

PAPER • OPEN ACCESS

Model for Measuring Country's Fragility under the Influence of Climate Changes

To cite this article: Kewei Chen 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **252** 042008

View the [article online](#) for updates and enhancements.

Model for Measuring Country's Fragility under the Influence of Climate Changes

Kewei Chen*

North China Electric Power University, Baoding, China

*Corresponding author e-mail: kw.chen@foxmail.com

Abstract. With continuous development and progress of human society, the global environment is also undergoing tremendous changes. These environment changes bring us a profound change in both human production and way of life, and even lead to the collapse of a country's government with poor governance capacity. Environmental change has become a worldwide problem. Therefore, this article established a model to measure a country's fragility and the impact of climate changes on fragility, and by applying improved models intervention, plans were put forward to mitigate the risks posed to a country by climate change. To begin with, based on the improved AHP, the article proposed basic model. By using principal component analysis, the article selected the two most representative of the three main categories that affect national vulnerability respectively: safety equipment, economy, public services, population pressure precipitation and temperature. Then, the weight of each factor was figured out and the calculation formula of fragility index was got. However, weights based on expert evaluations have been found to be too subjective. Therefore, an improved model was established, which changed the parameter judgment matrix to the interval judgment matrix, thus greatly reduced the subjectivity of the model. By analyzing the top 60 countries in the 2017 Fragile Country Index, a new formula for calculating the Vulnerability Index was found, and the Fragility Assessment Interval was divided. Next, the article applied the model to specific countries to analyze how climate changes affect a country's fragility and it designed intervention programs for countries to mitigate the risks posed by climate change. Firstly, Somalia was chosen from the ten most vulnerable countries. And we drew the conclusion that Somalia's fragility index would rise year by year because of the worsening climate and might even surpass South Sudan, the most fragile country released by the Fond for Peace in 2017, becoming the theoretically most fragile country only 8 years later. Secondly, seven feasible intervention plans and the cost of implementing each intervention method was proposed. In North Korea, for example, the article calculated the minimum cost by using the optimization method.

1. Introduction

1.1. Background

The state is the most important carrier of human civilization and wealth, and security is the basic requirement of national development. The high-profile emergencies that have taken place in recent years have caused tremendous spiritual and property losses to human society and seriously threaten the living environment. Studies have shown that climate change can affect people's way of life and may lead to



the collapse of social structure and make a country more fragile. Figure 1-1 is the distribution of world fragile countries released by the Fund for Peace in 2017.

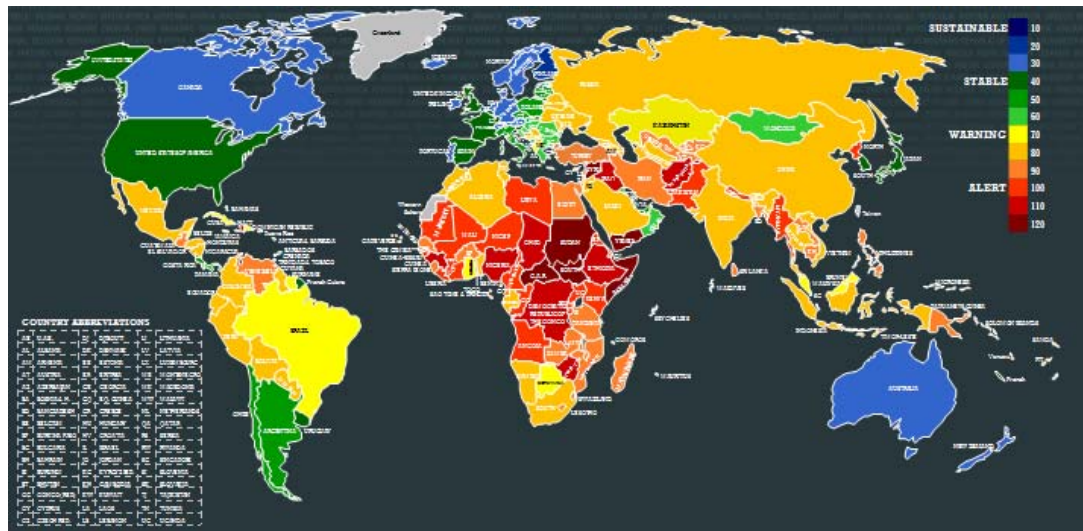


Figure 1-1. World fragile countries

In view of this, a fragile country will be more fragile to climate change and thus more fragile. If we can calculate the fragility index of each country through a scientific algorithm, then we can prescribe the right remedy. We can more specifically solve the problems that a country currently faces. This will be beneficial to the development of our country and to the happy life of people.

In this article, our goal is to create a credible model that looks specifically at the impact of climate on a country's fragility. To achieve this goal, we consulted the relevant information, used IAPH and other analytical methods.

2. Basic Model

2.1. Basic Model Assumptions

- (1) We assume that the data we used in our models were accurate under any circumstance.
- (2) It is practical for us to evaluate the qualified value of two factors by expert evaluation.
- (3) We assume that the government of the country we are discussing will not change during the time our model is discussed.
- (4) We model 2017 as the "current" year due to availability of data.
- (5) Both the expert's judgment and the quantified values have consistency.

2.2. Terms, Definitions and Symbols

- C_1 : Demographic Pressure
- C_2 : Economy Decline
- C_3 : Security Apparatus
- C_4 : Public Services
- C_5 : Precipitation
- C_6 : Temperature
- x_{ij} : Quantified value
- CI : Consistency index
- RI : Consistency random index.
- CR : Consistency index ratio.

2.3. Model was established

There are many factors that affect a country's fragility. In order to determine the fragility of a country, we propose a mathematical model that combines various factors and quantifies the fragility. As shown in Figure 2-3.

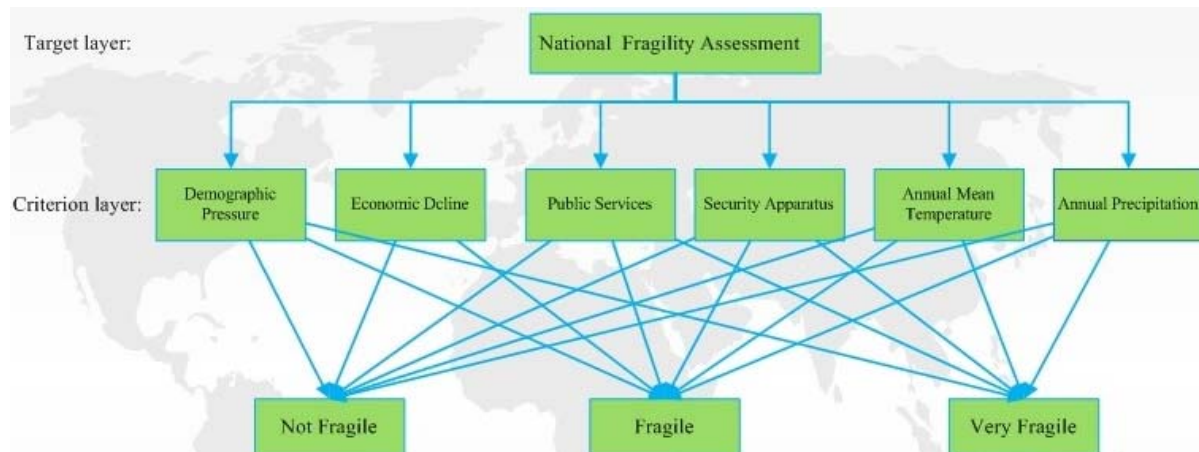


Figure 2-3. Hierarchy index system

As for why we choose the above factors, these six factors have strong representativeness and practicability. We first selected more than 20 factors, but too many factors make our calculations more difficult, and it is more efficient to choose the most representative ones. So we use the software SPSS for principal component analysis, and select these six factors that contribute the most to country's fragility. These six factors can be broadly divided into three broad categories that cover all the factors that affect the country's fragility. Demographic pressure and economy are the first category: factors of social development level. And overpopulation and slow economic growth are the two major factors hindering social development. Security apparatus and public services are the second category: government governance capacity. These two aspects are the concentrated reflection of the government's ability to deal with such issues as rising temperatures, natural disasters and land drought. Precipitation and temperature are the third category: the direct impact of climate change on country's fragility.

We consider that it is usually more complicated to compare all kinds of factors together, and it is easier to compare two factors. Therefore, we compare the degree of influence of each two selected factors on the national fragility, and quantify the comparison results to obtain a comparative matrix. In order to make the comparison judgment between two factors accord with the principle of reasonableness and the principle of transmission, we set up a new index scale.

First of all, we classify the judgment into: equally important, slightly important, important, obviously important, strongly important, extremely important six levels. If we know the level of comparison of A against B and B against C, A is transitive to the comparative level of C. If A is slightly important to B and B is strongly important to C, then A is extremely important to C. Let the score be a when the comparison result is slightly important, 1 for equally important, a^2 for important, a^4 for significantly important, a^6 for strongly important, and a^8 for extremely important. And there is $A:C = (A:B)/(B:C)$. The limit of digital judgment is 9, and there should be $a^8 = 9$, that is $a = 1.3161$ (Note: the values above a_8 are recorded as 9). So we can get the following index scale table 2-3-1.

Table 2-3-1. Index scale

scale	Scale definitions
1	A is as important as B.
1.3161	A is slightly more important than B.
1.7321	A is more important than B
3	A is apparently more important than B.
5.1966	A is strongly more important than B.
9	A is extremely more important than B.

Compared with other scales, this index has a good reasonableness of judging transmissibility and scale value, which is helpful for the decision makers to improve the accuracy in the process of comparison.

Second, based on expert ratings and our index scale, we get the following matrix of judgments. As shown in Table 2-3-2.

Table 2-3-2. Judgment matrix

	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆
C ₁	1	0.759821	1.7321	1.3161	5.1966	3
C ₂	1.3161	1	1.3161	1.3161	5.1966	5.1966
C ₃	0.577334	0.759821	1	0.759821	3	1.7321
C ₄	0.759821	0.759821	1.3161	1	5.1966	3
C ₅	0.192434	0.192434	0.333333	0.192434	1	0.759821
C ₆	0.333333	0.192434	0.577334	0.333333	1.3161	1

Assuming $T_i = (y_{i1}, y_{i2}, \dots, y_{in})$, it's weights $d_i^{(1)} = (d_{i1}^{(1)}, d_{i2}^{(1)}, \dots, d_{in}^{(1)})$. Make T_i dimensionless, as for the bigger the better indicators, assuming $\bar{y}_{ij} = \frac{y_{ij}}{\max\{y_{ij}\}} (j=1, 2, \dots, n)$. As for the smaller the

better indicators, assume that $\bar{y}_{ij} = \frac{\max\{y_{ij}\} - y_{ij}}{\max\{y_{ij}\} - \min\{y_{ij}\}} (j=1, 2, \dots, n)$.

Standardize $\bar{y}_i$, assume $d_{ij}^{(2)} = \frac{\bar{y}_{ij}}{\sum_{j=1}^n \bar{y}_{ij}}$, and we can get the weights $d_i^{(2)} = (d_{i1}^{(2)}, d_{i2}^{(2)}, \dots, d_{in}^{(2)})$.

According to the above method, we obtain the weight of each indicator, as shown in Table 2-3-3.

Table 2-3-3. Index Weight

	d ₁	d ₂	d ₃	d ₄	d ₅	d ₆
weight	0.2401	0.2787	0.1534	0.2092	0.0484	0.0703

At last, we get the country's fragility formula based on the six indicators of our choice:

$$NF = \sum_{i=1}^n d_i \times C_i$$

2.4. Discussion

Although our basic model can determine the fragility of a country, the determination of the quantitative value in it is more subjective and less convincing. The subjectivity of the basic model is too strong, the accuracy of the model depends on the expert's judgment. Once the quantified value is in error, the result calculated by the model will be greatly deviated. Therefore, we next propose a refined model.

3. Refined model

3.1. Refined Model Assumptions

For the refined model, the same assumptions apply, with the following additions and modifications:

The comparison interval assessed by the experts is credible within the margin of error.

3.2. Construct interval judgment matrix

Different from the basic model, the element of the judgment matrix of the refined countries fragility assessment model is the interval number, that is, the judgment matrix is an interval matrix. Firstly, a reasonable quantitative method is established as the criterion for the importance of the two elements, and then the experts judge the importance of the two elements. As different experts may have discrepancies in judgments, and there is subjectivity in the judgments themselves. Adopting the method of comprehensive judging result and expressing the judging result by the evaluation interval will greatly reduce the subjectivity of the evaluation result and the loss of the evaluation information so as to effectively improve the objectivity and credibility of the evaluation result.

We use reciprocity 1-9 scaling as a criterion. As shown in Table 3-2-1.

Table 3-2-1. Reciprocity 1-9 scale method

Ranking	The degree of language description
1	Equally important
3	Slightly important
5	Significantly important
7	Strongly important
9	Extremely important
2, 4, 6, 8	The median of the above adjudication level

After our comprehensive judgment, the judgment interval matrix $R(x_{ij})$ of the six factors is as the following Table 3-2-2:

Table 3-2-2. Judgment interval matrix

	C_1	C_2	C_3	C_4	C_5	C_6
C_1	[1,1]	[0.5000,0.2500]	[3,5]	[3,4]	[5,7]	[4,5]
C_2	[4,2]	[1,1]	[3,4]	[2,3]	[6,7]	[5,6]
C_3	[0.2000,0.3333]	[0.2500,0.3333]	[1,1]	[0.5000,0.3333]	[4,5]	[3,4]
C_4	[0.2500,0.3333]	[0.3333,0.5000]	[3,2]	[1,1]	[4,6]	[4,5]
C_5	[0.1428,0.2000]	[0.1428,0.1667]	[0.2000,0.2500]	[0.1667,0.2500]	[1,1]	[0.5000,0.3333]
C_6	[0.2000,0.2500]	[0.1667,0.2000]	[0.2500,0.3333]	[0.2000,0.2500]	[3,2]	[1,1]

The elements of the judgment matrix have the following relation:

$$0.1 < x_{ij}^- \leq x_{ij}^+ \leq 0.9, x_{ij} = [x_{ij}^-, x_{ij}^+], x_{ij}^- + x_{ij}^+ = 1$$

3.3. Consistency processing for judgment matrix

Appropriate changes to the judgment matrix are to meet the consistency requirements. The matrix of judgment is respectively summed by rows and summed by columns:

$$\text{Sum over the rows:} \quad r_i = \sum_{j=1}^n x_{ij}, \quad i = 1, 2, \dots, n$$

$$\text{Sum over the columns:} \quad r_j = \sum_{i=1}^n x_{ij} \quad i = 1, 2, \dots, n$$

$$\text{Then make the following transformation:} \quad r_{ij} = \frac{r_i - r_j}{2(n-1)} + 0.5$$

$$\text{Among them:} \quad r_{ij} = [r_{ij}^-, r_{ij}^+] \quad i = 1, 2, \dots, n$$

From this we can get an interval consistency judgment matrix $R(r_{ij})_{n \times n}$, $i, j = 1, 2, 3, \dots, n$

$$R(r_{ij}) = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix}$$

3.4. Interval index hierarchy order:

The obtained consistency interval judgment matrix is hierarchically sorted according to the following formula (1) to obtain the weight vector W of the indicator layer to the target layer.

$$(w_1, w_2, \dots, w_n) = ([w_1^-, w_1^+], [w_2^-, w_2^+], \dots, [w_n^-, w_n^+]) \quad (1)$$

$$w_i = \frac{1}{n(n-1)} (\sum_{i=1}^n r_{ij} + \frac{n}{2} - 1)$$

3.5. Interval weight comparison:

The elements in the obtained section weight vector we are compared by the following formula (2). We can get a comparative matrix P of relative advantage. The meaning of matrix P is the relative advantage of $w_i > w_j$ when w_i and w_j of the interval weight vector are compared.

$$P(a > b) = \begin{cases} 1 - \frac{1}{2\rho^{x-0.5}}, & \text{when } x = \frac{a^+ - b^-}{a^+ - a^- + b^+ - b^-} \geq 0.5 \\ \frac{1}{2\rho^{x-0.5}}, & \text{when } x = \frac{a^+ - b^-}{a^+ - a^- + b^+ - b^-} < 0.5 \end{cases} \quad (2)$$

In the formula, ρ takes a natural number e .

$$\text{Calculate the relative advantage matrix } P \text{ is: } P(r_{ij}) = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{bmatrix}$$

The following gives a matrix of the relative advantages for calculating the country's fragility. As shown in Table 3-5-1.

Table 3-5-1. Relative Advantage Matrix

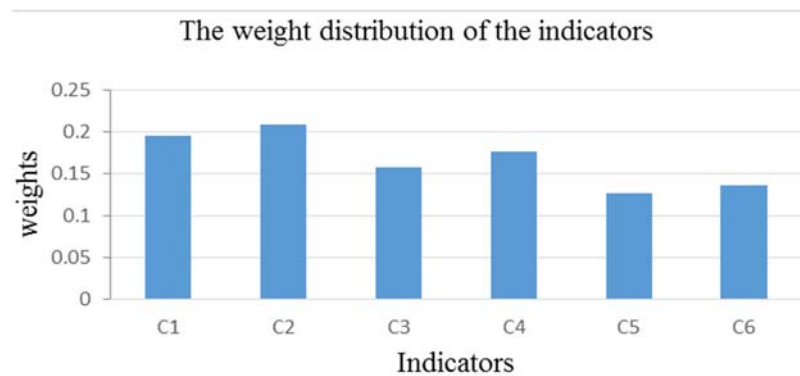
0.5000	0.3138	0.9057	0.8159	0.9677	0.9440
0.6862	0.5000	0.9833	0.9507	0.9956	0.9878
0.0943	0.0167	0.5000	0.1762	0.9225	0.8451
0.1841	0.0493	0.8238	0.5000	0.9674	0.9284
0.0323	0.0044	0.0775	0.0326	0.5000	0.3292
0.0560	0.0122	0.1549	0.0716	0.6708	0.5000

Calculate the weights of the indicators. As shown in Table 3-5-2.

Table 3-5-2. Weights of the Indicators

indicators	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆
weight	0.1956	0.2087	0.1578	0.1757	0.1262	0.1360

Draw EXCEL graphics:

**Figure 3-5.** The weight distribution of the indicators

The national fragility is calculated as follows:

$$NF = \sum_{k=1}^n Q_k \times C_k$$

3.6. Fragile level of division

We analyze the top 60 countries based on the 2017 National Vulnerability Index rankings. We think 60 will not be fragile in the future, 60-39 will be more fragile, 40-21 will be fragile and 20-1 will be very fragile. We choose the 1st, 20th, 40th, and 60th to divide the range of fragile regions. They are South Sudan, Niger, Mozambique and Senegal. The indicators of the four factors of population pressure (C_1), recession (C_2), public service (C_3) and safety device (C_4) in these four countries can be found on the National Vulnerability Data released by the Fund for Peace. For precipitation and temperature two factors we consider the following indicators of division.

Precipitation indicator evaluation table:

Table 3-6-1. Average rainfall assessment criteria table

point	Average annual rainfall
[0,1)	[1500,∞)
[1,2)	[1100,1500)
[2,3)	[1000,1100)
[3,4)	[900,1000)
[4,5)	[700,900)
[5,6)	[500,700)
[6,7)	[400,500)
[7,8)	[300,400)
[8,9)	[200,300)
[9,10)	[125,200)
10	[0,125)

Temperature index evaluation table:

Table 3-6-2. Temperature index evaluation criteria table

Climatic characteristics	point
Inland, no drought, developed agricultural technology, rich biodiversity	[0,2)
Inland, no drought, developed agricultural technology, biological diversity is not rich	[2,4)
Inland, no drought, underdeveloped agricultural technology, not rich in biodiversity	[4,7)
Inland, drought, undeveloped agricultural technology, biodiversity is not rich	[7,8.5)
Coastal, drought, underdeveloped agricultural technology, biological diversity is not rich	[8.5,9.5)
Large area of sea, agricultural technology is very backward, climate is very dry	[9.5,10]

Finally, we get the indicators assessment results for four countries as shown in Table 3-7-3:

Table 3-6-3. Table of Indicators assessment results for four countries

indicators	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆
South Sudan(1st)	9.9	10	10	10	3.8	8.8
Niger(20th)	9	7.5	8.7	9.5	5.8	8.5
Mozambique(40th)	9.2	8	6.7	8.7	4	7
Senegal(60th)	8.1	7.4	5.2	7.5	5.5	7.2

We then calculated their vulnerability based on the weight of the indicators we obtained based on the IAPH model and got the following results as shown in Table 3-7-3:

Table 3-6-4. Fragility level decision table

Fragility interval	Fragile level
(0,6.9405]	Not fragile
(6.9405,7.5119]	More fragile
(7.5119,8.2557]	Fragile
(8.2557,9.0349]	Very fragile

3.7. How climate change affects fragility

● Temperature:

The direct impact of climate change on nature is the temperature rise, the temperature increases will lead to glacier melting sea level rise, which will have the following effects:

- (1) Sea level rise, erosion of the coast, will submerge some cities in some countries;
- (2) Increased salinity of surface water and groundwater, affecting urban water supply;
- (3) The increase of groundwater table will reduce the additional stress in the soil and greatly reduce the bearing capacity of foundation

- Economic:

Studies have shown that there is a significant negative correlation between average temperature and per capita income, whether it is transnational or within a country: For different countries, the per capita income drops by an average of 8.5 %; For residents within a country, the per capita income will drop 1%-2% on average for every 1°C rise in temperature [1]. The impact of precipitation on the differences of per capita income among countries or in China is not statistically significant.

- Population:

Long-term changes in climatic conditions such as temperature, precipitation and light will affect agro-ecological conditions and production potential, thus affecting agricultural output. Calculating the potential of agricultural production allows one to estimate the expected agricultural yields that a region may reach. What's more, we can estimate the region's population carrying capacity.

The impact of these climate changes directly or indirectly increases the fragility of countries.

4. Applying the model to top ten fragile countries

4.1. Reasons for choosing Somalia

We selected Somalia for analysis from the top ten fragile countries. Somalia is a country located in the Horn of Africa with the longest coastline on the continent of Africa. Its terrain is dominated by plateaus, plains and plateaus. For climate, Somalia has annual high temperatures, cyclical monsoons and irregular rainfall. In Somalia, the average maximum daily temperature is between 30°C and 40°C as it is close to the equator [3]. Annual rainfall in northern Somalia is less than 100 millimeters; at the central height, it is about 200 to 300 millimeters; in the northwestern and southwestern parts of the country, the average annual drop is 510 to 610 millimeters. [2] Although the coastal areas are hot and humid throughout the year, the hinterland is usually dry and hot.

4.2. How climate change will influence the fragility of Somalia

Considering that Somalia encounters climatic interferences such as major droughts and rain and snow disasters, it has a significant impact on precipitation and temperature in Somalia. We consider that the conditions in Somalia have changed in some special circumstances, leading to an increase in the indicators of precipitation and temperature. MATLAB is now used to simulate climate change, precipitation and temperature indicators of the growth process, of which the annual growth rate obey N (0.02, 0.01) distribution. We increase the precipitation indicator to see how the fragility of Somalia changes. Now give the results of the simulation:

Changes in vulnerability in Somalia with increasing precipitation indicators shown in Figure 4-2-1:

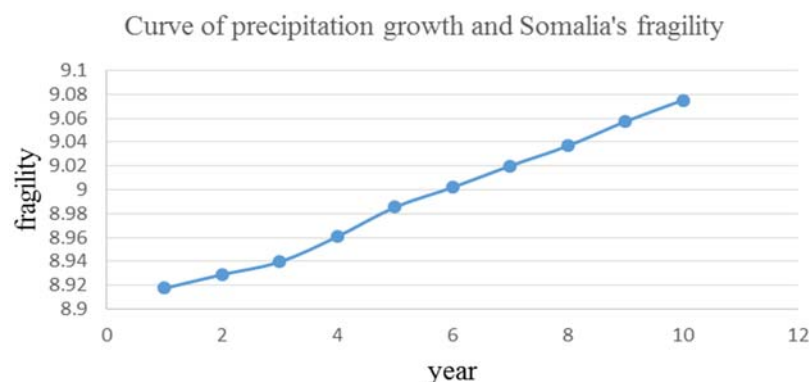


Figure 4-2-1. Curve of precipitation growth and Somalia's fragility

Changes in vulnerability in Somalia as temperature indicators increase shown in Figure 4-2-2:

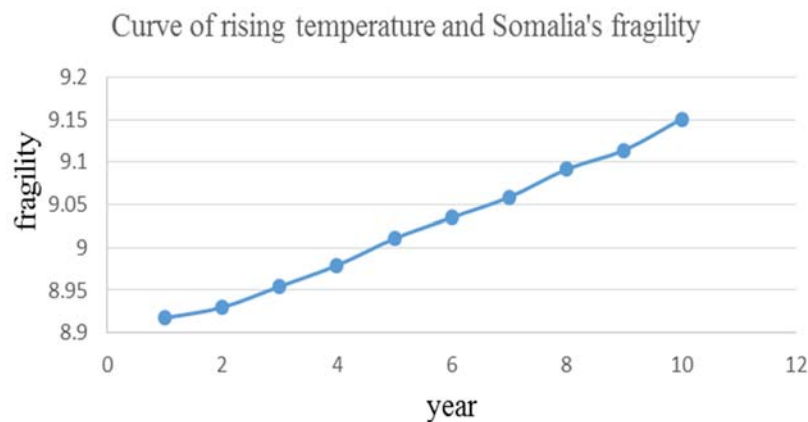


Figure 4-2-2. Curve of rising temperature and Somalia's fragility

4.3. Conclusion

The results of the simulation show that the fragility index in Somalia has risen year by year and may even surpass South Sudan, the weakest country released by the Peace Foundation in 2017, becoming a theoretically more fragile country due to the increase of climate deterioration, temperature and precipitation indicators. Our simulation considers only the two indicators of climate growth. If we take into account the indirect social and economic impact of the deteriorating climatic environment, the consequences of climate deterioration will be disastrous. If the climate does not continue to deteriorate like our assumptions, the fragility of Somalia will not rise at least with all other factors. However, Somalia has the potential to sustain its development and reduce its fragility only if climate conditions are not deteriorating. Therefore, the climate factor will be one of the keys to getting these countries such as Somalia out of the very fragile state of affairs.

5. Human interventions

5.1. Intervention plan

As we can see from the model that human interventions can mitigate the risk of climate change and prevent a country from becoming a fragile country. Here is our intervention plan:

- Plant trees and return farmland to forest and grass.
- Vigorously develop new energy sources to reduce carbon dioxide emissions.
- Introduce public bicycle systems, electric taxis, and electric buses to call for environmentally friendly travel.
- Develop a carbon emission plan to limit the annual carbon emissions and shut down unqualified factories.
- Strengthen public awareness of environmental protection and reduce waste of resources.
- Construct dam, pay attention to the construction of flood control facilities.
- Improve the drainage system.

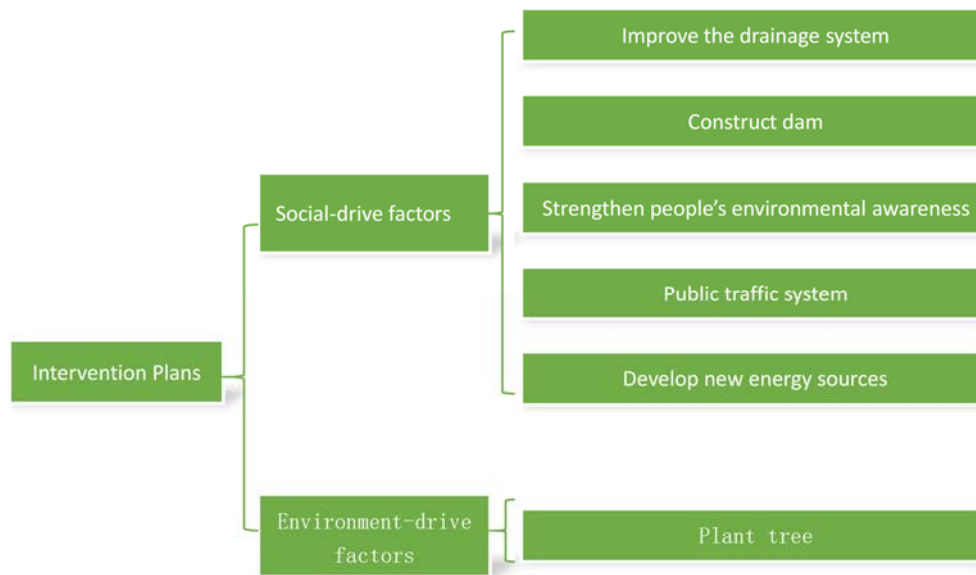


Figure 5-1. Intervention plan

5.2. The cost of the plan

According to the information, in the case of a net increase of 2053333.33 square kilometers of forest area in China, a net increase of 1.128 billion cubic meters of live stumpage was recorded [4]. In order to facilitate the calculation to illustrate the problem, we assume here that there is a linear relationship between the size of the forest area and the stock volume and that the stock volume is the amount of precipitation. From here, we can expand the calculation. By getting the area of forest needed for a 1 mm precipitation in a given area, we then derive the "cost of human intervention" we need by reforestation costs. The following is the calculation process:

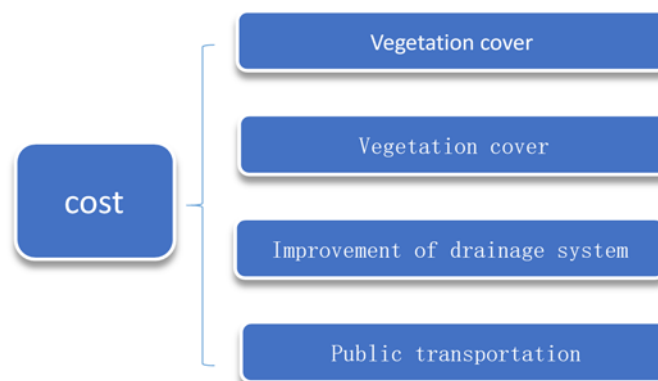


Figure 5-2-1. Cost of human intervention

The forest per square meter can store 5.4935mm (assuming that the water storage is precipitation, calculated on the basis of China's land area), while the planting cost of each two-thirds of the square kilometers of trees is 4764.4761dollar [5]. Therefore, we can calculate the cost of trees planting: 1.3009dollar / mm. The formula is as follows:

$$11.28 \times 10^{14} \div (3.08 \times 10^8 \times 666.6667) \times 30000 \div 666.6667 = 8.1915$$

$$8.1915 \div 6.2966 = 1.3009(\text{dollar} / \text{mm})$$

The cost of a public bike is about 1111.2699 dollars. Its parts design, production, processing, bicycle maintenance, network APP research and development, staff transfer and many other aspects of the cost.

Taking all these into account, the total cost of a bicycle is about 1111.2699 dollar. An average of 6430 square kilometers of the bustling city is to layout 200,000 bikes, so the cost is about 0.3455dollar per square meter [6].

The cost of constructing a small dam will average about 8 million dollars, a medium-sized dam will cost about 800 million dollars, and a large dam will cost about 31.75 billion dollars [7].

An area of 22,190 square kilometers of large urban drainage arrangements needs about 571.4 million dollars [8]. Therefore, the cost of drainage facilities is about 0.003dollar per square meter

And then, we would like to take North Korea as an example to predict the optimization result of the intervention's total cost for this country.

Data show that there is a clear spatial difference in the change of vegetation in North Korea between 2000 and 2016, with 39161 square kilometers reduced area, accounting for 31.9% of the total land area. Such areas are mainly distributed in the northern and southern plains of the mountainous areas, the western and southern plains. Among them, the decrease of vegetation in the places where Pyongyang, Salliya, Haizhou, Wonsan and Xianxing were located was particularly serious; the area increased was 28 972 km², accounting for 23% of the total land area. 6%. Such areas are mainly distributed in southern Korea, parts of the northwest and the Gaima plateau in the north [9]. We can roughly calculate that the vegetation cover area needed to increase is 10189 square kilometres. North Korea's urbanization population rate as of 2008 was 63% and its land area was 122,762 square kilometers [10]. From this we can roughly calculate the area of public bicycles to be covered for mitigating the risk of climate change is 17320.11 square kilometres. And the area for urban drainage construction is about 77340.06 square kilometers [11]. To reduce the risk of environmental change, at least one small, medium and large dam should be newly built.

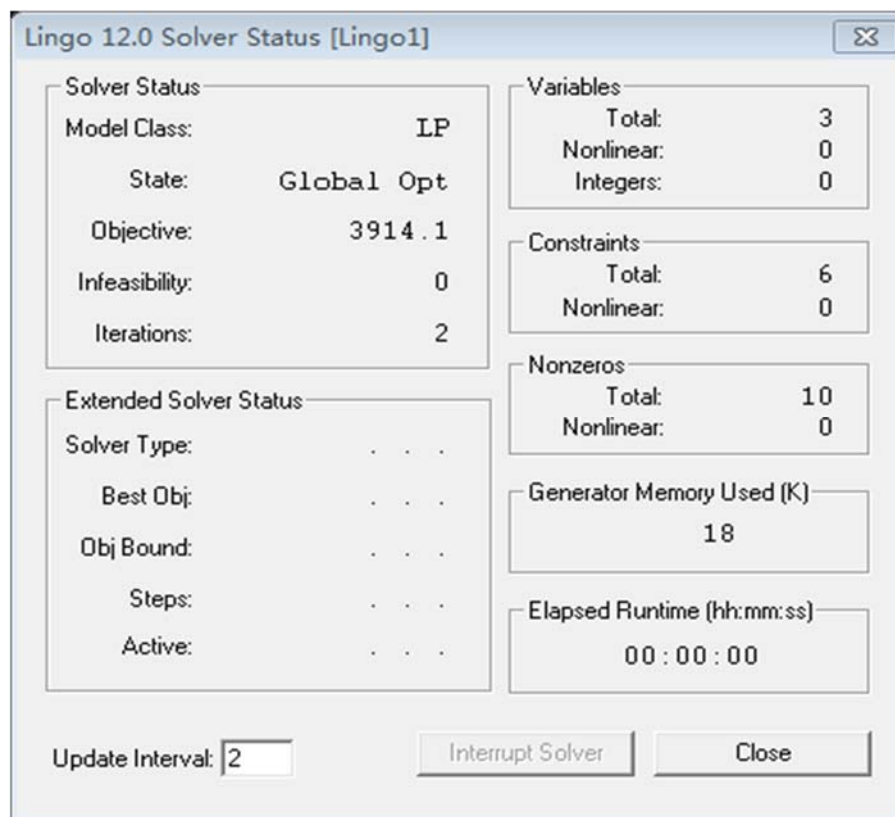


Figure 5-2-2. Cost optimization calculation

After software analysis, we conclude that in order to greatly decrease North Korea's fragility, it needs to invest about 3.9141 billion dollars.

6. Conclusion

6.1. *The strengths and weaknesses of our model*

Strengths:

- (1) Our model is highly accurate and the results are visually identifiable. It can clearly show how fragile the specific country is and accurately predict a country's future changes in fragility.
- (2) Our model needs fewer factors to be identified, and the calculation is relatively simple. The six determining factors of our model are representative and encompass nearly all drivers.
- (3) The data required in our model is easy to find in the database of international organizations.
- (4) Our model adopts the method of interval evaluation, which greatly reduces the impact of subjective factors on the model results

Weaknesses:

- (1) Our sample for determining fragility interval may not contain enough number of countries.
- (2) Some of our model assumptions may not actually correspond with some special countries. It may influence the accuracy of our model.

6.2. *Future work*

For future work, we suggest collecting further data about the contribution of different industries in each country to climatic factors such as precipitation and temperature. With these data, we can better design specific intervention programs for different industries. This will help us reduce the risks of climate change at a lower cost. Meanwhile, in the future, we must keep observing the latest trends of the climate to improve our model to make a more accurate prediction for country's fragility.

References

- [1] Xu Wei, Zhu Chao, Yang Xiaoyue, Dong Chao. Temporal and Spatial Variations of Urban Heat Island Effect in Shanghai in Recent 10 Years [J]. Atmospheric Sciences Research and Application, 2014 (02): 65 - 73.
- [2] Lin Meijing, Fan Ke, Wang Huijun. Prediction of the change of Somali jet stream in the context of global warming [J]. Journal of meteorology, 2008 (05): 756 - 764.
- [3] David Haim, Eric M. White, Ralph J. Alig. Permanence of agricultural afforestation for carbon sequestration under stylized carbon markets in the U.S. [J]. Forest Policy and Economics, 2014, 41.
- [4] Fu Jie. Danzhuang Freeway Soil and Water Conservation Design of a number of issues [D]. Dalian University of Technology, 2003.
- [5] Wu Qinxiao, Zhao Hongyan. Basic rules and conclusions of soil and water conservation [J]. Journal of soil and water conservation, 2001 (04): 13-15+19. Shared cyc.
- [6] Zhou Fen, Hu Chengyu. A literature review on the research literature of le cost management and profit model [J]. Modern business, 2017 (32): 176 - 178.
- [7] Bao Yongqing. Analysis on the environmental effects of dam construction [J]. China high-tech zone, 2017 (03): 108 - 109.
- [8] Liu Linyan. Study on the influence of natural social factors on urban drainage systems in different spatial forms [D]. Tsinghua university, 2012.
- [9] Qi Dekang, Wang Jianwen. Study on dynamic change of vegetation cover in north Korea and its driving force in 2016 [J]. Anhui agricultural science. 2017, 45 (21): 59 - 64.
- [10] Zhou Kuan. Research on the dynamics of north Korean vegetation and its response to climate change [D]. Northeast normal university, 2013.
- [11] Fan Liang, Wang Xuedong. Research on the influence and countermeasures of Korean culture on Qingdao's urban culture [J]. Korean studies, 2015 (02): 280 - 291.