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The Impacts of Climate Change on Regional Instability

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Abstract: The effects of Climate Change may have the potential to cause the weakening and breakdown of social and governmental structures. In this paper, we construct a fragile index evaluation model to determine the fragility of different countries and measure the impacts of Climate Change. In the first part, by selecting 10 indicators on economic, political, social and national cohesion, we establish a fragile index evaluation model. Applying the calculation method of each indicator value and the Grey slope correlation model, we determine the weight of each indicator and obtain the fragile indicator value. Then we set up the five-level standards of fragility and determine the destructive levels of equally destructive climate disasters in different countries of fragility. In the second part, we study the fragility of Somalia. Based on the fragile index evaluation model, we obtain that Somalia is at a severe fragility level. Then, by analyzing the impact of the drought on the fragile index of Somalia, we obtain that the meteorological drought would cause ecological drought, hydrological arid and agricultural drought, moreover it would lead to food scarcity, environmental degradation and increased conflict, thus contributing to the increasing of the fragile index on Somalia. In the third part, we study the fragility of Cuba. According to the fragile index evaluation model, we conclude that Cuba is at a relatively stable level. By analyzing the historical data of the North Atlantic hurricane, we obtain that with the rising frequency of hurricanes and floods in the Caribbean would push up fragile index of Cuba. We also estimate that fragile degree of Cuba is likely to shift from a relatively stable level to a relatively fragile level within 30 years. In the fourth part, simulation with Global Mapper shows that the sea level rise of 1.5 meters would inundate most of Maldives territory, threatening the stability of the country seriously. While constructing the artificial island is a feasibility intervention to mitigate the threat. According to the economic situation of the country, we propose the phased construction plan with an estimated cost of 3-4 billion dollars. Finally, we test the sensitivity of model. The result shows this model is sensitive to the indicator values but insensitive to indicator weights. In order to adapt to the assessment of large area and small area, we propose the expansion of evaluation index and the optimization plan of weight distribution.

Keywords: Climate Change, Fragile Index, Fragile Index Evaluation Model

1. Introduction

Climate change can lead to a series of meteorological disasters such as increased drought, frequent floods and the rise of sea level in different regions. The IPCC believes these effects may increase a country's fragility. [1]

Regarding the impacts of climate change on regional instability, relevant scholars have studied this issue. Literature [2] has established WRF model. By the analysis of the simulation results, to study the impacts of future urbanization on regional climate change. In literature [3], the author analyzes the impact of climate change on the annual variation of shallow groundwater levels in Latvia. The long-term annual regime of shallow groundwater levels is analysed in two different time periods according to the dominance of continental and oceanic air masses in Latvia [3]. This paper constructs a fragile index evaluation model to determine the fragility of different countries and measure the impacts of Climate Change. In order to adapt to the assessment of large area and small area, proposing the expansion of evaluation index and the optimization plan of weight distribution.

2. Research Content

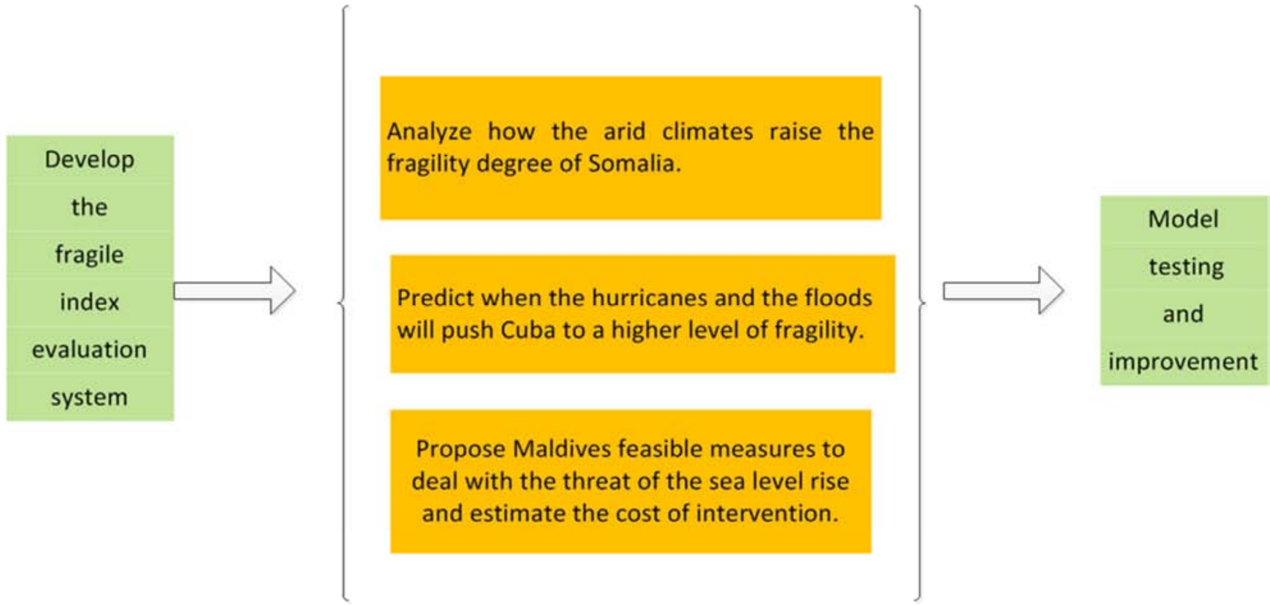

Figure 1. *Work.*

Task 1: We need to build a fragile evaluation model to measure the fragility degree of a country and establish the link between the fragile index and the meteorological disasters.

Task 2: Using the built fragile index evaluation model to measure the fragility degree of the top 10 countries in the FSI rankings. We should also analyze how climate disasters affect the country's fragility, and use the model to show if this climate disaster does not exist, the country's vulnerability would be lower.

Task 3: Using the built fragile index evaluation model to measure the fragility degree of the top 10 countries in the FSI rankings. We should also analyze the extent to which climate disasters promote the country's fragility. And we have to predict the frequency of climate disasters in the future based on the historical data, and estimate at what time the country's fragility degree will change significantly.

Task 4: For a country, we are expected to put forward interventions to achieve an effective response to climate disasters, and estimate the cost of intervention.

Task 5: We need to test the stability and sensitivity of the model. And we should propose the improvements for the problems existing in the model.

3. Fragile Index Evaluation Model

3.1. Determination of Fragile Index

Hurricanes are extremely destructive and often responsible for the deaths of hundreds and occasionally thousands of people. Many meteorologists agree that global warming has occurred in the last several decades at the earth's surface, and the trend is likely to continue.

3.1.1. Index Selection

There are many factors influencing the Fragile States Index. We divide these factors into four components: cohesion risk C, economic pressure E, political pressure P and social pressure S, which are called first-level indicators (blue). Then we select the representative ten factors as the second-level indicators (orange) for first-level indicators, which are military risk C1, social support risk C2, health level stress S1, food and nutrition risks S2, migrant risk S3, external intervention pressure S4, corruption level pressure P1, political power unity risk P2, public security risk P3, per capita GDP level pressure E1. As shown in Figure 2.

To facilitate understanding, we explain ten second-level indicators.

1. Military risk: The military capabilities of a country mean the abilities to resist aggressions of countries and maintain internal stability. If a country has less powerful military capabilities, then its political power is also more vulnerable. [4]

2. Social support risk: For the authorities, public support is an important factor in their long-term stability. A government with a lower social support rate is at a greater risk of its collapse. [5]

Figure 2. *Fragile States Index influencing factors.*

3. Per capita GDP level pressure: Per capita GDP reflects the average economic level of a country. A low level of per capita GDP would reduce the overall living standards of the country's people, causing public dissatisfaction. [6]

4. Corruption level pressure: A corrupt government tends to form a huge privileged class, which widens the psychological distance between the government and the general public, affecting normal market economy activities.

5. Political power unity risk: A country with a low degree of political power unity has a hard time pushing government policies, thus long-term policies concerning the long-term development of the country are not easy to be put into effect

6. Public security risk: A country with high public security risk has high governance costs and poor public security is not conducive to social stability. [7]

7. Health level Stress: In a country with low health level stress, sick people are less likely to be cured and even have higher rates to die because of their illnesses.

8. Food and nutrition risks: Food is the most basic material for people's lives. The deficiency of food can lead to malnutrition and it is possible to put the country into a turbulent situation easily. [8]

9. Displacement risk: The increasing number of the displaced persons may cause an increasing rate in the crime [9].

10. External intervention pressure: The external interventions include the positive and negative interventions. The positive interventions include financial assistance and peacekeeping forces. The negative interventions include military strikes from outside the country, economic sanctions, and support for the opposition government. [10]

3.1.2. Calculation of Index Attribute Values

As to the calculation of the second-level indicator attribute values, for a specific country, each index is related to the relevant organization's statistics and rankings. Calculation criteria are as follows:

	Data sources	Normalized formula	Remarks
C_1	[2]	1.5s	n: Ranking; j: Rank the total number of countries; s: Metadata value; For S1, the score is too low as 0.
C_2	[3]	(1.611-s)*6	
E_1	[4]	(n/j)*10	
P_1	[5]	(n/j)*10	
P_2	More sources	*	
P_3	[6]	(n/j)*10	
S_1	[7]	[1-(n/j)]*10	
S_2	[6]	[0.5+((s-42)/42)]*10	
S_3	[8]	[100n/121]*10	
S_4	More sources	*	

Figure 3. *The calculation of the second-level indicator attribute values. 3.2. Grey Slope Correlation Degree.*

For the weight distribution of the second-level indicators, we use an improved gray slope correlation method. Firstly, we calculate the correlation between the second-level indicators and fragile index (From Fragile States Index). Then, by equalization to the correlation, we obtain the weight of second-level indicators to fragile index. Finally, the first-level indicator weights are obtained by the sum of the second-level indicator weights.

We need to collect the data of countries' ten second-level indicators between 2007 and 2017 which needs to be analyzed. The second-level indicator attribute values and fragile index are used as time variable. Then we select the corresponding time periods from the two sequences consisting of the above time variables. The slope ratios of the corresponding time periods can reflect the correlation between the two sequences. The closer of the slope ratios are to one, the stronger the correlation between two sequences is. This improved model can not only be more reasonable to solve the problem about the positive and negative of the correlation, but also avoid the issue of weak rank preservation caused by the non-dimensional data.

Define the comparison sequence as follows:

$$X = \left(x(1), x(2), \dots, x(n)\right) \quad (1)$$

Define the slope of the sequence X over the interval [k, k+1]:

$$\alpha = x(k+1) - x(k) \; k = 1,2,\dots,n \quad (2)$$

Suppose that there are the reference sequence X0 and the comparison sequence Xi, and the two sequences are equal in length. Where X0 is the time sequences consisting of the country's fragile index and Xi is any one of ten sets of time series consisting of ten second-level indicator attribute values respectively. The formula is as follows:

$$X_0 = \left(x_0(1), x_0(2), \dots, x_0(n)\right) \quad (3)$$

The slopes of the sequence X0 and Xi in the interval [k-1, k] are:

$$\Delta x_0(k) = x_0(k+1) - x_0(k) \; \Delta x_i(k) = x_i(k+1) - x_i(k)$$

$$i = 1,2,\dots,10 \quad (4)$$

The sequences consisting of slopes are:

$$\Delta x_0 = \left(\Delta x_0(1), \Delta x_0(2), \dots, \Delta x_0(\mathrm{n}-1)\right) = \left(x_0(2) - x_0(1), x_0(3) - x_0(2), \dots, x_0(\mathrm{n}) - x_0(\mathrm{n}-1)\right) \quad (5)$$

$$\Delta x_i = \left(\Delta x_i(1), \dots, \Delta x_i(\mathrm{n}-1)\right) = \left(x_i(2) - x_i(1), x_i(3) - x_i(2), \dots, x_i(\mathrm{n}) - x_i(\mathrm{n}-1)\right) \; i = 1,\dots,10 \quad (6)$$

The sequence consisting of slope rates is:

$$\frac{\Delta x_0}{\Delta x_i} = \left(\frac{\Delta x_0(1)}{\Delta x_i(1)}, \frac{\Delta x_0(2)}{\Delta x_i(2)}, \dots, \frac{\Delta x_0(n-1)}{\Delta x_i(n-1)}\right)$$

$$i = 1,2,\dots,10 \quad (7)$$

The mean value is:

$$\overline{\left(\frac{\Delta x_0(k)}{\Delta x_i(k)}\right)} = \frac{1}{n-1}\sum_{k=1}^{n-1}\frac{\Delta x_0(k)}{\Delta x_i(k)} \; i = 1,2,\dots,10 \quad (8)$$

The improved slope correlation is calculated as:

$$\gamma(x_0, x_i) = \begin{cases} \dfrac{1+\overline{|\Delta x_0(k)|}}{1+|\Delta x_0(k)|+\overline{|\Delta x_0(k)-\Delta x_i(k)|}}, & \overline{\left(\dfrac{\Delta x_0(k)}{\Delta x_i(k)}\right)} \geq 0 \\ -\dfrac{1+\overline{|\Delta x_0(k)|}}{1+|\Delta x_0(k)|+\overline{|\Delta x_0(k)-\Delta x_i(k)|}}, & \overline{\left(\dfrac{\Delta x_0(k)}{\Delta x_i(k)}\right)} < 0 \end{cases} \quad (9)$$

Where,

$$\overline{|\Delta x_0(k)|} = \frac{1}{n-1}\sum_{k=1}^{n-1}\overline{|\Delta x_0(k)|} \quad (10)$$

$$\overline{\left(\frac{\Delta x_0(k)}{\Delta x_i(k)}\right)} = \frac{1}{n-1}\sum_{k=1}^{n-1}\frac{\Delta x_0(k)}{\Delta x_i(k)} \quad (11)$$

$$\overline{|\Delta x_0(k) - \Delta x_i(k)|} = \frac{1}{n-1}\sum_{k=1}^{n-1}|\Delta x_0(k) - \Delta x_i(k)|$$

$$i = 1,2,\dots,10 \quad (12)$$

According to the above method, we can calculate the gray slope correlations between the country's ten second-level indicator attribute values and the total fragile index, recorded as $\gamma_1, \gamma_2, \cdots \gamma_{10}$. Then, by equalization to the correlation, we obtain the weight of second-level indicators to fragile index. The formula is as follows:

$$\omega_r = \frac{\gamma_i}{\gamma_1+\gamma_2+\cdots+\gamma_i} \; i = 1,2,\dots,10 \quad (13)$$

Finally, we use the weighted summation method for second-level indicator attribute values to obtain Fragile States Index. Section 3.3 below is the result of the fragile index we obtained in Malaysia.

3.3. Fragile Index Results

After obtaining Malaysia's second-level indicator attribute values (φi) through the section3.1.2, we develop the Grey Slope Correlation Model to calculate the weight of second-level indicators to fragile index. Moreover, we use the weighted summation method to get the Malaysian fragile index, the formula is as follows:

$$\eta = \sum_{k=1}^{10} \Phi_i \cdot \omega_i \quad (14)$$

Its value is 2.3716. The specific calculation is as follows:

	C_1	C_2	E_1	P_1	P_2	P_3	S_1	S_2	S_3	S_4	η
φ_i	0.96	1.96	3.68	3.13	3.21	2.91	0	0.04	2.52	2	
ω_i	0.09	0.15	0.26	0.1	0.08	0.1	0.05	0.09	0.02	0.06	
$\varphi_i.\omega_i$	0.09	0.29	0.96	0.31	0.26	0.29	0	0.003	0.12	0.12	2.37

Figure 4. *Malaysia second-level indicators fragile index.*

3.4. Fragile Level of Division

Fragile is a relative concept in several countries at different levels. From Fragile States Index website, we select four countries at different levels according to the fragile index ranking in 2017, Somalia (ranked 2), Kenya (ranked 22), Cuba (ranked 119) and Switzerland (ranked 176) respectively. Then we apply the fragile index evaluation model to calculate the fragile index of four countries. The calculation results are as follows:

		C_1	C_2	E_1	P_1	P_2	P_3	S_1	S_2	S_3	S_4	η
Somalia	φ_i	5.51	5.34	9.63	10	9.7	6.69	10	6.87	9.49	5	
	ω_i	0.12	0.13	0.24	0.08	0.1	0.06	0.06	0.12	0.02	0.07	
	$\varphi_i.\omega_i$	0.66	0.69	2.31	0.8	0.97	0.40	0.60	0.82	0.19	0.35	7.80
Kenya	φ_i	2.06	3.06	7.74	8.24	7	5.35	6.9	4.68	3.73	3	
	ω_i	0.09	0.12	0.25	0.09	0.07	0.09	0.1	0.13	0.02	0.04	
	$\varphi_i.\omega_i$	0.19	0.39	1.94	0.74	0.49	0.48	0.69	0.61	0.07	0.12	5.72
Cuba	φ_i	1.98	1.56	4.21	3.41	4.21	4.36	0	0.02	2.54	3	
	ω_i	0.12	0.13	0.26	0.1	0.09	0.05	0.05	0.09	0.03	0.08	
	$\varphi_i.\omega_i$	0.24	0.20	1.10	0.34	0.38	0.22	0	0.002	0.076	0.24	2.79
Switzerland	φ_i	1.06	0.56	0.11	0.28	1.87	0.23	0	0.03	0.06	0	
	ω_i	0.15	0.09	0.26	0.06	0.1	0.09	0.05	0.06	0.04	0.1	
	$\varphi_i.\omega_i$	0.16	0.05	0.029	0.017	0.19	0.02	0	0.002	0.02	0	0.49

Figure 5. *Fragile index in four countries.*

In order to visualize the data, we fit the Fragile Indexes of these four countries to the rankings and fit the Fragile States Index website' s Fragile Index for 178 countries in 2017 as a reference, as shown below:

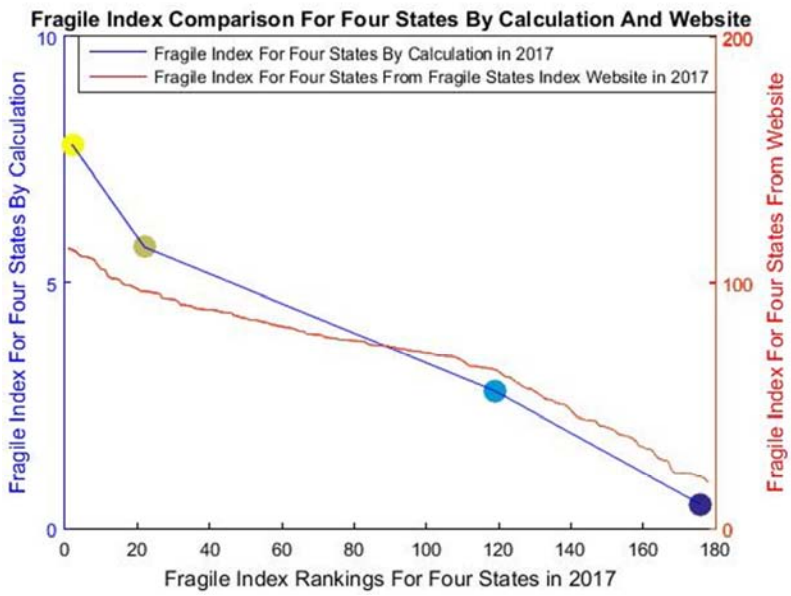

Figure 6. *Fragile index comparison for four states by calculation and website.*

As can be seen from the figure, it is relatively consistent between the Fragile Index calculated using the fragile index evaluation model and the Fragile States Index website standard. This indicates the fragile index evaluation model is more reliable. According to the distribution range of the fragile index, we divide the equilibrium into five levels as shown:

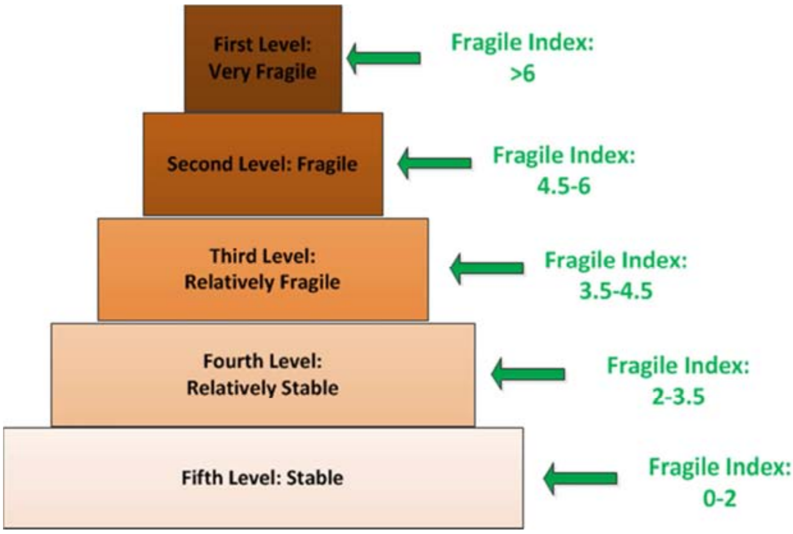

Figure 7. *Fragile level of division.*

3.5. Quantifying the Impacts of Climate Change on Countries with Different Fragile Levels

Droughts and floods are the most serious impacts caused by climate change. For low-altitude countries and small island states, the hazards of climate change also include sea level rise. To illustrate the impact of climate disasters to fragile Index, we make a structural diagram of the impact of climate disasters as shown below:

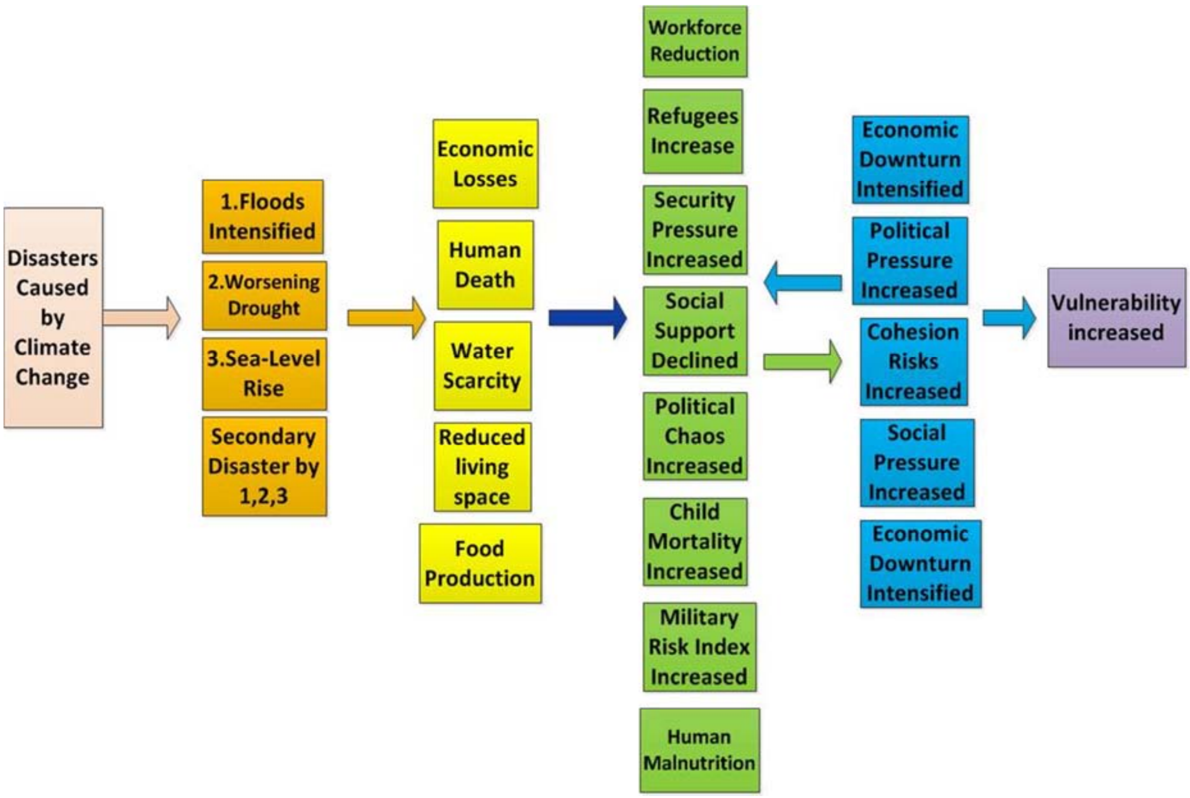

Figure 8. *The impact of climate disasters to fragile Index.*

The feasible quantitative method

The harm caused by climate change will be gradually and accumulatively amplified in the process of transmission, leading to a series of chain reactions. The degree of the amplification of the same destructive climate disasters varies from country to country: The larger and more stable countries can easily digest this kind of disaster; but the smaller and weaker countries are more destabilized under the impact of disasters, while the dangers of climate disasters are greatly magnified. For a specific country, it is hard to try to extract the value of the fragile index contributed by the climate change factor from the population and observe its influence. [11]

However, we can give an initial damage value to climate disasters to simulate how much the damage value has been amplified during the transmission. In this model, the magnification is divided based on the level at which the calculated vulnerability index is located. In order to facilitate the calculation, we set that climate disasters contain 1-level to 10-level magnification in the process of transmitting at all levels. As to the magnification mentioned here, we have taken the interactions between the same levels of indicators into account. At the same time, the effects of the vicious circle are also taken into consideration. First of all, we calculate the magnification ratio of the original damage value to the second-level index. Then, we calculate the magnification ratio of the second-level index to the first-level index. Finally, we obtain the total magnification. The specific division is as follows:

Fragile Level	1	2	3	4	5
Original damage value to second level	9	7	5	3	1
Second level to first level	10	8	6	4	2
Total magnification	90	56	30	12	2

Figure 9. *Magnitude of the impact of the disaster.*

3.6. Model Summary

Step1 We have selected 10 indicators covering the four aspects of economy, politics, society and national cohesion to measure the fragility of a country comprehensively.

Step2 We determine the calculation of the indicator values. By the fragile index evaluation model, we get the indicator weights.

Step3 We select four countries that are at different levels from the fragile index ranking in Fragile States Index in 2017. We apply the fragile index model to calculate the fragile index for these countries. Then we fit the fragile index and the score provided by Fragile States Index into a graph. The fitting result shows consistency, which proves the rationality of the model.

Step4 Based on the distribution of fragile indices, we define a grade scale for the fragile degree. Finally, we propose a feasible quantitative method for the impact of climate disasters on countries with different levels of fragility.

Next, we will use the fragile index evaluation model to analyze three countries separately, which are at different levels of fragility and affected by different meteorological disasters.

4. Somalia Affected by Severe Drought

Somalia has been influenced by droughts and conflicts for years. It is estimated that 2.444 million people are in food crisis and the 866000 are in extremely dangerous situation. Compared to 2016, the number of the Somalis on the brink of famine increased almost tenfold. It is estimated that by 2018 there will be 1.2 million children undernourished, 232,000 of whom will likely die as a result of severe malnutrition. [12]

4.1. Somalian Fragile Index

Applying the fragile index evaluation model to Somalia, we get the following result:

	C_1	C_2	E_1	P_1	P_2	P_3	S_1	S_2	S_3	S_4	η
φ_i	5.51	5.34	9.63	10	9.7	6.69	10	6.87	9.49	5	
ω_i	0.12	0.13	0.24	0.08	0.1	0.06	0.06	0.12	0.02	0.07	
$\varphi_i \cdot \omega_i$	0.66	0.69	2.31	0.8	0.97	0.40	0.60	0.82	0.19	0.35	7.80

Figure 10. *Somalia's fragile index.*

Fragile index in Somalia of 7.8022 is at its highest level of vulnerability. So the amplification effect of its disasters may be 56-90 times and the consequence is disastrous.

4.2. Disaster Data Support

Somalia has been influenced by droughts and conflicts for years. In the year of 2017, tens of thousands of people have been forced to leave their homes because of the continuing effects of droughts and conflicts. It is estimated that 2.444 million people are in food crisis and the 866000 are in extremely dangerous situation. Compared to 2016, the number of the Somalis on the brink of famine increased almost tenfold. It is estimated that by 2018 there will be 1.2 million children undernourished, 232,000 of whom will likely die as a result of severe malnutrition [12].

4.3. Impact of Drought on Fragile Index η

Worsening drought mainly cause the growth of the seven second-level indicator values such as C2, E1, P2, P3, S1, S2, S3, which results in a further increase in the fragile index η. If drought can be drastically alleviated, then the fragile index will decline and the magnifying effect of disasters will be diminished. At the same time, improving the level of political governance can also contribute to the vigorous recovery of Somalia that is in the quagmire of crisis.

5. Cuba Affected by Hurricane and Flood

In May of 2012, there was a persistent heavy rain in central Cuba. Based on an assessment of the damage caused by the torrential rain, more than 1,000 houses were damaged. On October 25,2012, Hurricane Sandy struck Cuba, resulting in the damage of 194,767 houses. [12]

5.1. Cuba Fragile Index

Applying the fragile index evaluation model to Somalia, we get the following result:

	C_1	C_2	E_1	P_1	P_2	P_3	S_1	S_2	S_3	S_4	η
φ_i	1.98	1.56	4.21	3.41	4.21	4.36	0	0.02	2.54	3	
ω_i	0.12	0.13	0.26	0.1	0.09	0.05	0.05	0.09	0.03	0.08	
$\varphi_i \cdot \omega_i$	0.24	0.20	1.09	0.34	0.38	0.22	0	0.002	0.08	0.24	2.79

Figure 11. *Cuba's fragile index.*

The fragile index in Cuba is 2.79 which is at a relatively stable 4-stage state. The amplification effect of its disasters may be between 2-12 times.

5.2. Data Support

In May of 2012, there was a persistent heavy rain in central Cuba. Based on an assessment of the damage caused by the torrential rain, more than 1,000 houses were damaged or destroyed, over 3,300 hectares of farmland were flooded and more than 8,000 people evacuated. On October 25, 2012, Hurricane Sandy struck Cuba, resulting in the damage of 194,767 houses. What's more, 32,521 houses were destroyed and thousands of people lost their homes after the attack on Sandy [12].

5.3. Disaster Development in Future

Compared to other Caribbean countries such as Haiti, the meteorological disasters in Cuba are not serious, which may be an important factor in the fact that Cuba's fragile index is at a low level. We collected the number of hurricanes that formed in the North Atlantic from 1950 to 2013. Using SPSS to draw the image as follows:

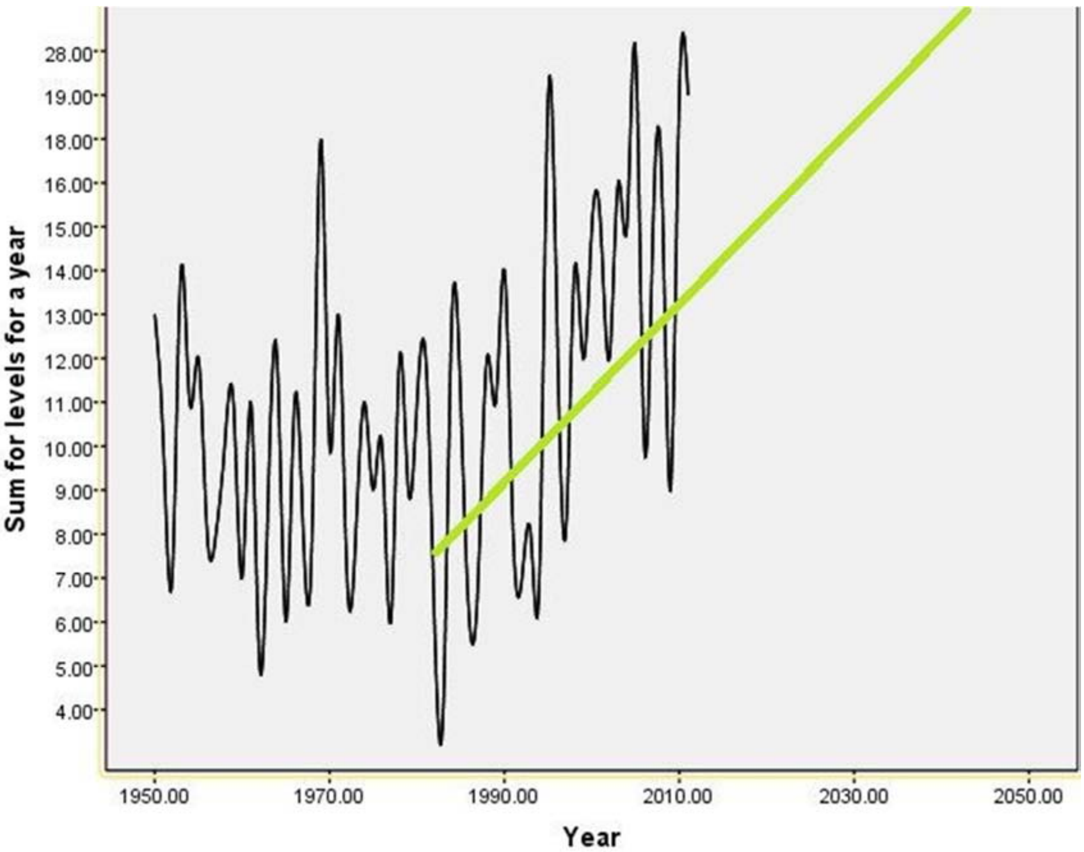

Figure 12. *Changes in the number of hurricanes in the North Atlantic.*

It can be seen that in recent decades, the number of hurricanes formed in the North Atlantic has shown a rapid increase. This trend means that there will be an increase in the number of hurricanes landing in Cuba in the future, as well as the floods, which caused by heavy rainfall because of hurricanes. Secondary floods and other infectious diseases will also increase.

Only hurricanes and floods are considered, according to the current trend, the frequency of the meteorological disaster will be likely to double in 2050. Assuming that the current meteorological disaster contributes 0.5 to the Cuban fragile index, then the contribution value in 2050 will exceed 1.0. At the same time, given the increased magnification of disasters caused by the rising fragility index, it is quite likely that before 2050 the fragile index of Cuba would have far exceeded 3.5, shifting from a relatively stable country at level 4 to a relatively vulnerable country at level 3.

6. Precarious Maldives

6.1. Maldivian Fragile Index

Applying the fragile index evaluation model to Maldives, we get the following result:

	C_1	C_2	E_1	P_1	P_2	P_3	S_1	S_2	S_3	S_4	η
φ_i	0.2	0.9	3.53	5.4	3	4.42	0	2.51	1	2	
ω_i	0.12	0.13	0.26	0.1	0.09	0.05	0.05	0.09	0.03	0.08	
$\varphi_i.\omega_i$	0.024	0.12	0.92	0.54	0.27	0.22	0	0.23	0.03	0.16	2.51

Figure 13. *Maldives's fragile index.*

According to the evaluation model, the Maldives fragile index is 2.5057, so Maldives is relatively stable at the fourth level. However, we have weakened the impact of the ecological environment. Given the special geographical environment of Maldives, its fragile level may well be far above the assessment result.

6.2. Maldives under the Influence of Sea Level Rise

Because of the thermal expansion of sea water and the melting of glaciers into the sea which are caused by global warming, and the sea level is constantly rising. As shown below:

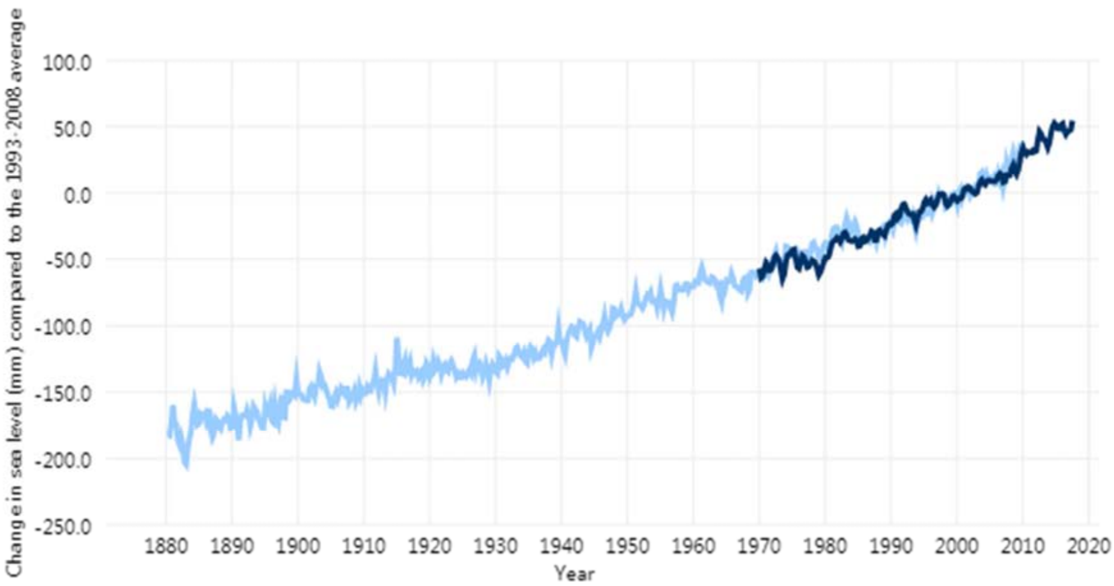

Figure 14. *Global sea level change.*

According to the data provided by NOAA, since 1993, the rising rate of global sea level has risen from 1.7mm/year in the twentieth century to 3.4mm/year now, and there is still a chance of accelerating in the future.

We download the elevation data of Maldives, using the Global Mapper to make the image of the elevation in Maldives (as shown in the upper part of Figure 15). Then, we simulate the situation when elevation increases by 1.5m (as shown in the lower part of Figure 15).

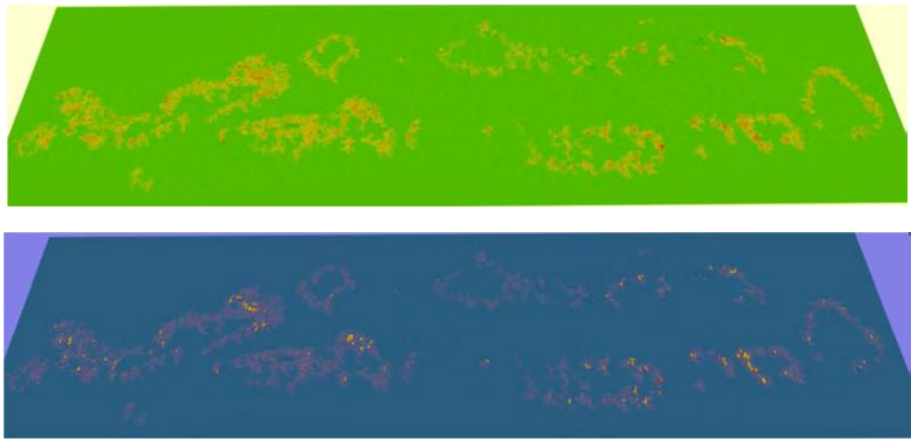

Figure 15. *Maldives's elevation image.*

The vast majority of Maldives natural elevation is only between 0 and 1 meter. The highest natural elevation is 2.4 meters. Some coral reefs are almost at sea level. Therefore, most of the Maldives will be submerged in a hundred years, according to the current trend of global sea level rise. In addition to this, the living space of the country's population will be further compressed. What's worse, sea level rise will put pressure on coastal ecosystems, causing the huge losses to the livelihood tourism in the country and economy hard and the fragile index would be pushed up significantly.

6.3. Feasible Intervention Methods

Suppressing the sea-level rise requires the joint efforts of all countries in the world. For Maldives, inflating artificial reefs and building offshore platforms which would be a viable option to survive in the native land.

As the country's main source of income relies on the tourism, we have to consider the ecological effects when constructed the artificial islands or offshore platforms. We should minimize the damage to the original ecosystem and keep it attractive to tourists. Meanwhile, the economic benefits should also be considered.

Artificial islands are expensive to build. Because of the difference of geographical environment and construction standard, there is a big difference in unit construction cost. Artificial islands are expensive to build. Because of the difference of geographical environment and construction standard, there is a big difference in unit construction cost. An artificial island covering 1.88 square kilometers has been finished in Maldives, which is expected to hold 100,000 people. The initial cost of the island is about 1 billion dollars. [13] Three artificial islands in the same scale may be necessary if all the people around the country live here in the future. Then 3 billion dollars will be invested. The GDP of Maldives in 2016 was 3.591 billion dollars. Therefore, the construction of artificial islands should be carried out in stages. Taken into account the construction costs in the future rise, as well as the configuration of additional facilities, the total cost of construction may well exceed 3 billion. However, due to the year-on-year growth of Maldives' tourism revenue, these inputs should be affordable.

After the completion of the artificial island, the living space of humans in the country will be expanded and the tourism industry will get sustainable development. The pressure on the economic level, which will contribute the most to the fragile index, will gradually decrease and the fragile index will decrease accordingly.

7. Sensitivity Analysis and Improvement

First, we calculate the fragile indices of Malaysia and Switzerland and call themη1, η2, respectively. Then, we exchange the weights of the ten second-level indicators of the two countries to calculate again. Then we call the new fragile indices as η3, η4 respectively.

		C_1	C_2	E_1	P_1	P_2	P_3	S_1	S_2	S_3	S_4	η	
Malaysia	φ_i	5.51	5.34	9.63	10	9.7	6.69	10	6.87	9.49	5	η_1	η_2
	ω_i	0.12	0.13	0.24	0.08	0.1	0.06	0.06	0.12	0.02	0.07	7.80	7.80
	$\varphi_i \cdot \omega_i$	0.66	0.69	2.31	0.8	0.97	0.40	0.60	0.82	0.19	0.35		
Switzerland	φ_i	1.06	0.56	0.11	0.28	1.87	0.23	0	0.03	0.06	0	η_3	η_4
	ω_i	0.15	0.09	0.26	0.06	0.1	0.09	0.05	0.06	0.04	0.1	0.49	7.80
	$\varphi_i \cdot \omega_i$	0.16	0.05	0.029	0.017	0.19	0.02	0	0.002	0.02	0		

Figure 16. *Maldives's elevation image.*

The fragile indices of the two countries have changed about 1% and 10% respectively. This shows that for the change of indicator weights, countries with low fragile index are more sensitive than those with high vulnerability index. It also shows that the fragile index η is more dependent on the second level index attribute value φi, while it is not sensitive to the change of the weight ωi of each indicator. Therefore, in assessing the fragile index, we should pay particular attention to collect and process the original data and optimize the second level index attribute value φi.

For Maldives, a small island nation, the reliability of the vulnerability index assessment model has been tested. In the assessment criteria, the impact of environmental factors is somewhat weakened, while the environmental impact of the Maldives is very large. In small countries or regions, the factors that affect fragile index tend to focus on a few specific aspects. As to such small countries, we should consider the weight of each indicator specially to assign the appropriate weights to the key indicators.

In large areas such as the Middle East, the fragile index is more affected by the situation in various countries in the region and the relations among countries. The collapse of a country may seriously affect neighboring countries. Another example is the same basin of several countries, the use of water resources will have a great impact on each other. In order to measure the fragile index of such a large region accurately, we should include these country-to-country impacts as an indicator in the assessment model.

8. Conclusion

Meteorological disasters caused by climate change would increase the fragility of a country. As the fragile index of a country rises, the harmfulness caused by the climate disasters becomes more serious and contributes to making the country more fragile. The climate disasters may be more frequent and worse in the future. The more vulnerable countries are, the more they should actively respond to the disasters caused by climate change so as to prevent themselves from sliding to the brink of collapse. The international community should also actively cooperate to jointly cope with climate change and help vulnerable countries to get out of their predicament.

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