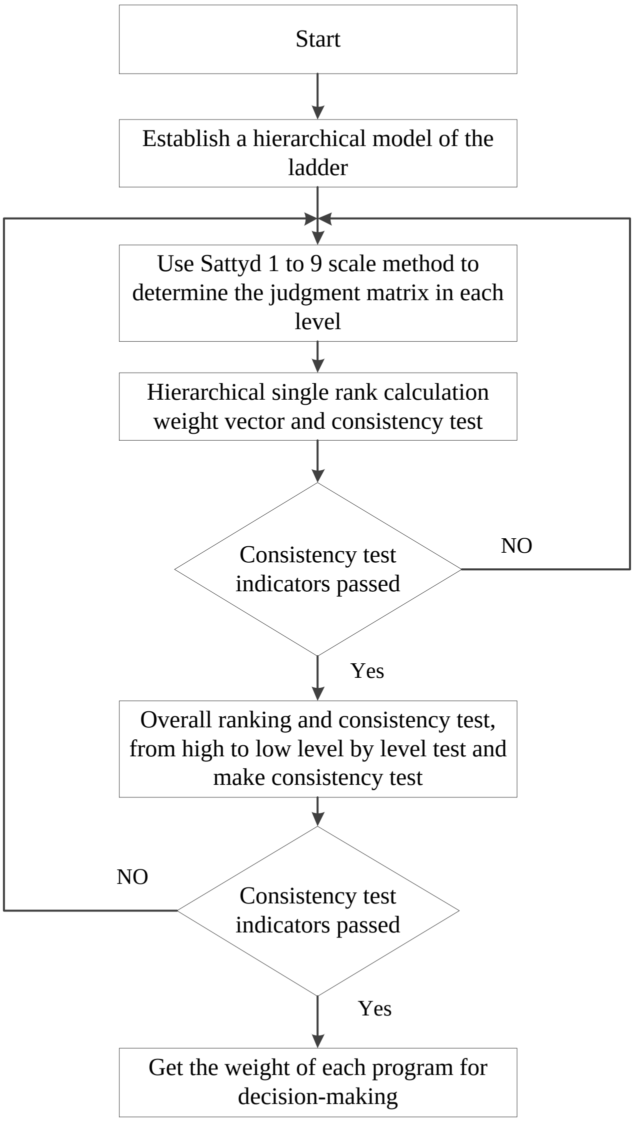
For a country, the costs of interventions and the measure of interventions for climate change vary from time to time, such as in different season. Based on this, we can add the time as the influencing factor to the model, so that the weight of the secondary indexes can change dynamically and have the characteristics of time. Thus, the solution of the problem become more accurately.

References

[1] Si Shoukui, Sun Zhaoliang, Sun Xi Jing Mathematical Modeling Algorithm and Application[M]. National Defense Industry Press, 2015.
[2] Jiang Qiyuan, Xie Jinxing, Ye Jun. Mathematical model. Third Edition[M]. Higher Education Press, 2003.
[3]J.J.Messner, Fragile States Index Annual Report[R].FUND FOR PEACE, 2017
[4] Liu Sanming. Multi-objective programming theory and application [M]. Shanghai Jiaotong University Press, 2014.
[5] Gao Yingying. Overview of multi-objective programming [J]. Shenzhou Xun Journal, 2013 (1): 159-159.
[6] Climate Change and China's National Strategy - An Interview with Professor Wang Jisi [J]. Journal of International Political Science. 2009 (04)
[7] Climate change 2013:the physical science basis[M/OL]. IPCC. http://www.ipcc.ch/report/ar5/wgl/#.Uq_tD7KBRRl . 2013.
[8] Wei Yiming, Mi Zhifu, Zhang Hao.Recent Advances in Research on Comprehensive Assessment Models of Climate Change [J] .Systems Engineering -Theory & Practice, 2013, 33 (8): 1905-1915.

Appendices

Appendix A AHP flowchart



Appendix B Judgment matrix of secondary indicators

	Security Apparatus	Factionalized Elites	Group Grievance
Security Apparatus	1.00	2.00	0.50
Factionalized Elites	0.50	1.00	0.33
Group Grievance	2.00	3.00	1.00

	State Legitimacy	Public Services	Human Rights
State Legitimacy	1.00	2.00	1.00
Public Services	0.50	1.00	0.50
Human Rights	1.00	2.00	1.00

	Demographic Pressures	refugees and IDPs
Demographic Pressures	1.00	2.00
refugees and IDPs	0.50	1.00

	Economy	Economic Inequality	Human Flight and Brain Drain
Economy	1.00	3.00	2.00
Economic Inequality	0.33	1.00	0.50
Human Flight and Brain Drain	0.50	2.00	1.00

Appendix C Evaluation form for vulnerability of the country

Country	Score	Country	Score
Afghanistan	8.7	Lebanon	7.2
Albania	5.7	Lesotho	6.8
Algeria	6.7	Liberia	7.9
Angola	7.6	Libya	7.9
Antigua and Barbuda	4.9	Lithuania	4.3
Argentina	4.0	Luxembourg	2.7
Armenia	6.3	Macedonia	5.8
Australia	2.2	Madagascar	7.3
Austria	3.2	Malawi	7.9
Azerbaijan	6.3	Malaysia	5.3
Bahamas	4.9	Maldives	6.4
Bahrain	5.6	Mali	8.0
Bangladesh	7.1	Malta	4.3
Barbados	4.8	Mauritania	7.9
Belarus	6.2	Mauritius	4.3
Belgium	3.4	Mexico	6.3
Belize	5.8	Micronesia	7.1
Benin	6.9	Moldova	6.3
Bhutan	6.3	Mongolia	5.2
Bolivia	6.3	Montenegro	5.2
Bosnia and Herzegovina	6.2	Morocco	6.4
Botswana	6.0	Mozambique	7.9
Brazil	5.9	Myanmar	7.4
Brunei Darussalam	5.1	Namibia	6.5
Bulgaria	5.2	Nepal	7.6
Burkina Faso	7.4	Netherlands	3.3
Burundi	8.3	New Zealand	2.3
Cambodia	7.0	Nicaragua	6.3
Cameroon	7.7	Niger	8.0
Canada	2.8	Nigeria	8.3
Cape Verde	6.3	North Korea	7.8
Central African Republic	9.1	Norway	2.7
Chad	9.0	Oman	5.0
Chile	4.0	Pakistan	8.0
China	6.2	Panama	4.4
Colombia	6.2	Papua New Guinea	7.1
Comoros	7.3	Paraguay	5.9

Congo Democratic Republic	8.8	Peru	5.5
Congo Republic	7.8	Philippines	6.8
Costa Rica	4.1	Poland	4.3
Cote d'Ivoire	7.8	Portugal	3.7
Croatia	5.0	Qatar	4.3
Cuba	5.4	Romania	4.9
Cyprus	5.7	Russia	6.3
Czech Republic	4.1	Rwanda	7.6
Denmark	2.8	Samoa	6.0
Djibouti	7.7	Sao Tome and Principe	6.7
Dominican Republic	5.9	Saudi Arabia	6.1
Ecuador	6.3	Senegal	7.3
Egypt	7.8	Serbia	6.2
El Salvador	6.2	Seychelles	5.4
Equatorial Guinea	7.0	Sierra Leone	7.9
Eritrea	8.4	Singapore	3.3
Estonia	4.2	Slovak Republic	4.5
Ethiopia	8.4	Slovenia	3.8
Fiji	6.4	Solomon Islands	7.1
Finland	2.8	Somalia	9.4
France	3.8	South Africa	5.9
Gabon	6.3	South Korea	3.8
Gambia	7.9	South Sudan	9.3
Georgia	6.4	Spain	3.9
Germany	3.2	Sri Lanka	6.9
Ghana	6.4	Sudan	9.1
Greece	5.6	Suriname	5.9
Grenada	5.6	Swaziland	7.5
Guatemala	6.6	Sweden	2.8
Guinea	8.4	Switzerland	2.9
Guinea Bissau	8.2	Syria	9.0
Guyana	6.2	Tajikistan	7.1
Haiti	8.5	Tanzania	7.2
Honduras	6.5	Thailand	5.9
Hungary	5.0	Timor-Leste	7.7
Iceland	3.0	Togo	7.2
India	6.4	Trinidad and Tobago	5.0
Indonesia	6.0	Tunisia	6.5
Iran	7.1	Turkey	6.5
Iraq	8.5	Turkmenistan	6.3
Ireland	3.0	Uganda	7.9
Israel and West Bank	6.2	Ukraine	6.4
Italy	4.7	United Arab Emirates	4.4
Jamaica	5.9	United Kingdom	3.5
Japan	4.2	United States	3.4
Jordan	7.0	Uruguay	3.3
Kazakhstan	5.9	Uzbekistan	6.9
Kenya	7.8	Venezuela	6.7
Kuwait	5.3	Vietnam	6.1
Kyrgyz Republic	6.8	Yemen	9.2
Laos	6.8	Zambia	7.8
Latvia	4.4	Zimbabwe	8.4