Methodology to detect the impact of climate change on national stability

Yutao Chen, Liangzhen Xie, Chang Li

School of Management, Huazhong University of Science & Technology, Wuhan, China

Abstract

This study explored the influence of climate factors on national stability by establishing a hierarchical model of three layers based on indices in different fields. We verified the effectiveness of our model with data from nine countries around the world by obtaining a strong correlation between the stability scores of our model and the FSI system. Moreover, we identified the impact pattern of the chosen climate factors (temperature, precipitation, and climate disaster index) towards the national stability of the nine countries, obtaining that the factors affect the stability indirectly by functioning on secondary indices rather than final scores. Then, we applied our model to case studies of three countries, to analyze the impact of climate factors from different aspects. In the case study of Yemen, we examined how the existence of these climatic impacts influences the stability score with a controlled test; In the case study of Germany, we performed time series analysis and prediction on its climate change trend with the moving average method; In the case study of Egypt, we proposed potential human-involved methods to offset the negative effects or limitations caused by climate factors, and estimated the costs of such approaches.

Keywords: National Stability Index (NSI); Pearson correlation test;

Moving Average Method

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1 Introduction

1.1 Background

Climate change has been an unneglectable issue identified globally in the 21th century. Historically, the evolution of climate change was triggered by factors such as biotic processes, variations in solar radiation received by Earth, plate tectonics, and volcanic eruptions. Recently, human activities have also been identified generally as primary causes of ongoing climate change such as global warming.

Along with the exacerbation in global climate, the living environment as well as the natural resources degenerates in unequal degrees in different regions of the world, which is likely to increase the fragility of nations in these areas. Countries like Rwanda, Africa, are likely to become the victims for such process. Droughts of varying intensity are common in sub-Saharan Africa, and the continent has suffered eight serious droughts since World War II. The pressure brought by the increasing population against the decreasing arable land areas and productivity tensed the interactions between the tribes inside the country. This potential instability eventually deteriorates to an appalling genocide launched by the Hutu led government towards the Tutsi members in 1994.

Though lack of explicit clues to verify the casual relationships between climate change and national fragility, the worsening climatic and environmental conditions in those countries along with severe social unrest still shed light to us on exploring the potential linkage of climate change and country fragility. In this paper, we try to analyze the impact of climate factors on national stability with our multi-layer hierarchical model, which will be elaborated in section two.

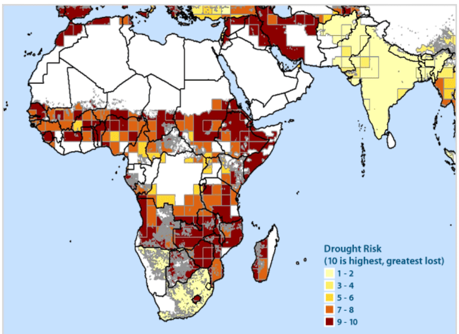

Figure 1: Natural Disasters Hotspots

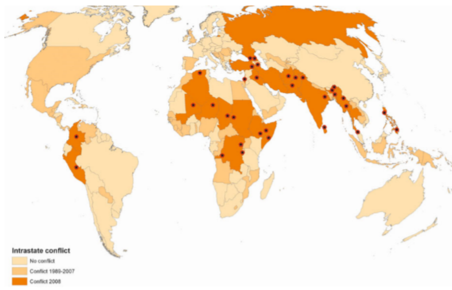

Figure 2: Contemporary Armed Conflicts in 2008

1.2 Literature Review

Previous investigators provided some fundamental ideas for the fragility of states. Basically, a fragile state is always a low-income country characterized by weak state capacity and/or weak state legitimacy leaving citizens vulnerable to a range of shocks. Generally, fragile states are characterized by ($Wikipedia$):

- post-conflict/crisis or political transition situations
- deteriorating governance environments
- situations of gradual improvement and
- situations of prolonged crisis or impasse

Concerning research conducted on the associations between climate change and social stabilities, few of qualitative methods have been put forward or validated. Amy Richmond proposed a regression model to analyze the relationship between political stability with non-violence (PSV) and arable land as well as the ratio of population having access to improved water. The result shows a significant positive correlation between the dependent variable and independent variables, which means countries with more arable land and access to improved water will perform better in political stability with non-violence. (*Modeling Environmental Security in Sub-Saharan Africa, Amy Richmond Krakowka,2012*)

A thorough collection of the discussion of challenges for society stability associated with climate change is *Climate Change, Human Security and Violent Conflict* edited by Jürgen Scheffran, et al. This literature illustrates the influence attributed to climate change on security, securitization discourse and migration as well as some cooperative policies and capacity-building approaches to improve the climate condition. Some modelling frameworks and theories to study the linkage between climate factors and state stability are also presented.

2 Hierarchical Model

2.1 Reference Model

In the second section, the methodology and structure of our national stability evaluation model will be demonstrated. The hierarchy of our model refers to the structure of fragility states index (FSI). FSI is an annual ranking of 178 countries based on the different pressures they face that impact their levels of fragility. The assessment method of this system is based on The Fund for Peaces proprietary Conflict Assessment System Tool (CAST), an analytical approach, which requires three primary streams of data: quantitative, qualitative, and expert validation. The data are triangulated and subjected to critical review to obtain final scores for the FSI.

The model assigns scores to the states from four aspects: cohesion, economy, political and society, each representing a mediate indicator. Every indicator consists of three root indicators as Figure 3 suggests. The altogether 12 root indicators are the final scoring indices, and the original score for each root indicator ranges from 0 to 10. The rank is made by the total summing up scores of the root indicators. A higher score will be interpreted as a sign of greater fragility.

Figure 3: FSI Model Indicators

2.2 Assumptions and Annotations

In order to successfully extract the essential elements in the relationship of climate and country fragility and build a general model, we made the following assumptions to simplify the framework of the model:

- The pattern that meteorological factors influence the stability of each country is set to be undifferentiated regardless of the individuality of the countries. That is to say, the climate factors identified to account for national fragility are fixed for all the sample states. When expressed in mathematical forms, the structures of the impact functions for different states are assumed to be the same. The differences of the countries are expressed only through the discrepancy of the coefficients of the functions, though we admit the possibilities of diverse influence patterns for countries in different areas.

- The pattern that meteorological factors influence the level of fragility of a country in each time period is also assumed to be constant. Since the time span of the data in this study is relatively small, we do not put the time-related differences into the structures of the impact functions. This sort of differences is indicated by variance in the coefficients of different time periods.

The following annotations notify the components of the multi-layer model we defined. The indicators in the bottom layer, whose scores are derived from existing external evaluation indicators, are of the third layer, while others of the second and first layer are indicators defined by us, whose values are derived from those in the third layer.

First-layer indicator	Notation	Second-layer indicator	Notation	Third-layer indicator	Notation	Third-layer indicator	Notation
Political stability index	P	Administration Index	ADI	Institutions and Infrastructure	II	Talent attract	GTCIA
Social stability index	S	Financial Index	FNI	Democracy index	DI	Talent growth	GTCIG
Economical stability index	E	Military Index	MLI	Crime Index	CI	Talent remain	GTCIR
Natural Environmental stability index	N	Equality Index	EQI	Financial deficit indicator	FD	Population density	PD
		Welfare Index	WFI	Global Fire Power	GFP	cultivated area	CA
		Security Index	SCI	Gini coefficient	GINI	Cereal production	CP
		Democracy Index	DEI	Health & education & training	HET	Per capita renewable freshwater resources	PCRF
		Macro Economy Index	MEI	Global Terrorism Index	GTI	Forest area	FA
		Employment Environment Index	EEI	Number of refugees	NOR		
		Population Pressure Index	PPI	GDP	GDP		
		Natural Resource Index	NRI	Unemployment Rate	UR		

Figure 4: Indicator Notation

2.3 Model Structure and Methodology

Our multi-layer model of national stability has a similar hierarchy to that of the FSI model. We extended the reference model to a three layered one while replaced several indicators in the FSI with other indices which are more suitable to analyze the climatic impact (e.g., cultivated area, renewable freshwater resources and forest area). The visualized structure of our model is presented in Figure 5:

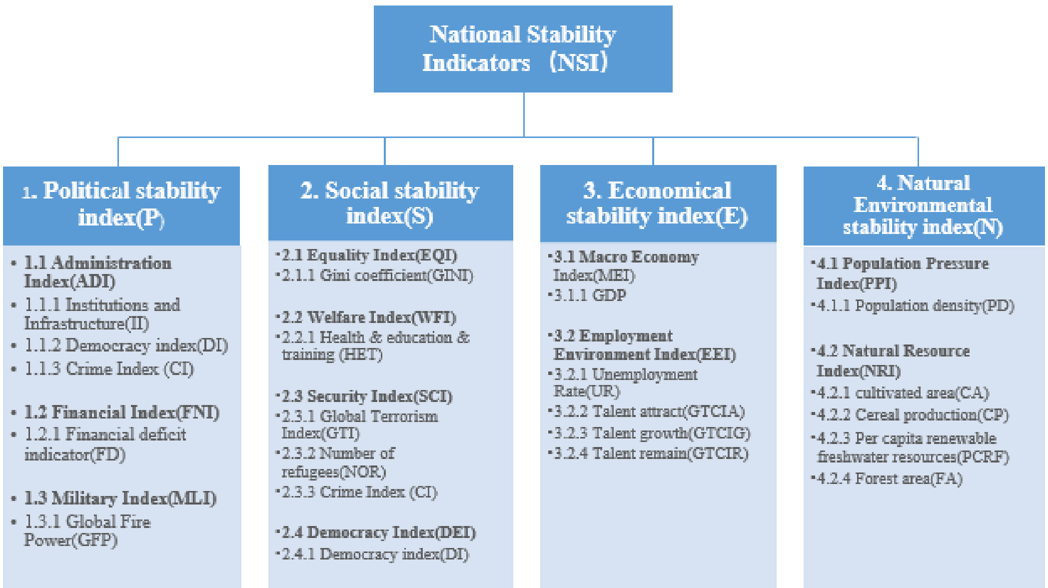

Figure 5: Multi-layer (NSI) Model Structure

The third layer of the model consists of widely acknowledged indices like GDP and GINI coefficient (measuring the gap between the rich and the poor) as well as objective indices such as cultivated area and renewable freshwater resources. The selected indices are highly relevant to the fragility of nations in accordance with the FSI-*methodology*. The indicators in the first and second layer are produced by the same logic, being clustered from secondary indicators (i.e. the second layer indicators are calculated from its secondary indicators in the third layer) based on empirical rules and reference to the FSI indicators (see in Appendix. Figure 15). In addition, an original dimension in the first layer of the FSI, cohesion, is replaced because of great overlap it shows with other dimensions. Instead, we added the dimension of natural environment into this layer due to the idea that the environment is easily affected by climate change while also takes an explicit place in state stability.

The model can function as a ranking system like the FSI model, but the difference is that we measure the opposite side of state fragility-national stability. Thus, the model can hereof be named as the NSI model. The ranking methodology of this model is through assigning scores to the countries to be evaluated, where a higher score implies a higher level of stability. The sequence of scoring is from the bottom (third layer) to the top, which means the first step is to handle the external data from the third layer indicators to obtain the values for second layer indicators. The mathematical expressions for this step are:

$$ADI = \frac{II + DI + CI}{3} \tag{1}$$
$$FNI = FD \tag{2}$$
$$MLI = GFP \tag{3}$$
$$EQI = GINI \tag{4}$$
$$WFI = HET \tag{5}$$
$$SCI = \frac{GTI + CI + NOR}{3} \tag{6}$$
$$DEI = DI \tag{7}$$
$$MEI = GDP \tag{8}$$
$$EEI = \frac{UR + \frac{GTCIA+GTCIG}{2} + GTCI}{3} \tag{9}$$
$$PPI = PD \tag{10}$$
$$NRI = \frac{CA + CP + PCRF + FA}{4} \tag{11}$$

The basic logic for this step is to score the second layer indicators by gaining the average value of subordinate indicators in the third layer. Noticing that in equation (9), we combine the indicators of GTCIA and GTCIG into one index since they both reflect the increase of talents in a state. The procedure of scoring the first layer indicators and the final NSI is in consistence with those in the second layer. The specific equations are listed below:

$$P = \frac{ADI + FNI + MLI}{3} \tag{12}$$

$$S = \frac{EQI + WFI + SCI + DEI}{4} \tag{13}$$

$$E = \frac{MEI + EEI}{2} \tag{14}$$

$$N = \frac{PPI + NRI}{2} \tag{15}$$

$$NSI = (\frac{P + S + E + N}{4}) \times 100 \tag{16}$$

Additionally, data preprocessing is necessary for eliminating the effect of the scale of the data. We standardized and normalized the data by dividing them with the sum of all values under the same index, in order to constraint the input data into [0,1]. Some indices like UR are actually negatively correlated to their parental indicators. In this case, we conducted linear transformation to the values of these indices to make them positively correlate to parental indicators, which suits our scoring criteria.

After the scoring and ranking process, we are able to assess the level of stability of a nation. We are required to categorize the countries in three states: stable, vulnerable and fragile. The assessment ideology is derived from the concept of long tail theory, which indicates that about 20% of the population accounts for 80% of the social wealth. When this theory is applied to the study of national stability, most countries should be viewed as stable or vulnerable states, and only a few ones that have assembled the most destabilizing factors, should be labeled as fragile states. Hence, we set up the rules for national stability classification as Figure 6 suggests:

Assessment	FSI Rank	FSI Score	NSI Score
Fragile	1-10	>106	<7
Vulnerable	11-60	82-106	7-10
Stable	61-180	<82	>10

Figure 6: Assessment Benchmark

2.4 Model validation

The method of model validation is based on the Pearson correlation analysis of final stability (fragility) scores between our model and the reference model (see Appendix Figure 16). If the correlation test shows a significant correlation between our model and the FSI, then the effectiveness of our model is verified.

Correlations

		NSI	FSI
NSI	Pearson Correlation	1	-.741*
	Sig. (2-tailed)		.022
	N	9	9
FSI	Pearson Correlation	-.741*	1
	Sig. (2-tailed)	.022	
	N	9	9

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 7: FSI & NSI Correlation Table

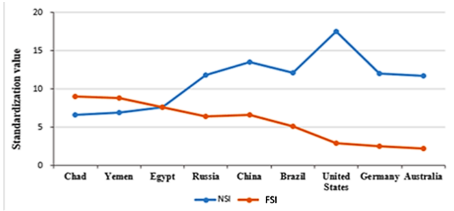

Figure 8: Scoring Trend Comparison of FSI & NSI

We did the test based on a sample containing relevant data of 9 countries in 2014. The test results are displayed in Figure 7 and Figure 8.

The results indicate that the scores of our model have a strong negative correlation to the FSI model, which is consistent with our expectation. Therefore, the model is qualified to identify the stability of countries.

2.5 Climatic Factor Impact Mechanism

The impact of the climatic factors on national stability (fragility) is divided into two patterns: the direct pattern and the indirect pattern. In our study, the direct pattern is interpreted as a strong correlation between the climatic factors and the final NSI scores, while the indirect impact is defined as climatic factors posing impact through the subordinate indicators of the model, such as those in the second or third layer of the model.

The climatic factors we chose incorporate three dimensions: temperature, precipitation and climatic disasters. The disaster dimension is measured by the natural disaster risk index, while temperature is measured by annual average temperature and precipitation is calculated by the annual rainfall depth with climatic data inquired from NASA and World Bank. The correlation test shows that the climatic factors affect the stability in an indirect pattern as Figure 9 suggests, instead of a direct way (see Appendix. Figure 17). The specific approach is that temperature functions on NRI and MLI while precipitation affects NRI and natural disaster risk impacts on MLI, WFI and EEI. (see Appendix. Figure 18)

The Pearson correlation test indicates that the climate factors defined in our model are likely to possess linear correlations to the indicators. We formulated the mathematical functions in a linear relationship to explicitly illustrate the impact pattern:

$$Climate factors = [t, p, d]$$

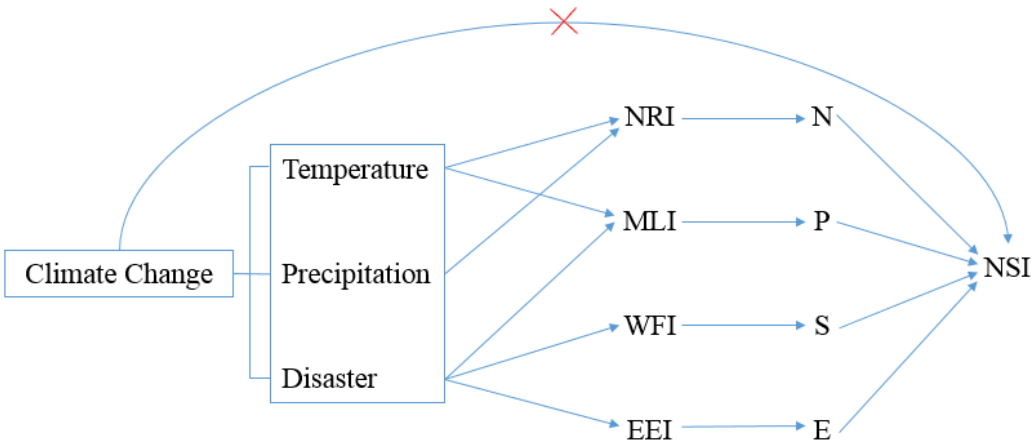

Figure 9: Impact Mechanism Chart

$$
\begin{aligned}
MLI &= A_{ij} \times t + B_{ij} \times d + \alpha_{ij} \\
NRI &= C_{ij} \times t + D_{ij} \times p + \beta_{ij} \\
WFI &= E_{ij} \times d + \gamma_{ij} \\
WFI &= F_{ij} \times d + \delta_{ij}
\end{aligned}
\tag{17}
$$

$$
t - temperature \quad p - precipitation \quad d - disaster \quad i - indice\ of\ countries
$$

$$
j - indice\ of\ time\ serials \quad X_{ij} - coefficient\ of\ climate\ factor\ impact
$$

3 Case Study

3.1 Analysis of Yemen-Controlled Analysis of Climatic Factors

Yemen is a country located in the southwest of the Arabian Peninsula, where the amount of precipitation is relatively small compared to the global average level. In the FSI system, Yemen is listed at the fourth place which indicates a comparatively higher fragility than most other states. In our sample, Yemen is categorized as a fragile country with a total NSI score of 6.95. These signals provide us with clues to look into the impact that climate factors might impose on Yemen.

The analysis was progressed by a controlled test. The experimental group's score is calculated by an adjusted NSI model, whose second layer indicators that are influenced directly by the climate factors are removed. Meanwhile, the control group uses the ordinary NSI model. That is to say, the adjusted NSI model does not include the second layer indicators of MLI, NRI, WFI and EEI. Thus, the equations for the first layer indicators are changed into the following formats:

$$P = \frac{ADI + FNI}{2}$$
$$S = \frac{EQI + SCI + DEI}{3}$$
$$E = MEI$$
$$N = PPI$$

After such adjustment, the NSI score for Yemen increased from 6.949 to 7.485 (increase of 7.32%) as the left graph shows. From the four dimensions in the first layer, we can see that in political, social and natural environmental stability indicators, the elimination of climatic factors has improved value performance more or less. Particularly, the value of natural environmental index obtained an obvious enhancement. The removed subordinate indicator for this index is NRI, which accounts for the resources in the country and is impacted by precipitation and temperature. This is consistent to the prior experience mentioned above. The scarcity in precipitation has reduced the amount of natural resources in Yemen, which in turn exacerbate the fragility of the nation. Surprisingly, the value of economic stability index decreased at the absence of climate factors. In the dimension of economic stability, the removed index is EEI. It is probably because that the contribution made by other subordinate elements (e.g. GTCIA and GTCIG) of EEI largely overweighs the limitation formed by the climate condition, making the removal of EEI a loss in the overall score of the economic stability index. But the existence of climate factors lessens the stability of Yemen, conclusively.

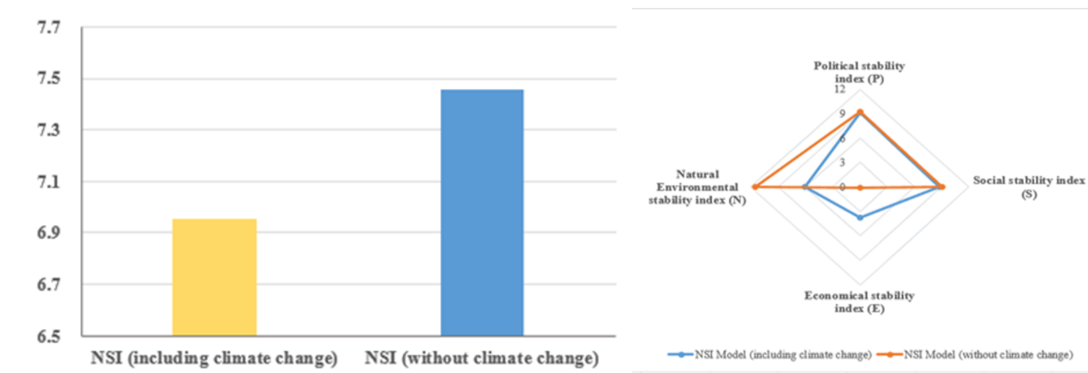

Figure 10: Scores Comparison of Yemen before and after the separation of climate factors

3.2 Analysis of Germany-Time Series Analysis

Germany is located in the middle of Western Europe, with abundant precipitation and suitable temperature. In the FSI list, Germany ranks the 165th, and in our NSI index evaluation system, it is also a country of great stability. This is in line with the fact that it is labelled as a developed country. However, as the deterioration of the global climate, it is reasonable to worry about that stable states like Germany might fall into a chaotic situation someday. Therefore, we choose Germany to conduct the time series prediction analysis.

The method for prediction of the temporal fluctuation of climate factors is realized by applying simple moving average method. This method estimates the future values of the object by averaging the values in nearest time-points. We use the data of Germany from 2011 to 2015 as the basis for moving. The step length is self-defined, and we set it to be two since this value could lead to a maximized sensitivity towards past data. In order to precisely measure the impact of climate factors, we set the other scoring indices to be fixed in the simulation.

Based on the climate factors impact pattern we detected, we also compared the temporal variations in the impact of meteorological factors by contrasting the climate factors coefficients in the period of 2011-2015 to those in the period of 2011-2045 (predicted). From Figure 13, while most coefficients stay in positive states, we can find out that the coefficient D and F switch from positive to negative, indicating that there might be a reversal in some specific trend of the factors' impacts. Taking the coefficient F as an example, F measures the correlation between natural disaster risk and welfare index, and the coefficient is positive in the period of 2011-2015, indicating that the occurrence of natural disasters might prompt the German government to provide more subsidies or other forms of social security to improve people's situation in the face of possible natural disasters. In the period from 2011 to 2045, the coefficient is negative, which possibly implies that in the later stage of the forecast period (after 2015), the increase of disaster risk might make the government more vulnerable and unable to continue to bear high welfare policies.

According to the above statistics (see Figure 11,12), if the climate factors vary in the same pattern as in 2011 to 2015, Germany is unlikely to become unstable by 2040. On the opposite, its NSI scores might even experience an increase and finally reach a higher level. This simulation result indicates that the impact brought by climate factors is majorly positive at present. This could be verified through the positivity of the coefficients. However, in this analysis we neglect the

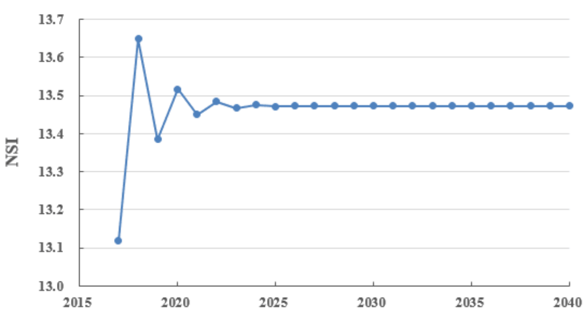

Figure 11: Germany's Simulation Chart

Year	NSI	Year	NSI
2017	13.120	**2028**	13.473
2018	13.649	**2029**	13.472
2019	13.384	**2030**	13.472
2020	13.517	**2031**	13.472
2021	13.450	**2032**	13.472
2022	13.483	**2033**	13.472
2023	13.467	**2034**	13.472
2024	13.475	**2035**	13.472
2025	13.471	**2036**	13.472
2026	13.473	**2037**	13.472
2027	13.472	**2038**	13.472

Figure 12: Predicted Time Series Data

		A	B	C	D	E	F
2011-2015	coefficient	0.002475	0.773344	0.000690	0.000014	0.640953	0.692704
	std	0.003195	1.382909	0.000445	0.000008	0.290564	2.880074
2011-2045	coefficient	0.005010	0.507085	0.063764	-0.000773	0.591862	-1.135084
	std	0.001896	0.841814	0.027230	0.000510	0.074496	0.874938

Figure 13: Germany's Climatic Coefficient Table

possibility of great variance in the coefficients as well as that of the patterns of climate change, which cannot be obtained through the trend of past data. When those coefficients become negative and large enough in absolute value, which is always associated with terrible climate influences, the stability of Germany might be swung.

3.3 Analysis of Egypt-Estimation of Human Interventions

Egypt is located in the northeast Africa, where most of the country is in a dry and hot condition with growing population. Based on these traits, it is suitable for us to target Egypt for research on human intervention to reduce the impact of adverse weather conditions. We brought Egypt's data of 2017 into the model to calculate its stability score, and then compared it to the threshold values. The result shows that it is in a vulnerable level. We have already known that the indicators related to climate change are military strength (MLI), social welfare (WFI), employment environment (EEI) and natural resources (NRI). According to these four indicators, the government could take relevant measures to enhance the stability of the country, that is, raising the NSI value from the aspect of climate conditions. We proposed specific measures for improving some of the above indicators to mitigate the impact of harmful climate change and roughly estimated the cost of these interventions.

In terms of natural resources (NRI), Egypt is an extremely water-scarce country. Per capita availability of fresh water, forest area, grain yield and other indicators are far below the world average. The shortage of natural resources such as water resources has increased the vulnerability of the country. In response to this issue, we tried to firstly improve the NSI score of Egypt at the angle of NRI, especially making up for its lack in natural precipitation. We can take methods like improving sanitation water coverage in urban and rural areas, sewage management, optimizing water resource usage by improving irrigation efficiency and agricultural drainage reuse and building a desalination project base to make up for shortages of water. Among these approaches, we hereof highlight the construction of desalination projects. In 2017, the Egyptian government plans to start construction of 16 seawater desalination plants in five provinces along the coast. After the completion of the project, the daily output of these desalination plants will reach 473,000 cubic meters. Egypt currently has 39 seawater desalination plants, daily freshwater production of 235,600 cubic meters.

We assume that the cost of investment is 1 billion US dollars, and the variable cost of the project depends on how desalination is done. In our study, the way of desalination is reverse osmosis, costing about 0.8 US dollars / ton, with a desalination rate about 60%. This measure can make per capita renewable water (PCRF) increase, and the final NSI score will increase as a result. Then we estimated the total cost of this method:

$$\begin{aligned} Totalcost &= fixed\ cost\ of\ investment + variable\ cost \\ &= fixed\ cost\ of\ investment + unit\ cost \times amount\ of\ desalination \\ &= fixed\ cost\ of\ investment + unit\ cost \times annual\ output/desalination\ rate \end{aligned} \tag{18}$$

In terms of social welfare policies, the government could raise the level of medical insurance and increase the guarantee for natural disasters, so as to stabilize the quality of life sacrificed by climate change and other factors. We assumed that the investment of social security system can increase the WFI by 13% with one billion dollars. Combining the investment on desalination with that on social security, we can calculate the minimum annual freshwater output needed to be increased to lift Egypt to a stable state in ten years. The calculation is presented as the following equation:

$$\begin{aligned} \Delta NSI &= 100 \times (0.25 \times 0.25)\Delta WFI + 100 \times (0.25 \times 0.25 \times 0.5)\Delta PCRF \\ &= 6.25 \times 0.13 \times WFI + 3.125 \times \Delta PCRF \end{aligned} \tag{19}$$

Given the original WFI and NSI, the result for additional minimum annual freshwater output is about 0.74 per capita. Considering an approximate total population in Egypt of one hundred million, the overall freshwater needed could be seventy-four million cubic meters. The predicted NSI score sequence is shown in Figure 14:

However, these improvements require over two billion dollars according to our assumptions. A trade-off is likely to be made between the huge cost and the goal to achieve stability, though the fixed cost might not be that much in other conditions. The Government could also smooth the burden of investment by reducing the intensity of one-time investments and lengthening the investment cycle for its policies.

Besides, Egypt's employment rate and talent related indices are also well below average. In terms of the employment environment (EEI), the government need to provide more jobs for unemployed people caused by adverse climate conditions and other reasons. The government also needs to strengthen its training and support of qualified personnel and enhance the level of talent related indices, so as to raise its economic stability.

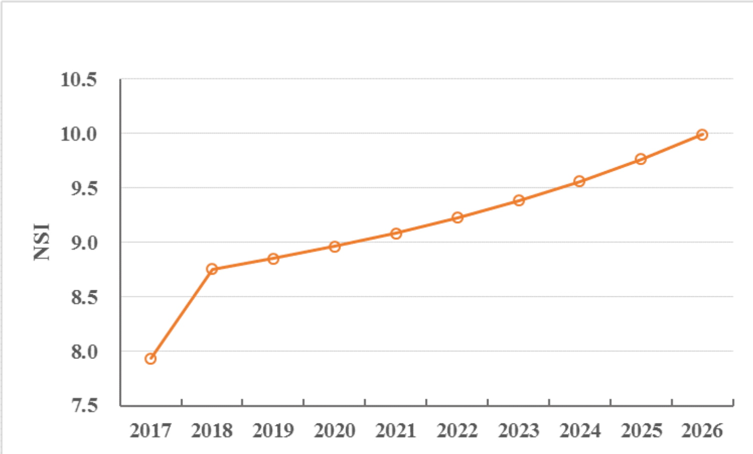

Figure 14: Egypts Trend Prediction

3.4 Possible Application to Citys/Continents

In our opinion, the applicability of our model largely depends on whether the necessary data is attainable. The NSI model determines countries' stability based on their composite scores from various indicators. The indicators for each country are scored from well-known reports or indices, which can be obtained through multiple publications and websites (*e.g. World Bank, Wikipedia*). In the cases of continents or cities, the indicators and criteria we need to consider are roughly similar.

For larger regions, such as continents, if some necessary data are not provided, the NSI scores can be obtained by averaging or weighted averaging the country data in that continent. For example, the GDP indicator can be used in evaluating the economic strength of a country, and we can also use the average GDP of Asian countries to assign the value for the scoring of NSI of Asia. However, for smaller regions, such as cities, the lack of data is difficult to make up for, which will increase the difficulty of using our model. In the case where the accuracy requirement is not high, the NSI score of a country can be used to approximate the stability score of the cities in that country. The best solution is to get all the index data you need for scoring.

Besides the model itself, we want to highlight the analytical methodology raised in this study. For different regions, or larger and smaller regions, the influence pattern of climate factors can be varied. Further researchers can test the correlations between the climate factors they choose and the NSI index, so as to determine their specific impact models of climate factors and the indicators directly affected. We believe that this identification approach would not be limited by the scale of analysis objects (i.e., countries, cities or continents).

4 Strengths and Weaknesses

One of the main advantages of this model is that the indicators are relatively comprehensive, describing multiple dimensions and indices for researchers to detect climate change impact on national stability. The model expression is relatively simple and easy to be comprehended, and the calculation is relatively easy and the data are not difficult to obtain, which can be found in those relevant reports. The scores we calculated from our model have strong correlations with the FSI index, which shows that our model is effective. Through the calculation of each index, we can not only get the final NSI scores, but can also obtain the index values of specific dimensions (i.e., political, social, economic and environmental) of a country, which provides further insights for policy-making to deal with undesirable climate changes.

In addition to the model, the identification method we used in this study, which focuses on the Pearson Correlation test also provides more flexibility for the application of the model. Subsequent researchers can conduct correlation tests between the climate factors determined according to their own needs and the indicators in NSI to identify the impact pattern of climate, rather than being limited to the temperature, precipitation and climate disaster index selected in this project.

Meanwhile, the defects of the model also exist. They are mainly from the model hypothesis, the linear relationship hypothesis, subjectivity of index selection and the similarity between indices. In the model hypothesis, we assume that the impact structure is fixed among different countries and periods, which might not hold true in reality. The linear relationship hypothesis refers to the fact that in this model, we limit the conversion between indices in different layers and the correlations between climate factors and indicators to a linear form. Other possibilities, such as exponential relationships, were not considered in this study. In terms of the selection of model indicators, although we referred to the FSI model and conducted a certain correlation test, subjectivity could not be completely eliminated when indicators were deleted or added to our model. Finally, because some indicators themselves may be converted by other indices in this model, there might be some overlap or collinearity between the indicators, which reduces the value of regression analysis and the internal distinction of the model.

5 Conclusion

In this study, we conducted a modeling analysis on the impact of meteorological factors on national stability and successfully identified the mechanism by which climate factors affect national fragility (stability). The main contributions of this paper are listed as follows:

1.We successfully built the model on the relatively well-established FSI system.

Based on the two-layer structure of the reference model, we refined the model to three layers and re-evaluate important indicators to construct an NSI model, which is more suitable for analyzing climate impacts. The model can give an overall and individual index stability scores to the object country, and we referred to the long tail theory to divide the scoring results into fragile, vulnerable and stable states. The model has been validated through the Pearson correlation test with the reference model.

2.Based on the self-established NSI model, we used the Pearson correlation test to complete the pattern analysis of the impact of meteorological factors on national stability. We found that the climate factors affect national stability indirectly by acting on the indicators in the second layer rather than directly affecting the national stability index (NSI Score).

3.Combined with a controlled experiment, the moving average method or cost analysis, we analyzed or predicted the specific influences brought by climate factors in the sample countries and put forward some advice or interpretations on handling these influences.

6 Further work

In the follow-up process, we will collect large quantities of data for model revision and tests, select better indicators and continuously improve the mathematical expressions and effectiveness of the model. In analyzing the impact of climate change, we have selected only a few representative indicators as climate factors. We would also like to collect more data about other climate characteristics in order to describe the impact of climate change from different climate factors.

Besides, we would like to explore the potential individuality we avoided in this general model, to extend our model to suiting diversified conditions. Also, we are interested in exploring the climate impact pattern in other formats other than linear relationships, such as exponential relationships.

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Appendices

	SA	FE	GG	EC	UD	HF	SL	PS	HR	DP	RD
ADI	*	*	*				*	*	*		
FNI				*							
MLI	*						*				
EQI		*			*						
WFI					*			*		*	
SCI	*							*		*	*
DEI		*	*				*		*		
MEI				*							
EEI				*	*	*					
PPI										*	
NRI										*	

Figure 15: Indicators Correlation Between NSI and FSI

Country	NSI Score	FSI Score
Chad	6.6235	108.7
Yemen	6.9493	105.4
Egypt	7.6087	91
Australia	11.7586	26.3
Russia	11.857	76.5
Germany	12.0084	30.6
Brazil	12.1566	61.4
China	13.5252	79
America	17.5126	35.4

Figure 16: NSI versus FSI Scores for Nine Sample States

Correlations

		NSI	t	p	d
NSI	Pearson Correlation	1	-.607	.458	-.387
	Sig. (2-tailed)		.083	.215	.304
	N	9	9	9	9
t	Pearson Correlation	-.607	1	.050	.298
	Sig. (2-tailed)	.083		.898	.436
	N	9	9	9	9
p	Pearson Correlation	.458	.050	1	-.119
	Sig. (2-tailed)	.215	.898		.761
	N	9	9	9	9
d	Pearson Correlation	-.387	.298	-.119	1
	Sig. (2-tailed)	.304	.436	.761	
	N	9	9	9	9

Figure 17: NSI Correlations with Climate Factors

Correlations

		MLI	WFI	NRI	EEI
t	Pearson Correlation	-.676*	-.488	-.733*	-.415
	Sig. (2-tailed)	.046	.182	.025	.266
	N	9	9	9	9
p	Pearson Correlation	.255	.372	.581	.393
	Sig. (2-tailed)	.509	.324	.101	.296
	N	9	9	9	9
d	Pearson Correlation	-.749*	-.725*	-.314	-.691*
	Sig. (2-tailed)	.020	.027	.410	.039
	N	9	9	9	9

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Figure 18: NSI Indicators Correlations with Climate Factors