Analysis of the impact of environmental change on the vulnerability of Sudan

Bao Wang*

School of North China Electric Power University, Baoding, China

*Corresponding author e-mail: 3360675177@qq.com

Abstract. Whether you realize it or not, the global climate is changing imperceptibly. What’s worse, the Intergovernmental Panel on Climate Change suggests that the net damage costs of climate change are likely to be significant. It may influence regional instability and even have the potential to cause the weakening and breakdown of social and governmental structures. In this paper, we develop a creative model to analyze the impact of climate change on country’s fragility and put forward a series of measures to alleviate and eliminate stress which climate change bring to. First, we develop the CAI model based on the PCA and AHP to determine a country’s fragility. Later, we evaluate 178 countries’ fragility and identify when a state is fragile, vulnerable, or stable through K-means algorithm and Grey prediction. Then, we analyze the correlation between climate change and other indicators with Grey relative analysis method. We choose Sudan for analysis. By correlation analysis, we find that, on the one hand, declining rainfall caused the prolonged drought in some parts of areas and conflict the water shortages problem. On the other hand, it indirectly affects the growth of crops, while the Sudan is mainly agricultural and animal husbandry, which leads to food problems... As a result, the fragility increase. Then, without considering climate change, we reassess the fragility. The result is much different from the previous, so climate change has a considerable impact on the fragility of Sudan.

Keyword. Sudan, climate, national vulnerability, prediction, AHP.

1. Introduction

The global climate is changing imperceptibly, it has subtly impact on every life on earth. By analyzing a series of data, we undertake an intriguing discovery, human behavior would be affected by the climatic variation in some degree. If climate change has negative influence on mankind, such as persistent drought, shrinking glaciers and so on, they will adopt a series measures as responses in order to eliminate their adverse effects. It is well enough your motherland is strong enough when encounter this situation. Nevertheless, if your country does not obtain good ratings in Fragile State Index assessment, which measures the resilience of a country in the event of a catastrophic situation, you are not so lucky because your native land do not have enough capability to help you through difficult times. Generally speaking, weak national public service system is often poorly, it is difficult to dredge the negative moods that surround the crowd. If things authentically continue this way, your county has great chances of getting
in a state of frequent violence, and then political instability. Consequently, destabilized governments could result in fragile states.

In a nutshell, climate change and regional instability can be linked by many factors. Numerous people tried their best to search for some significant indicators to analyze and evaluated the correlation of these factors and achieved remarkable result. On this basis, we had successfully established our analytical models that could analysis these factors quantitatively.

We first introduce the relationship between climate change and regional instability, determine the influence of climate factor level on the national vulnerability index through data accumulation and analysis. Then, we develop a climate index to depict the vulnerability of a country, through the index set, judge the state of a country is very fragile, brittle weak or stable. Afterwards, we study the effects of climate change on national vulnerability and the impact of climate factors on national vulnerability in ten vulnerable countries. Furthermore, we describe another country in which the effects of climate change on national vulnerability values and find out the decisive factors, determine the climate country enter the limit to limit the most vulnerable countries, explain the definition of limit value method to calculate and predict the country arrive the limit value. Besides, we carry out the sensitivity of the model, and analyze the risk of the change of the climatic factors of the model from the perspective of national intervention measures, and predict and evaluate the effect of human intervention. Estimate the cost of intervention for the most effective intervention.

Finally, Sudan was selected by us for its special environmental factors and used in the model for national vulnerability analysis.

2. Assumption and Symbol Explanation

2.1. Assumptions and Justifications

The way climate change influence regional instability is a complex interdisciplinary issue with international significance. Contained within the problem are variables pertaining to politics, economics, culture, biology, climatology and many other disciplines. It is vital to fully model every possible relevant factor. As such we make several far-reaching assumptions.

The data we collect from online database is accurate, reliable and mutually consistent. Because our data sources are all websites of international organizations, it’s reasonable to assume the high quality of their data.

The country we select will follow the numerous development trends in worldwide based on various factors. This assumption enables us to predict the situation of the selected country by using the result of relationship quantization among influential factors determined by worldwide data.

In addition, each of the particular models we constructed has their own sets of assumptions.
2.2. Symbol Explanations

| Abbreviation | Full Name                  | First appearing page |
|--------------|----------------------------|----------------------|
| CAI          | Change-actuality-intervene |                      |
| PFA          | Percentage of forest area  |                      |
| MPD          | Mean precipitation depth   |                      |
| EW           | Extreme weather            |                      |
| CDE          | Carbon dioxide emissions   |                      |
| PGR          | Population growth rate     |                      |
| GPP          | Growth rate of poor population |                |
| GDP          | Growth Domestic Product    |                      |
| PGR          | Primary school graduation rate |            |
| IWS          | Improved water source      |                      |
| IS           | Improved sanitation        |                      |
| NPI          | National Policies inclusive |                 |
| DRC          | Disaster reduce capacity   |                      |
| AC           | Absolute correlation       |                      |
| IOS          | Initialization of the original sequence |   |
| ITS          | 1-AGO of the original sequence |              |
| MP           | Model parameter            |                      |
| AVC          | Analog value calculation   |                      |
| PCE          | Percentage of carbon monoxide emissions |     |
| POE          | Percentage of other greenhouse gas emissions | |
| PDE          | Percentage of carbon dioxide emissions | |

3. Build a national vulnerability analysis model

3.1. Data Pre-processing

The availability of data is a pivotal issue. We searched the database and found indicators of various countries in the world firstly. The data is from UN data, the World Bank and National Bureau of Statistic. Consequently, it is essential to ensure the continuity and authenticity of the research data. Nevertheless, some data is missing because not all data is afforded.

We have improved this situation and proposed four ways to improve the data, as follows:

Listwise Deletion (SPSS and SAS). If there is a missing variable in a case, the corresponding case would be kicked out.

Mean Imputation. For numeric data, if we can obtain the before and after value, the average value would be adopted to fill the vacancy. For numeric data, the object which appears the most in all other objects is selected to complement according to the principle of mass number in statistics.

Hotdeaking. If two groups are similar adequately, the missing group can be replaced by the value of the same site of the other group.

Multiple Imputation. By using software generates a series of random values and selects reasonable data according to the correlation to supplement the actual data.

Regression Imputation. Selecting several independent variables to predict the missing value, and then establish the regression equation to estimate the missing value, after all replace the missing value with the conditional expectation of the missing data.

If the indicator values are smooth enough, we can use previous data to replace it.

We can adopt the interpolation method to fitting the data.
3.2. Primary Indicators System
A lot of work has been done in data searching and sorting these days, 90 initial indicators are selected firstly to represent regional instability index. We can see that there are a great deal of indicators related to national vulnerability, the method of PCA (Principal Component Analysis) is adopted to reduce the number of primary indicators. The selection of the initial 90 indicators for is on the basis of national vulnerability assessment system.
National vulnerability index exist four levels, such as cohesion, economic, political and social. Each level has its own secondary indicators obviously shows in the image below.

![Auxiliary indicator](image)

**Figure 1.** Auxiliary indicator.

Based on the reference of the above model, we determine to develop our own model CAI (change-actuality-intervene) and set up the evaluation system by combine grey prediction method and regression analysis. The CAI is mainly as follows:

| Second-class indicators | Primary indicator | Description | Unit |
|-------------------------|-------------------|-------------|------|
| **Actuality**           | PFA               | It reflects the state of a country's forest resources. | %    |
|                         | MPD               | It represents the degree of precipitation | mm/y |
|                         | EW                | It is used to describe the proportion of people affected by natural disaster. | 1    |
| **Change**              | CDE               | It refers to carbon emission of a country. | kt   |
|                         | PGR               | It denotes demographic change of a country. | %    |
|                         | GPP               | It reflects the changing situation of the poor in a country. | %    |
|                         | GDP               | It means the progress of the economy of a country. | tri  |
|                         | PGR               | It presents a country's education status. | %    |
| **Intervene**           | IWS               | The investment of a state in improving water resources is appeared. | %    |
|                         | IS                | A country's commitment to improving the health of the medical condition is presented. | %    |
|                         | NPI               | The pros and cons of a country's current policy are reflected. | 1    |
|                         | DRC               | The ability of a country to respond to disaster risk can be seen. | 1    |

3.3. Metric of the fragility of country

3.3.1. Analytic Hierarchy Process (AHP). We set up a hierarchical structure at first. In this model, the elements at the upper level act as the guidelines for the next level of related elements.
Target layer: There is only one element in general it is to analyze the problem of the intended target or ideal results.
Guideline layer: this level contains the intermediate links involved in achieving the goal, which can be made up of a number of hierarchies, including the criteria and sub-criteria for consideration.
Scheme layer: this level includes various measures, decision-making schemes, etc. for the realization of the objectives.

And then, we determine the weight and construct the judgment matrix. We take two factors $x_i$ and $x_j$, $a_{ij}$ refers the influence of $Z$ caused by $x_i$ and $x_j$, the matrix $A = (a_{ij})_{m \times n}$ reflects all the comparison results which is called judgment matrix of $Z - X$. We can easily get $a_{ij} = x_i / x_j$.

$$A = \begin{bmatrix} W_1 & W_1 & \cdots & W_1 \\ W_1 & W_2 & \cdots & W_n \\ \vdots & \vdots & \ddots & \vdots \\ W_n & W_n & \cdots & W_n \end{bmatrix}$$

Where, $\eta$ is the characteristic root of ‘$A$’. $W = (W_1, W_2, \ldots, W_n)^T$ is the eigenvector of characteristic root.

After that, we obtain the eigenvector as follows:

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}, M_i = \sum_{j=1}^{n} \bar{a}_{ij}, \lambda_{max} = \sum_{j=1}^{n} (AW)_{ij} W_j, (i,j=1,2,3,\ldots,n)$$

Afterwards, we tested the consistence indicator and the inspection coefficient in order to evaluate the stability of our model.

$$CR = \frac{CI}{RI} \quad CI = \frac{\lambda_{max} - n}{n - 1}$$

Last but not least, we do the total hierarchical order analysis.

4. Model analysis based on the situation of Sudan

4.1. Analysis of the state of the union

Sudan, located in the northeast of Africa, along the red sea coast and the eastern end of the Sahara Desert. With an area of 1886,068 square kilometers, it is the third largest country in Africa and the 15th largest country in the world. Its capital is Khartoum. Sudan has a single economic structure, mainly agricultural and animal husbandry, backward industry, weak foundation and strong dependence on nature and foreign aid. Sudan is one of the least developed countries in the world declared by the United Nations. It was rated "the most fragile state in the world" by the list of fragile states index.

4.2. The Result of Fragility Assessment

![Figure 2. The Result of Fragility Assessment.](image-url)
According to the above criteria, the indexes which can reflect three dimensions of the country is calculated. The result is shown in figure 3 and figure 4 as fellows.

**Figure 3.** The index value of the selected city.
**Figure 4.** The index value of the selected city without climate change.

The left figure is the fragility of country assessment value of Sudan in 2017, and the right figure is the fragility of country assessment value of Sudan in 2017 without climate change.

4.3. **Analysis of the Effect of Climate Change on Fragility of Country.**
Sudan fragility indicator values are relatively high. The degree of risk and the dependency of foreign aid are outstanding. As a result of climate change, on the one hand, the change of rainfall caused the water resource problem directly. On the other hand, it indirectly affects the growth of crops, while the Sudan is mainly agricultural and animal husbandry, which leads to food problems, affecting GDP per capital... increased fragility of country. As for high external dependence, for example, the Mclover dam, the largest hydropower station in Africa, is a model of modern Chinese support for Sudan. The largest hydropower station in Africa is under the Nile, the world's largest river. This is basically in line with what we know.

Without the effects of climate change in 2017, compared with the left figures, the fragility of country assessment value of Sudan increased significantly, the right significantly reduces risk degree, sensitivity and foreign aid dependency decreases, and adaptability increases.

5. **Conclusion**
In this paper, based on PCA and AHP to develop CAI models, we have designed an innovative model to study the impact of climate change on the vulnerability of Sudanese countries. According to relevant data published by international organizations, we conduct analysis of use, and the results, climate change for Sudan National vulnerability has had a considerable impact, and its level of risk and dependence on foreign aid are outstanding. Climate change has not only led to water problems in Sudan, but also indirectly affects the growth of crops, leading to food problems and a major impact on Sudan's agriculture and animal husbandry. Therefore, in order to change the impact of environmental changes on the vulnerability of Sudanese countries, domestic policy support is needed, and economic investment needs to be increased in the field of environmental protection. At the same time, sponsorship and support from international organizations and friendly countries are needed.

**References**
[1] Nana Wang. Analysis of vulnerability assessment and influencing factors in climate change [D]. Shaanxi normal university,2016.
[2] Zhiqing Zhao. Based on the urban vulnerability evaluation system of climate change research [A]. Urban planning society of China, shenyang municipal people's government. Planning for 60
years: achievements and challenges, proceedings of 2016 annual meeting of China's urban planning (01 city safety and disaster prevention planning) [C]. : urban planning society of China, shenyang people's government, 2016:15.

[3] Kexian Li. Effects of climate change on Chinese agricultural production and control methods [J]. Seed technology, 2013,35(12):14+17.

[4] Mingde Cao. China's legal position and strategy in international climate governance: from the perspective of climate justice [J]. China law,2016(01):29-48.