Contents

1 Introduction

1.1 Background

Climate change is a change in the statistical distribution of weather patterns when that change lasts for a period of time. The effects of climate change, including increased droughts, shrinking glaciers, changing animal and plant ranges, and sea level rise, are already being have significant influence on food supplies and other resources that are vital to humans. Some regions will suffer from increased dryness, heat, water shortages, triggering reduced agricultural production. Weather-related events like more hurricanes, monsoons, floods in regions around the world have an enormous impact on conditions society, as they influence food supply, conditions in cities and communities, as well as access to clean water and energy [1]. The IPCC asserts that climate change and its follow-on effects pose a severe risk to political, economic, and social stability with over 400 million people living in drier, subtropical, often over-populated and economically poor regions. Countries, which lack the resources and capabilities required to adapt quickly to the severe conditions, are very likely to break down. Historical and contemporary events have demonstrated that environmental often results in conflict, and the governments are altered to fragile states.

In order to define a fragile state, twelve conflict risk indicators are used to measure the condition of a state at any given moment. The indicators provide a snapshot in time that can be measured against other snapshots in a time series to determine whether conditions are improving or worsening. So we can define fragile states as countries that lack the essential capacity and will to fulfill sets of critical government responsibilities. Being a fragile state increases the vulnerability of a country's population to the impact of such climate shocks as natural disasters, decreasing arable land, unpredictable weather, and increasing temperatures. Non-sustainable environmental practices, migration, and resource shortages, which are common in developing states, may further aggravate states with weak governance. Environmental stress alone does not necessarily trigger violent conflict, but evidence suggests that 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 [2].

1.2 Restatement of the Problem

We are required to analyze how climate change influence regional instability. Then we need to establish a model to determine a country's fragility and simultaneously measures the impact of climate change. Our model should meet the following requirements:

- Identify when a state is fragile, vulnerable, or stable.

- Identify how climate change increase fragility through direct means or indirectly.

In addition, we should evaluate how climate change may have increased fragility of a country selected from one of the top 10 most fragile states according to SFI (the State Fragile Index). And the model should also show in what way(s) the state may be less fragile without these effects. Besides, we should select another state which is not in the top 10 list to measure its fragility and our model can determine the ways that climate change may push the country to become more fragile and identify any definitive indicators.

Moreover, we should develop a model to accurately define a tipping point and predict when a country may reach it. Then use our model to show which state driven interventions could mitigate the risk of climate change and prevent a country from becoming a fragile state. Furthermore, we should establish a model to explain the effect of human intervention and predict the total cost of intervention for this country.

Finally, we should to make analysis and assessment of our models, to figure out whether or not our model work well on smaller 'states' or larger 'states', assess the strength and weakness of them and modify our models.

2 Assumptions

To simplify our problems, we make the following basic assumptions, each of which is properly justified. Further improvements of these simplified assumptions will be achieved later with reliable data that are more reliable..

- **The statistical data is valid.** We suppose that the true value of every index locates nearby the statistical data. Consequently, we assume that the data is believable.
- **The state runs independently and does not affect each other.** The institutional structure and the operating mechanism within each country depends on the country itself only and will not be interfered by others.
- **We assume that effects of external factors on our model obey the Gaussian Distribution.** We made this assumption based on reality, because the kinds of external effects considered in our study (e.g. international aids) seldom have abnormal strong impacts on the original model. Under this assumption, we can easily quantify the external effects in our study.
- **There are varieties of indicators based on different trends of the countries' development.** And these relationships generally hold true. We can use the data to predict the fragility of a country.

3 Notations

Symbols	Definitions
G_g	The group grievance index
S_l	The state legitimacy index
H_r	The human right index
S_a	The security apparatus index
W_s	The percentage of the population with access to improved drinking water source
A_v	The agriculture value(the percentage of GDP)
F_p	Food Production

4 Model for State Fragility

4.1 Indicators of Fragility

In order to give a well-rounded description of fragility of a country, a series of indicators are used, which are called Indicators of Fragility. As stated previously, we define fragility as countries lacking the capacity and/or will to foster an environment conducive to sustainable and equitable economic growth; to establish and maintain legitimate, transparent, and accountable political institutions; to secure their populations from violent conflict and to control their territory; and to meet the basic human needs of their population. With this definition, we aim to capture government responsibilities commonly considered core functions of statehood. This definition informs our selection of a set of indicators that measures the fragility of a state. Specifically, the fragile state index lies on three “baskets”， each of the three baskets consists of indicators that are proxies for one core aspect of state function. The indicators system is showed in **Figure 1.**

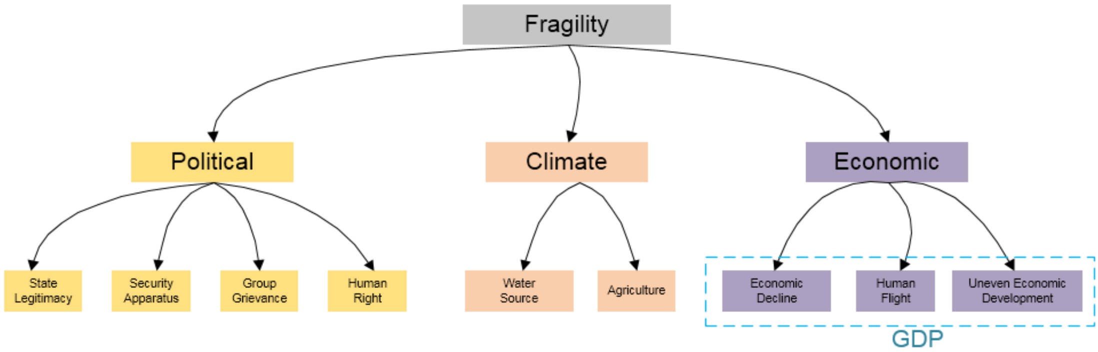

Figure 1 Fragility Indicators System

- **Political** indicators assess the quality of a state's political institutions and the extent to which its citizens accept as legitimate their system of governance [2]. Weak political institutions are the central driver of fragility. This indicator consists of four small indicators:

  1. **The State Legitimacy Indicator** considers the representativeness and openness of government and its relationship with its citizenry. The Indicator looks at the population's level of confidence in state institutions and processes, and assesses the effects where that confidence is absent, manifested through mass public demonstrations, sustained civil disobedience, or the rise of armed insurgencies.

  2. **The Security Apparatus Indicator** considers the security threats to a state, such as bombings, attacks and battle-related deaths, rebel movements, mutinies, coups, or terrorism. The Security Apparatus also takes into account serious criminal factors, such as organized crime and homicides, and perceived trust of citizens in domestic security.

  3. **The Group Grievance Indicator** 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. Group Grievance may also have a historical component, where aggrieved communal groups cite injustices of the past, sometimes going back centuries, that influence and shape that group's role in society and relationships with other groups.

  4. **The Human Rights** and Rule of Law Indicator considers the relationship between the state and its population insofar as fundamental human rights are protected and freedoms are observed and respected. The Indicator looks at whether there is widespread abuse of legal, political and social rights, including those of individuals, groups and institutions (e.g. harassment of the press, politicization of the judiciary, internal use of military for political ends, repression of political opponents).

- **Economic** indicators assess a state's ability to provide its citizens with a stable economic environment that facilitates sustainable and equitable growth. They take into account recent economic policies, whether the environment is conductive to private sector development, and the degree to which income is equitably distributed. Economic growth is a necessary condition for poverty reduction, but also that economies can only thrive in countries where there is peace, stability and good governance. Economic growth cannot happen without strong institutions. Most fragile states have weak institutions and consequently often experience a chronic lack of (both external and internal) investment in both human development and state infrastructure [3]. Initially, we use three key indicators (**Economic Decline, Human Flight, and Uneven Economic Development**) to mirror the economic indicator. Later, we figure out that even with all other contributing factors remaining constant, if a state averages a GDP per capita of US$ 250 or below, there is a 15% risk of seeing a civil war in the following five years. Yet, this risk level is reduced to below 1% if GDP per capita reaches over US$ 5,000 as **Figure 2** shows. 7. Low levels of GDP per capita are associated with reduced state capacity. If a state cannot raise revenue from its population in order to provide public services for that population, it will be weakened. So we use GDP per capita to illustrate the economic indicator.[4]

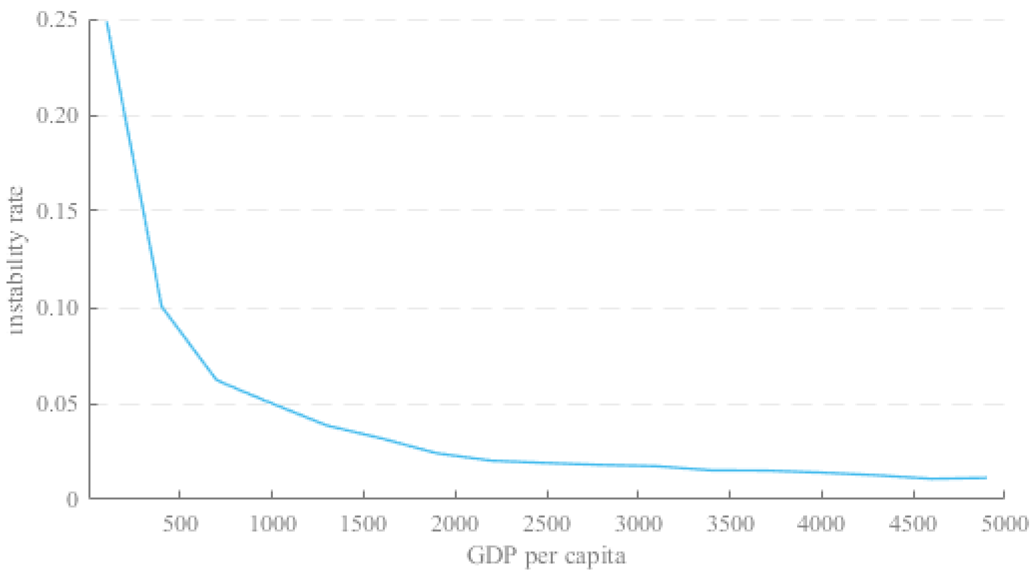

Figure 2 Instability Rate

- **Climate** conditions or a predisposition to natural hazards (earthquakes or floods for example) will have similar consequences: harsh weather can destroy crops, and make land difficult to cultivate, and natural hazards can mean that, overnight, any physical development or state investment in infrastructure can be destroyed. Climate change have direct influence on accessible clean water, energy and food supply. But we failed to obtain reliable data regarding energy. So we use **Improved Water Source** (the percentage of the population using an improved drinking water source.) and **Agriculture Value**(the percentage of the GDP) to represent the **Climate indicator.**[5]

4.2 Measurement of Fragility

We use **Fragility State Index** to completely measure fragility. Data normalization ways are introduced. The **Fragility State Index** consists of a visual map of three factors describing various kinds of instability country could experience that would cause it to be considered fragile. What can the Fragility State Index be used for:

- User can easily determine which sector or sectors of the country of interest are most in need of improvement to decrease the overall fragility of the country.
- The Fragility Index of different countries can be plotted together to compare side by side the nature and severity of the fragility issues effecting each country.
- The Fragility Index can also be used to track changes in a country's fragility over time, and as a tool to assess the efficacy of a development intervention by comparing the Indices before and after the introduction of a development initiative.

4.2.1 Data Normalization

A set of nine indicators are classified to three main indicators that were regarded as the most important for determining the fragility of a state. Indices incorporate factors generally thought to influence or correlate with the fragility and instability of a state. In order to normalize the date we have got so as to clearly measure the fragility, the indicators are defined such that：

- All the date is collected from authoritative database, which is reliable.
- Each index was on a scale of 0 to 10 except economic index which ranges from 0 to 1.
- Higher numbers indicate greater fragility.
- All factors included in a given index were initially weighted equally.
- Values were obtained from the same data set for each country (In all but a few cases in which there was missing data).

1) Political Index

Political Index quantifies the integrity of the infrastructure systems and the development of the institutions. The political indicator is the central driver of fragility.

$$\text{Political Index} = \frac{G_g + S_l + H_r + S_a}{4}$$

Where

G_g is the group grievance index from the FSI.

S_l is the state legitimacy index from the FSI.

H_r is the human right index from the FSI.

S_a is the security apparatus index from the FSI.

All the four indices are on the scale of 1 to 10.

2) Economic Index

We use **Spline Interpolation** to obtain economic index from GDP per capita data. As is showed in Figure 2, the relation curve between **Instability Rate** and **GDP per capita** is drawn according to the statistical data. There is a definite function relation between **Instability Rate** and **GDP per capita**. Then we extract enough points from the original curve and implement Spline interpolation fitting. Finally, we can get the target data (**Instability Rate**) by inputting **GDP per capita**. Low levels of GDP per capita are associated with reduced state capacity. If a state cannot raise revenue from its population in order to provide public services for that population, it will be weakened. We use the **Instability Rate** to indicate the **Economic index.**

3) Climate Index

Climate change have direct influence on **Improved Water Source** (the percentage of the population using an improved drinking water source.) and **Agriculture Value** (the percentage of the GDP).

Improved Water Source (IWB) can't reflect the fragility. By consulting the literature, we find that political stability increases with the increase of IWB[6], and the changing trend approximately fits the sine function relation. We fit the sinusoidal function and implement Taylor Series expansion. So we can get the formula as follows:

$$\text{IWB index} = 10(1 - \frac{(1-W_s)^3}{3!} + \frac{(1-W_s)^5}{5!})$$

Where W is the percentage of the population using an improved drinking water source (the World Bank).

We use Agriculture Value index to measure the influence of Agriculture to fragility.

$$A_v \quad index = 10(\frac{A_{vmax} - A_v}{A_{vmax} - A_{vmin}})$$

Where A_{vmax} is the maximum of Agriculture Value (the World Bank); A_{vmin} is the minimum of Agriculture Value (the World Bank).

Finally, we get the **Climate Index:**

$$\text{Climate Index} = 10\left(1 - \frac{(1-W_s)^3}{3!} + \frac{(1-W_s)^5}{5!}\right) + 10(\frac{A_{vmax}-A_v}{A_{vmax}-A_{vmin}})$$

4.2.2 State Fragility Index

The fragility is based on the three main indicators. Taken together, the 20 indicators yield a balanced picture of how developing countries perform or fail to perform along multiple dimensions. These indicator indices are standardized, ranging from 0.0 (worst) to 10.0 (best) except Economic Index (ranging from 0 to 1). So we can use the model of **State Fragility Index** as follow to completely represent the State Fragility.

$$\text{State Fragility Index} = \frac{G_g + S_l + H_r + S_a}{4} + 10\left(1 - \frac{(1-W_s)^3}{3!} + \frac{(1-W_s)^5}{5!}\right)$$

$$+10\left(\frac{A_{vmax} - A_v}{A_{vmax} - A_{vmin}}\right)$$

This model can determine a country's fragility and simultaneously measures the impact of climate change. We ran our State Fragility Index on all countries with available data calculated from the formula. Countries colored grey have missing data. The darker the color is, more fragile should the country be.

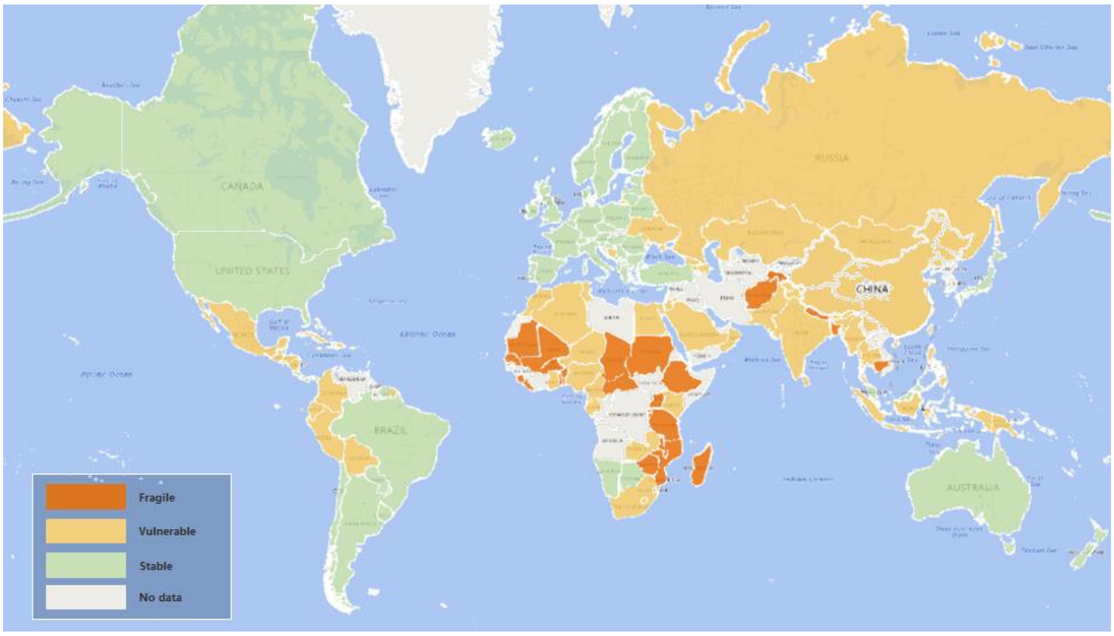

Figure 3 Worldwide view of country State Fragile Index scores

4.3 Results

4.3.1 Fragility Country Rankings and Analyze

We acquire original data from World Bank Database. The data cover all the 9 indicators in our Indicator System. We choose the top15 countries based on the **State Fragility Index** score in 2014. The rankings are showed in Table 1. The higher the score is, the more fragile a country is. In order to test and verify the accuracy of our model, we compare the most fragile countries got from our model with the countries defined as fragile in the Work Bank.

Table 1 Country Rankings according to **State Fragility Index**

Rank	Country	Overall Score	Whether or not fragile in World Bank
1	Burundi	2.74	Fragile
2	Central African Republic	2.55	Fragile

3	Madagascar	2.08	Fragile
4	Malawi	2.07	Fragile
5	Liberia	1.81	Fragile
6	Ethiopia	1.70	Fragile
7	Afghanistan	1.70	Fragile
8	Mozambique	1.55	Not mentioned
9	Togo	1.47	Fragile
10	Sudan	1.47	Fragile
11	Guinea	1.34	Fragile
12	Sierra Leone	1.31	Fragile
13	Uganda	1.29	Not mentioned
14	Rwanda	1.27	Not mentioned
15	Chad	1.21	Fragile

Analyze: As we can see from the table above, all the countries that are considered the most fragile in the model are also defined vulnerable in the World Bank statistics, except for those countries that are not counted in the World Bank, so it can prove that our model is very accurate. It can be used to determine a country's fragility.

4.3.2 Three Levels of Fragility and Analyze

According to the rankings, we have drawn a scatter diagram of Rankings and SFI. We can divide fragility into three levels according to the aggregation of scattered points, and this classification method is very consistent with the World Bank data. **Figure 3** shows the classification.

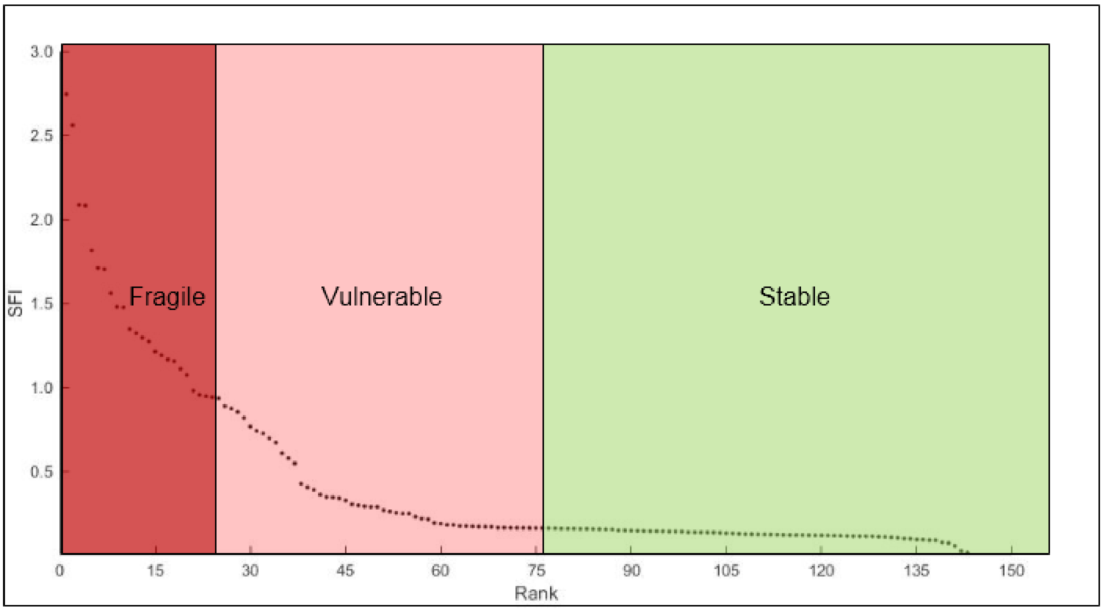

Figure 4 Three levels of fragility

Analyze: We divide fragility of a state into three categories: fragile, vulnerable, stable. From **Figure 3**, we can analyze that when a country has greater State Fragility Index (SFI) than 0.9, that country is identified as a fragile state, and when a country has smaller SFI than 0.3, it is identified as stable. When a country's A is between 0.3 and 0.9, it belongs to vulnerable.

4.3.3 Influence of Climate on Fragility

To clearly show how climate change influence fragility, we use an assumption diagram to illustrate. As is showed in **Figure 3.**

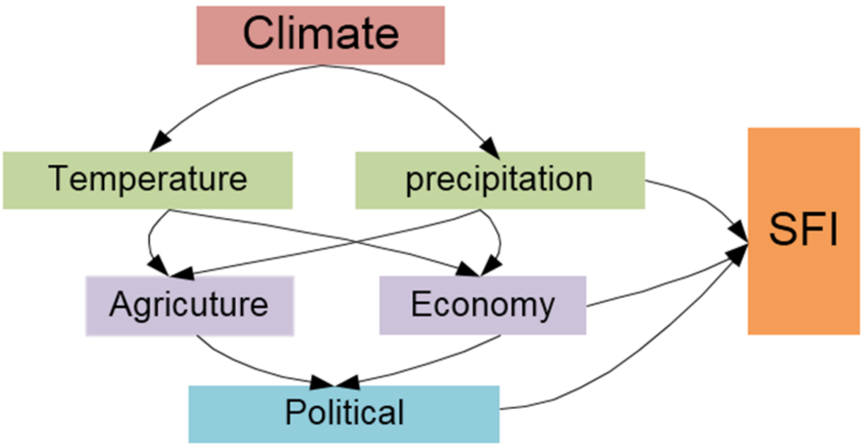

Figure 5 How climate change influence SFI

Climate change directly exerts influence on temperature and precipitation. Next the temperature and precipitation affect the agriculture and economy which have impact on political stability to great extent. All the factors can influence SFI. In addition, these factors also affect each other.

4.3.4 How Climate Change Increases Fragility of Sudan

We use the temperature from 2006 to 2016 in Sudan to represent the climate change. As is shown in **Figure 4**, we use the data calculated from the previous model to draw the curve which reflects their change over time.

Figure 6 The change of indices over time

Analyze: Comparing the changing trend of the four curves, we find that there is almost no change in **Access to Water Source** and **Economy Rate**, which indicates that climate change exerts a very tiny effect on the two indices. However, the changing trend of **AGR Score** and **Temperature** is almost the same. So we can conclude that **climate change have a significant impact on agricultural production, thus affecting the country's fragility index.**

4.3.5 Without Climate Change

We simultaneously draw the **SFI Scores** and **SFI Scores (without climate change)** in one diagram. We can obviously find that **SFI Scores** will decrease without climate change, say, the country will become less fragile under such circumstance.

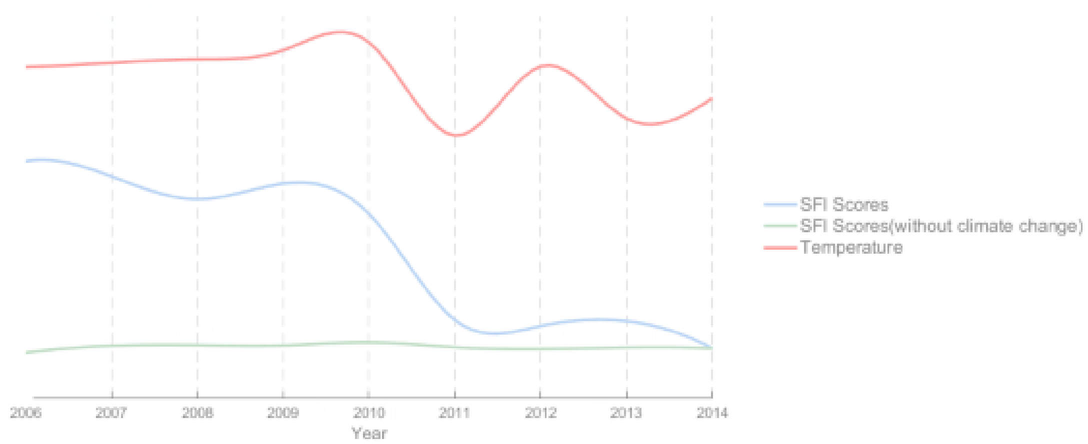

Figure 7 Without climate change

5 Dynamic Climate-Fragility Simulation Model

Because of the complicated interaction of all indicators, it is difficult to quantify the specific relationship between factors and determine the exact way of how climate change increase the fragility. To measure the fragility of a country which doesn't belong to the top 10 list and see how climate change may increase the fragility of a country, we establish a dynamic C**limate-Fragility Simulation Model** with the help of **Netlogo**. It can simulate the dynamic change and get a critical point to predict when a country might reach it. It also found the relationship between climate and vulnerability, which is very progressive.

5.1 Background of Kenya

Located in the equator, Kenya has a pleasant, tropical climate. During the daytime, its average temperatures is between 20°C/68°F and 28°C/82°F, but it is much warmer on the coast. The precipitation in the coastal areas has reaches 1000 mm. and the temperature will stay mild through the rainy period apart from the mountainous districts where the temperature commonly drops below zero. With regard to the economy, the rise rate of GDP in Kenya is up to 5.8%. Consequently, the GDP per capita has increased to $3162. According to the Fragile State Index presented by T**he Fund for Peace,** Kenya ranked 22nd with 96.4 SFI score while it ranked 26th in SFI. To improve the current condition, we've conducted a Climate- Fragility model.

5.2 Description of the Model

The model generally simulates the geography of Kenya, as is showed in **Figure 8**. There are mountains in the left side representing Kilimanjaro. The water in the peak freeze in the winter while melt when spring approaches as the temperature changes according to the seasons. On the right side of the model is the Indian oceans. The pink dots move upward, representing the evaporation of water. Some of the water transforms to cloud while some of them not. When the temperature is low, the amount of water will decrease or even stop evaporating. So **temperature exerts great significance on water circulation.** Set up the distribution of water resources in the model according to the survey of Kenya water distribution by **Oxform** [7]**.** In addition, every creature in the program represents 2,000,000 animals or people. Netlogo operates by executing actions every tick, over time, and we scaled all movement, distance, and rates so that every tick is equivalent of a year.

Our model simulates a completed water cycle, which affects the distribution of water resources dynamically which refers to the water cycle model in the Netlogo. Every water source has a storage. When the storage is less than zero, it will disappear. Taking into account the influence of evaporation of water, the storage will decrease linearly. Meanwhile, rain and snow can increase it. The middle green and brown parts are continents, where lives the plants and animals, humans, etc. According to data provided by the World Bank, we've roughly assumed that 63 percent of people in Kenya currently have access to water near the water source. The model also simulates their survival, reproduction, and death based on the S-shaped curve of predator-prey according to **Logistic Growth Model.** And water-point refers to the percentage of population with access.

$$w = \frac{A}{B}$$

Where A is the number of people near the available source of water, while B is the total population.

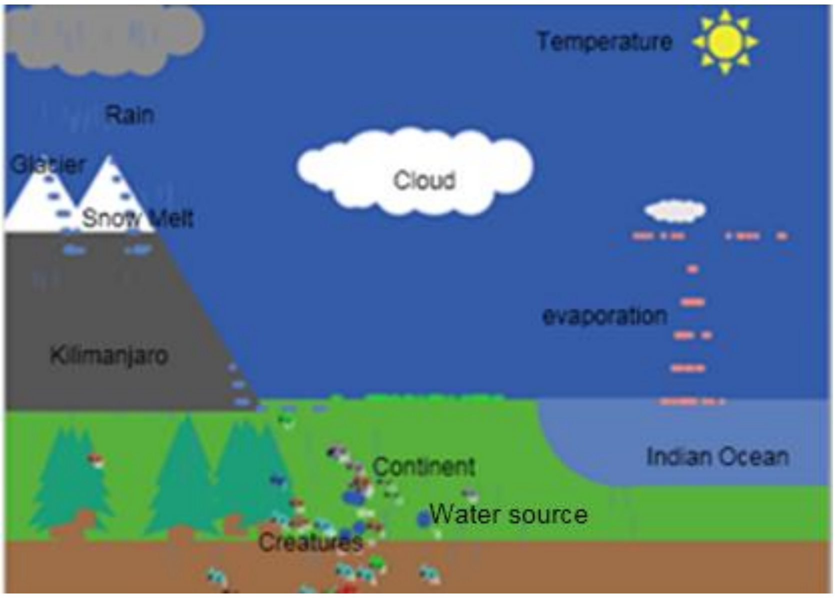

Figure 8 Simulation Diagram in Netlogo

5.3 Implementation and Verification

By looking up climate data in Kenya, we're replacing the relative humidity, air temperature, ocean temperature, mountain temperature, and land temperature with Kenya's average climate data for easier to simulate.

At first, we set a relative humidity of 38, air temperature of 22, seawater temperature of 29, mountain temperature of 35, and continental temperature of 34. This is a set of data that is slightly lower than the average climate in Kenya. After a period, we can conclude from the graph that water (% of population with access) and SFI Index are stable overall. We assume that Kenya's average temperature skyrocketed by 3°C/3°F in 2031, then adjust other climate parameters. Surprisingly, the vulnerability index remains stable over the next decade. Here, SFI Index's calculations follow the model mentioned above. We've ignored the political and economic implications, and consider food production to be the sum of the part of animal and plant energy available for human consumption.

$$F_p = \frac{E_a}{A} + \frac{E_v}{B}$$

Where:

E_a is the energy in animals which have been set in the model

E_v is the energy in vegetation.

The movement, reproduction and growth will reduce energy. Nevertheless, when animals intake water and food, their energy will be increased. If the energy is less than zero, the individual will die. Similarly, D is the plants' energy.

Over the next period, we imitate that Kenya is suffering from climate change. Its average temperature was suddenly increased by 6.5°C, and other climatic parameters were adjusted accordingly. It is easy to find that the temperature of **28.5**°C is the **tipping point** because after that time, water (% of population with access) and food production fell down rapidly, leading to the SFI Index increased significantly, and **exceeding the threshold for fragile states**, finally **making Kenya extremely vulnerable**. Based on these premises, Kenya will reach tipping point on **2042 and** then becomes extremely vulnerable. As is showed in **Figure 9**.

Further simulation: keep the temperature constant, only change the relative humidity, and then carrying out the experiment. After analyzing the curve showed in **Figure 10,** the relationship between humidity and vulnerability is not significant, which is not the decisive factor of Kenya fragility, while others (including air temperature, seawater temperature, mountain temperature, and continent temperature) affect the fragility of Kenya.

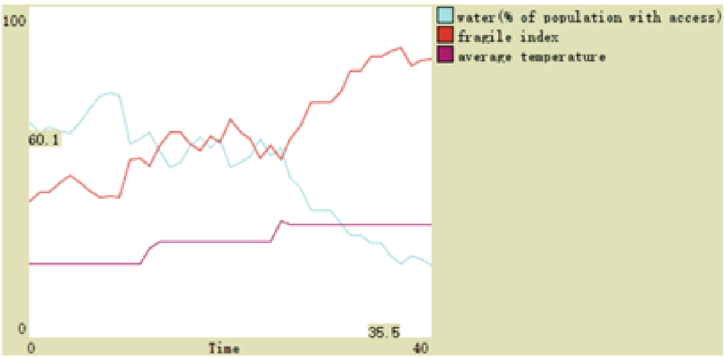

Figure 9 Trend with Temperature Change

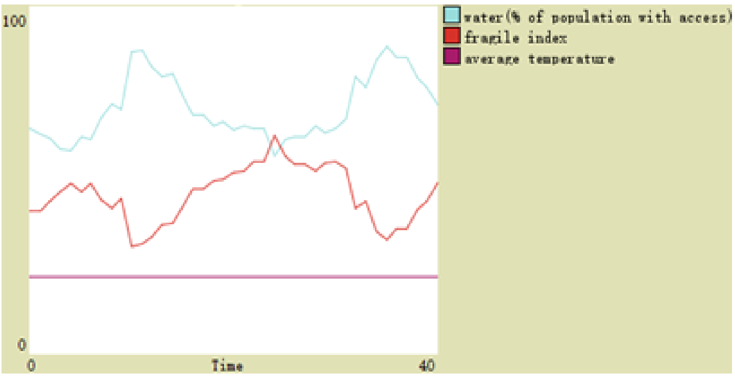

Figure 10 Trend with Temperature Constant

6 Intervention Forecasting Model

6.1 Methodology

To show which state driven interventions could mitigate the risk of climate change and prevent a country from becoming a fragile state. To be detailed, we forecast each index by **Autoregressive Integrated Moving Average Mode**l [8]. And with state driven interventions, we use a **dynamic system and structure equation modeling** [9] for all indices we have chosen to improve the model. Therefore we can implement our model to some programs and the policy of interventions.

6.2 Why This Method

Actually we have many mathematical techniques to evaluate. We would like to mention some traditional statistics or artificial weighting methods such as principal component method, SVM (support vector machine), AHP (Analytic Hierarchy Process), and fuzzy synthetic evaluation model (FCEM). But these method are too subjective to make others convinced due to the need of professional background knowledge. In addition, other methods like **Heuristic Search Algorithm, GA, BP Artificial Neural Network,** are essentially improvement of random search, so the results largely depends on something uncertain. These algorithm is hardly appropriate for measuring fragility, let alone apply to forecast.

On the contrary, our model is stable due to invoking a series of significance test to ensure the reasonability of the results.

6.3 Sensitivity Analysis

We choose Kenya to implement our model by using the data from the World Bank. Sensitivity is always used to test the robustness of a model. And we invoke sensitivity analysis to evaluate the ability of each index to influence the results. We rank these indices and list the most effective indices to the SFI. We rank indices decreasingly by absolute value of difference quotient:

$$\mathrm{d(SFI)} = \frac{SFI(I + \Delta I_i) - \mathrm{SFI(I)}}{\Delta I_i}$$

Where I reprents the indicator data, and ΔI_i is the variation of index i.
We can get the most effective index is **Improved Water Resource** through this method.

6.4 Intervention Measures

- **Better water distribution system**

The Kenyan water sector underwent far-reaching reforms called Pipeline Corporation through the Water Act No. 8 of 2002. Previously service provision had been the responsibility of a single National Water Conservation and Pipeline Corporation as well as of a few local utilities established since 1996. This is a kind of improved water distribution system whereby Kenya could get a better use of limited water resources, to improve access to fresh water and resistance of agriculture to drought.

- **Reformed water storage and manage system**

The annual average percentage of the population affected by extreme weather in Kenya is 6.478 according to World Bank. An effective water storage and manage system could help when dealing with some short-term crisis, maintaining water supply for residential and agricultural use. In our model, the outcomes of these intervention above perform as more stable parameters (especially water and agriculture) when facing extreme climate.

6.5 Intervention Cost Model

Kenya is a typical agricultural country with 1/3 of its GDP consist of agriculture. Climate change in Kenya is projected to lead to an increase in the extent and frequency of extreme climatic events with mostly negative impacts on agriculture and water [10]. Stern estimates that the central economic costs of climate change could be equivalent to 2.6% of GDP each year by 2030. As is shown in Figure 11, 70% of the land in Kenya is arid or semi-arid and most these land have not been exploited yet, while the remaining 30% of the land is fertile and have been fully used [11]. The annual average percentage of the population affected by extreme weather in Kenya is 6.478, and nearly 37% of the population lives without access to improved water source, according to World Bank.

6.5.1 Basic assumptions

We have four assumptions relying on the characters mentioned above:

- Climate change exert its impact on Kenya's SFI only in the field of agriculture and water supply.

- To exploit arid and semi-arid lands requires corresponding investment which can be measured by range and cost per unit.
- GDP loss is totally agricultral4. We can mitigate the effect of climate change by making up GDP loss brought by climate change and maintaining a stable supply of improved water source.

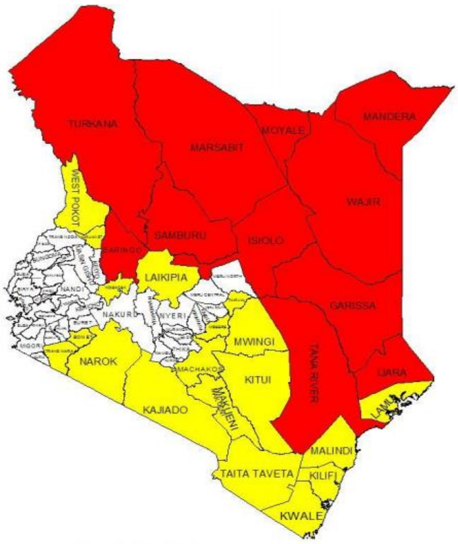

Figure 11 Map of Kenya showing arid and semi-arid districts

6.5.2 Implementation and Results

Having applied all the characters and assumptions in our model, we can tell out that in Kenya, climate change increase SFI by affecting A_{vg} Index through reducing agricultural income and IWB Index. The state driven intervention should be able to maintain a stable agricultural income and water supply when climate change strikes. Considering the agricultural land distribution, to secure the agricultural income, the best way is to take fully advantage of those arid or semi-arid lands in the northern and southern part of Kenya. And an effective water storage and manage system could help when dealing with some short-term crisis, maintaining water supply for residential and agricultural use.

In our model, the outcomes of these intervention above perform as more stable parameters (especially A_v, W_s and GDP) when facing extreme climate. If we are to totally eliminate the effect brought up by climate change, we have to fully make up the GDP loss brought by climate change and build up a reformed water storage and manage system. Therefore, we could have an equation as follow:

$$L_m = G_{dpl} = GDP \times 2.6\%$$

$$A_{vps} = \frac{A_{va}}{L_{ea}}$$

$$L_m = A_{vps} \times L_{te}$$

$$C_t = L_{te} \times C_{ps} - C_{wm}$$

$$C_{at} = C_t - L_m = \frac{GDP \times 2.6\%}{\frac{A_{va}}{L_{ea}}} \times C_{ps} + C_{wm} - GDP \times 2.6\% = 2.35 \quad billion$$

Where L_{ea} is Exploited Agricultural Land (276,300 Sq. km) ; $G_{dp} is$ GDP(63.768 billion); $A_{va}$is agricultural value added (21.236 billion); $A_{vps}$is agricultural value per Sq. km; G_{dpl} is GDP loss L_{te} is the land to be exploited; $C_{ps}$is the cost for (semi) arid area development (1.5e-4 Billion per Sq. km); C_{wm} is the cost for water storage and manage system (0.75 billion); C_t is the total cost (billion); $L_m$is the Made up GDP loss (billion); C_{at} is the actual cost (billion).

7 Model Analysis

7.1 Strengths

- **Accuracy.** The data is strictly official. All the countries that are considered the most fragile in the model are also defined vulnerable in the World Bank statistic.
- **Intuitionistic**. In the **Climate-Fragility Stimulation Model**, the program has magnificent user interaction, so anyone can understand the process of assessment without any background knowledge. Users can easily understand and analyze the geometric relationships.
- **With strong professional background**. In the Climate-Fragility Stimulation model, the program has magnificent user interaction, so anyone can understand the assessment without any background knowledge. Users can easily understand and analyze geometric relationships.
- **Meaningfu**l. It quantifies the relationship between climate and state fragility, which is significant to policymakers. We also give an analysis of Kenya's current situation, future policies and budgets, in order to improve Kenya's development. It can also be used to predict the crisis.

7.2 Weaknesses

- For larger countries, our models are not very accurate to fit exactly. But it doesn’t mean it’s impossible to achieve. We can divide the whole country to several parts to study. Then integrate all the results.
- We have to update our model to fit every specific country for the reason that the model is largely depend on the characteristics of country so as to ensure th accuracy of the model. For instance, when analyze Mongolia, the model needs to be revise because it is a landlocked country, where no ocean exists in the water cycle.
- The value of correlation between very few factors is not totally professional. For

instance, the distribution of Kenyans and the correlation of water sources, based on the data from the World Bank, are linked to each other with parameter of 63%.

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[10] TOWARDS A COHERENT AND COST-EFFECTIVE POLICY RESPONSE TO CLIMATE CHANGE IN KENYA: COUNTRY REPORT by Camco Advisory Services (K) Limited Stephen Mutimba Rachel Wanyoike