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The Impact of Climate Change on National Vulnerability

Lei Xiao, Xunhao Huang, Li Zhong
North China University of Science and Technology, Tangshan, 063210, China

Abstract: Climate change is a global threat to security in the 21st century. Fragile countries are more likely to be affected in all aspects of climate change. Therefore, an accurate model is needed to determine a country's fragility and simultaneously measure the impact of climate change. First, we select 17 indicators that affect national vulnerability and establisha model for assessing the degree of national vulnerability based on the VSD framework. Then we use the method of entropy to quantify the influencing factors of vulnerability, divide the vulnerability into five levels more precisely, and get the relationship between national vulnerability and climate change. Then, in the top 10 countries given in FSI, we choose Syria as the research object. According to the establishedmodel, we conclude that climate change is the indirect cause of Syria's vulnerability, especially for rainfall, temperature and CO2 emissions. Finally, In order to better optimize the model, we have given a vulnerability framework of Coupled Human-Environmental System so that the model can work on both small cities and large continents theoretically.

Keywords: Fragile states; Climate change; National vulnerability assessment model based on VSD framework; Sensitivity analysis

1. Introduction

Climate change is one of the most important global issues today. It affects, directly or indirectly, socio-economic and natural systems. Evidence shows that global climate change has affected many aspects, including rising sea levels, floods and droughts, and the reduction of species diversity. The impact of climate change on the survival and development of mankind is a major challenge that all nations face together.

Fragile countries have a series of problems such as poor natural environment, internal social conflicts and low level of economic development. Climate change is one of the most important and complex factors. Climate change has shifted from a controversial scientific issue to a political, economic, environmental and even moral issue.

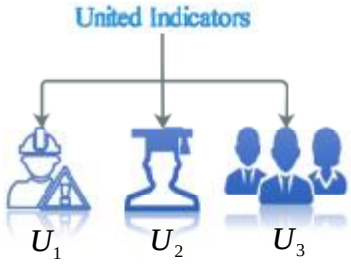
Vulnerability is a highly abstract and vague concept. Academics have not formed a unified view on the connotation of the national vulnerability, and the scope of the measurement of vulnerability varies. Therefore, an accurate model is needed to determine a country's fragility and simultaneously measure the impact of climate change.

2. Establishment of National Vulnerability Assessment Model Based on VSD Framework

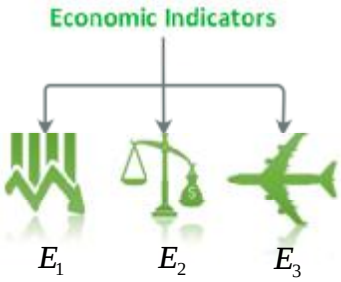
2.1. The composition of the VSD framework

The VSD framework consists of three parts, which are exposure, sensitivity and adaptability.Exposure mainly includes two factors, natural stress and artificial stress,which are defined as the degree of disturbance and the changes of the external environment that the system faces.The intensity of the stress factor affects the extent of exposure. The higher the degree of exposure, the greater the social and economic interference. Therefore, the more fragile the system is. Sensitivity is the inherent property of the system itself. It also reflects the degree of coercion that the exposed unit is susceptible to positive or negative effects. When external conditions change, the sensitivity of the system increases, and the vulnerability of the system is stronger. Adaptive capacity refers to the resilience of the system to external stresses or internal disturbances. In the framework of the VSD, this is mainly reflected in the ability of human society to reduce the negative impact of disturbance through the formulation of relevant strategies. The stronger the adaptability, the greater the likelihood that the system will be restored to equilibrium, the lower the vulnerability.

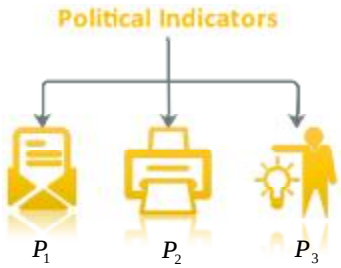
2.2. Establish indicators that affect national vulnerability



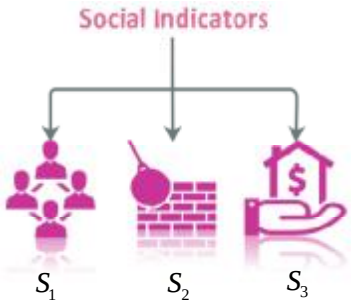
- U_1 : Security Apparatus
- U_2 : Factionalized Elites
- U_3 : Group Grievance



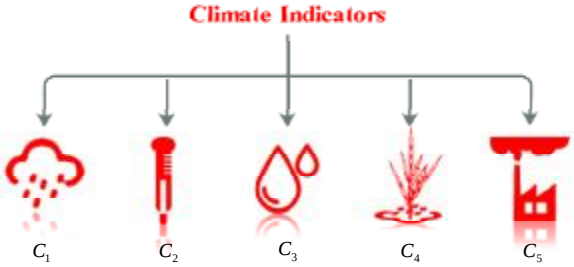
- E_1 : Economic Declineand Poverty
- E_2 : Uneven Economic Development
- E_3 : Human Flight and Brain Drain



- P_1 : State Legitimacy
- P_2 : Public Services
- P_3 : Human Rights and Rule of Law



- S_1 : Demographic Pressures
- S_2 : Refugees and Internally Displaced Persons
- S_3 : External Intervention



- C_1 : Rainfall
- C_2 : Temperature
- C_3 : Improved water source
- C_4 : Cereal yield
- C_5 : CO_2 emissions

2.3. Establish VSD indicator system

In assessing the extent of national vulnerability, we construct a vulnerability assessment indicator system based on the connotation of the VSD framework. As each country is more differentiated, its exposure, sensitivity and adaptability are different. Therefore, we will establish the evaluation system is divided into the dimension layer, index layer and parameter layer. The above seventeen indicators that affect national vulnerabilities constitute the five indicator layers, namely, climate, politics, economy, society and unity. The five indicator layers belong to three dimensions respectively. Climate and politics are classified as exposure dimensions, societies and economies as sensitivity dimensions, and convergence as adaptive dimensions.

The main framework of the system is as follows:

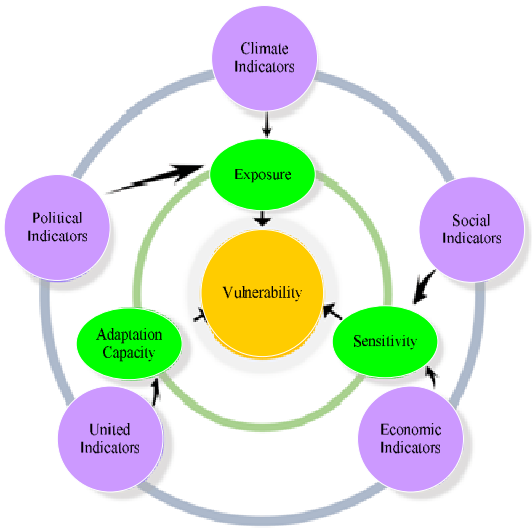


Figure 1. The establishment of the overall VSD indicator system

In order to verify the feasibility of the VSD framework in the evaluation of the national vulnerability level, we use

the entropy fuzzy matter-element model to quantitatively evaluate the framework.The fuzzy matter-element model mainly evaluates the multi-factor by studying the change rules of the names, characteristics, and values of things.In the VSD framework, the contribution rate of each index we choose to the evaluation unit is different. Therefore, we introduce the entropy of information to calculate the weight, so as to reduce the human intervention and make the final evaluation result more objective and credible.

3. Establish Entropy Fuzzy Matter-element Model

The Entropy fuzzy matter-element model can not only compare the impact of different factors on the national vulnerability from a horizontal perspective, but also measure the vulnerability of different countries vertically.Specifically, we use the method of entropy fuzzy matter-element analysis to establish the vulnerability assessment model.We start with the evaluation framework of VSD framework, introduce the concept of information entropy and apply the entropy fuzzy matter-element model to calculate the Euclidean proximity of the evaluation index and the standard sample.And then get the factors that affect the change of national vulnerability, so as to realize the horizontal comparison of different factors on the impact of national vulnerability, and at the same time, we can make a vertical division of the degree of vulnerability of each country.

Entropy fuzzy matter-element model of the national vulnerability assessment process is shown as follows in Figure 2.

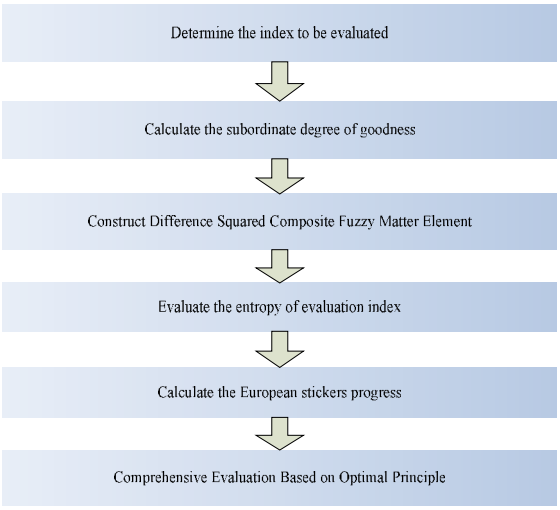


Figure 2. Flowchart of evaluation of national vulnerability

3.1. Establish fuzzy matter element model

3.1.1. Fuzzy Matter Element and Compound Fuzzy Matter Element

In the matter-element analysis of things M and its characteristic C and the value of x composition $R=(M,C,x)$ or $R=(M,C,x)$, while the name of things, features and values called the three elements of the element. If the value x has fuzziness, it is called R fuzzy matter element. If something M has n-dimensional blur element, the $C_1,C_2,\mathbf{L},C_n$ has a feature that has a value of $x_1,x_2,\mathbf{L},x_n$. Combining the n-dimensional fuzzy matter elements of m things together, we can form an n-dimensional composite element R_{mn} of m things, denoted as:

$$R_{mn}=\begin{bmatrix} & M_1 & M_2 & \mathbf{L} & M_m \\ C_1 & x_{11} & x_{21} & \mathbf{L} & x_{m1} \\ C_2 & x_{12} & x_{22} & \mathbf{L} & x_{m2} \\ \mathbb{M} & \mathbb{M} & \mathbb{M} & & \mathbb{M} \\ C_n & x_{1n} & x_{2n} & \mathbf{L} & x_{mn} \end{bmatrix} \quad (1)$$

For the national vulnerability assessment system, M is the country to be evaluated, C is the seventeen indicators identified in the previous text, and x_{mn} is the membership of the countries to be assessed for the seventeen corresponding indicators we selected.

3.1.2. Subordinate degree fuzzy object matter

The subordinate degree of subordination refers to the corresponding fuzzy value of each individual evaluation index, and belongs to the degree of subordination of corresponding fuzzy values of each evaluation index corresponding to standard things.The principle established by the subordinate degree of subordination is called the subordinate degree of subordination principle.Because the characteristics of each evaluation index have different evaluation methods, they can be divided into profitability index and cost index. The bigger the profitability index, the better the cost index. For the above two cases, we respectively adopt the following two formulas to convert the fuzzy value x_{ij} of the compound fuzzy matter element into a subordinate degree u_{ij}. The expression is as follows:

Cost indicators:

$$z_{ij}=\frac{\min x_{ij}}{x_{ij}} \quad (2)$$

Profitability index:

$$z_{ij}=\frac{x_{ij}}{\max x_{ij}} \quad (3)$$

Among them, $\max x_{ij}$ and $\min x_{ij}$ are respectively the maximum value and the minimum value of each index.

From this we can construct the subordinate degree fuzzy matter R'_{mn} as:

$$R_{mn}^{'}=\begin{bmatrix} & M_1 & M_2 & \mathbf{L} & M_m \\ C_1 & z_{11} & z_{21} & \mathbf{L} & z_{m1} \\ C_2 & z_{12} & z_{22} & \mathbf{L} & z_{m2} \\ \mathbb{M} & \mathbb{M} & \mathbb{M} & & \mathbb{M} \\ C_n & z_{1n} & z_{2n} & \mathbf{L} & z_{mn} \end{bmatrix} \quad (4)$$

3.1.3. Construct Difference Square Compound Fuzzy Matter Element

In order to calculate the degree of closeness, we need to construct a difference squared fuzzy matter element $R_{mn}^{''}$ on the basis of fuzzy membership ment $R_{mn}^{'}$ of the optimal membership degree.The standard fuzzy matter element R_{on} refers to the maximum value or the minimum value of the subordinate membership degree of each evaluation index from the fuzzy matterelement $R_{mn}^{'}$ of the optimal membership degree, and the value of the processed value is set as the optimal one.

We use $q_{ij}(i=1,2,\mathbf{L},m;\ j=1,2,\mathbf{L},n)$ to denote the square of the difference between the standard fuzzy matter element R_{on} and the complex subordinate fuzzy matter element $R_{mn}^{'}$, and its mathematical expression is as follows.

$$q_{ij}=(z_{ij}-1)^2 \quad (5)$$

The resulting fuzzy difference square matrix e is expressed as follows.

$$R_{mn}^{''}=\begin{bmatrix} & M_1 & M_2 & \mathbf{L} & M_m \\ C_1 & q_{11} & q_{21} & \mathbf{L} & q_{m1} \\ C_2 & q_{12} & q_{22} & \mathbf{L} & q_{m2} \\ \mathbb{M} & \mathbb{M} & \mathbb{M} & & \mathbb{M} \\ C_n & q_{1n} & q_{2n} & \mathbf{L} & q_{mn} \end{bmatrix} \quad (6)$$

3.2. Entropy method to determine the index weight

In the evaluation system of vulnerability degree, the different indicators to be evaluated are selected in all fields, so the influence degree to each evaluation unit is different, and the corresponding weights need to be determined according to their contribution to the evaluation unit.In information theory, information entropy is a variable that reflects the degree of information disorder, and can also be used to represent the system's uncertainty and stability.If the degree of variation of the evaluation index is greater, then the greater the amount of information provided, the greater the weight.If the entropy value is smaller, then the smaller the systematic degree of disorder is, so the entropy of information can be used in the weight calculation of each evaluation index.

The concrete steps are as follows:

Step.1 Normalized Processing

After the formula (1) - (6) - transformed matrix $R_{mn}^{''}$ is normalized, the matrix is as follows.

$$P=\begin{bmatrix} & M_1 & M_2 & \mathbf{L} & M_m \\ C_1 & p_{11} & p_{21} & \mathbf{L} & p_{m1} \\ C_2 & p_{12} & p_{22} & \mathbf{L} & p_{m2} \\ \mathbb{M} & \mathbb{M} & \mathbb{M} & & \mathbb{M} \\ C_n & p_{1n} & p_{2n} & \mathbf{L} & p_{mn} \end{bmatrix}, \text{ among then } p_{ij}=\frac{b_{ij}}{\sum_{k-1}^{m} b_{ik}} \quad (7)$$

Step.2 Calculate the information entropy e_i

The existing information entropy formula is used to calculate the information entropy of the x-th evaluation index. The formula isas follows.

$$e_i=-\frac{1}{\ln m}\sum_{i=1}^{m} f_{ij}\ln f_{ij} \quad (8)$$

Among then:

$$f_{ij}=\frac{1+p_{ij}}{\sum_{i=1}^{m}(1+p_{ij})} \quad (i=1,2,\mathbf{L},m;\ j=1,2,\mathbf{L},n) \quad (9)$$

Step.3Calculate the degree of deviation s_i

We consider the characteristics of information entropy disorder, the greater the value, the greater the disorder of the evaluation results.In other words, the smaller the deviation between the selected evaluation indicators.However, the more the deviation between the more indicators reflect the importance of the indicator, so we need to calculate the deviation of each indicator, which is calculated as follows.

$$s_i=1-e_i,(i=1,2,\mathbf{L},m) \quad (10)$$

Step. 4Calculate the information entropy weight of each indicator in the evaluation system of national vulnerability

To normalize the deviation degree s_i, we can get the weight vector as follows $W=(w_1,w_2,\mathbf{L},w_m)$,Among then:

$$w_i=\frac{s_i}{n-\sum_{i=1}^{n} e_i} \quad (0\le w_i\le 1,\sum_{i=1}^{n} w_i=1) \quad (11)$$

It is feasible to determine the weight of information entropy of each indicator in the evaluation system of national vulnerability through the method of information entropy and make full use of the data of each indicator and have certain reliability.

3.3. Closeness and comprehensive evaluation

When assessing the extent of national vulnerability, we incorporate the notion of proximity that provides an intuitive indication of how the impact of the indicators to be assessed has on the level of national vulnerability, as well as on how closely the indicators are internationally formulated.The smaller the difference between the two more distant, the greater the closer the difference.It can be based on closeness index scheme classification. Taking all factors into consideration, this paper calculates the

closeness of the Euclidean distance by using the algorithm of first multiplication and post-summation.
The formula is as follows.

$$rH_i = 1 - \sqrt{\sum_{j=1}^{n} w_j \cdot q_{ij}} \quad (12)$$

You can construct the Euclidean composite matrix metamorphic matrix f as follows.

$$R_{rH} = \begin{pmatrix} & N_1 & \mathbf{L} & N_m \\ rH_i & rH_1 & \mathbf{L} & rH_m \end{pmatrix} \quad (i = 1,2,\mathbf{L},m) \quad (13)$$

Where rH_i is the degree to which the i-th evaluation sample and the standard sample are close to each other. Taking the value of rH_i as a reference, we can make a horizontal comparison of the national vulnerability assessment system, so that the whole evaluation system is more credible. The breakdown of vulnerability is shown in the following table.

Table 1. The Vulnerability tables

DEGREE	RANGE DIVISION
STABLE	< 0.3
LESS FRAGILE	0.3-0.4
FRAGILE	0.4-0.6
MORE FRAGILE	0.6-0.7
THE MOST FRAGILE	> 0.7

The table provides a more detailed breakdown of the country's vulnerabilities, making the hierarchy more explicit and clearlyidentify when a state is fragile, vulnerable, or stable.
Through the above model, we candetermine a country's fragility and simultaneously measures the impact of climate change. It can also identify how climate change increases fragility through directly or indirectly.

4. The Relationship between Vulnerability and Climate Change

Five parameters of the climate of the indicator layer: rainfall, cereal yield, temperature, CO2 emissions and improved water source can best reflect the relationship between vulnerability and climate change. When the effects of climate change interact with other factors such as social, economic and political factors, the compounding effect can overburden the disadvantaged countries, stimulate social unrest and even trigger violent conflicts. Even a seemingly stable country may be pushed to instability if the pressure is high enough or the shocks are too great. That is to say, environmental stress alone may not necessarily trigger violent conflict, but it enables violent conflict when it combines with weak governance and social fragmentation. This confluence can enhance a spiral of violence, typically along latent ethnic and political divisions.
Its specific realization is:
Precipitation, temperature: Extreme weather events and disasters, such as heavy rains and droughts, can exacerbate the vulnerability of nations and may increase people's grievances, especially in countries affected by the conflict.
Improving water resources: With water scarcity and people's demand growth, coupled with the impact of climate change, water competition may increase the pressure on national and regional governance.
Cereal production: Climate change is likely to undermine food production in many areas, causing price increases and market turmoil, further increasing the risk of people's protests, riots and internal conflicts.
Carbon Dioxide Emissions: Rising sea levels caused by the greenhouse effect will threaten the lives of people in low-lying areas and may even lead to an increase in the number of immigrants. At the same time, differences in maritime borders and marine resources may increase.

5. Theexample—the Impact of Climate on Syria's Vulnerability

5.1. Syrian model analysis

In the top 10 countries given inFSI, we chose Syria as the research object. For Syria, studies have shown that there is a necessary link between climate change and the Syrian civil war, with the Mediterranean coast and the Middle East heating up significantly over the past decades, leading to a worsening drought cycle. According to the UN statistics, 50,000 families migrated from rural areas in 2010, and Syria's food prices have risen after the drought, aggravating the situation in Syria.
According to the established model, the related data are calculated to calculate the weight of each indicator. The weight of the VSD evaluation framework and the Syrian indicators on the country's vulnerability are shown in the following table.
The following conclusions can be drawn from the above table:
According to the relevant information, Syria has been in a state of civil war from 2011 till now, indicating that civil war is the main reason leading to the change of Syria's vulnerability and leading to the civil war. The main factor is the change in climate. Therefore, we can see that climate change is the indirect cause of Syria's vulnerability.

The top of the parameter layer is mainly rainfall, temperature , CO2 emissions, economic decline, uneven economic development, etc. From these parameters, it can also be seen that climate change is the main influence on the change of national vulnerability.

Table 2. VSD framework and weight assignment

Dimension layer	Weights	Indicator layer	Weights	Parameter layer	Weights
Exposure Ie	0.462	Climate C	0.723	Rainfall C1	0.683
				Temperature C2	0.639
				Water source C3	0.028
				Cereal production C4	0.052
				CO2 emissions C5	0.653
		Political P	0.325	State LegitimacyP1	0.236
				Public ServicesP2	0.257
				Human Rights and Rule of LawP3	0.212
Sensitivity Is	0.416	Economic E	0.525	Economic DeclineE1	0.654
				Uneven Economic DevelopmentE2	0.462
				Human Flight and Brain DrainE3	0.031
		Society S	0.437	Demographic Pressures S1	0.025
				Refugees and IDPS S2	0.241
				External Intervention S3	0.359
Adaptation Capacity Iac	0.564	United U	0.436	Security ApparatusU1	0.232
				Factionalized ElitesU2	0.156
				Group GrievanceU3	0.365

5.2. Further analysis

Syria The impact of climate on national vulnerability in recent years is shown in the figure below:

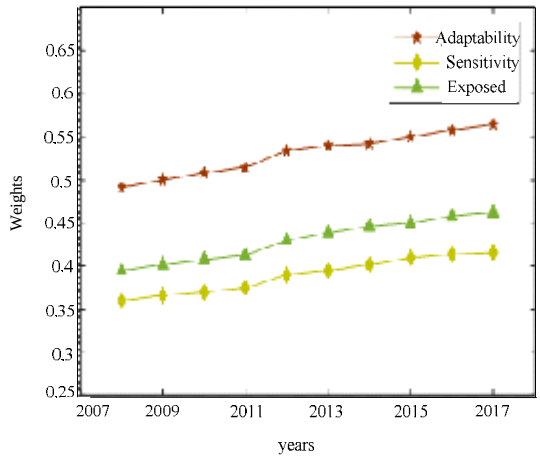


Figure 3. Syrian climate change on the impact of vulnerability chart

From the figure we can see that the weight of exposure, sensitivity and adaptability has been increasing year by year, indicating that the degree of vulnerability of Syrian countries is increasing year by year. The exposure curve was abruptly changed in 2011 and the adaptive curve also changed. According to the relevant information, we can see that Syria has been in a drought state in recent decade and civil war took place in 2011. From this we can see that the degree of vulnerability affecting Syrian countries is the country's development instability. The successive years of war have deepened the extent of the country's vulnerability. The main factor leading to the war is the climate. Therefore, the climate change indirectly deepens Syria's vulnerability.

According to the changes in the degree of vulnerability in Syria in the past 10 years and the related literatures, when the indirect factor of climate change is removed, the vulnerability of the country will be lessened and the factors of economy, agriculture and society will tend to be steady. Finally, Syria The vulnerability of countries is reduced.

5.3. Depth analysis

According to a study by the National Oceanic and Atmospheric Administration (NOAA), this shift to more dry conditions can't be explained by natural changes alone. Increasing anthropogenic greenhouse gases and aerosols, as well as sea surface temperature increases, are also major factor.

The Syrian government has been supporting excessive agricultural projects, subsidizing water-intensive crops, promoting overgrazing, and inefficient irrigation practices and groundwater mining that lead to soil and water consumption. People do not have enough resources and ability to develop the economy. The state wants to improve the crisis. Some erroneous economic policies have been implemented, the people are being exploited and the civil war in Syria accelerated. It has made Syria vulnerable and deepened its vulnerability.

6. Sensitivity Analysis

In the above, we chose Syria as the research object and concluded that climate change indirectly affects the vulnerability of Syria, thus aggravating the conclusion of

internal conflicts. Among them, the change of climate is mainly reflected in precipitation, temperature change and carbon dioxide emission. After the sensitivity analysis of the model and the removal of these three factors, we analyze the factors that make the vulnerability of Syria weaken. The curve of the vulnerability of the countries obtained in the last ten years is shown in the figure below:

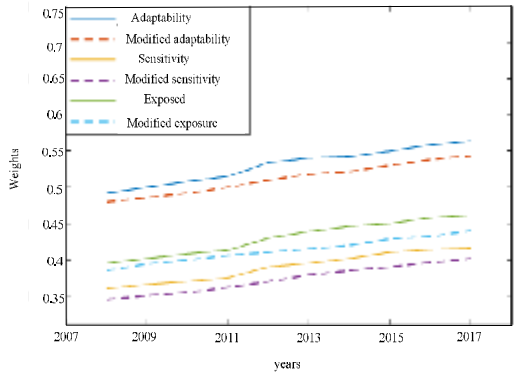


Figure 4. Vulnerability change after removing climate factors

As can be seen from the figure, after removing the influencing factors of climate change, the exposures, sensitivities and adaptability all show an upward trend, that is, the degree of national vulnerability will be weakened and the stability will be enhanced. It can be seen from this that climate factors have an impact on the country's vulnerability.

7. Conclusions

In order to make the model more universal, the VSD model we initially established can be applied to any country and region.So our model can work on both small cities and large continents theoretically. According to the actual situation of "states", the concrete model analysis can be carried out by adjusting the parameters and indexes.

The advantage of the VSD model is that it has a well-defined definition that breaks down the vulnerability into three dimensions of exposure, sensitivity and adaptation potential, with good compatibility.The level of exposure is a parameter that reflects the degree of interference or intimidation due to external influences, which can vary from place to place and can be adjusted according to the actual situation.Sensitivity is determined by exposure type and system characteristics, and it related to the critical condition of the system being destroyed.The potential for adaptation is a variable parameter that can be changed and adjusted, including the inherent self-regulation of the system and the potential for adaptation under external interventions.They are all adjustable.

In order to better show the model, we give a vulnerability framework of Coupled Human-Environmental System.The framework is composed of the following three levels: one is the human and environmental conditions in the coupled system; the other is the humanities and environmental conditions and the disturbances or pressures they face in the process of their interaction; the third is the exposure that is characterized by the vulnerability of the coupled system and sensitive Sexuality and resilience.

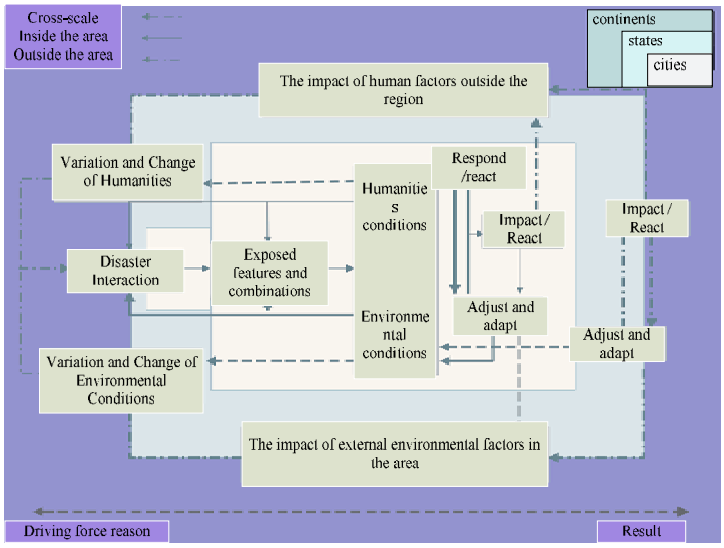


Figure 5. Coupled Human-Environmental System

From this, we can also know that exposure and coercion in large areas will indirectly affect small areas, and adaptive management also cross-regional effects through government or related organizations. Due to differences in natural conditions and adaptation potentials, regions also exist the same level of interaction.

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