Study on Migration Path of Climate Refugees Based on Grey Prediction and Analytic Hierarchy Process

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Abstract. Earth is undergoing climate changes that are affecting our environment. Some of these changes are easy to adjust to, however, some changes of the climate are severe and require immediate drastic solutions. In this paper, we present a solution to dangers posed by rising sea levels in the Maldives. It is a tropical paradise, but it is vulnerable to storms and tsunamis, and due to slowly rising sea levels it could one day disappear completely! The Maldivians will eventually need to migrate to higher ground somewhere. First, we identify the metrics that will influence the process of the transfer of EDPs, while enabling the preservation of culture and language. Then we establish a **grey prediction model** to predict future changes in population, and identify when the chosen host country will be completely unfit for human habitation. Next we use the **Analytic Hierarchy Process** combining with the objective situation and subjective thoughts of EDPs to determine the relationship between factors represented by each variable. Finally, we propose policies considerate of all the possibilities so as to maximize the benefits for all involved parties.

Keywords: Climate refugees, Migration path, Grey prediction model, Analytic Hierarchy Process.

1. Introduction

1.1. Defining Our Problem

The Amazon forest's wildfires, melting ice sheets in Greenland, extinction of the Carolina Parrot and the Taal volcanic eruption are all signals from nature that the earth is changing. However, there are some irreversible changes on our planet, prevention may be too late. We need to make up for our mistakes, work together, and take measures to save what can be saved - like our lives, for instance.

One issue demanding our attention is that of the rise of sea level. Currently, the sea level in the Maldives is rising 3.6 millimeters per year. At this rate, in 80 years, the sea level will have risen by 1 meter [1], and an estimate of 77% of the Maldives' current land will be immersed. 147 million to 216 million people that live on land will be affected by the end of this century. [2,3] Some coastal cities in other countries can accommodate such a rise of sea level by making coastal mangroves or building a seawall, but this won't work for the Maldives. A 10-meter tsunami could completely wipe out the entire population. The two figures below demonstrate the rise of the sea level visually.

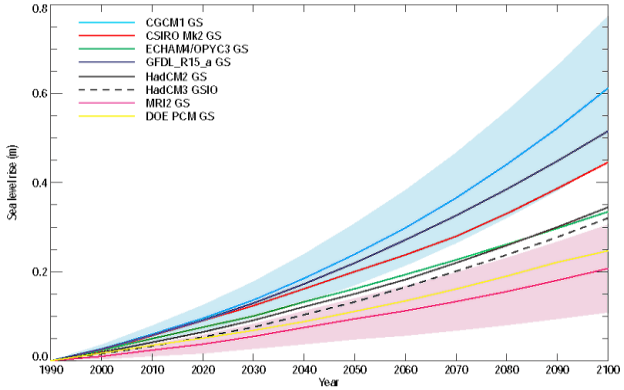


Figure 1. The sea level rise in different models (with time) [4]

Language is essential in the cultural development of a country, making each country and its individuals unique. The Maldivians have their own spoken language, Dhivehi, and writing system, Tana, that is unique to them alone. Losing their culture to a battle against the climate would be a pity for humanity. We need to prevent this precious culture from extinction.

With our models, we identify metrics that will process the transfer of EDPs, while enabling the preservation of culture and language. Then, we established a grey prediction model to predict future changes in population and the function of sea level change over time. We also can find the best suited host country for Maldivians. Finally, we combined the given situation and our subjective thinking to determine the relationship between the factors represented by each variable.

1.2. Our Task

1) Identifying the metrics that will influence the process of the transfer of EDPs, while enabling the preservation of culture and language.

2) Establish a grey prediction model to predict future changes in population, and identify when the chosen host country will be completely unfit for human habitation.

3) Using the **Analytic Hierarchy Process**, we combined the objective situation and subjective thoughts of EDPs to determine the relationship between factors represented by each variable.

4) Propose policies considerate of all the possibilities so as to maximize the benefits for all involved parties.

2. Model

2.1. Metrics

Herein are the main factors influencing the environmentally displaced persons (EDPs)

- **Economic Index**

To be fair to the Maldivians and the host country, the difference between the economies of the two countries should not be too large, otherwise it will be an imbalance that can cause conflict. We identify the economic index as β_1 and the variable representing the economic factor is $\mathbf{X_{1f}}$.

- **Socio-cultural Index**

Our purpose is not only to house the Maldivians, but also to protect their unique language, culture and religion. Here, we try to measure the weight of this factor, and find the optimal solution based on the overall combination. We identify the socio-cultural index as β_2 and the variable which can represent socio-cultural factor is $\mathbf{X_{2f}}$.

- **Population Density Index**

It is difficult for a country with a very dense population to receive an influx of immigrants. Therefore, the country where the Maldivians will be transferred to should have a compatible population density. We identify the population density index as β_3 and the variable which can represent population density factor is $\mathbf{X_{3f}}$.

- **Resources Index**

Countries with abundant natural resources have the potential for great economic development, but some of them have resources yet lack the capacity for development. These kinds of countries need human resources to help. For EDPs, the resources they can contribute to the host nation can greatly increase the host country's acceptance of them. We identify the resource index as β_4 and the variable which can represent resource factor is $\mathbf{X_{4f}}$.

- **Distance Index**

To relocate an entire population, distance is a factor that has to be taken into account. The greater the migration distance, the greater the cost. Additionally, the readjustment and travelling can trigger sickness amongst the Maldivians. We identify the distance index as β_5 and the variable which can measure distance factor is $\mathbf{X_{5f}}$.

2.2. Home Country Population Model

In order to establish an effective model, in this study we will use Maldives as an example.According to the data from National Bureau of Statistics of Maldives [5]. We obtain its population information. We use **Gray Prediction** to forecast their population in 30 years.

(1) Known element sequence data of home country's population (the data from 2010-2018):

$$P_0 = | P_0(1), P_0(2), \ldots\ldots, P_0(n) |$$

(2) In order to ensure the feasibility of the gray prediction, a step test is required on the original sequence data.

(3) After testing, do an accumulation to generate (1-AGO) sequence:

$$P_1 = | P_1(1), P_1(2), \ldots\ldots, P_1(n) |$$

Where $P_1(k) = \sum_{i=1}^{k} P_0(i)$, k = 1, 2, ……, n

(4) The gray differential equation model of GM (1,1) is established as:

$$P_0(k) + az_1(k) = b$$

(5) The formula to get the forecasted population is:

$$P_0(k+1) = P_1(k+1) - P_1(k) = \left[P_0(1) - \frac{b}{a}\right](1 - e^{a})e^{-ak},\ k = 1, 2, \ldots\ldots, n-1$$

From here we can get the population of Maldives in 2050 is **916, 951**, which are the population need to be transferred. And the host countries' GDP per capita.

2.3. Movement Place Selecting Model

In this part, we compound the objective and subjective factors using rating system to select the movement of EDPs. It considers the right of every party which involves in. We choose three alternatives for the Maldives, which have commonly used language, similar culture and climate.

$$\mathbf{Y = \beta_1 X_{1f} + \beta_2 X_{2f} + \beta_3 X_{3f} + \beta_4 X_{4f} + \beta_5 X_{5f}}$$

In this model, the index $\boldsymbol{\beta}$ represents the weight of each factors. These data are from survey in "The level of importance for you to choose your target moving country". This survey aims to find what factors people more care about in choosing their residential country. After we get the result, we use **The Analytic Hierarchy Process** to find the weight.

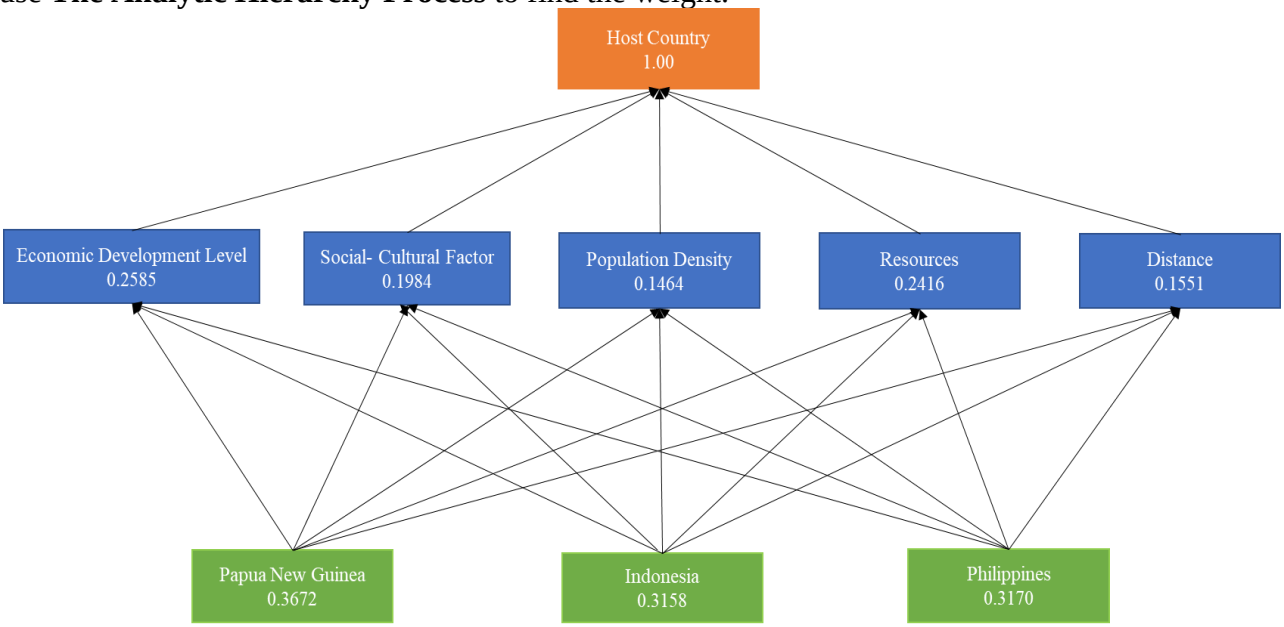


Figure 2. The Analytic Hierarchy Process

Table 1. Formula of the Variables

Variables	Formula
$\mathbf{X_{1f}}$	$\frac{GDP_{ti}}{Pop_{ti}}$(GDP per capita)
$\mathbf{X_{2f}}$	$\frac{1}{N}\sum_{k=1}^{N}\left[\left(I_{gkt} - I_{gct}^{2}\right)/Vg\right]$[6]
$\mathbf{X_{3f}}$	$\frac{Pop_{ti}}{S_a}$
$\mathbf{X_{4f}}$	Category score [7]
$\mathbf{X_{5f}}$	d_{ik}

Table 2. Value of the Indexes.

Index	Value
$\boldsymbol{\beta_1}$	0.2585
$\boldsymbol{\beta_2}$	0.1984
$\boldsymbol{\beta_3}$	0.1464
$\boldsymbol{\beta_4}$	0.2416
$\boldsymbol{\beta_5}$	0.1551

Note:1. We use Min-Max scaling normalization to deal with all the variables in the table.

2. Formula: $\boldsymbol{X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}}}$

First independent variable $\mathbf{X_{1f}}$, we use GDP per capita to measure the economic development level of the target country. In order to produce easier comparison results, we will normalize the value of this variable so that all data are distributed between 0 and 1.

Second independent variable $\mathbf{X_{2f}}$, we use the thought of analogy to quote institutional distance to compare the differences in sociocultural factors between different countries.

Third independent variable $\mathbf{X_{3f}}$, our formula for measuring population density is to divide the estimated total population at some point in the future by the total area of the target country.

Fourth independent variable $\mathbf{X_{4f}}$, we, use the rankings of natural resources in the world and invert the number of bits and use the normalization method to unify the data so that the value of the data ranges from 0 to 1.

Fifth independent variable $\mathbf{X_{5f}}$, we normalize the distance between the affected country and the transferring country so that all variable values are between 0 and 1. So the data measure system will be completed.

Therefore, our model for the Maldives to move to other country is:

$$Y = 0.2585 \times \frac{GDP_{ti}}{Pop_{ti}} + 0.1984 \times \frac{1}{N}\sum_{k=1}^{N}\left[\left(I_{gkt} - I_{gct}^{2}\right)/Vg\right] + 0.1464 \times \left(-\frac{Pop_{ti}}{S_a}\right) + 0.2416 \times Category\ score + 0.1551 \times (-d_{ik})$$

In order to make the experimental data more convincing, we chose three experimental groups which are Indonesia, Papua New Guinea, and the Philippines. We added Russia as a comparison.

Table 3. Result of Evaluation Based on the Proposed Model

	Economic development level	Social-cultural factor	Population Density	Resource	Distance	Total score
Indonesia	0.831886	0.096305	-0.33556	0	-0.54573	0.100381
Papua New Guinea	0	1	-0.04356	0.639344	0	**0.346488**
Philippines	0.916371	0	-1	0.07377	-0.18316	0.079897
Russia	1	0.173503	0	1	-1	**0.379423**

By inputting data to the model, we have built, we discovered Russia has the highest score in this evaluation among our choices. However, weighing in the potential for economic development and the differences in climate and the culture, we infer that **Papua New Guinea** is still our best choice for providing the Maldivians a new home.

3. Policy

1) All EDPs will be considered as climate refugees.

Climate refugees are people who are forced by environmental circumstance to move from their home country. They can legally process documents to immigrate to developed countries. If they are accepted to immigrate to the USA, Canada, Australia, etc., they do not need to relocate to the new host country.

2) The nations contributing to climate change are obliged to financially support EDPs and its host nation.

Countries such as China, the European Union, the USA, Russia and Japan have the highest greenhouse gas emission[8]. These countries combined contribute to 62.88% of the entire Earth's greenhouse gas emission. The citizens of these countries are not affected by the rise of sea level. Yet these countries are inducing the rise of sea level indirectly and affect the lives of islanders, like the Maldivians. Their financial contribution will be based on their greenhouse gas emission. They will finance the EDPs move and settling down by providing money for their daily expenses and housing for the first year.

These nations can also invest in the business of the Maldivians as they settle into their new home on case to case bases.

3) There will be one country, two systems for the host country and the EDPs.

The EDPs will belong to the host nation for 50 years, geographically. In that 50-year period, the EDPs will have their own local government and law which is subject to the host nation's government.

4) There will be work exchange programs between the EDPs and its host nation.

The Maldives went from a poor country in the 1970s to a middle-income country in just 40 years[9]. Despite the difficulty of overcoming the challenges they face in running a country of scattered islands, they have been able to grow their fishing business and tourism business. They are known for their luxury resorts and seafood cuisine selection. The Maldivians will teach their craft for fishing to the host nations. Also, people of the host nation will have opportunities to work in the businesses of the Maldivians.

5) The EDPs are subject to the host nation's taxes.

The EDPs will pay taxes to the host nation as is.

4. Conclusion and Remarks

4.1. Evaluation of the Model

Strengths:

1) The model fully demonstrates the requirements of the problem, which not only meets the problem of population migration, but also gives the opportunity for the inheritance of local cultural factors.

2) The models involved in this article are supported by reliable theoretical and research data. Our model draws on the opinions of multiple experts in their previous papers.

3) The model not only takes into account the social-cultural factor of EDPs, which includes the human rights, individual choice, culture, governing policies, but also regards the conditions of the host country, thereby achieving a win-win situation and reducing the possibility of conflict. (objective and subjective)

4) All data in the article are from official and expert evaluations, which increases the reliability of our model estimation.

5) This paper combines Gray Prediction and the Analytic Hierarchy Process. The former is used to forecast the population and GDP of host and home country. The latter is used in this model to factor in situations where there is uncertainty and subjective information, and also allows the logical use of experience, insight and intuition.

4.2. Weaknesses

1) The variables of the model in the article have missing variable biases, there are possibly other factors that cannot be measured or are temporarily unknown.

2) Because climate cannot be accurately predicted, sea level rise data may differ from reality. Room for error is needed for the time needed to relocate the EDPs.

3) In our case of model building, our selected location is Maldives, if another selected location far different from the Maldives was to be tried with this model, there will be definite errors.

4.3. Future work

In our model, the drawbacks need to be reevaluated, such as the key variables that are not included and incomplete sea level rise information. Future researchers who are interested can obtain more information to update our model and make it suitable for a variety of countries which will have EDPs. Thus, providing not only struggling countries but the whole world a calculated solution.

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