

# States Fragility Assessment Model Based on Climate Change

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**Abstract.** Various climate changes, including global warming, etc., have different impacts in different parts of the world and even lead to an increase in the fragile of social and governmental structures. Timmerman P proposed the concept of vulnerability in 1981 firstly. The Fund for Peace (FFP) started publishing the annual Fragile States Index (FSI)[1] in 2005. It is widely used by researchers, educators, and governments across the world. Based on FSI, this paper adds the influence of climate change on national vulnerability, and establishes a new model defined as States Fragility Assessment Model (SFAM) by using entropy weighting method. Taking the North African country Egypt with serious climate problem as an example, SFAM combines with grey prediction to analyze the vulnerability of Egypt and predict its trend from 2019 to 2032. Finally, this paper put forward effective suggestions for the current situation that the fragility of Egypt is decreasing year by year.

**Keywords:** Fragile States Index, Climate Change, Entropy Weight Method, Gray Prediction Model, Egypt, MATLAB.

## 1. Introduction

With the prosperity of the global economy, the living conditions of people have been raised, people are beginning to realize the importance of climate. Increasing environmental and climatic problems are unknowingly changing the impacts of our lives and climate change, including increased droughts, shrinking glaciers, changes in the range of animals and plants, sea-level rise that vary with the region different. Just a slight change in the climate can produce unpredictable results. For example, these effects will change human lifestyles and may lead to the breakdown and collapse of social and government structures. An unstable government system may increase the country's vulnerability and put it in crisis. The instability of the country further aggravates the impact of climate change, and the greater the loss suffered by the people, the problems arising therefrom will further aggravate the international instability and form a vicious cycle. On the contrary, if the stability of the country is high, and the country has sufficient capital and ability to defend the people's lives and property, then the development of the country will be better.[1].

## 2. Select Indicators

The Fund for Peace (FFP) is a US non-profit, non-governmental research and educational institution founded in 1957. It works to prevent violent conflict and promote sustainable security. FFP started publishing the annual Fragile States Index after 2005. It is used by researchers, educators, and governments across the world. Here we get 12 indicators for assessing vulnerabilities from Fragile States Index (FSI), their types and names are shown in Table 1:

States Fragility Assessment Model not only measures the degree of vulnerability, but also the effects of climate change, we first select the above 12 indicators by Analytic Hierarchy Process and obtain eight indicators with weights in the top eight. Then, we have learned from the literature that military spending can describe the security situation of a country very well.[2] Therefore, we use the military budget as a third indicator. According to the World Bank's measure of the impact of climate change, we selected 4 indicators to characterize its impact on climate change. Finally, we got the system of vulnerability assessment including five second-level indicators and 13 third-level indicators. Because of the double attributes of some of the 13 indicators we give, such as refugees, here we only

select the most prominent attributes of the 13 indicators to simplify and divide them into five second-level indicators, see the following Table 2 for details.

Table 1.12 indicators in FSI

Type	Indicators
COHESION INDICATORS	Security Apparatus Factionalized Elites Group Grievance
ECONOMIC INDICATORS	Economic Decline Uneven Economic Development Human Flight and Brain Drain
POLITICAL INDICATORS	State Legitimacy Public Services Human Rights and Rule of Law
SOCIAL AND CROSS-CUTTING INDICATORS	Demographic Pressures Refugees and IDPs External Intervention

### 3. Model Establishment

#### 3.1 Obtaining Weight Based on Entropy Weight Method (EWM)

Entropy weight method is an objective weighting method. It determines the weight based on the size of the information provided by the observed values of each indicator. The greater the amount of information, the less uncertainty, and the smaller entropy is, and vice versa. Entropy is used to determine the degree of dispersion of each indicator, and the impact of the comprehensive evaluation indicators of each indicator is obtained, and the weight is obtained. Since the current indicators are not uniformed, the target treatment is needed to reduce the dimension of indicators firstly. So we adopt the entropy weight method based on correlation coefficient to solve this problem. The detailed algorithm is shown as follows in Fig. 1.

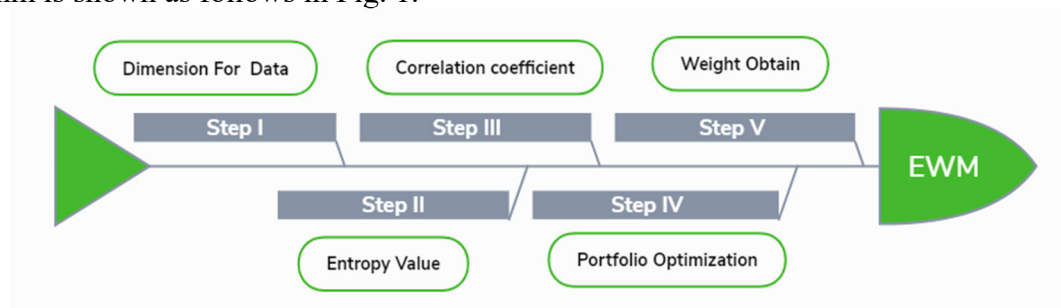


Fig. 1 Step of EWM

After 5 above steps, we get the weight of 5 second-level indicators:

$$W = (0.3027, 0.3259, 0.1421, 0.0642, 0.1652)^T$$

#### 3.2 Solve the Weight of Third-level Indicators

Coefficient of variation method is the direct use of the information contained in the indicators, indicators calculated by the weight, is a method of objective empowerment. The basic approach of this method is as follows: In the evaluation index system, the bigger the index value difference is, the harder it is to achieve. Such indicators better reflect the gap between the units being evaluated. In this paper, we take the coefficient of variation coefficient to get the weight of 13 third-level indicators:

Table 2 .States Fragility Assessment Index

Type	Indicators
Safety Condition (30.27%)	Security Apparatus(22%) Military Budget(42%) Group Grievance (36%)
Politics Situation (32.59%)	External Intervention(39%) Public Services(61%)
Economy Development Level (14.21%)	Economic Decline(34.7%) Uneven Economic Development(65.3%)
Social Security and Harmony Degree (6.42%)	Demographic Pressures(63.7%) Refugees and IDPs(36.3%)
Climate Change Degree (16.52%)	CO2 emissions per capita(34.7%) The forest coverage rate(20.3%) Arable land Per capita(25.7%) Global Mean Sea Level(19.3%)

It focuses on divisions and schisms between different groups in society – particularly divisions based on social or political characteristics – and their role in access to services or resources, and inclusion in the political process.

### 3.3 Model Establishment

According to the needs of the model, we have accessed to a large amount of data and databases and obtained nearly nine years' data of 13 indicators in ten countries. First, we make the data consistent and standardized, then multiply the data of the third indicators by Weight, the value of the second-level index is obtained, and then the value of the second-level index is multiplied by the weight in succession to obtain the total index SFA used to measure the vulnerability of each country.

Then, the data of the third-level indicators of nine years in ten countries are averaged, multiplied by their weights in turn, and the values of the five second-level indicators - SC, PS, EDL, SSHD, CCD of ten countries are obtained. The model is fitted by Regress (y, x) function in MATLAB:

$$f(x_1, x_2, x_3, x_4, x_5) = 0.1560x_1 + 0.2777x_2 + 0.1489x_3 + 0.1718x_4 + 0.2456x_5 \quad (1)$$

This is the model we use to measure national vulnerability based on the above analysis. And  $x_1, x_2, x_3, x_4, x_5$  represent SC, PS, EDL, SSHD, CCD,  $y$  represents SFA.

The final result of 10 countries' second-level indicators data and the SFA index shows below.

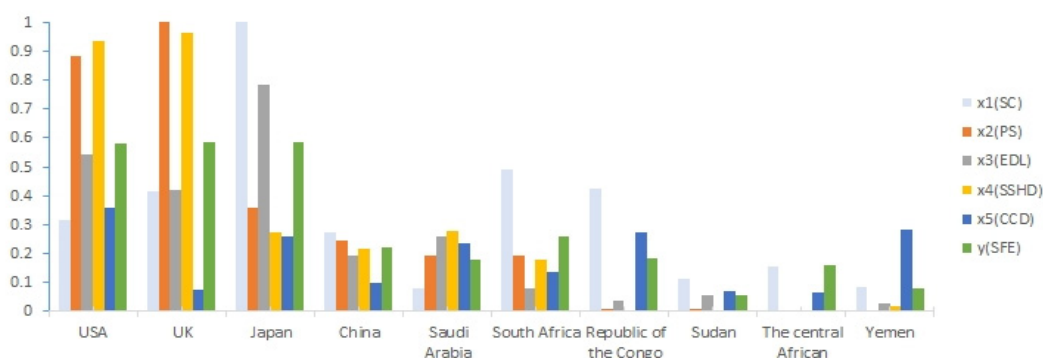


Fig. 2 10 Countries SFA

### 3.4 Correlation Coefficient Method for the Impact of Climate on other Indicators

Climate refers to hot and cold, wet and dry[2], the most scientific measure of climate change is the two indicators of temperature and precipitation, we are based on 10 countries 25 years of average annual temperature and precipitation data[2], the temperature and precipitation by 1: 1 the importance of getting a measure of climate change indicators C1, then according the for formula(2)

$$\rho_{XY} = \frac{Cov(X,Y)}{\sqrt{D(X)}\sqrt{D(Y)}} \quad (2)$$

Using the formula (2) to solve the correlation coefficient between climatic index and SC, PS, EDL, SSHD and CD separately, it can be obtained from the function *corrcoef*(x, y) in MATLAB:

Table 3. Correlation Coefficient

	SC	PS	EDL	SSHD	CD
$\rho_{XnY}$	-0.6702	-0.6041	-0.7388	-0.6032	-0.1058

The above correlation coefficient can quantitatively measure the impact of climate change.

### 3.5 Fragility Threshold

In order to define the standard of fragile, moderate, or stable, we get the following threshold through the qualitative analysis according to the data in Tab.2 and the data of other countries in the world:

Table 4. Fragility Threshold

Fragile	Moderate	Stable
$0 < y < 0.112$	$0.112 \leq y < 0.39$	$\geq 0.39$

We randomly selected 8 countries from 197 countries and regions to conduct tests. Combined with the FSI, we judged whether they met the proposed standards, and the results were in line with expectations.

## 4. Model Modification and Application

To verify the accuracy of the model established in this paper and to test whether the model can reflect the fragility of a country in a more practical way, this paper chose Egypt as a test sample. Egypt is dry and rainless, and the climate is dry and hot. The Nile Delta and the northern coastal areas have a subtropical Mediterranean climate with a relatively mild climate.[5] The area comprises 5.5% of the area of Egypt, but has over 95% of its people and its agriculture. Egypt's Mediterranean coast and the Nile Delta have been identified as vulnerable to sea level rise. The rate of sea level rise for the Nile Delta ranges between 3.2 - 6.6mm/year, coastal areas will be more vulnerable to an increasing frequency and intensity of extreme coastal storms associated with sea level rise. As with many climate change modeling outcome, regional projections at the spatial scale of the Nile Delta suggest that the southern Mediterranean has Already seen a measurable increase in the number of natural disasters: from an average of three natural disasters/year in 1980; to an average of >15/year in 2006. An increase in frequency and severity of storm surges is already evident; and the Continuation of rising seas, sinking lands, and more frequent and intense storms is a necessary inference from the review of recent trends and future climate change forecasts. [6]

The population of Egypt is huge. According to the World Bank's 2016 data, the population of Egypt has reached 97.60 million, so the impact caused by climate change will cause greater losses.

The paper collected data on secondary indicators for Egypt for the past five years and used the SFAM to calculate the five-year SFA in Egypt. The vulnerability index in Egypt is not satisfactory, as shown in the chart below.

Table 5. Egypt Data Based on SFAM

	2017	2016	2015	2014	2013
SC	0.1683	0.1200	0.2765	0.2293	0.2800
PS	0.2639	0.1828	0.2371	0.2384	0.1539
EDL	0.0804	0.2466	0.1966	0.2334	0.2684
SSHD	0.1772	0.2618	0.2610	0.2271	0.2761
CCD	0.2044	0.1626	0.1891	0.1960	0.2621
SFA	0.1935	0.1746	0.2369	0.2272	0.2340

The Gray Prediction Model has the advantages of simple operation, high precision, and strong sequence generation, and is suitable for predictions with less original data. The steps are as follows:

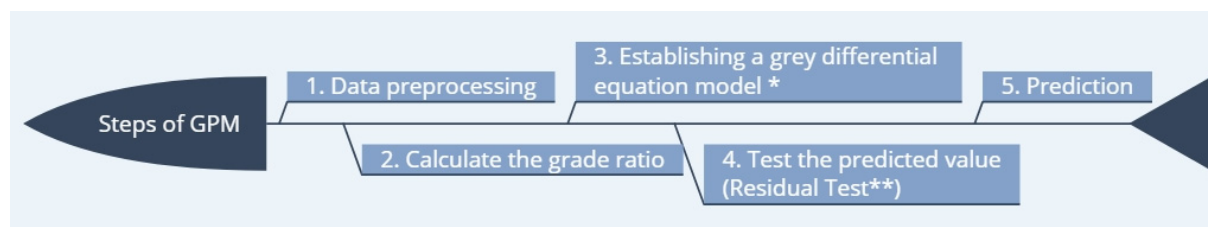


Fig. 3 Steps of GPM

In the picture above, \* represents the grey differential equation:

$$x^{(0)}(k) + \alpha z^{(1)}(k) = b, \quad k = 2, 3, \dots, n \quad (3)$$

\*\*represents the formula of Residual Test:

$$\zeta(k) = \frac{x^{(0)} - \hat{x}^{(0)}(k)}{\hat{x}^{(0)}(k)}, \quad k = 1, 2, \dots, \text{where } \hat{x}^{(0)}(1) = x^{(0)}(1) \quad (4)$$

In order to study the impact of future climate change on Egypt, this paper uses Gray Prediction Model (GM (1,1)) to predict SFA of the country in the next fifteen years (2018-2032) based on the SFA of the past five years. Using MATLAB, we get the line chart Fig. 4 and data Table 6 are as follows:

Table 6. Projected SFA from 2018-2032 in Egypt

	2018	2019	2020	2021	2022
FSI	0.1792	0.1697	0.1607	0.1522	0.1441
	2023	2024	2025	2026	2027
FSI	0.1364	0.1292	0.1223	0.1158	0.1097
	2028	2029	2030	2031	2032
FSI	0.1039	0.0983	0.0931	0.0882	0.0835

Since the Critical Value Determined in this Paper has a Certain Degree of Volatility, it can be seen that the Fluctuation is Around 0.4. from the Results Chart Above, we can Find that the Fragility of

the Egypt Decreases Over Time. the Value in 2026 is 0.1158; the Value in 2027 is 0.1097, So the Threshold Value 0.112 of "Fragile" is Reached in 2026-2027.

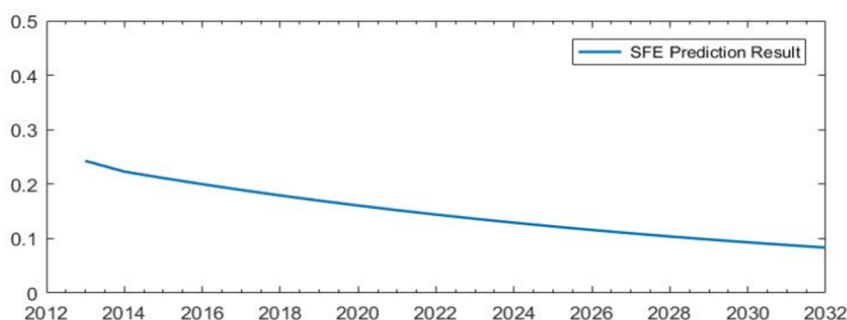


Fig. 4 Egypt SFA Prediction Line Chart

Egypt is a unique country with respect to its water resources. More than 95% of the water budget of Egypt is generated outside its territory. Although we cannot yet predict the impact of climate change on the Nile Basin, there are indications that the impacts will be significant. Any decrease in the total supply of water, coupled with the expected increase in consumption due to the high population growth rates will have drastic impacts. Water management is thus one of the most important adaptation actions. Adaptation of supply includes measures to improve rain harvesting techniques, increase abstraction of ground water, recycle water, desalinate water, improve its transportation and rationalize its use. Meanwhile, adaptation of demand requires minimizing the need for water and optimizing the economic return of its unit volume.[5].

## 5. Conclusion

Based on the Fragile States Index, this paper establishes a States Fragility Assessment model based on climate change, and takes Egypt as an example for application. Among them, the index weight is obtained by entropy weighting method, and the result is objective and credible. A grey prediction model was used for the prediction of future SFA in Egypt, and the results were highly accurate. Finally, based on the prediction results, this paper proposes effective containment measures for the future impact of climate change in Egypt. Under the premise that the region or country under study is not subject to extreme climate change in recent years, the data that SFAM needs is available and accurate, then the model can be used in a wider range to provide a reference for national and regional governments to make decisions.

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