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One Earth, One Home

Summary

It is the best of times, it is the worst of times, it is the age of wisdom, it is the age of destruction. Human beings use their unparalleled creativity to bring endless wealth and have begun to seek sustainable development. However, climate change brought about by human activities is feeding back to ourselves, resulting in more and more people losing their homelands and being displaced. Where do these people, abandoned by the environment(namely, EDPs), go? Based on the principle of international burden-sharing, we embark on figuring it out.

Firstly, to predict the exact number of EDPs by 2050, we have established Malthusian Population Model and Sea Level Prediction Model (using the ARIMA Model) and then combined the conclusion to obtain the results. From the predicting charts, we conclude that, by 2050, nearly **12 million** inhabitants of the coastal countries worldwide will face the migration problems because of environment changing.

Then, to make full use of the advantages of different countries' own resources, K-means Cluster Analysis has been employed to divide 25 selected countries to four categories that claim different responsibility after taking the economic capacity and population density into account. Before getting the final result, we take the advantage of Principal Component Analysis and Soft Max to determine how many tasks each country claims. Our conclusion is: 25 countries (United States, Australia, Germany, Japan, China and so on) ought to claim different responsibility with different proportion.

Thirdly, to fully respect the rights of migrants, we have classified migrants into two types, voluntary 'migrants'(survival-oriented) and forced 'refugees'(culture-oriented). Considering the environmental accommodation index and cultural diversity index, we use Fuzzy Comprehensive Evaluation Model based on Analytic Hierarchy Process to quantify migration choices.

Remarkably, we have proposed **Markov Chain Model based on cultural and survival evolution**, which distinguishes different kinds of migrants and takes the resistance of self-driven, cultural similarity, policy and cultural diversity into consideration. In calculating and simplifying, we make the comparison of the results of cultural and survival transfer in both short term and long term. We summarize that policies do have influence on the integration.

In addition, we simulate what happens if island countries don't pay attention to planned migration when natural disasters strike and what migrants will experience. Based on the model results, our team proposed to UN **a policy framework** on the protection of life and culture of EDPs **in further discussion**:

- Give play to the advantages of each country and share responsibility.
- Island countries ought to attach great importance to planned migration.
- Countries receiving immigrants should issue policies related to settlement, basic life(employment, housing, education, health) and culture(reflected in religion and language).

Finally, our team suppose that while more researchers and experts pay attention to EDPs, we have to think about the future of island-dwelling species. Where should they go and who can protect them? That is a meaningful issue as well.

Keywords: Arima;PCA;K-Means; EDPs; Markov Chain;

Contents

1 Introduction

1.1 Problem Background

Can you imagine how many people are currently faced with the risk of losing both their initial home and precious cultural heritage due to extreme environmental issues? Even more, can you guess how will the number climb till 2050? What does it mean to be a member of such a group? The answer will shock you.

According to a 2015 study carried out by **the Institute for Environment and Human Security of the United Nations University**, till 2050, 200 million is the most cited and acknowledged answer(but not completely reliable)[1]. Just take a minute to think about their situation. Confronted with the disturbance of adapting into a totally strange community, they may feel desperate on the way and scared of discrimination, worried about the loss of their unique culture. *"My greatest wish is to sleep on a pillow."*. That is the most plain but still hard to achieve dream for them, a group called *"environmental migrant/climate refugees*that is displaced by environment(EDPs)[2].

Figure 1: *"climate refugees"[3](Environmentally Displaced persons)from Europe and Asia respectively and the exhaustion and depression can be easily told from their faces*

Who leads to the awful situation? All of us. Nowadays, more prosperous our world seems, more environmental problems are prone to emerge and constantly rising sea levels is the one urgently required to be dealt with. It is not difficult to find such press:*'Climate Migrants Might Reach One Billion by 2050'*,*'Millions of future climate refugees may need protection, U.N. committee warns'* and so on[4-5]. Where should they go? How to guarantee their human rights and try our best to preserve various culture? How to make our earth a better living place collectively? These are all serious issues remaining to be discussed and require a new, additional focus in both academic research and policy planning.

Generally speaking, with the broad aim of shouldering the responsibility concerned with climate refugees and protect our earth collectively regardless of religion, country and races,three major problems are discussed in our paper, which are:

- Estimate the number of EDPs and propose a plan to accommodate them
- Protect human rights of migrants and ensure them a quality life
- Meet their higher requirement of preserving unique culture,namely, aviod assimilation

1.2 Literature Review

To begin with, **the Norwegian Nobel committee** (2007) awarded the Nobel Peace Prize to Al Gore, Jr. and the Intergovernmental Panel on Climate Change (IPCC) for their contribution to the problems that climate-induced migration and resource scarcity could cause violent conflict and war within and between states[6].

"Global Adaptation Governance" has been proposed in 2010 because of the fact that possibly accelerating climatic change has resulted in an urgent need to address the plight of so-called "climate change refugees" ("climate refugees" in short and mainly used in below), who are vulnerable to climate[7-9]. According to a large number of research, there almost no such estimation of specifically how many people may become homeless due to rising sea levels[10-12]. However, one convincing research estimated that 200 million people worldwide will live below the sea level line by 2100, which confirms the severe situation[13]. We refer to Nature Communications and find that a majority of countries are prone to be influenced from one research.

As to the question that who should take the responsibility of accommodating these refugees, what we ought to bear in mind is *"no climate change, no climate refugees"*, thus taking carbon dioxide emissions into consideration is necessary. In addition, as Crate and Nuttall explain, *"as the earth literally changes beneath their feet, it is vital to understand thecognitive reverberations and cultural implications to a peoples sense of homeland and place"*[14-15].Doing our utmost to preserve different culture is essential as well.

1.3 Overview of our work

Here,we present our work with a vivid chart (see Fig. 2). We break our total jobs into four main parts, which deal with "When and how many","Who and how much","Choose" and "What should UN do" by order. Principle methods and essential factors are included as well.

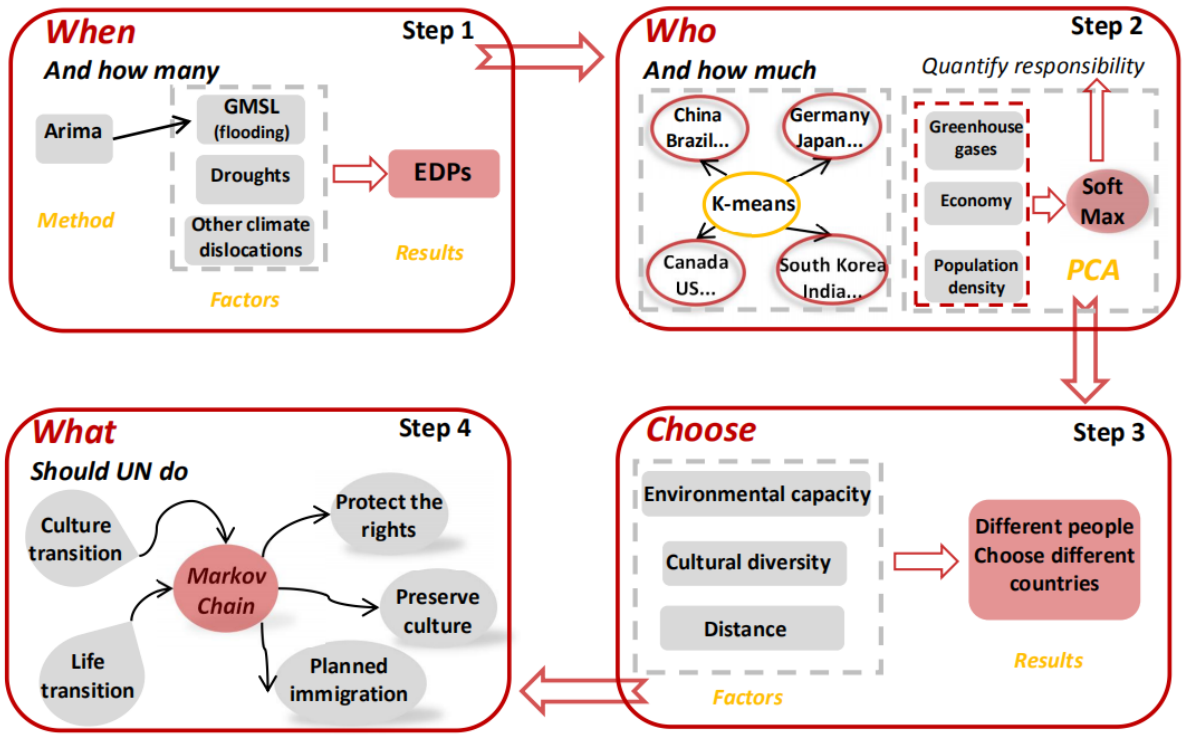


Figure 2: *Overview of our work*

2 Notations

Table 1: *Notations List*

Notation	Description
GMSL	Global Mean Sea Level
δ	Proportion of population affected by every millimeter rise in GMSL
θ	Proportion of population affected by sea level rise in EDPs
h_t	Global mean sea level at year t
P_{it}	Population of island country i at year t
r_j	Responsibility distribution by country (j=1,2,... 25)
b	Birth rate
d	Mortality rate
c	Cultural diversity
s	Cultural similarity
p_1	Cultural policy impact factor
p_2	Economic policy impact factor

3 Model 1: When and How many

With the increasingly rising sea level, more and more island countries tend to disappeared and 'population pressure' emerges. As mentioned before, the number of people who are currently and will face the dilemma of losing their home and adapting themselves to another community is an essential but rarely to be exactly quantified. Till 2050, 200 million is a widely cited number but still lack of evidence. Allowing for the reality, we have set up a model to predict the number of people at risk in the future years. To address this issue, our idea is: 1)building a **Malthusian Population Model** to predict population growth in the next 30 years; 2)achieving sea level rise data accordingly using the **ARIMA Model**; 3)combing the results of 1) and 2) and getting the final number of EDPs.

3.1 Assumptions

- During the next three decades, the population growth of the countries we analyzed will not be restricted by resources(such as water and food). In countries that do not take the "family planning" policy into consideration, their population growth rate is basically stable with sufficient resources thus it is reliable and convincible to make such an assumption.
- The proportion of population affected by rising sea levels increases by the same and constant amount. For example, for every 1mm rise in sea level, the proportion of influenced population is δ, then for every Xmm rise, the proportion of influenced population is correspondingly Xδ. We make this seemingly much more ideal situation based on the fact that the coast slopes around the world are almost increasing averagely.
- The proportion of the population of N island nations that we analysed in the population of all coastal nations remains constant over time bcause we assume that the population of all countries under consideration grows at an ideal level, then our simplification is consequently appropriate.

3.2 Malthusian Population Model

Based on the statistics (from World Bank) on the population of 233 countries and regions in the world, we finally selected the population data of coastal countries from 1950 to 2019 after discussion and further deduced the growth of population.By fitting the Marthas Population Model, we obtained the population growth of each country in the next three decades. And the model is established based on the equations as below:

$$\frac{dN(t)}{dt} = rP(t) \tag{1}$$

$$P(t_0) = N_0 \tag{2}$$

where t represents time, t_0 represents the initial moment, P(t) indicates the population at time t and r indicates net population growth.

Finally, the model obtained the population evolution data of these countries in the next 30 years and the fitting effect is good. As a result, we believe that estimating the number of victims in this way is reliable.

3.3 Sea Level Prediction Model

As we all know, greenhouse gases refer to some material in the atmosphere that can absorb long-wave radiation reflected from the ground and re-emit it, which makes the earth's surface warmer, resulting in the term- "greenhouse effect". The main greenhouse gases include carbon dioxide (CO_2), nitrous oxide (N_2O), freon, and methane (CH_4). Due to the fast development of industry and various unreasonable human activities, global greenhouse gas emissions have remained high. Although various countries have designated agreements such as the **Copenhagen Accord** to control greenhouse gas emissions, the problem still has not yet been properly and completely addressed. As a consequence, glaciers and icebergs in the north and south poles are accelerating melting, together with consantly burgeoning global sea level.

We employed the ARIMA Model, which requires only endogenous variables and is suitable for predicting future changes of sea level height, to predict sea level height based on NASA's global sea level detection data from 1880-2019.

$$(1 - \sum_{i=1}^{p} \varnothing_i L_i)(1-L)^d h_t = (1 + \sum_{i=1}^{q} \theta_i L^i)\varepsilon_t \tag{3}$$

where p is autoregressive coefficient, q is moving average, d represents number of differences, L represents lag operator, ε_t indicates zero mean white noise sequence, h_t is the estimated value, $\varnothing_i$ is the cofficient of AR and θ_i indicates the cofficient of MA.

We find that the time series of sea levels has a clear upward trend, which is a typical non-stationary time series. Therefore, a stationary time series can be obtained after diffence. The ARIMA Model can be described as above and then we obtained the prediction series h_t of sea level heights in 2020-2050 (see Figure 3(a)).

3.4 Determine the number of EDPs

We take N typical island nations as our analysis object and the population of island nation i in year t is P_{it}. Based on the data on the impact of sea level rise on the population of developing

countries released by **World Development Indicators**, we got the average δ of the proportion of four affected continents(Africa, North America, South America, and Asia) as the proportion of people in these island nations influenced by rising sea levels. Note that the average value of the proportion of impact in Africa, North America, South America, and Asia is δ_i(i = 1,2,3,4). Also pay attention to δ, the proportion of population influenced by each 1mm rise in sea level. The fact that the majority of island countries globally are developing countries, to a certain extent, rationalized our approach.

Then, the proportion of the population affected by sea level rise at time t is $h_t\delta$. Based on it, we got the proportion of population in EDPs is $\frac{h_t\delta}{\theta}$. After that, we obtained the number of people at risk Δp.

$$\Delta p = \frac{\sum_i^N P_{it} h_t \delta}{\theta} \tag{4}$$

Eventually, the number of EDPs in all coastal countries is TP.

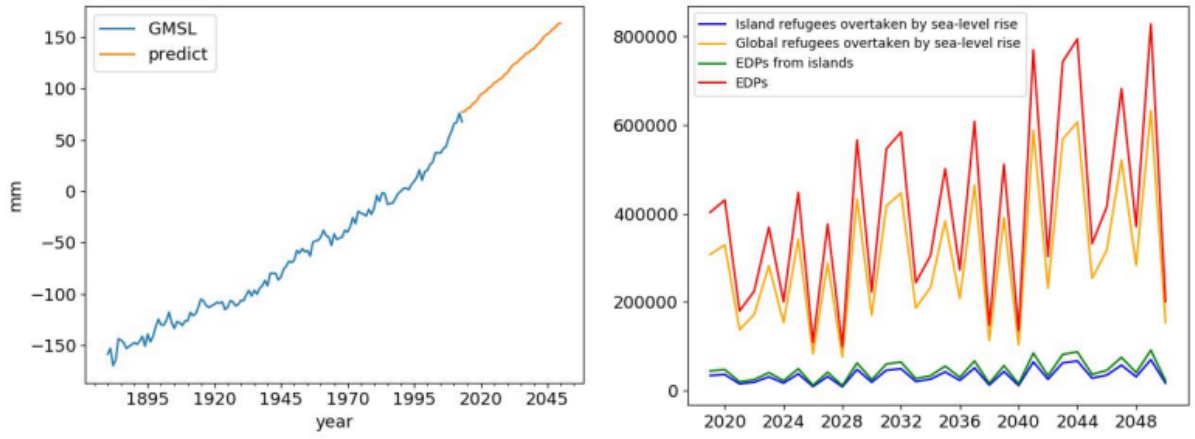
$$TP = \frac{\Delta p}{\gamma} = \frac{\sum_i^N P_{it} h_t \delta}{\gamma\theta} \tag{5}$$

3.5 Calculating and Simplifying

We selected five typical island nations, namely Tuvalu, Marshall, Maldives, Kiribati, and Nauru for calculation, based on the population data of all countries. The proportion of the population of five island nations to that of all coastal nations is $\gamma = 0.01209$ (from World Bank).

We refer to several papers and get the proportion of population affected by sea level rise in total EDPs $\theta = 0.7642$.

Based on the proportion of sea level rise affecting the population of countries in four continents, we calculated the average of these proportions to replace the proportion δ of the population affected by sea level rise in the five island countries.($\delta = 1.28 \times 10^{-5}$)



(a) Forecast of 2019-2050 GMSL (b) Forecast of population of EDPs

Figure 3: *The results of prediction*

Finally, we calculated the number of people affected by the sea level rise in the five island countries and all coastal countries, and the number of EDPs in the five island countries and all countries and the result is presented in Figure 3(b).

4 Model 2:Who and How much

In a bid to solve the problem of resettlement of people displaced by environmental changes, we divided the 25 countries in the world ranking the top in terms of greenhouse gas emissions into four categories. Based on the economic capabilities and population density of these countries, the **Cluster Analysis** of the index yielded a two dimensional clustering result, which helps determine whether receiving EDPs or providing migration funds. After that, we conducted **Principal Component Analysis(PCA)** and **Soft Max** based on the greenhouse gas emission index, economic capability index, and population density index to obtain the responsibility share of each country, thereby solving the problem of the division of responsibility of each country in handling EDPs resettlement.

4.1 Assumptions

- We assume that the top 25 countries in the world for greenhouse gas emissions are countries participating in the responsibility division.

  Explanation:The greenhouse effect is almost the most important cause of sea level rise and climate anomalies while the top 25 emission countries account for more than 85% of the total emissions, which indicates that it is reasonable for us to make such an assumption.

- Take the per capita GDP as the economic capability index.

  Explanation:After we have determined the top 25 countries with greenhouse gas emission indicators, we found that basically these countries are so-called large ones, so it is acceptable to use GDP per capita as the economic capability index.

- Directly converting the cost required to resettle migrants into the funds. For those countries that do not pay migration funds but need to receive EDPs, they can first claim the task according to the amount of money, and then convert it to how many people they receive, which makes it easier and flexible to divide responsibilities.

  Explanation:Considering that there are various ways to help address EDPs, such as receiving refugees, providing financial assistance, protecting the environment, etc., we have distinguishly summed up two ways in which different countries provide help: directly receiving refugees and providing financial assistance. In order to make the two approaches quantifiable and interchangeable, we quantify the cost of resettlement of refugees into specific amounts for the establishment of models. That is smart and feasible.

4.2 K-means Cluster Analysis

Using the GDP per capita (from World Development Indicators) and population density data(from Wikipedia) of 25 countries, we conducted a two dimensional K-means cluster analysis to classify the 25 countries according to four categories(low-high,low-low,high-low,high-high),which are based on a combination of economic capacity and population density:

As indicated in Figure4, the result is relatively satisfying and then we divided 25 countries into the following four categories. What is more, according to the different capabilities of each type of country, we assigned different tasks to these four countries:

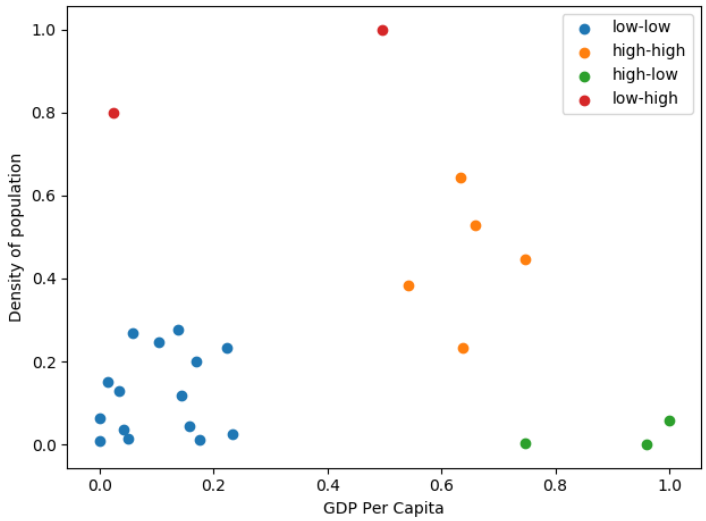


Figure 4: *The result of Cluster Analysis shows that 25 selected countries can be divided into four groups: low-low, high-high, high-low, low-high.*

- Countries with low economic capability index and low population density index (ie **low-low** type) do not need to pay migration funds, but have to receive more EDPs.
- Countries with high economic capability index and high population density index (ie **high-high** type) do not need to receive EDPs, but have to pay more migration funds.
- Countries with high economic capacity index but low population density index (ie **high-low** type) need to pay both migration funds and EDPs.
- Countries with low economic capability index and high population density index (ie **low-high** type) are not responsible, but have to shoulder more greenhouse gas reduction tasks.

Table 2: *Country Classification based on the result of Cluster Analysis*

Category	Countries
low-low	China, Brazil ,Russia, Indonesia, Mexico, Myanmar Central African Republic, Sudan, Turkey, Thailand Poland, Ukraine, Mozambique, Argentina
high-high	Japan, Germany, United Kingdom, France, Italy
high-low	United States, Canada, Australia
low-high	India, South Korea

4.3 Principal Component Analysis and Soft Max

In this part, we need to determine how many tasks each country claims. For the countries that receive EDPs, as mentioned before, we convert the resettlement cost of migrants into money, allocate the unified funding responsibility, and then convert it into the number of people ought to be received.

Through PCA, we reduced the three dimensions of greenhouse gas emissions, economic capacity index, and population density index into one-dimensional index scores g_j. We quantify

responsibility ratio $r_j(j = 1,2,,25)$ of each country by **"Soft Max"**.

$$r_j = \frac{e^{g_j}}{\sum_{i=1}^{25} e^{g_j}} \tag{6}$$

4.4 Calculating and Simplifying the Model

The results of this analysis (the sepecific responsibility proportion divided to different countries) are presented in Table.

Table 3: *Results of PCA ordered by percentage.*

Country	Share of Responsibility	Country	Share of Responsibility
United States	6.943%	Turkey	3.227%
Australia	6.342%	Russian Federation	3.090%
Germany	6.047%	Thailand	3.080%
Japan	5.821%	Brazil	3.070%
Korea,Rep.	5.743%	Mexico	3.066%
United Kingdom	5.709%	Indonesia	2.976%
Canada	5.209%	Ukraine	2.775%
France	5.062%	Myanmar	2.741%
Italy	4.868%	Sudan	2.711%
India	3.496%	Bolivia	2.710%
China	3.448%	Mozambique	2.627%
Poland	3.432%	Central African Republic	2.581%
Argetina	3.231%		

Next, we will get the total amount of equivalent funds (including real required funds and resettlement costs) required to fully address the problems of EDPs. This is done for 25 countries to claim responsibility. Firstly, the cost of placing a migrant C_0 consists of land costsC_s and other costs C_x in each country can be derived:

$$C_0 = C_s + C_x \tag{7}$$

Then, the cost TC required to accommodate all migrants (the number of migrants is y) is expressed as:

$$TC = yC_0 = y(C_s + C_x) \tag{8}$$

In addition, the total equivalent capital TD is equal to the sum of the original required capital TD_0 and the cost required to resettle all migrants:

$$TD = TD_0 + TC \tag{9}$$

We allocate responsibility according to the amount of funds allocated by each country. For the recipient country, the equivalent of the funds is converted into the resettlement cost to get the number of recipients, so they will lose a part of the money. Eventually, we can obtain the figure of how EDPs will flow.

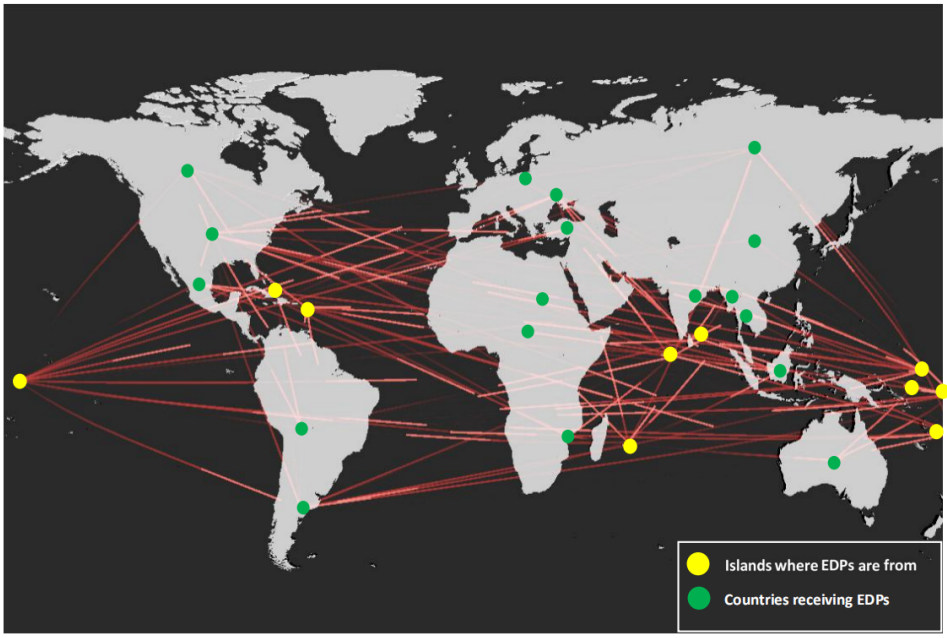


Figure 5: Flow diagram of EDP globally. The simulation of how EDPs flow from endangered countries to those countries divided with responsibility of receiving them is dynamic and here we select the state at a certain moment.(Illustration generated by e-charts)

5 Model 3: Choose and What should UN Do

Based on the facts that immigrants tend to consider when choosing a country to settle: the environmental accommodation index and the cultural diversity index(including linguistic diversity index and religious diversity index), we divide the factors into two categories. *By the way, linguistic diversity index is the probability that two people selected from the population at random will have different mother tongues; it therefore ranges from 0 (everyone has the same mother tongue) to 1 (no two people have the same mother tongue)(from Wikipedia). And religious diversity index depends on the percentage of each countrys population that belongs to eight major religious groupsChristian,Muslim,Unaffiliated, Hindu,Buddhist,Folk Religion,Other Religion, Jewish.ăThe closer a country comes to having equal sharesăof the eight groups, the higher its score on a 10-point Religious Diversity Index(from Wikipedia).*The environmental accommodation index includes population density, food production, and per capita GDP. Obviously, the indicators we choose determine the survival and quality of life of immigrants. And the cultural diversity index includes the linguistic diversity index and the religious diversity index because we take into account the needs of immigrants for basic normal life and communication, along with the needs of those who believe in religion.

After discussion, we consider immigration into two categories–voluntary “migrants” and forced “refugees”;

- **forced “refugees”(survival-oriented)**: This kind of immigrants are forced to migrate(the loss of their home due to irreversible environmental change), hoping to survive and live well, and pay much more attention to the environmental accommodation index of the country they are going to.

- **voluntary “migrants”(culture-oriented)**: This kind of immigrants value their own unique culture and attach more importance to the cultural diversity and cultural tolerance of the country they are going to.

5.1 Fuzzy Comprehensive Evaluation Model based on Analytic Hierarchy Process

We select three first-level indicators, namely the environmental accommodation index and cultural diversity index, and distance. The environmental accommodation index is divided into three secondary indicators: population density, food production, and per capita GDP with their weight distribution ratios are:$\frac{1}{3},\frac{1}{3},\frac{1}{3}$ respectively. While the cultural diversity index is divided into two secondary indicators as well: the linguistic diversity index and the religious diversity index with their weight distribution ratios are:$\frac{1}{2},\frac{1}{2}$ respectively. Next, we aggregate the two-dimensional indicators. We summarize the process of this part as Figure 6.

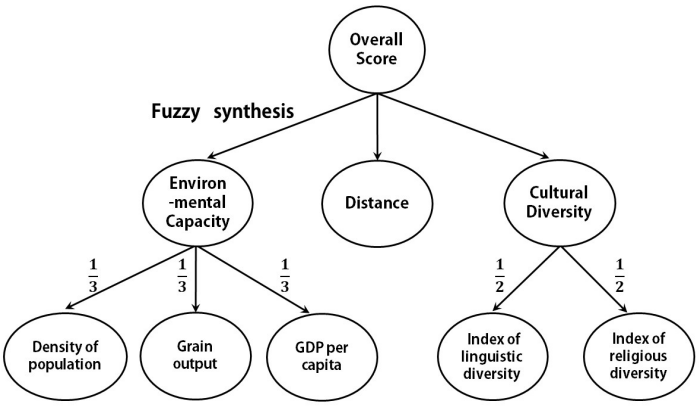


Figure 6: Aggregation process

We perform fuzzy evaluation to obtain the membership matrix of each country corresponding to three first-level indicators, and the membership ranges are all (0,1). Then two types of immigrants are analyzed separately to obtain a comparison matrix and corresponding eigenvalues as weight vectors. The judgment matrix matrix of forced 'migrants' is B_1:

$$B_1 = \begin{pmatrix} 1 & 1/5 & 1/3 \\ 5 & 1 & 3 \\ 3 & 1/3 & 1 \end{pmatrix}$$

Then we get the maximum eigenvalue of the matrix and use it as a weight vector for survival-oriented immigration after normalization:(0.105,0.637,0.258). The judgment matrix of voluntary 'refugees' is B_2:

$$B_2 = \begin{pmatrix} 1 & 5 & 3 \\ 1/5 & 1 & 1/3 \\ 1/3 & 3 & 1 \end{pmatrix}$$

We also can get the maximum eigenvalue of the matrix and use it as a weight vector for culture-oriented immigration after normalization:(0.637,0.105,0.258). After that, we performed a consistency check. The consistency between the theoretical maximum eigenvalues λ_{max} and the order n of B_1 and B_2 is used to test the consistency. The consistency index is:

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{10}$$

By calculating $CR = \frac{CI}{RI}$, we obtain that the CR values (the value of RI is obtained by looking up the table, that is, $RI = 0.58$ when $n = 3$) of the two judgment matrices are both 0.033 (less than 0.1 and when $CR < 0.1$, the judgment matrices are consistency is acceptable.)

Finally, we multiply the weight vector with the feature membership matrix of the three first-level indicators to obtain the weight value of each country and sort them. Here, we take Maldives(an island country) as an example to show the immigration selection tendency map we got (the destination country is the 18 countries that need to receive EDPs obtained by our cluster analysis):

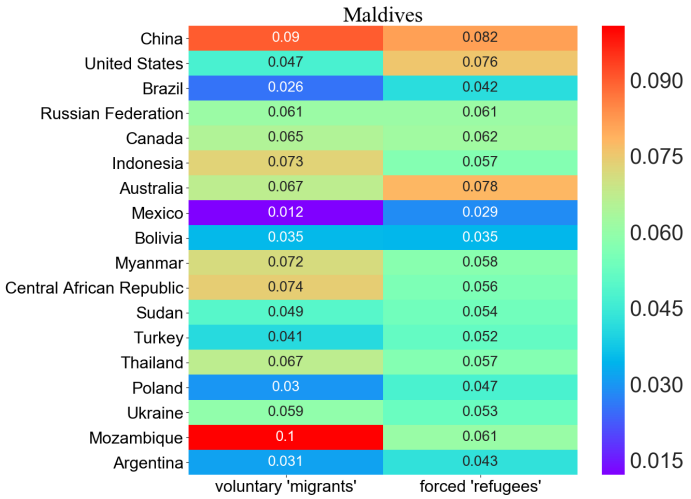


Figure 7: Take Maldives as an example of where migrants tend to go

5.2 EDPs Survival and Cultural Evolution Model

We formulated a Markov Chain Model to simulate the survival and cultural evolution of EDPs after migration, so as to analyze the impact of policies on the degree of life and cultural retention. In the model, we divided the analyzed immigrants into five types according to the degree of cultural retention, and into three types according to their living conditions, which have been summarized in Table 4.

Table 4: *Notations of different kinds of immigrants*

Notations	Meaning
X_1	Immigrants who fully retain their unique culture.
X_{12}	Immigrants who retain their unique culture while learning the new local culture as well
$X_{12'}$	The next generation of X_{12}
X_2	Immigrants completely assimilated by local culture
X_2'	The next generation of X_2
Y_1	Immigrants who have just moved into a new country and their survival issues have not yet resolved
Y_2	Immigrants who solve survival problems and can live normally in a new country
Y_3	Immigrants with high happiness index

5.2.1 Assumptions

- The newly moved EDPs completely retain their own culture and do not understand the new local culture.
- It is diffucult for the newly moved EDPs to solve the livelihood problem under natural circumstances. Here we do not consider those extremely rich EDPs.
- Most EDPs have the ability to learn a new culture, but they their learning resistance varies.
- Host countries will impose support policies related with culture and survival on EDPs instead of sitting idly by. In the following part, we simulated the impact of the host country's policy and obtained the evolution results.
- New EDPs are continuously input during the evolution process, namely, our model is dynamic.
- Survival-oriented EDPs (voluntary 'migrants') and culture-oriented EDPs (forced 'refugees') are affected by various factors to different degrees. For example, voluntary 'migrants' tend to retain their own culture, so they have greater self-driving resistance to learning new cultures, while forced 'refugees' have less self-driving resistance to picking up new cultures.
- The process of losing the cultural heritage of EDPs will only occur in the offspring after the first generation of EDPs become cultural learners.

5.2.2 Markov Chain Model based on cultural evolution

The schematic diagram of this model is shown in Figure 8, which vividly simulates a series of changes that EDPs will experience in new countries.Here, we make some specific explanation for the formula used.

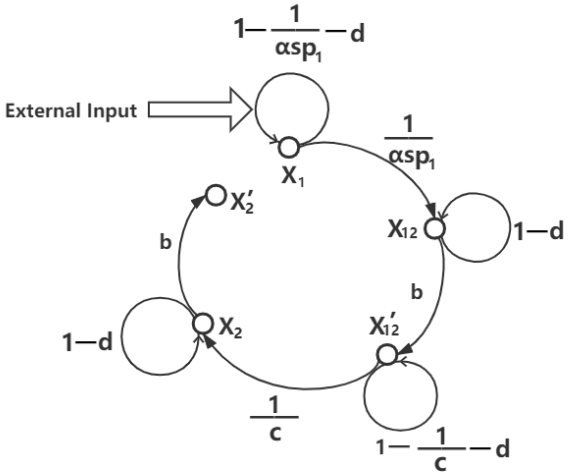


Figure 8: Markov Chain Model based on cultural evolution

- The initial EDPs are all immigrants who completely retain their unique culture. Based on this, we obtained the population distribution vector of the initial EDPs on the degree of cultural retention:$\pi = (X_1, 0, 0, 0, 0)$

- In the process of X_1 becoming X_{12} (both retains the original culture and understands the new local culture by learning the local new culture), we take the self-driving factor α of the immigrants, the cultural similarity s and cultural policy p_1 into account. Then its transition probability can be expressed as: $\frac{1}{\alpha s p_1}$.
- Considering that our model is dynamic, we take birth rate b, and mortality d into account. X_{12} multiplies to get the next generation X_{12}'. Similarly, the immigrant X_2 who is completely assimilated by the local culture will multiply to the next generation X_2'.
- When X_{12}' becoming a fully assimilated immigrant X_2, we take into account the key factor of the cultural diversity of the host country, and express the transition probability as: $\frac{1}{c}$.

Further, because we divide all immigrants into two types and the cultural composition and the policies of each host country are different, the factors we consider in different scenarios have different impacts. The difference in the degree of such impact is mainly reflected by :

- Self-driven resistance α:

$$\alpha = \begin{cases} 2, & forced \quad refugees \\ 4, & voluntary \quad migrants \end{cases}$$

- Cultural similarity resistance s:

$$s = \begin{cases} 2, & high \quad cultural \quad similarity \\ 4, & low \quad cultural \quad similarity \end{cases}$$

- Policy resistance p_1:

$$p_1 = \begin{cases} 1, & Government\ actively\ encourages\ immigrants\ to\ learn\ new\ culture \\ 2, & Government\ does\ not\ interfere\ with\ immigrants'\ learning\ of\ new\ culture \\ 4, & Government\ intends\ to protect\ immigration\ culture \end{cases}$$

- Resistance to cultural diversity c:

$$c = \begin{cases} 2, & High\ cultural\ diversity\ index \\ 4, & Low\ cultural\ diversity\ index \end{cases}$$

The Markov transition matrix based on cultural evolution can be expressed as below:

$$A = \begin{pmatrix} 1-\frac{1}{\alpha s p_1}-d & \frac{1}{\alpha s p_1} & 0 & 0 & 0 \\ 0 & 1-d & b & 0 & 0 \\ 0 & 0 & 1-\frac{1}{c}-d & \frac{1}{c} & 0 \\ 0 & 0 & 0 & 1-d & b \\ 0 & 0 & 0 & 0 & 1-d \end{pmatrix}$$

Through the initial distribution vector and transition matrix, we can get the distribution status of various types of immigration at any time in the future.

$$\pi_t = A\pi_{t-1} \tag{11}$$

$$\pi_t(0) = \pi_t(0) + R_t \tag{12}$$

where R_t represents new immigrants to the country in year t.

5.2.3 Markov Chain Model based on survival evolution

In this model, three immigrants Y_1, Y_2, Y_3 we divided into according to their living conditions can be completely converted to each other. On top of that, the initial EDPs are all immigrants whose survival problems have not been solved, namely Y_1. Based on this, we obtain the distribution vector of the initial EDPs on living conditions:$\pi' = (Y_1, 0, 0)$.

- Both Y_1 and the barely living immigrant Y_2 can be improved by self-driving factors β and host country policy factors p_2, so that Y_1 is promoted to Y_2 and Y_2 is promoted to Y_3 (Y_3 is an immigrant with a higher happiness index). The transition probability is expressed as $\frac{1}{\beta p_2}$.
- We consider directly upgrading Y_1 to Y_3, which is based on small probability events. We define such probability as m. Similarly, Y_3 may go bankrupt and become Y_1, the probability of which is K. Y_2, Y_3 has a certain probability of experiencing the asset decays, resulting in Y_2 to Y_1, and Y_3 becomes Y_2, which is defined as f.

We take into account that different policies of the host country will have different impacts and different self-driven resistances to change. The relevant factors are defined as follows:

- Self-driven resistance β:

$$\beta = \begin{cases} 2, & Y_1 \to Y_2 \\ 4, & Y_2 \to Y_3 \end{cases}$$

- Policy resistance p_2:

$$p_1 = \begin{cases} 1, & \textit{Government does not interfere with immigrants' learning of new culture} \\ 2, & \textit{Government subsidizes immigrants} \end{cases}$$

The schematic diagram of the Markov chain model based on survival evolution is as follows:

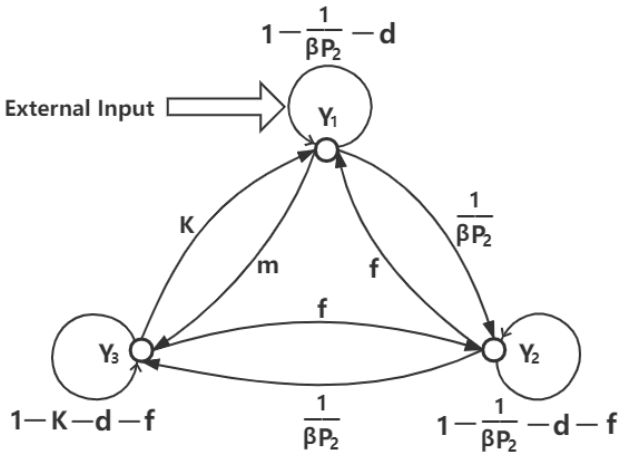


Figure 9: Markov Chain Model based on survival evolution

We include all transition probabilities to obtain the model's transition matrix:

$$\begin{pmatrix} 1-\frac{1}{\beta p_2}-d & \frac{1}{\beta p_2} & m \\ f & 1-\frac{1}{\beta p_2}-d-f & \frac{1}{\beta p_2} \\ k & f & 1-k-d-f \end{pmatrix}$$

Finally, through the initial distribution vector of survival conditions and the transition matrix of this model, we can obtain the distribution results of the proportion of various types of immigrants at any time in the future. We will discuss the short-term and long-term evolution results of the model evolution in the subsequent quantitative calculations.

$$\pi_t' = A'\pi_{t-1} \tag{13}$$

$$\pi_t'(0) = \pi_t'(0) + R_t \tag{14}$$

5.2.4 Calculating and Simpliyfying

Take the host country China as an example to analyze the cultural and survival evolution of EDPs. For a selcted country, its cultural diversity and cultural similarity are basically balanced, so we analyze the impact of the national policy on the culture and survival of EDPs. As mentioned before, there are three types of national cultural policies for EDPs: *encouraging immigrants to learn new local culture, not interfering with immigrants' learning of the new local culture and intentionally protecting the unique culture of immigrants*. Besides, there are two national survival policies for EDPs as well, that is: *not interfering with the survival of immigrants and actively subsidizing immigrants*.

We make short-term (2050) and long-term (2100) predictions and analyses of both cultural and survival conditions.

- Short-term (2050) cultural and survival changes:

Table 5: Short-term cultural transfer results

State of Short-term Forecasting(2050)		Distribution Proportion				
		X_1	X_{12}	X_{12}'	X_2	X_2'
P	Encourage EDPs to Learn New Cultures	33.10%	60.00%	1.10%	5.40%	0.40%
	Non-interference with EDPs	39.00%	54.70%	1.65%	4.30%	0.35%
	Protect the Original Culture of EDPs	43.46%	50.82%	2.40%	3.11%	0.21%

Table 6: Short-term survival transfer results

State of Short-term Forecasting2050		Distribution Proportion		
		Y_1	Y_2	Y_3
P	Non-interference with EDPs	46.80%	40.00%	13.20%
	Subsidize EDPs	29.90%	42.60%	27.50%

Based on the results, we can conclude that the local evolution of different policies will lead to different results:
(1)Compared with the result of the policy of *"do not interfere with the culture of EDPs"*, the policy of *"encouraging immigrants to learn a new local cultur"* will reduce the original culture of EDPs, while the policy of *"intentionally protecting the original culture of EDPs"* will protect the unique culture of EDPs.
(2)Compared with the result of the policy of *"not interfere with the survival of EDPs"*, the policy of *actively subsidizing EDPs"* will improve the original living standard of EDPs.

- Differences in cultural transfer results in the long and short term:

Table 7: *Short-term and long-term cultural transfer under the policy of encouraging EDPs to learn a new culture*

Non-interference with EDPs		Distribution Proportion				
		X_1	X_{12}	X'_{12}	X_2	X'_2
Time	Short Term (2050)	33.10%	66.00%	1.06%	5.44%	0.40%
	Long Term (2100)	10.59%	64.09%	1.24%	19.74%	4.34%

Table 8: *Short-term and long-term cultural transfer under the policy of "non-interference in EDPs culture"*

Non-interference with EDPs		Distribution Proportion				
		X_1	X_{12}	X'_{12}	X_2	X'_2
Time	Short Term (2050)	39.00%	54.73%	1.59%	4.32%	0.31
	Long Term (2100)	15.16%	61.27%	2.02%	17.76%	3.80%

Table 9: *Short-term and long-term cultural transfer under the policy of "protecting the original culture of EDPs"*

Protect the Original Culture of EDPs		Distribution Proportion				
		X_1	X_{12}	X'_{12}	X_2	X'_2
Time	Short Term (2050)	43.50%	50.82%	2.40%	3.11%	0.21%
	Long Term (2100)	20.59%	57.68%	3.50%	15.11%	3.12%

We analyze the short-term and long-term effects on cultural transfer under different policies. The results are as above.

The conclusion is that no matter what policy is adopted, the original culture of EDPs will slowly decay over time. However, policies such as "protecting the original culture of EDPs" have a better blocking effect on retaining the attenuation of the original culture of EDPs.

6 Sensitivity Analysis

6.1 The similarity of different cultures

In this section, we simulate what will happen in United States, which is more similar to the culture of EDPs While cultural evolution process without corresponding policy intervention is compared with China. We find that by 2050, the proportion of three types of immigrants in cultural evolution will be 31.1%, 63.6%, and 5.3% respectively. It can be seen from the results that even in the absence of relevant cultural policies in the United States, due to the similiarity of their own culture and EDPs, culture learners still occupy a relatively high proportion. Therefore, for host countries sharing similiar culture with EDPs', it is necessary to introduce related policies to protect immigrant cultures, reducing the conversion from culture learners to those who lose their unique cultural heritage.

6.2 Inadequate attention to planned migration

Here we simulate a severe natural outbreak in 2045, and suggest that island nations do not pay attention to planned immigration. In the case of a sudden and catastrophic natural disaster, all citizens can only be relocated. We discover that:

Occasion 1: If the host country's policies do not interfere with the development of immigrants' lives, in the short term to 2050, the distribution of the three types of immigrants whose lives have evolved will be 61.1%, 36.9%, and 2%. A high percentage of immigrants who have just moved in and have not been able to integrate into society, which means that if island nations do not pay attention to planned immigration, it will bring heavy social pressure on the host country.

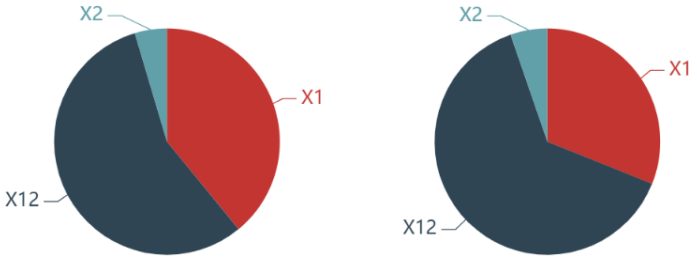


Figure 10: *Comparison of cultural population structure between China(left) and the United States(right) in 2050*

Occasion 2: If the host country has issued corresponding policies to subsidize the lives of immigrants, the distribution of the three types of immigrants living in the short term to 2050 will be 36.5%, 55.3%, and 8.2%. It can be seen that if the host countries use policies to subsidize immigrants, they can quickly improve the living conditions of refugees and reduce social unrest.

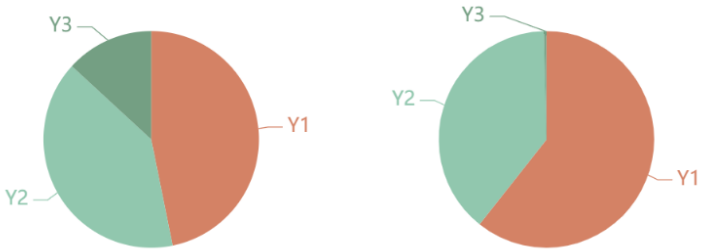


Figure 11: *Without planned resettlement, survival transfer(life evolution) without policy intervention*

7 Further Discussion

7.1 Suggestions on policies

Here, we consider the United Nations as the leading institution to coordinate various countries regardless of economy to formulate related policies to plan and deal with related issues of EDPs. We propose policies based on three different positions of the United Nations, the affected island countries, and the host countries. The United Nations coordinates and supervises all parties to implement.

From the perspective of the affected island countries, they pay attention to planned migration rather than wait until imminent natural disasters force them to nowhere. In addition, the affected island countries must formulate plans and regulations in advance for migration matters and adopt an "N-step" strategy based on the country's environment and population status. With each step of implementation, the problems exposed during the resettlement process are summarized and adjusted in a timely manner to ensure that the migration plan can be well realized.

Besides, for the United Nations, it is vitally significant to speak for the affected island countries. UN needs to call on nations around the world to share responsibility and actively develop treaties to be implemented. Based on our model of responsibility division, UN can reasonably divide the responsibilities of countries, in the process of which, we should give full play to the advantages of each country. Only by assigning reasonable tasks to the advantages of each country can we better solve the problems related to EDPs. The figure below is our policy framework.

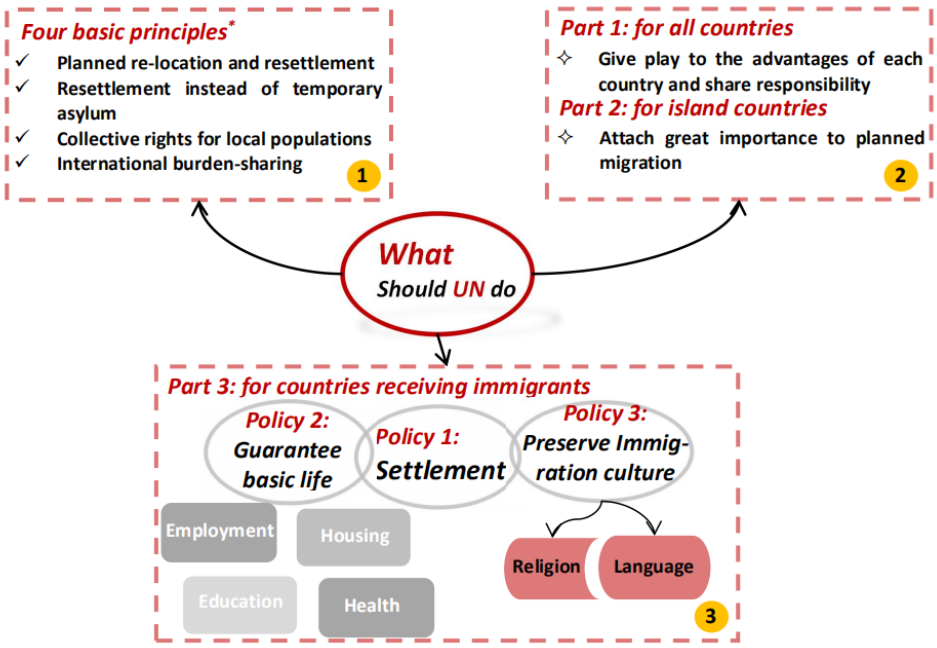


Figure 12: *Suggestions for UN on policy(* indicates that we refer to the article and improve it)*

Specifically, in terms of host countries, they need to carry out the following policies:

1. Reasonable resettlement policy.

Various countries need to formulate appropriate resettlement policies when accepting immigrants. After comprehensive consideration of the situation of the immigrants, they should be given the permanent residence qualifications or temporary residence qualifications correspondingly. For example, immigrants who are unable to return to their homes due to rising sea levels are more likely to require permanent residency in the host country.

2. EDPs basic security policy.

- **Health**. Health is the foundation for EDPs to survive normally. Host countries need to introduce a reasonable medical policy so that EDPs can get basic medical resources. Only by solving medical problems can EDPs stay healthy and actively participate in the new society.
- **Housing**. The housing problem of EDPs is prominent because it means that host countries need to allocate reasonable land or houses to EDPs. The shelter can eliminate the wandering feeling of EDPs. This is one of the foundations for EDPs to rest and live normally.
- **Education**. It is inevitable that there are groups of children in EDPs and that EDPs will multiply to get their offspring. Such children need basic education, and only with basic

education can they acquire socially-based skills in the future, which is significant, as it will prevent host countries from worrying about the future of these people.

- **Employment**. Host countries needs to register the personal skills information of EDPs. The purpose of doing so is to arrange suitable jobs for people with different skills in the crowd. Only by solving the basic employment problem can EDPs be self-reliant. On the one hand, solving the employment problem will greatly eliminate the factors of social instability. On the other hand, work allows EDPs to gain a sense of identity and belonging.

3. Cultural protection policy

Every culture is equal and valuable, and cultural diversity is one of the most important characteristics of this planet. The culture of EDPs is on the verge of disappearing, and we must introduce corresponding policies so that unique cultures can be preserved. We divide culture into two parts: language and religion. Host countries allow EDPs to maintain their unique language and religion. They need to protect the unique culture of EDPs while encouraging them to understand the new culture, and find a balance between the two.

7.2 From human beings to species

The emergence of the term 'climate refugees' indicates that more and more countries and institutions start to pay much more attention to global environmental issues(such as the sea level rise). Also, not only do they care about when, where and how to resettle themselves, but also attach great importance to the refugees human rights and cultural demands. These are all improvements and worthy to be addressed.

However, one question that has been ignored but still essential is related to species. We can help human beings in those countries at risk due to the rising sea level, then what about species dwelling in the same dangerous places? For example, New Zealand, the Seabird Capital of the world, has approximately 100 different species of seabirds breeding on its shores and islands. Habitat loss has caused the nations seabird numbers to plummet, though. New Zealand storm-petrel is such a victim by climate change which almost extincts[16]. According to history researches, the arrival of humans on oceanic islands has precipitated a wave of extinctions among the islands' native birds[17]. Then what will happen to these species? Will the number and types of them increase again briefly or they may also face the risk of extinction again?

What is more, if these species go to other countries to settle down, can they receive a relatively equal and humane treat? What our team believe is that human beings are not the leader in the world, and as seemingly smarter ones, we are obliged to do more to help other species, thus bringing a win-win result. We suppose that if we can deal with the problems related to people, we can apply the effort to other species as well.

8 Strengths and Weaknesses

8.1 Strengths

- Fully respect the choice of migrants and consider the actual situation to divide migrants into two categories, voluntary 'migrants'(cultural-oriented) and forced 'refugees'(survival-

oriented). Different types of migrants take various factors for choosing a country into account.

- Employ K-Means cluster analysis to classify the countries that need to bear responsibility into four categories, in which different countries shoulder different duties, making full use of each country's own resource advantages.
- Use PCA and 'Soft Max' to quantify duties based on greenhouse gas emissions, economy and population density in each country.
- The Markov chain was used to simulate the cultural and survival evolution of refugees in the host country. From time, policy, Cultural similarity and the importance that island nations place on planned immigration discussed the evolution of refugee culture and life.

8.2 Weaknesses

- In order to simplify the model when predicting the number of EDPs, the average proportion of the impact of sea level rise on the population is used, and it is assumed that the composition of the climate refugees will not change.
- When determining the preference of different types of EDPs for indicators, the pairwise comparison matrix used is subjective.
- When simulating refugee life and cultural evolution, the influence of parameters such as policy and cultural similarity uses subjectively specified constants.

References

1. $http://www.ipsnews.net/2017/08/climate-migrants-might-reach-one-billion-by-2050/$
2. $https://en.wikipedia.org/wiki/Environmental_migrant$
3. $https://kirkleescampaignagainstclimatechange.wordpress.com/2017/02/14/europes-first-climate-refugees-conference-held-in-london/$
4. $https://www.change.org/p/uk-parliament-give-climate-refugees-the-recognition-that-they-urgently-require$
5. $https://www.cbsnews.com/news/climate-change-refugees-united-nations-rules/$
6. Hartmann, B. (2010). Rethinking climate refugees and climate conflict: Rhetoric, reality and the politics of policy discourse.ăJournal of International Development: The Journal of the Development Studies Association,ă22(2), 233-246.
7. Biermann, F., & Boas, I. (2010). Preparing for a warmer world: Towards a global governance system to protect climate refugees.ăGlobal environmental politics,ă10(1), 60-88.
8. Bravo, M. T. (2009). Voices from the sea ice: the reception of climate impact narratives.ăJournal of Historical Geography,ă35(2), 256-278.
9. Farbotko, C. (2010). Wishful sinking: disappearing islands, climate refugees and cosmopolitan experimentation.ăAsia Pacific Viewpoint,ă51(1), 47-60.
10. Berchin, I. I., Valduga, I. B., Garcia, J., & de Andrade, J. B. S. O. (2017). Climate change and forced migrations: An effort towards recognizing climate refugees.ăGeoforum,ă84, 147-150.
11. Biermann, F., & Boas, I. (2008). Protecting climate refugees: the case for a global protocol.ăEnvironment: Science and Policy for Sustainable Development,ă50(6), 8-17.
12. Farbotko, C., & Lazrus, H. (2012). The first climate refugees? Contesting global narratives of climate change in Tuvalu.ăGlobal Environmental Change,ă22(2), 382-390.
13. https://www.statista.com/chart/19884/number-of-people-affected-by-rising-sea-levels-per-country/
14. Crate, S. A., & Nuttall, M. (2016). Introduction: Anthropology and climate change. InăAnthropology and climate changeă(pp. 9-36). Routledge.
15. Ahmed, B. (2018). Who takes responsibility for the climate refugees?.ăInternational Journal of Climate Change Strategies and Management.
16. $https://www.pbs.org/wgbh/nova/article/eight-extinct-species-rediscovered/$
17. Blackburn, T. M., Cassey, P., Duncan, R. P., Evans, K. L., & Gaston, K. J. (2004). Avian extinction and mammalian introductions on oceanic islands.ăScience,ă305(5692), 1955-1958.

Appendix: Data Resources

Table 10: Data Resources

Data	Reference
Population by country	https://datacatalog.worldbank.org/dataset /world-development-indicators
Global mean sea level (GMSL)	https://research.csiro.au/slrwavescoast/ sea-level/measurements-and-data/ sea-level-data/
Impact of sea level rise on island population	The Impact of Sea-Level rise on Developing Countries: A Comparative Analysis by Dasgupta, Laplante, Meisner, Wheeler and Yan
Proportion of people affected by sea level rise among all EDPs	Myers, Norman. 2002. Environmental Refugees: A Growing Phenomenon of the 21st Century. Philosophical Transactions: Biological Sciences 357 (1420): 609613.
Greenhouse gas emissions by country	https://datacatalog.worldbank.org/dataset/ world-development-indicators
GDP per capita (by country)	https://datacatalog.worldbank.org/dataset/ world-development-indicators
Grain production	https://knoema.com/atlas/ranks/ Cereal-production
National Language Diversity Index	https://en.wikipedia.org/wiki/ Linguistic_diversity_index
Religious Diversity Index by Country	https://www.pewforum.org/2014/04/04/ religious-diversity-index-scores-by-country/
Distance between countries	https://distancecalculator.globefeed.com/ Distance_Between_Countries.asp