Research on the Impact of Climate Change on the Fragility of a Country Based on Analytic Hierarchy Process

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Abstract. National fragility can reflect a country's level of development, potential wind risks, and is crucial for the country to formulate future development strategies. This paper uses the Analytic Hierarchy Process to establish a fragility evaluation index system based on social factors, economic factors, political factors, and climate factors, and obtains the weight values of the four factors. It uses the Likert five-point method to predict the degree of national stability, and then analyzes the country’s Fragility index. The analysis shows that climate factors have a large weight and are uncontrollable factors, which have an important impact on the country's fragility. Taking Bangladesh as an example to analyze the impact of climate change on the country's fragility, analyze the total score of the country’s stability assessment when climate factors are not considered and considering climate factors. The results show that the degree of national fragility in Bangladesh is affected by climatic factors. Larger. This study will provide relevant evidence for the analysis and application of national fragility assessment.

Keywords: Analytic Hierarchy Process; Likert five-point method; Climate change; Fragility.

1. Introduction

A fragile country is a country where the government is unable or unwilling to provide its people with basic necessities. State fragility is not a newly emerging issue, reflecting the development of the country. As a fragile country, the population of a country is affected by climate shocks such as natural disasters, reduced arable land, weather changes and rising temperatures.

Of the many factors that affect the country’s vulnerability, climate is uncontrollable and changes are diverse. In recent years, climate change has become increasingly significant, adversely affecting economic and social activities such as agriculture, forestry, animal husbandry, and fishing, and thus changing humankind’s way of life. This has caused the weakening and disintegration of social and governmental structures and exacerbated the country’s vulnerability.

Many scholars at home and abroad began to pay attention to the role of climate change in boosting and impeding the vulnerability of the country. In the 1970s and 1990s, Adger WN [1] analyzed the social vulnerability based on the volatile and extreme climate of coastal cities; Yu Ou [2] used model simulations, the single index method and the comprehensive index method have quantitatively summarized the vulnerability of regional climate change and promoted research and development in this
area. Analytic Hierarchy Process decomposes complex problems into several levels and several factors. Simple comparison and calculation among various factors can give weight to different factors. This paper firstly adopts Analytic Hierarchy Process, and establishes a fragility evaluation index system based on social factors, economic factors, political factors, and climatic factors, and constructs a judgment matrix to determine the index weight of each factor. The degree of fragility is negatively correlated with the level of stability. If the degree of stability is higher, the fragility is lower. With the help of Likert's five-point method, the overall level of national stability is divided into very stable, relatively stable, generally stable, relatively unstable, and very unstable. Focusing on the analysis of the impact of climate change on the country's fragility, the indicator evaluation system is applied to the exploration of Bangladesh's national fragility affected by climate change.

2. Construction of national fragility evaluation index system

2.1. Introduction of Analytic Hierarchy Process
Analytic Hierarchy Process is a decision-making method that decomposes the elements that are always related to decision-making into targets, criteria, programs, etc., and performs qualitative and quantitative analysis on this basis. It is a combination of qualitative and quantitative, systematic, hierarchical analysis.

2.2. Establishing Analytic Hierarchy structure factors

2.2.1. Social factors. Social factors are factors directly related to the country’s local area. They are also factors that reflect people’s living standards and satisfaction. Among them, population pressure factors, the proportion of refugees and internally displaced persons, and the degree of brain drain can all affect social factors. The impact on the country's fragility.

2.2.2. Economic factors. The degree of economic development of a country is an important measure of the government’s commitment to social commitment and standards of living standards of the people. Due to the imbalance of economic development, people’s satisfaction with the government is reduced and mistrust, and the proportion of people living in poverty is the degree of economic recession will cause the government's burden to increase.

2.2.3. Political and military factors. Political and military factors are important criteria for measuring the stability of a country. Whether it can provide public services such as health, education, and health services is an important criterion for measuring people's satisfaction.

2.2.4. Climate factors. The cost of net damage from climate change can be significant. When it is combined with weak governance and social fragmentation, it can lead to violent conflict and further increase national vulnerability. Among them, drinking water and irrigation water directly affect the way of life and level of the local people. The destruction of the infrastructure caused by extreme weather affects the people’s living standards and people’s satisfaction with the government. The spread of germs spreads out the extent of the disease to people’s health and the government’s Prestige has a direct connection.

Based on the above analysis of the factors affecting the country's fragility, combined with World Bank data surveys, public opinion surveys, and expert interview results, the hierarchical structure is shown in Figure 1.
Figure 1. Hierarchy structure of national fragility factors

According to Figure 1, we have constructed a hierarchical structure in which a national fragility level is used as a target level indicator, social factors, economic factors, political and military factors, and climatic factors are used as criterion indicators. Each criterion level indicator is affected by three programmatic indicators.

2.3. Determination of index weights

In order to be able to determine the weight of each criterion layer on the target, according to the World Bank data and two rounds of Delphi expert questionnaire survey method, a judgment matrix is established according to Table 1, and weights are calculated according to the judgment judgment matrix. The reference numbers 1-9 and their reciprocals are used as scales to define the judgment matrix $A = (a_{ij})_{n \times n}$.

Judgment matrix can be expressed as:

$$A = \begin{pmatrix}
    a_{11} & a_{12} & \ldots & a_{1n} \\
    a_{21} & a_{22} & \ldots & a_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    a_{n1} & a_{n2} & \ldots & a_{nn}
\end{pmatrix}$$

Weighting based on Analytic Hierarchy Process [3]

Use arithmetic average weights to get:

$$W_i = \frac{1}{n} \sum_{j=1}^{n} \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}, \quad i = 1, 2, 3, \ldots, n$$

According to the degree of influence of the four factors on the degree of fragility of the country, the indicator factors are compared in pairs, relying on data support and expert evaluation, and the appropriate scale is selected to form Table 1.
Table 1. Judgment matrix factors

|                     | Social factors | Economic factors | Political and military factors | Climatic factors |
|---------------------|----------------|------------------|--------------------------------|------------------|
| Social factors      | 1              | 1/5              | 1/2                            | 1/4              |
| Economic factors    | 5              | 1                | 3                              | 2                |
| Political and military factors | 2          | 1/3              | 1                              | 1/2              |
| Climatic factors    | 4              | 1/2              | 2                              | 1                |

Build a judgment matrix

\[
A = \begin{pmatrix}
1 & 1 & 1 & 1 \\
5 & 1 & 3 & 4 \\
2 & 1 & 1 & 2 \\
4 & 1/2 & 2 & 1
\end{pmatrix}
\]

Hierarchical consistency test:
First you can find \( \lambda_{max} = 4.0211 \), into the formula is:

\[
CI = \frac{\lambda_{max} \cdot n}{n - 1} = 0.007
\]

Look up table shows RI = 0.89.
Calculate the proportion of consistency available:

\[
CR = \frac{CI}{RI} = 0.008 < 0.10
\]

So to judge the consistency of the matrix is acceptable.
Calculate the weight of each guideline index is available:

\[
W_1 = \frac{1}{4} \sum_{j=1}^{4} \frac{a_{ij}}{\sum_{k=1}^{4} a_{kj}} = 0.108 \\
W_2 = \frac{1}{4} \sum_{j=1}^{4} \frac{a_{2j}}{\sum_{k=1}^{4} a_{kj}} = 0.476 \\
W_3 = \frac{1}{4} \sum_{j=1}^{4} \frac{a_{3j}}{\sum_{k=1}^{4} a_{kj}} = 0.154 \\
W_4 = \frac{1}{4} \sum_{j=1}^{4} \frac{a_{4j}}{\sum_{k=1}^{4} a_{kj}} = 0.262
\]

2.4. Rating criteria for each indicator—Likert five-point scale method
The Likert 5-point scale method risk assessment is the basis of vulnerability assessment. Vulnerability assessment evolves from risk assessment. Therefore, vulnerability assessment can be included in the risk assessment model as an element or step. The degree of vulnerability is negatively correlated with the level of stability; if the degree of stability is higher, the vulnerability is lower. The following table is a Likert five-point scale designed for this problem.
Table 2. Likert five-point scale

| Stability evaluation | The corresponding level | Assignment |
|----------------------|--------------------------|------------|
| Very stable          | A                        | 5          |
| Relatively stable    | B                        | 4          |
| Generally stable     | C                        | 3          |
| More unstable        | D                        | 2          |
| Very unstable        | E                        | 1          |

The establishment of the model according to the above Likert five-point scale method, we evaluate the various indicators of the system are hierarchical and assignment, combined with the above calculation of the weight of each indicator [4], using multi-objective linear weight function method to establish the evaluation model, that is

$$P = \sum_{i}^{m} \left( \sum_{j=1}^{n} p_{ij} \times w_{ij} \right)$$

The functional model achieves a quantitative evaluation of the degree of national fragility. The level of fragility is negatively correlated with the level of stability. The higher the level of stability is, the lower the fragility is, while the other is the higher.

3. Example application

We selected Bangladesh as the subject to be studied. Bangladesh is located in the north of the Bay of Bengal and belongs to the subtropical monsoon climate. The coast belongs to the monsoon-type tropical grassland climate. Rivers are densely distributed and the rivers are developed. The rainy season is prone to flooding and tropical hurricanes often occur.

For the program level indicators, we need to calculate their weights for the criteria layer. We use the climate factor as an example. Through the collection and analysis of data, we select the appropriate scale and form Table 3.

Table 3. Climate factor scale judgment matrix factor table

|                | Drinking water and irrigation water | Extreme weather damage to infrastructure | The spread of germs to expand the epidemic |
|----------------|-------------------------------------|-----------------------------------------|-------------------------------------------|
| Drinking water and irrigation water | 1                                  | 5                                       | 7                                        |
| Extreme weather damage to infrastructure | 1/5                               | 1                                       | 2                                        |
| The spread of germs to expand the epidemic | 1/7                               | 1/2                                     | 1                                        |

The calculation can be obtained through the consistency test. And get the weights of indicators in the climate factor criteria layer as follows:

$$w_1 = 0.738; \quad w_2 = 0.168; \quad w_3 = 0.094$$

After the same calculation method, the weights of the indexes of other criterion layers can be obtained as shown in Table 4.
Table 4. Weights of indicators in other criteria levels

| Indicator         | Social factors | Economic factors | Political and military factors | Climatic factors |
|-------------------|----------------|------------------|-------------------------------|-----------------|
| w1                | 0.232          | 0.261            | 0.123                         | 0.738           |
| w2                | 0.696          | 0.633            | 0.557                         | 0.168           |
| w3                | 0.072          | 0.106            | 0.320                         | 0.094           |

Criticizing Bangladesh without considering the influence of climatic factors, the calculation of the national stability evaluation score $P'$ is available:

$$P' = 2.389$$

According to the actual conditions of selected countries, the climate-level programmatic indicators are re-set objectively and reasonably. They are flood, tropical wind, pests and diseases, and low temperatures.

Re-set the weight of the climate-level programmatic indicators and select the appropriate scale through analysis to form Table 5.

Table 5. Judgment factor matrix

| Indicator         | Flood | Tropical wind | Low temperature | Pests and diseases |
|-------------------|-------|---------------|-----------------|--------------------|
| Flood             | 1     | 3             | 7               | 5                  |
| Tropical wind     | 1/3   | 1             | 5               | 3                  |
| Low temperature   | 1/7   | 1/5           | 1               | 1/2                |
| Pests and diseases| 1/5   | 1/3           | 2               | 1                  |

The calculation can be obtained through the consistency test. And get the weights of indicators in the climate factor criteria layer as follows:

$$w_1 = 0.563; \quad w_2 = 0.267; \quad w_3 = 0.062; \quad w_4 = 0.108$$

Various program-level indicators for climate factors in Bangladesh are scored to form Table 6.

Table 6. Plan level indicator score

| Climatic factors | Flood | Tropical wind | Low temperature | Pests and diseases |
|------------------|-------|---------------|-----------------|--------------------|
|                  |       |               |                 | 1                  |
| Flood            | 154   | 62905         | 13088400        |                    |
| Tropical wind    | 73    | 55973         | 4805979         |                    |
| Low temperature  | 20    | 2378          | 654281          |                    |
| Pests and diseases| 12    | 5120          | 644897          |                    |

The following is a brief summary of the reasons why each indicator is scored, and how the various indicators reflect changes in the climate and thus the impact on the country’s fragility.

Table 7. Natural disasters in Bangladesh from 1960 to 2015[5]

| General category of natural disasters | The number of occurrences | The death toll | Losses ($) |
|--------------------------------------|---------------------------|----------------|------------|
| Flood                                | 154                       | 62905          | 13088400   |
| Tropical wind                        | 73                        | 55973          | 4805979    |
| Hypothermia                          | 20                        | 2378           | 654281     |
| Pests and diseases                   | 12                        | 5120           | 644897     |

According to the table, floods in Bangladesh have the highest number of incidents, causing the highest number of casualties and economic losses. After tropical cyclones, the effects of diseases, pests,
and low temperatures are relatively minimal and approximately equal, but they still cause a large number of deaths. So we first Taking flood as the main influencing factor, followed by tropical cyclones, pests and low temperatures at the same time as the lowest impact, after many considerations of various factors on the economic and social impact and the destruction of the country's fragility, we decided to flood, tropical cyclones, pests and diseases, low temperature. The stability scores were rated 1, 2, 3, and 3, respectively.

Calculate the national stability evaluation total score $P$ after re-setting the climatic factor plan level indicators:

$$P = 1.839$$

Comparing $P$ and $P'$, it can be seen that $P'>P$ indicates that the degree of national fragility in Bangladesh is affected by climate factors and has a strong influence.

4. Conclusion

Using the analytic hierarchy process to establish a judgment matrix, it has strong logic, practicality, and systematicness. The weight values that can accurately determine the social, economic, political, and climatic factors affecting the country's fragility are 0.108, 0.476, 0.154, 0.262. It can be seen that climate change has a greater impact on the country's fragility.

With the help of Likert's five-point method, the overall level of national stability is divided into very stable, relatively stable, generally stable, relatively unstable, and very unstable. According to the above-mentioned Likert five-point scale method, each index of the evaluation system is graded and assigned. Combined with the above calculation of the weight of each index, a multi-objective linear weighting function method is used to establish the evaluation model. The function model achieves a quantitative assessment of the degree of fragility of a country. The level of fragility is negatively correlated with the level of stability. The higher the level of stability, the lower the fragility. On the contrary, the higher the level of fragility.

According to the World Bank data, Bangladesh is used as an example to analyze the impact of climate change on the country's fragility. When the climatic factors are not taken into account, the national stability evaluation score $P'$ is obtained, and in combination with the characteristics of climate change in Bangladesh, floods, tropical cyclones, low temperatures, pests and diseases are considered, and the total national stability evaluation after resetting the climatic factors at the scenario level is obtained. Score $P$. Comparing $P$ and $P'$, it can be seen that $P'>P$ indicates that the degree of national fragility in Bangladesh is affected by climate factors.

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