

# TVM-Based Model for How Climate Change Influence Regional Instability

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**Abstract.** In this paper, a three-dimensional vector stratified model (TVM) is established based on the gray relational analysis to determine a country's fragility. Firstly, we classify the influence factors into three categories, involving economy, society and environment. Each aspect corresponds to a coordinate axis in three dimensions. Secondly, we classify the climate change into 8 levels. Different level will affect specific indicators of each dimension. Therefore, the impact of climate change on vulnerability can be indicated by angel and modulus of obtained vector in the model. It illustrates that climate change impacts the fragility mainly in an indirect way.

## 1. Introduction

Nowadays, research on fragile states has become a global issue. The effects of Climate Change, to include increased droughts, shrinking glaciers, changing animal and plant ranges, and sea level rise, are already being realized. Being a fragile state increases the vulnerability of a country's population to the climate shocks such as natural disasters, decreasing arable land, unpredictable weather. Therefore, the study of national vulnerability is of great significance to global sustainable development.

## 2. Assumption and Symbol Explanation

### 2.1. Assumption

To simplify our problems, we make the following basic assumptions.

- The political and economic environment of the country we choose is relatively stable.
- Human factors cannot interfere with the occurrence and change of climate itself.
- Assume that the state is a responsible and powerful sovereign state and the government is willing to provide the basic essentials to its people in the event of a serious climate disaster.



## 2.2. Symbol Explanation

$r_i$	the gray weighted relevance
$R_{ij}$	positive indexes
$D_i$	the mean of the variable
$\sigma$	the mean square deviation of the variable
$\omega_i$	the weight coefficient
$F$	The fragility of a state
$ \overrightarrow{OP}_i $	the rate of decay along the fragile direction

## 3. The TVM model

### 3.1. Indicator Selection

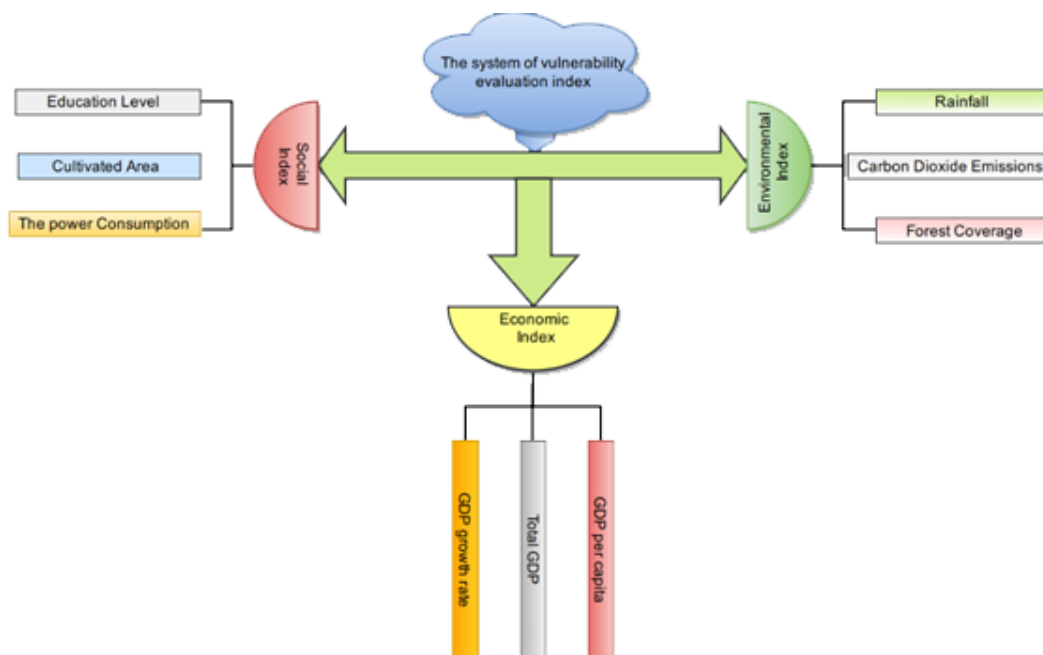
To begin with, we classify the influence factors into three categories.

**Economic Indexes (EI)** It characterizes the quality of and the number of economic development in a country.

**Social Indexes (SI)** It mainly reflects the social development status and predicting the future evolution.

**Environmental Indexes (ENI)** The indicators are defined as adjustment in natural and human systems in response to actual or projected changes.

For simplify, we select 9 major indicators by applying Grey Relational Analysis:



**Figure.1** Specific national vulnerability indexes

### 3.2. Quantification of qualitative indicators

Considering the dimensions of the 9 indicators are different, the data can't be directly compared. To normalize the data, all the data is converted to number between 0 and 1. So we homogenized the data and weighted it with the average variance method.

Positive indexes:

$$R_{ij} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}} \quad (1)$$

Negative indicators:

$$R_{ij} = -\frac{(x_{ij} - x_{\max})}{x_{\max} - x_{\min}} \quad (2)$$

where

$R_{ij}$  represents the variable value of  $x_j$  after standard treatment,

$x_{\max}$  is the maximum value of the  $j$  index

$x_{\min}$  is the smallest of the  $j$  index

The following is the determination of index weight.

**Table.1** Determination of index weight

First-class index	Second-class Index	Weight
Economical	GDP per capita	0.214
	Total GDP	0.254
	GDP growth rate	0.532
Social	Education Level	0.36
	Cultivated Area	0.51
	The power Consumption	0.13
Environmental	Rainfall	0.24
	Carbon Dioxide Emissions	0.46
	Forest Coverage	0.30

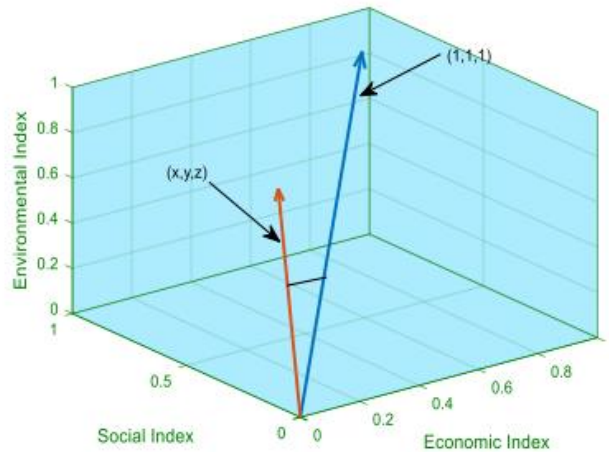
### 3.3. Space Vectorization

The three aspects mentioned before correspond to each coordinate axis of space rectangular coordinate system respectively. X-axis represents the EI while y-axis is a symbol of SI and z-axis means ENI.

Next, we define a standard vector delegating when a country is the least fragile. It points to (1, 1, and 1) from the coordinate origin. Since the projection of standard vector on each axe is 1, we can assume that the state it represents is experiencing the most balanced direction and velocity of development. Then we obtain an arbitrary vector which coordinate is (x, y, z). By comparing this vector with the standard one, the fragility can be described through two variables-

$\theta$  : denotes the degree of deviation from the optimal direction.

$\overrightarrow{OP_i}$ : denotes the rate of decay along the fragile direction.



**Figure.2** Three-dimensional vector diagram

Emphatically, the less fragile the country is. The greater the modulus value is, the faster the decay towards fragility. The formula that measuring the fragility can then be presented by

$$F = 1 - \frac{\alpha \frac{45 - \theta}{45} + \frac{\overrightarrow{OP_i}}{\sqrt{3}}}{1 + \alpha} \quad (3)$$

● As for developed nation,  $0 < \alpha < 1$ , because we attach more importance to the decline speed along fragility direction.

● As for developing nation,  $\alpha > 1$ , because the direction matters more.

In short, we can adjust the weight according to the actual situation in order to adapt to the different countries. A larger vulnerability index implies a weaker ability for a country to handle the balance between different indicators and external influence, and a harder work for it to solve its safety problem.

#### 4. Hierarchical Climate Impact On TVM

##### 4.1. The Climatic Suitability Exponent formula

The degree of climate fitness we hypothesized is defined by the suitability of human habitation. Taking all the elements into consideration, we formulate a hierarchical climate impact model to account for how climatic change would affect the overall fragility of a particular country in terms of the relationship between climate change and human-being. Climate changes are measured through three following kinds of indicators.

**The Temperature-Humidity Index:** It demonstrates the heat exchange between the human body and surrounding environments via the combination of the temperature and humidity. We obtain

$$THI = 1.8t + 32 - 0.55(1 - f)(1.8t - 26) \quad (4)$$

**The Wind Effect Index:** It suggests the effect on the exposed body in different environments. It not only takes the surface heat dissipation into account, but also considers the heat added to the body after solar radiation. It can be described as shown below.

$$K = -(10 - v \sqrt{10.45 - v})(33 - t) + 8.55s \quad (5)$$

**The dressing index:** It refers to the thickness of the clothes needed to keep the body surface temperature constant or to keep the body comfortable. The formula is as follows.

$$ICL = \frac{33t}{0.155H} \frac{H + aR \cos \gamma}{6.62 + 19.0 \times \sqrt{v}H} \quad (6)$$

$f$  : Relative humidity     $v$  : speed     $s$ : sunshine duration

$H$  : represents the body's metabolic rate of 75% ( $W / m^2$ );

$a$  : represents the body's absorption of solar radiation

$R$  : represents the solar radiation received by the unit area of the vertical sunshine.

#### 4.2. Classify the impact of Climate Change

We divide the climate into seven levels, as shown in the following table

**Table.2** Climate levels

classification	Value	livability
Level 1	1~2	the most livable
Level 2	2~3	more livable
Level 3	3~4	Livable
Level 4	4~5	general
Level 5	5~6	poor
Level 6	6~7	poorer
Level 7	7~8	The poorest

Using the data from the World Bank, we analyze and adjust the impact of the CSE on national vulnerabilities

$$f(x) = \frac{me^{nx}}{100} \times 100\% \quad (7)$$

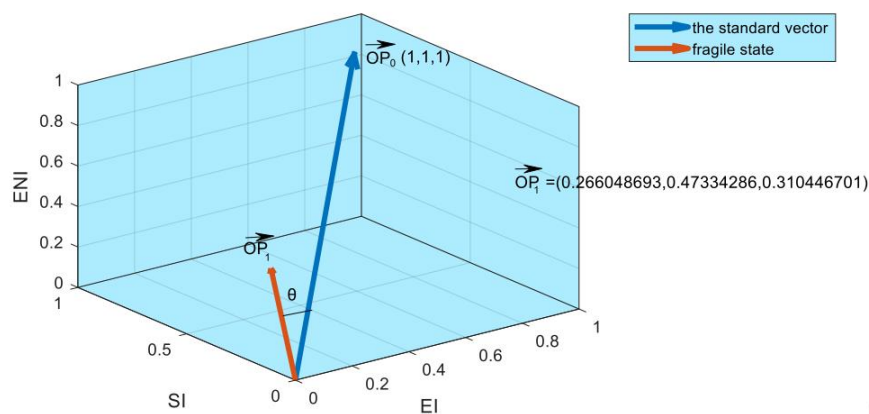
$$m = 78.83$$

$$n = -0.4275$$

#### 4.3. Example

We select Democratic Republic of the Congo as an example to analyze the process how climate change exacerbates the fragility of a country. Because Congo is one of the top ten most fragile states, we infer that the distinction between the vector ignoring climate change and the vector considering climate change is obvious.

We can obtain the following vector. Its module value is 0.625, while is 14.3036. Compared with the standard vector which module is  $\sqrt{3}$ , the results reflect that Congo is experiencing the impact of climate change in economic, social and environmental aspects.



**Figure.3** Three dimensional vector of Congo

#### 5. Conclusion

Compared with the analytic hierarchy process, the Three-dimensional vector stratified model has a more accurate extent. If ignoring the impact of climate change, we obtain a new vector and compare it to the vector that considers climate change. We find that the effect is weakened on economic, social and environment indicators by the comparison of angle and module. That means the country's fragility can be improved. It illustrates that climate change impacts the fragility in an indirect way.

#### 6. References

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