In this paper, we present a dynamic model that is used in the policy creation, implementation and economic evaluation of relocating people of small island-nations who are at risk of losing their homes to rising sea levels in the coming decades. We utilize actuarial and statistical techniques to forecast future sea levels. Then, a 3-D simulated island submersion model is used to evaluate how rising sea levels will impact different island-nations under multiple climate change projection scenarios over the coming decades. We then rely on developmental, micro and macro economic theory to develop policy that is beneficial to both Environmentally Displaced Peoples (EDPs) and the host countries while preserving the cultural heritage of the island-nation people.

A low error culture survival model is employed and illustrates that our model successfully protects and preserves the unique and distinct culture of EDPs. Our model is then simulated for four at-risk island-nations and is shown to produce a desirable projected social internal rate of return (IRR) of around ten percent for each separate simulation.

# Protect and Preserve:

Protecting and Preserving the Culture of Environmentally Displaced Island-Nation People

MCM 2020

## Contents

# 1 Introduction

Global warming has been an alarming concern of the international scientific community for decades, and has been largely under prepared for by current and past policy makers across the world. Ravaging fire seasons like those of California, Australia, and The Amazon, colder winters, and rising sea levels are all serious consequences of global warming that will devastate many people, especially without proper planning and preparation from the international community. Some of the people who will be impacted the most have been identified as the those who those who live on several small island-nations that are at risk of completely losing their islands due to rising sea levels. These environmentally displaced persons (EDPs) are put at an even greater risk if more countries and leaders continue to embrace nationalism and ignore or deny global warming and it's consequences in the coming decades. In this paper, we present a model to relocate EDPs focusing on these points:

1. Assess the scope and urgency of island-nation people at risk.

2. Invest in the long term development of EDP's human capital and create economic incentives for host countries to welcome EDPs through a cooperative international policy approach.

3. Over 10 years, hold countries temporarily financially responsible for their share of global C02 emission.

4. Preserve the rich and distinct cultures of EDPs.

5. Evaluate the long term economic impact of proposed policy under different climate change scenarios.

We use a combination of actuarial and statistical techniques to forecast yearly sea levels through 2090. We then utilize those predictions in an island change model that maps the island being observed and calculates the percentage of land lost each year as the sea level rises. Then, our international policy proposal is described with emphasis on the economic theory that guides the policy.

Furthermore, an exponential population model is used to evaluate the risk to an island's cultural heritage once they are established within a host country and simulate the decay over time. Finally, the economic impact of our policy is analyzed and shown to provide a desirable anticipated social IRR of roughly ten percent. The strengths and weaknesses of our model are then discussed and concluding remarks are given.

# 2 Assumptions

In order to create a model for a problem this complex, we had to make assumptions to justify our logic and work.

1. International cooperation assumption: This model assumes that nations of the world will comply to pay the green house gas financial responsibility.
2. Currency assumption: For ease of interpretation, all currency is expressed in 2020 USD and no inflation occurs.
3. Natural disaster assumption: Islands that have been effected by rising sea levels are at higher risk for tsunamis and hurricanes. Therefore, evacuation is preferred sooner rather than later.
4. Mode of evacuation assumption: Due to desire of minimal travel time and potential need of far travel, all travel will be made by a Boeing 737-700 plane, capable of transporting 149 passengers.
5. Evacuation deadline assumption: Islands that will be completely submerged need to be evacuated before their means of exit is submerged (i.e. airports).
6. Uniformly distributed population assumption: Population of the islands will be considered uniformly distributed across the given land. Similarly stated, the population density will be constant throughout the island.
7. Basic infrastructure assumption: In countries hosting the new culture, there will be basic infrastructure (sewage, water, electricity, etc.) that is easily expandable to the new community.
8. Non-corrupt government assumption: Any country hosting the new community will be assumed to have no corruption in their government that will impact the new community. Meaning all money allocated to this community will be used properly for the community.
9. Host country government assumption: All EDP's that have moved to the new community in a host country, will from then on be subject to the laws of the host country; thus not governed by their home country.
10. Building size and cost assumption: All costs and sizes of buildings will be based off of United States standards.
11. Hospital bed count assumption: The amount of hospital beds per 1000 people will be based on a world average, in order to optimize the amount of hospitals needed to build.

12. Return to education assumption: For simplicity, students are assumed to begin accumulating their returns to education immediately once they begin school in the host country and every student realizes the average returns to education per year. This shifts cash flow timings, but does not impact IRR results or aggregate returns.

13. Storm surge estimate: Storm surges vary in sizes depending on storms and many other factors. When looking at storm surge danger zones, we will use $30cm$ storm surge maximum, which is an acceptable maximum for the area [6].

# 3 Model and Justification

## 3.1 Climate Change and Sea Level Increase

In order to forecast yearly sea levels through 2090 predicted rates of Global Mean Seal Level (GMSL) rise under six different climate damage severity pathways ranging from low to extreme were considered [20]. Expected yearly rates of GMSL were computed for the years 2030, 2050 and 2090 were calculated under the conditional framework:

$$E(X_{ij}) = E(X_{ij}|\theta) \cdot f(\theta) \tag{1}$$

where

$$\theta = \begin{cases} \text{low severity} \\ \text{low-intermediate severity} \\ \vdots \\ \text{extreme severity} \end{cases}$$

and $E(X_{ij}|\theta)$ is the predicted GMSL rate of change conditional on severity $\theta$, $f(\theta)$ is the probability distribution function of $\theta$ and $E(X_{ij})$ is the expected average rate of GMSL change through year $i =$ (2030, 2050, 2090) and RCP pathway $j =$ (RCP 2.6, RCP 4.5. RCP 8.5). Once expected yearly average rate of change through each year $i$ was computed, the mean sea levels

$$y(X_i, n_i)_j = \sum E(X_{ij}) \cdot n_i \tag{2}$$

where

$$n_i = \begin{cases} 10 \text{ when } i = 2030 \\ 30 \text{ when } i = 2050 \\ 70 \text{ when } i = 2090 \end{cases}$$

were computed for each $j$. Then, linear interpolation was utilized to estimate the average returns for each year between points $y_{ij}$ and those estimated average returns were used to calculate yearly GMSLs through 2090. For forecasted values refer to appendix A.1

## 3.2 Island Change Model

Once the data for predicting sea level rise over time has been calculated, it is now possible to model the submersion of an island. Using gathered height map data of an island, we can make a scale model of an island, compared to the sea level, and show the process of an island being submerged.

This process will provide the percent land submerged per year and percent remaining land in a "danger zone" of storm surge. The percent land submerged then correlates to the amount of people displaced (due to assumption 6).

The algorithm begins by obtaining an $n \times n$ height map, $M$, of the island. $M$ is a grid of $z$ values, which associates to the elevation of an island. The value $n$ is defined by some mileage value such that $n^2$ creates $M$, where the entire island is represented by a point on the grid. Using the given yearly estimates of sea level changes, $S$, the model produces a yearly change in land mass percentage. This is done by taking $s_t \in S$, starting with $t = 0, 1, 2, ..., t_{max}$. To simulate sea levels rising, for all $x, y < n$, set $z_{x,y} = z_{x,y} - s_t$, which sets the height of the land section to be with respect to the year's new sea level. Once the model hits defined stopping points, all the citizens must be removed from the island or else they are at risk. These stopping points are defined as when the sea level reaches the same elevation as the local airport or when the entire country is at risk of storm surge. Using the produced data, we are able to see what percentage of land is submerged, land percentages at high risk to tsunamis and hurricanes, and the approximate amount of people that need to be displaced each year.

## 3.3 Timeline

Our model calls for a collaborative, intergovernmental multi-phase approach (figure 1) to be overseen by the United Nations in which every country is financially responsible for their share of global C02 emissions through 2030.

| Master Phasing Plan of Operation: Homeward Bound | | | | |
|---|---|---|---|---|
| Phase | Phase 1: Create Settlement Skeletons for New Communities | Phase 2: Create Living Areas for Upcoming EDP Arrivals | | Phase 3: Execute Transportaion of Displaced Peoples to New Living Communites and Monitor Results |
| Year | 2020 - 2024 | 2025 - 2029 | | 2030-2091 |
| Investment Strategy | | Construct Essential Parts of Cummunities (Clinics, Schools, Cultural Centers, etc.) | Construct Living Areas for first arriving EDPs within the Newly Established Communities | Maintain Timely Construction of New Living Areas for the Continually Arriving EDPs |
| Funding Strategy | Accumulate Finances based on Greenhouse Gas Emissions for Iitial Investment | Accumulate Financial Responsibility based on Greenhouse Gas Emissions for Later Costs | | |
| R&D | Determine Settlement Locations for EDPs and Construction Partners | | | Monitor Transition into New Communities and Financial, Social, and Political Impact of the Displaced Peoples in the Host Country |

Figure 1: Master Phasing Plan

The years 2020-2025 will be used as a research and development period in which administrative and logistical objectives are met. During this period, the first host countries are determined and the majority of the money will be collected from countries to fund all initial investment costs of building EDP communities and administrative costs. Then, from 2025-2030, the first EDP communities will be built with schools, hospitals, apartments and a cultural center, that will be built with the help of a local expert from the island-nation that understands their culture well. One goal of building these EDP communities, is to replicate the success that "China Towns" across America have had in preserving their culture for decades or longer, such as San Francisco's "China Town".

Starting in 2030, EDPs will start relocating to host countries and this continues on through 2090. During the last 60 years from 2030-2090, more apartments will be built inside existing communities to house the new arrival of EDPs each year. For simplicity, our model assumes that the infrastructure for all communities is completed by 2030 and the only new construction will be apartment buildings.

## 3.4 Selecting New Homes

Once a person is displaced from their home, there needs to be somewhere for them to go. This section is the process taken to determine what countries an EDP can be relocated to. When determining the potential host countries for a group of EDP's, we consider looking at climate, primary religion, acceptance of immigrants/refugees, current population size/density, and whether its on the coast.

To begin, the host country must have the same climate as the island in order to maintain the same lifestyle and feel of their home. Placing an EDP in a country with a different climate would result in a loss of weather based customs such as clothing, outdoor activities, etc. Another consideration to make, is the primary type of religion in the host country. Placing the EDP's into a country with the same religion would increase acceptance into an area as well as maintain the religion the EDP's follow. After that, we look at the general acceptance of immigrants and refugees in the host country. If the host country is generally accepting of people in these circumstances, then EDP's will be able to join an accepting culture. If the EDP's are sent to a nation experiencing rising nationalism, there may be more backlash, but in section 3.5, the proposal introduces incentives for countries to take in these EDP's. The next thing to consider, is the current population size and population density. When picking a county, we look at the current values, see what they would be with the addition of the new EDP's. If the new population and density is significantly changed, or if the current population density is too high, we move on to a different country. Lastly, we look specifically for larger island countries or countries that are on the coast. This way, the people can still practice their customs that pertain to being a coastal nation (such as Marshall Island's fishing techniques).

For countries that have larger populations on the island, it may be necessary to split the community into $g$ groups. In this case, we look for at least $g$ potential hosts, provide the EDP's the choice from the options, then build the new communities in the $g$ countries selected.

## 3.5 Economics

### 3.5.1 Developmental

It is extremely important for both the host country economy and EDPs that EDPs receive meaningful investments into their human capital development by the international community, especially in the form of healthcare and education [14]. Investments into basic healthcare needs, namely access to routine appointments for medicine, family planning and mental health services are very important and have high anticipated returns on investment.[18] In addition, investments into schools and education produce highly positive externalities in communities, due primarily to reductions in special education costs, healthcare costs, teenage pregnancies, crime and increased future tax revenues [17].

### 3.5.2 Micro

As an incentive to accept EDPs, host countries will receive a stipend per EDP. The stipend for our analysis is intended to offset any perceived negative externalities of refugees by the people or the government of the host country [14]. In addition, EDPs will be paid an amount equal to the median salary of the host country for the first year they arrive in the host country. This will allow EDPs to have financial independence so they can feed themselves and their families while they look for work and get settled into their new home. This benefits the EDPs by reducing the risk of malnutrition, allowing some parents to stay home and raise their kids, allowing them a chance to find meaningful work that is fit to their skill level, and introducing them into the economy.

#### 3.5.3 Macro

All of these benefits of paying EDPs and investing in their human capital are also realized to a certain extent by the host country's economy. With the new community members, the host country has more activity and money flowing through it, more diversity and ideas shared in the community, and more skilled labor.

In order to carryout the analysis presented in 4.4 estimates from [17] were used for the rate of return to education and estimates from [14] were used to estimate the investment multiplier that was used to calculate how the income given to the EDPs would impact the host county's economy.

### 3.6 Financial Costs of Building Communities

Building an entire new community is very expensive, but a necessary expenditure to facilitate the EDP population. We identified six categories of a community that needed to be built. When deciding and calculating the cost of building, we used prices and sizes (square footage) representative of the United States for the sake of simplicity. Additionally, to reduce cost and increase build speed all construction is assumed to be modular, meaning the construction company builds pieces of the structure in a factory, then ships and assembles the pieces on site. We chose modular construction because not only does it reduce cost and build times, but being able to build structures in possibly more remote areas is much easier if you can ship the whole structure there rather than all of the pieces and the people.

#### 3.6.1 Residential

The first building requirement for a new community was living spaces. To calculate the building cost of new apartments we calculated the cost of an apartment per square foot to be $106.25 [3], the average 2 bedroom apartment to be 941 square feet [15], and the average amount of people living in each apartment 2 bedroom apartment to be 3. Taking the product of the first two values and multiplying it by the total population of the EDPs over 3, gives us the cost of residential construction per person which we can scale up to as many people as we need to. It is important that EDPs get permanent structures that they can safely live comfortably in, because that will be their home. For this reason, we did not minimize costs by putting in tents or other temporary or undesirable housing structures.

#### 3.6.2 Medical

There will always be a need for hospitals and medical assistance in any nation, especially, like in our model, if people are coming from a different environment with different exposures and risks. To best calculate the cost of building clinics in the new communities we took the product of the world average number of hospital beds per 1000 people (5.4) [5], the average square footage of space per hospital bed ($1750ft^2$) [9], and the cost per square foot of constructing hospitals ($204) [1] to get cost per 1000 people. Using this number, we could scale the cost to any number of people entering a host nation.

### 3.6.3 Educational

Similar to Residential and Medical services, education is vital to a healthy society. As previously stated, and increase in education results in increased tax revenue and leads to declines in undesirable areas, such as teen pregnancies, crime, and healthcare costs. When calculating the costs of constructing schools in the new communities we followed a similar procedure to both Medical and Residential calculations. We found the product of the average number of schools per 1000 people (0.4) [4], the average square footage per school (101600) [13], and the average cost per square foot to build education centers ($179.35) [13], so we could easily scale the result up to any number of incoming EDPs.

### 3.6.4 Commercial

An important aspect of creating these new communities is to give EDPs a financially stable future. For this reason, commercial zones will be built within the communities for businesses both small and large to provide economic stimulus to the area. To calculate the cost of these zones we took the average commercial area per person in the US ($6.82ft^2$) [19], and multiplied that number with the cost per square foot of a commercial structure ($85) [12], to be able to scale up with any population.

### 3.6.5 Cultural Preservation

One of the most important aspects of this problem was preserving the cultural heritage of the displaced people within their new nation homes. Through research we saw how effective it was in places like Chinatown, San Francisco to have buildings and monuments dedicated to honoring the history and culture of a people in preserving the culture of that people within the community. To calculate the funding required for this we took product of the average acreage of community centers or parks per 1000 people in the US converted to square feet ($442{,}569.6ft^2$) [7], and the cost per square foot of community centers ($110.50) [2] to get a number that could be scaled up with the population of EDPs. This number accounted for the highest building cost.

### 3.6.6 Infrastructure

Every new city needs infrastructure (sewage, electrical, roads) to operate. To calculate the cost of infrastructure we took the total amount the US spends on infrastructure per year ($2.1B) [21] and divided that by the total population of the US (327.2M) to get the amount it spends per person. We then scale this number to the population of displaced peoples. This was our lowest building cost.

With the implementation of these six important characteristics of a community, the newly built communities will provide EDPs with the opportunity to thrive in their new homes.

## 3.7 Culture Risk

To model the risk of culture loss of the when EDP's are placed into their new home, we define a function $C(t)$ which returns the number of people practicing the culture. To achieve this, first we define the function $P(t)$, which calculates the growth of the new population over time:

$$P(t) = [P_0 e^{rt} + P_n(t)e^{rt}]$$

Where $P_0$ is the initial population of the new community, $P_n(t)$ is the total amount EDP's moved in after $t$ years, and $r$ is the population growth rate.

Next, we define the function $C_L(t)$, which is the number of people in the current population who do not practice the communities culture. This is shown as:

$$C_L(t) = (P_0 e^{rt} + P_n(t)e^{rt})C$$

Where $C$ is the culture loss per year. Using $P(t)$ and $C_L(t)$, we can define $C(t)$ as:

$$C(t) = P(t) - C_L(t) \tag{3}$$

# 4 Model Implementation and Results

## 4.1 Climate Change Data and Results

For this analysis, GMSL was forecasted out through 2090 under the three seperate RCP scenarios.

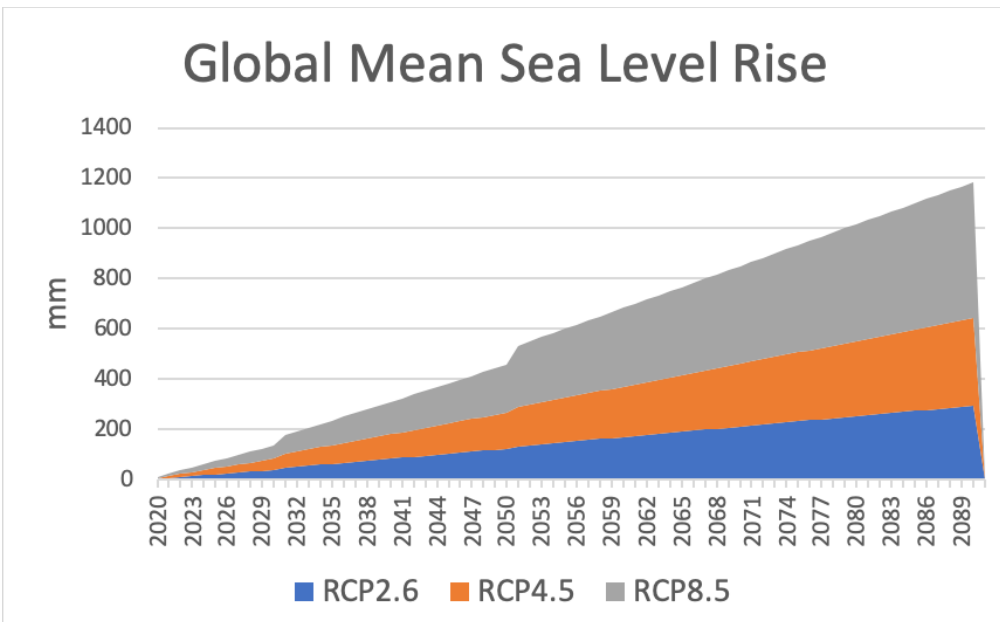


Figure 2: Global Mean Sea Level Rise

Clearly, the amount of GMSL rise varies significantly depending on which RCP takes place over the next 70 years. It is unlikely that we will experience a situation as drastic as RCP 4.5 or RCP 8.5. [20]

## 4.2 Island Change Results

For all islands, we have decided to model the sea level change based on the RCP 2.6 path. This is the path of choice because, as seen in the previous section, it is the most likely. Additionally, in the Paris climate agreement, the goal is to reach RCP 1.5; thus modeling based on the closest path will provide results closer to what may be in the future.

Using height map data collected online [10], then adjusted to fit the shape and scale of the island, we produce 4 initial island plots for Maldives, Tuvalu, Kiribati, and the Marshall islands, as seen in figure 3.

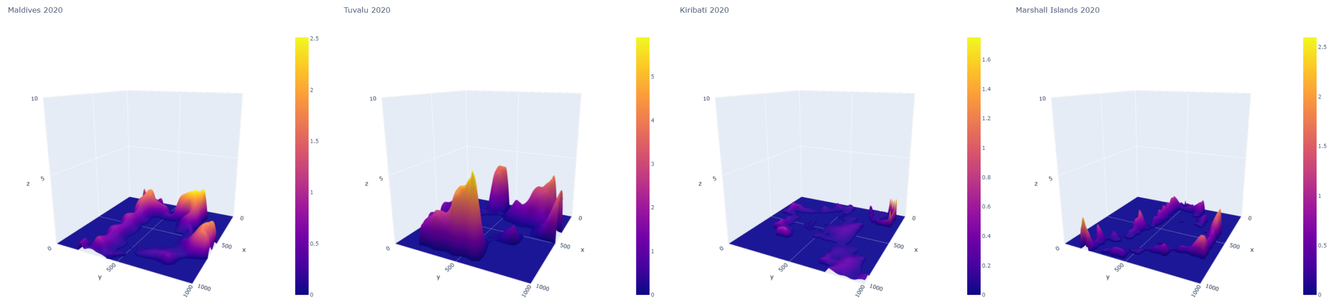


Figure 3: 2020 models of each island

In figure 4, a comparison of the landmass loss over time is made between each RCP value for every island. Refer to appendix A.2 for exact values of land mass percentages for all RCP values and appendix A.3.

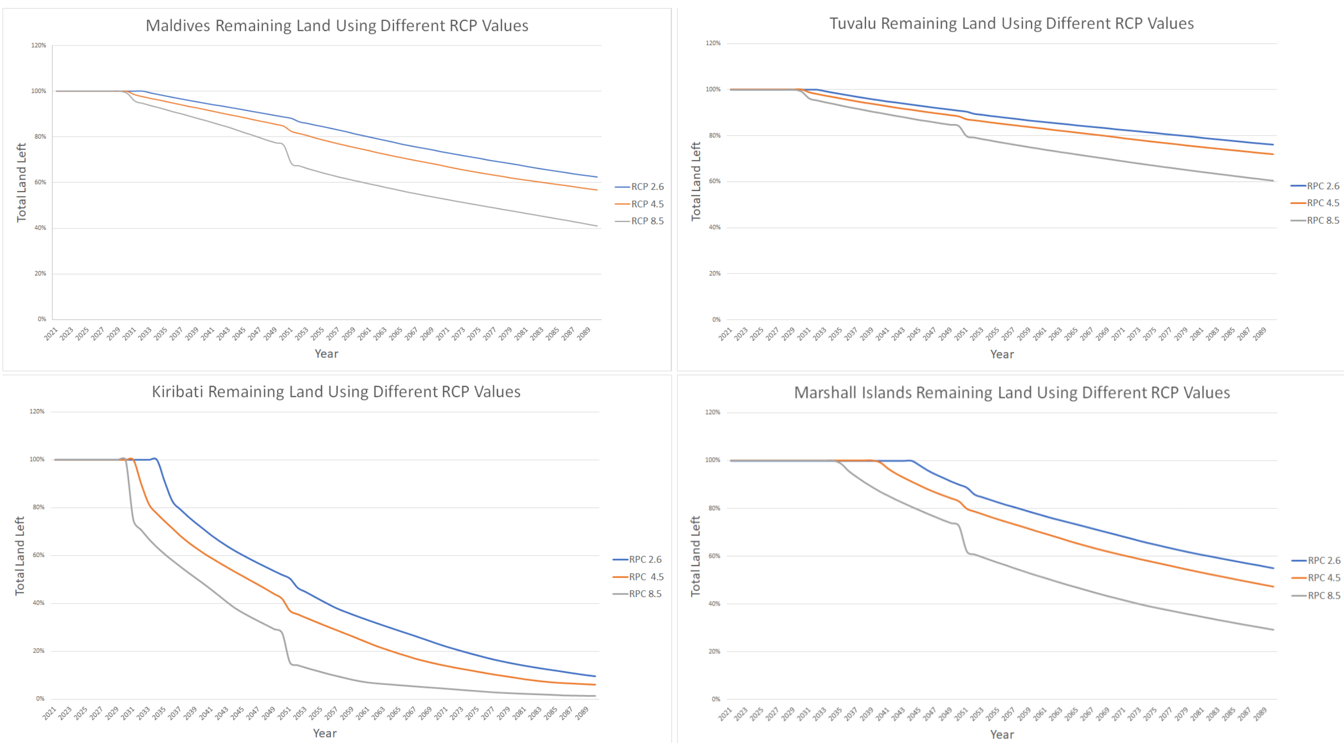


Figure 4: Plots of land loss over time comparison of RCP

#### 4.2.1 Maldives

For the RCP 2.6 path of the Maldives, the results show that the island will start submersion by 2033, losing its first percent of land; which is equal to 1.2 square miles of land. The island then proceeds to lose about 1% of land every year, displacing a total average amount of 2059 people. By the year 2090, 40% of the island will be submerged, creating a total of 350,052 EDP's. Additionally, with the rising sea levels, comes rising risk of tsunamis and storm surge affecting the island. From

2020 through 2090, an average of 41% of the remaining island will be at high risk of storm surge and tsunamis. Based on assumption 6, this means 41% of the remaining population in 2090 will be at risk. This equates to, out of the remaining 525,078 people not displaced, 215,282 people are at high risk of tsunami and storm surges. The process of the sea level rising can be seen in figure 5.

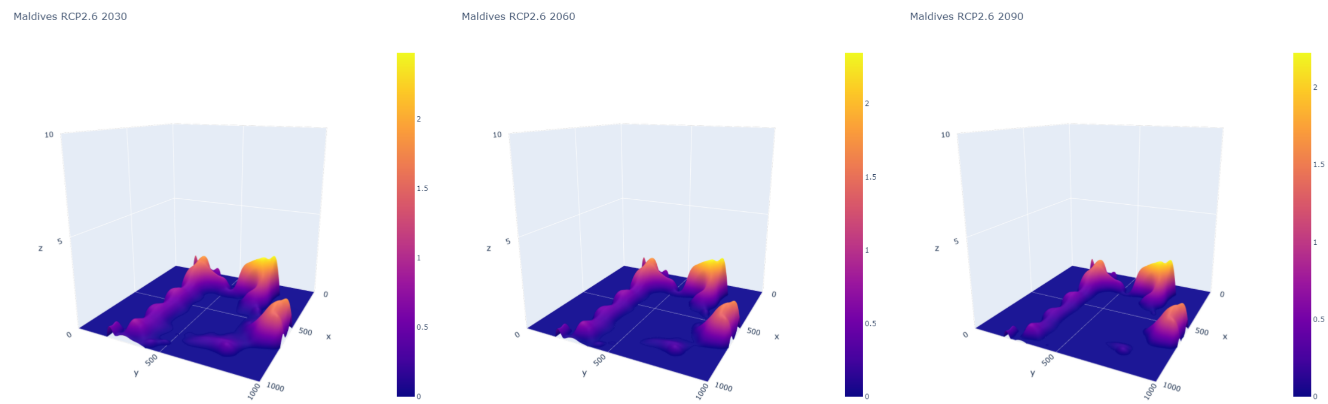


Figure 5: Models of the Maldives every 30 years for RCP 2.6

#### 4.2.2 Tuvalu

For the RCP 2.6 path of Tuvalu, the results show that the island will start submersion by 2033, losing 0.67% of land; this is 0.067 square miles of land, and will displace an estimated 83 people. The island will then lose about 0.67% of land every year, displacing an average amount of 83 more people yearly. By the year 2090, 24.23% of the island will be submerged, displacing a total of 3030 people. Additionally, from 2020 through 2090, an average of 25% of the island that year will be at high risk of storm surges and tsunamis. Based on assumption 6, this means 25% of the remaining population in 2090 will be at risk. This equates to, out of the remaining 14,825 people not displaced, 3706 people that are at high risk. The process of the sea level rising can be seen in figure 6.

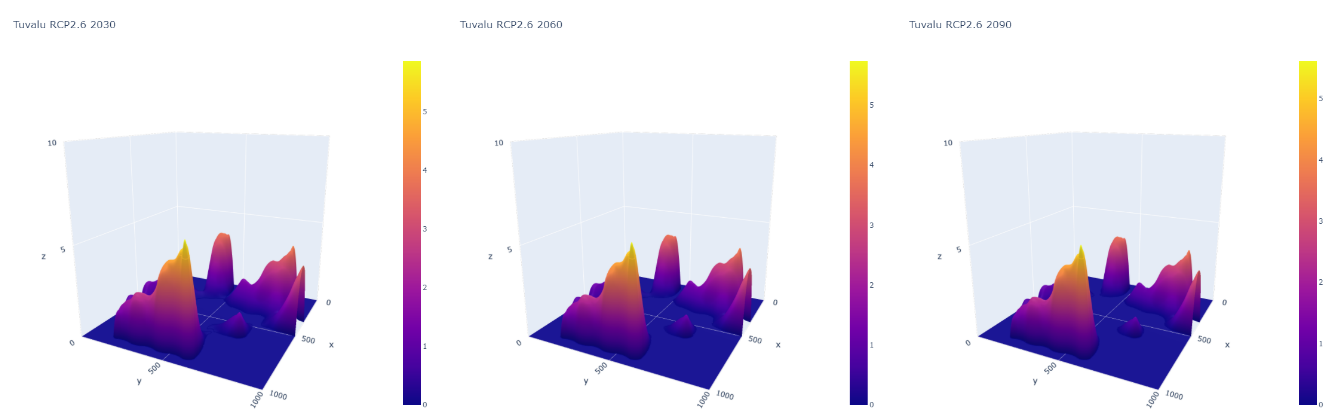


Figure 6: Models of Tuvalu every 30 years for RCP 2.6

### 4.2.3 Kiribati

For the RCP 2.6 path of Kiribati, the results show that the island will start submersion by 2035, losing 0.17% of land; this is effectively 0.53 square miles of land, displacing 222 people. Due to the shape of the island, it then proceeds to rapidly lose land each year. By the year 2090, 90.77% of the island will be submerged, displacing a total of 198,137 people. Additionally, from 2020 through 2090, an average of 93% of the island in that year will be at high risk of storm surge and tsunamis. This means 93% of the remaining population in 2090 will be at risk. This equates to, out of the remaining 19877 people not displaced, there are 18,486 people that are at high risk. The process of the sea level rising can be seen in figure 7.

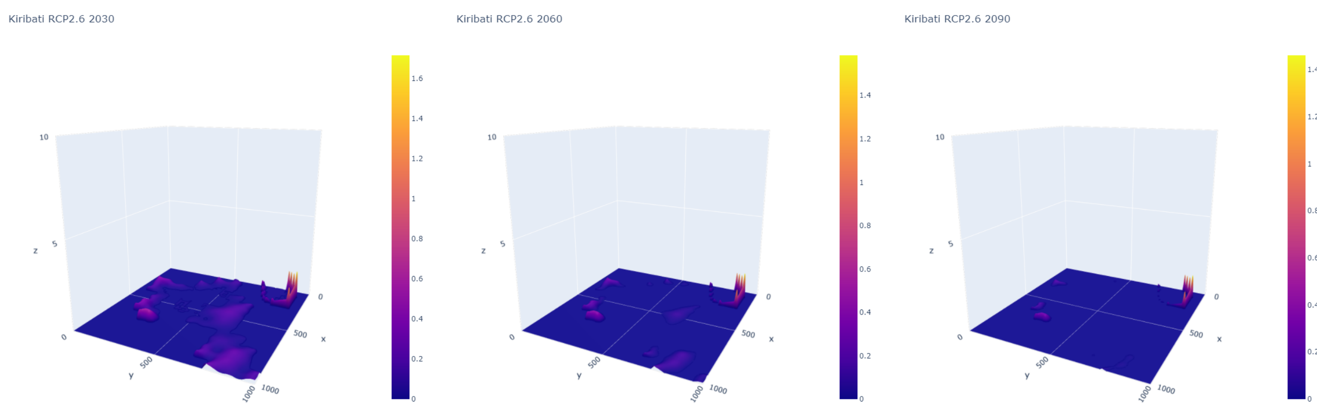


Figure 7: Models of Kiribati every 30 years for RCP 2.6

### 4.2.4 Marshall Islands

For the RCP 2.6 path of the Marshall Islands, the results show that the island will start submersion by 2045, losing 2% of land; this is 1.4 square miles of land, which will displace 1558 people. Each following year, the Marshall islands lose around 1% of land, displacing 897 people on average yearly. By the year 2090, 54.35% of the island will be submerged, displacing a total of 95,533 people. Additionally, from 2020 through 2090, an average of 54% of the island in that year will be at high risk of storm surges and tsunamis. This means 54% of the remaining population in 2090 will be at risk. This equates to, out of the remaining 80,761 people not displaced, 43,611 people that are at high risk of storm surges and tsunamis. The process of the sea level rising can be seen in figure 8.

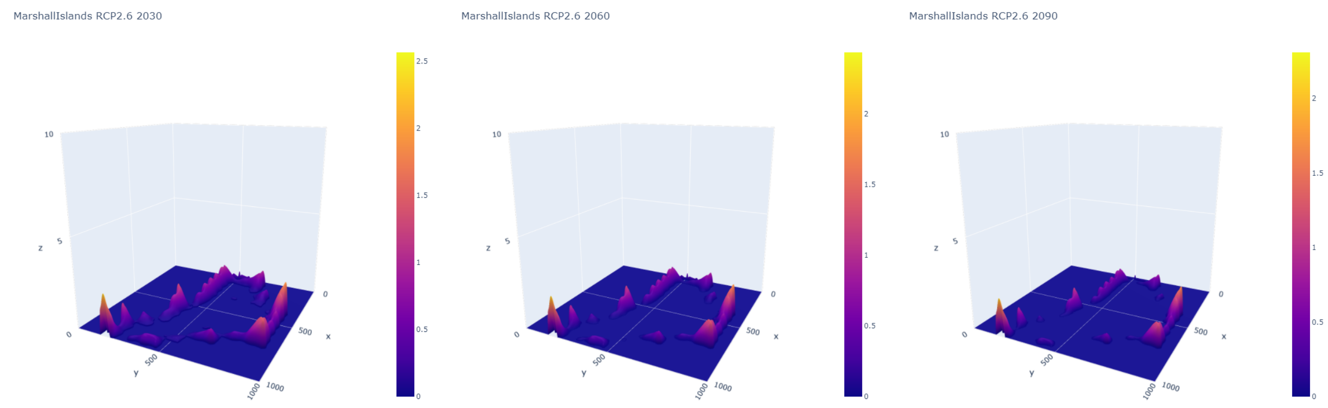


Figure 8: Models of the Marshall Islands every 30 years for RCP 2.6

## 4.3 Selecting Homes

For the 4 islands, careful consideration went into making sure that the final location of these cultures would preserve their people's customs and lively-hoods.This includes similar religions, climate, population density, and estimated willingness of the host country's population to welcome and assimilate the incoming displaced peoples. in figure 9, a visual of the potential host location can be seen.

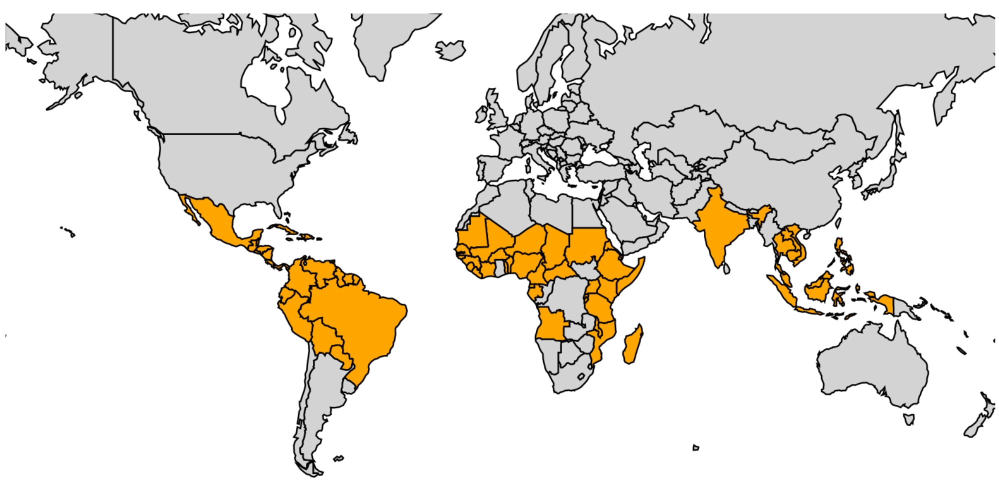

Figure 9: Options of tropical locations as host countries [11]

### 4.3.1 Maldives

The Maldives is a hot, tropical island country that, by law, practices Islam. So the host(s) that take in these people must be in the same climate and have a large practicing Muslim population. Due to the high population of the Maldives (472,639 people by 2033), the population will be split among two host countries, Malaysia and Indonesia.

Malaysia is the first choice as it satisfies both the climate requirement, and has a 61% Muslim population (as well as being the official religion). Malaysia's population density is 238 people per square mile, which is far lower than the current population density of the Maldives at 2,855. This means that the Maldivian people will experience far less overcrowding issues, such as traffic, as a result.

The second country is Indonesia. Indonesia is also a hot, tropical country and the primary religion of the area is Islam, with 87.2% of the population practicing the religion. Similarly to Malaysia, the population density of Indonesia is small, compared to the rest of the world, at 357 people per square mile; However, due to the Maldivian population density, this is an improvement from their current living space.

Both host countries selected would be a good fit for the Maldivian people as they are also in the same area of the world. There is plenty of coastal area, and there wont be any large cultural barriers that may create problems between the native people and the Maldivians. Additionally, all three countries are part of the Organisation of Islamic Cooperation, which is an organization dedicated to "safeguard and protect the interests of the Muslim world in the spirit of promoting international peace and harmony among various people of the world." We believe this will greatly influence Malaysia and Indonesia when taking in and supporting the Maldivians. [8]

#### 4.3.2 Tuvalu

The host country selected to take in Tuvalu will be the French Guiana. The French Guiana is a department of France that is located on the north eastern coast of South America. Tuvalu is a part of a group called the South Pacific Community (SPC), which serves as a support group for South Pacific countries, similar to the aforementioned Organisation of Islamic Cooperation. This support group also covers assistance due to environmental disasters. Because of this, any country in the SPC can be a good potential host. France is a member of the SPC, thus having the French Guiana hosting Tuvalu is a great match. The French Guiana is located in a tropical area on the coast, which will allow for the Tuvalu people to maintain customs and lifestyles similar to what they had on their home island. French Guiana's top two religious beliefs are Christian and no-religious, which is perfect for Tuvalu, as its people primarily practice Christianity.

#### 4.3.3 Kiribati

The host country selected to take in Kiribati will be Papua New Guinea (PNG). PNG is a close island neighbor to Kiribati, so they both share similar tropical climates. PNG is also extremely diverse with many different cultures, so it is expected that the people will have no problem accepting one more. Since PNG is a large island country, there is abundant coastline to help maintain the island culture and customs of the Kiribati people. Like Tuvalu, Kiribati is a part of the SPC and since PNG is also a part of the SPC, there is added incentive for the PNG government to accept the Kiribati people. PNG's top two religious beliefs are Roman Catholic or different forms of Christianity, which will not have any compatibility issues with Kiribati's Christian beliefs.

#### 4.3.4 Marshall Islands

The last nation to place into a host nation are the Marshall Islands. The Marshall Islands are in the same tropical region as Kiribati and Tuvalu, but has a past of business with the United States. The Marshall Islands declared Independence from the US in 1976, but remained an associated state that has access to services provided by the US. In addition, both the US and the Marshall Islands are a part of the SPC as well. All of these reasons mean that the US is a great fit to host the Marshallese people.

The Marshall Islands is also primarily Christian, which the United States shares as a primary religion. In regards to which state the Marshallese should be sent to, Florida has a similar climate and plenty of coastal areas to allow for the people of the Marshall Islands to continue their island customs. Lastly, the land size of the US can support the size of the Marshall Island people, as it is no larger than the size of many American cities.

## 4.4 Financial Impact

### 4.4.1 Cash Outflow

It is estimated that in order to relocate all the people of Tuvalu, Kiribati, The Marshall Islands and The Maldives would cost approximately $138B in total. While this is a very large amount, it is roughly twenty percent of the US Defense budget this year. The largest CO2 emitter is China, who will have to pay just over $20B over the first 10 years, or roughly $3B per year for the first three years and $2B per year in the second five years. On average, a country will owe approximately $330M over the ten years, which results in roughly $47.5M payments for the first five years and $19.1M payments for the second five years.

### 4.4.2 Cash Inflows

For this framework, the outflows the countries paid in the beginning is recognized as cash inflows:

1. To host countries when EDP communities are built.
2. To host countries when the host government receives their stipend.
3. To EDPs when they are supplied the host country's minimum wage.

The amount of money that goes to schools is considered the investment into education that produces the return on investment. Money that goes towards construction or directly to the EDPs is multiplied by the investment multiplier 3.6.4 to calculate the economic return to the economy as a whole.

As can be seen in the figures below, investments into education had the greatest returns.

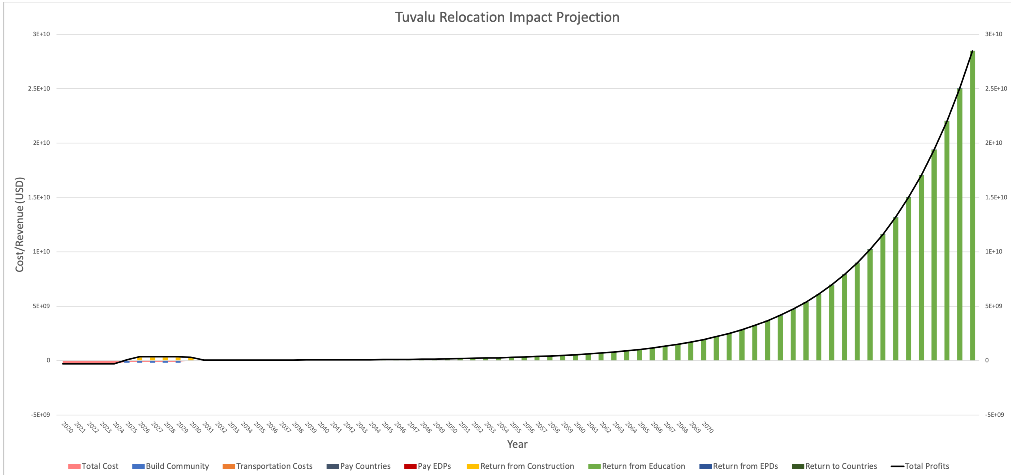


Figure 10: Tuvalu

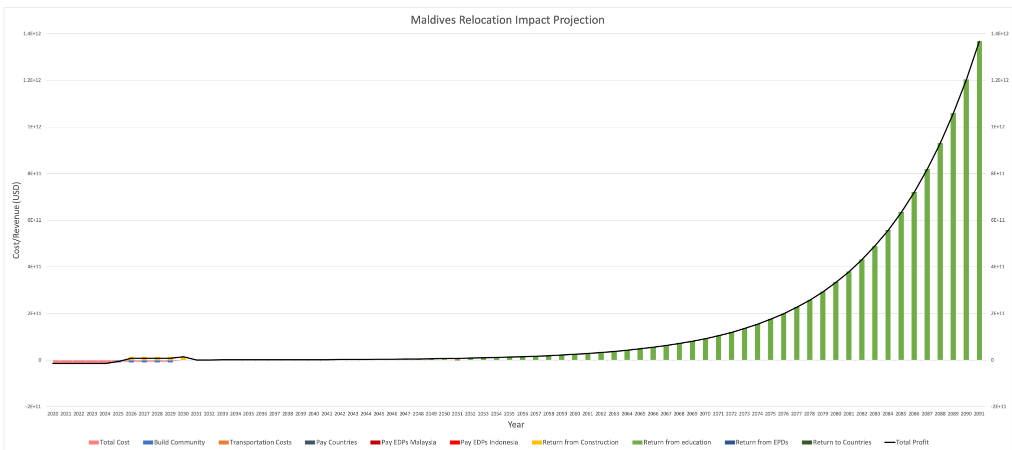


Figure 11: Maldives

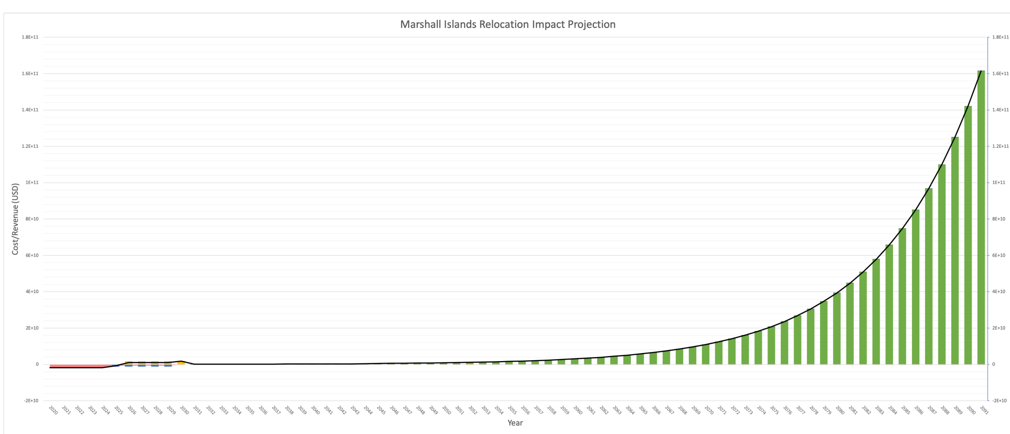


Figure 12: Marshall Islands

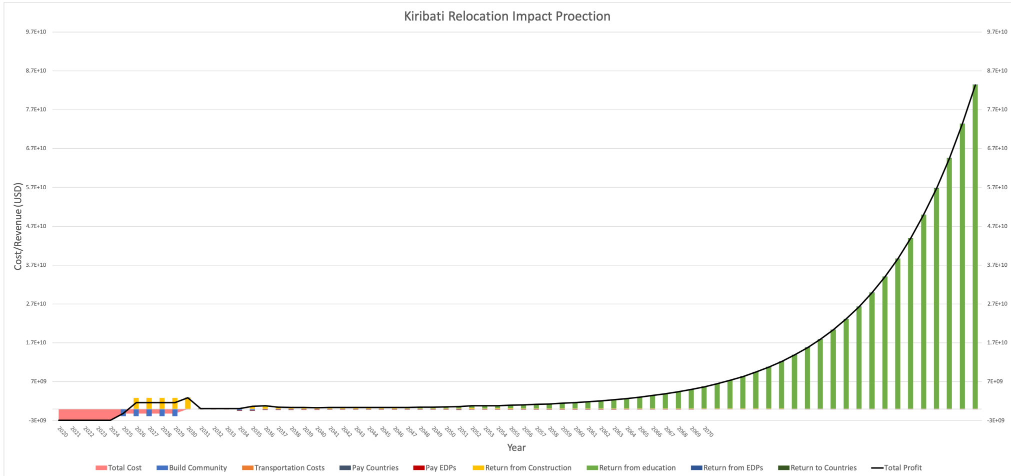


Figure 13: Kiribati

Also, it is clear that for every country net profits are positive, which is of high importance because if this endeavour was not profitable it would likely not occur and thousands of EDPs and society would lose all the potential economic gains these EDPs have to offer society. Also, it can be seen on each graph that by 2090, the profits from this model are well into the tens of billions of dollars, some countries into the hundred of billions. This highlights the importance of well thought out planning and execution of those plans so that this economic benefit shown in these graphs is realized in the future, not wasted away because world leaders failed to appropriately plan ahead.

More importantly, each of the four countries showed to have positive and very desirable IRRs that would be attractive for any investor.

| IRR by Country | | | |
|---|---|---|---|
| Maldives | Kiribati | Tuvalu | Marshall Island |
| 0.11 | 0.1 | 0.1 | 0.09 |

Figure 14: IRR

## 4.5 Culture Risk, Maintenance, and Results

Once the people of the islands are moved to their new homes, there is the risk of culture loss in the community. The model shown in section 3.7 was able to provide total population of people who still practice the culture. The culture loss value, $C$, (defined in section 3.7) will be 1.5%. Culture loss or "assimilation" is said to happen after 3 to 4 generations after a family immigrates to a new culture [16]. Since this community will have the goal of preserving the culture, the rate of culture loss should be much lower.

To begin, the Maldives will be relocated to Malaysia and Indonesia, and the model predicted that by 2090 the total population practicing their original culture (culture population) will be 1,478,390. This number makes sense, since as the people move to areas with a smaller population density, the population capacity becomes much higher. The predicted population of Maldivian people in the new community grew to 1,499,381 people. Therefore, there was a total of 20,991 people who have assimilated into the culture of their host country.

For the Tuvalu community in French Guiana, the model predicted that by 2090 the total culture population will be 20,394. The population from Tuvalu is relatively small compared to the Maldives, so smaller growth makes sense. The predicted population of the Tuvalu people in the new community grew to 20,705 people. Therefore, there was a total of 311 people who have adopted the French Guiana culture.

For the Kiribati community in Papua New Guinea, the model predicted that by 2090 the total culture population will be 228,018. The predicted population of the Kiribati people in the new community grew to 231,491 people. Therefore, there was a total of 3473 people who have adopted the culture of PNG.

For the last island community, the Marshall island people in the United States, the model predicted that by 2090 the total culture population will be 171,962. The predicted population of the Kiribati people in the new community grew to 174,580 people. Therefore, there was a total of 2618 people who have adopted the culture of the US.

# 5 Sensitivity Analysis

## 5.1 RCP Selection

In order to analyze the sensitivity of our model, the most conservative and most extreme possible climate scenarios plausible [20] were tested and the internal rate of return was computed for each island-nation under the extreme situations.

| IRR by Country and Extreme Climate Scenario | | | | |
|---|---|---|---|---|
| | Maldives | Kiribati | Tuvalu | Marshall Island |
| Low | 9% | 9% | 12% | 10% |
| High | 10% | 14% | 12% | 10% |

Figure 15: IRR 2

As can be seen in 15, the IRR generated from this model under extreme climate conditions are very similar for all four island-nations tested in our analysis. This is important, because it indicates that this is a profitable model to follow whether global warming increases or decreases in the coming decades.

# 6 Culture Model Error

In order to test and see if the Culture population model yields useful results, we chose to apply the model to a similar situation in the past. Since the model is predicting the growth of a groups culture when placed in a community that promotes the continuation of culture, we chose to model the culture growth of the Navajo Native American tribe. Making the assumption that people who live on a reservation practices the culture of their people, we are able to get the actual population of people who practice native culture after a defined amount of time.

In the 1890's the population of the Navajo reservation was counted to be 250,000 people, after 60 years in the 1950's, the population grew to 380,000 people. Using the same culture loss rate of 1.5% as the island communities, with the initial population of 250,000, over 60 years, the culture model results in 375,163 people living on the reservation. This result is a 1.273% error from the actual value after 60 years, which is the same time interval used when calculating the island communities cultural population.

# 7 Strengths and Weaknesses

## 7.1 Strengths

1. Our model establishes an an economic framework that incentivizes host countries to accept EDPs and provides desirable returns to both the host country and the EDPs across a wide range of potential climate change scenarios.

2. We fully simulate a 3-D model of all 4 islands that use forecasted rising sea level data to simulate the land submerged per year.

3. Our culture survival model simulates the loss of culture of an EDP population over time based on similar phenomena in history with a calculated accuracy of 98.727%.

## 7.2 Weaknesses

1. As is expected with extended forecasts, the credibility of our sea level rise estimates accuracy is low. We cannot know what future events will occur that will potentially change GMSL trajectory over the coming decades.

2. Normally investment in education doesn't show a return until about 10 years in the future as it takes time to go through the system; however, to simplify our model we assumed the return would start immediately which offsets cash flow timings, but not IRRs or aggregate totals.

# 8 Conclusion

There is no question that there will be many people in the coming decades who are displaced due to Global Warming. This paper focuses on the relocation of island-nation people who are at risk of losing their island, but there are many millions of more people who are also at risk of becoming EDPs due to desertification and other consequences of Global Warming. Although it is too late stop that, policy makers around the globe do have the chance to plan for it so that the ramifications are not as devastating when they occur. Our model gives sound framework for how policy might be crafted, implemented and evaluated to help ease the burden EDPs from shrinking island-nations will face in the coming decades and highlights the very desirable economic return of such policy.

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# A Appendix

## A.1 GMSL Forecast

| Year | RCP2.6 | RCP4.5 | RCP8.5 |
|---|---|---|---|
| 2020 | 3.4734 | 4.0353 | 4.7992 |
| 2025 | 20.8404 | 24.2118 | 28.7952 |
| 2030 | 38.2074 | 44.3883 | 52.7912 |
| 2035 | 63.412 | 74.148 | 98.04 |
| 2040 | 83.22825 | 97.31925 | 128.6775 |
| 2045 | 103.0445 | 120.4905 | 159.315 |
| 2050 | 122.86075 | 143.66175 | 189.9525 |
| 2055 | 149.202 | 176.184 | 274.536 |
| 2060 | 169.9245 | 200.654 | 312.666 |
| 2065 | 190.647 | 225.124 | 350.796 |
| 2070 | 211.3695 | 249.594 | 388.926 |
| 2075 | 232.092 | 274.064 | 427.056 |
| 2080 | 252.8145 | 298.534 | 465.186 |
| 2085 | 273.537 | 323.004 | 503.316 |
| 2090 | 294.2595 | 347.474 | 541.446 |

Figure 16: GMSL

## A.2 Island Submersion Model Results

| Year | Maldives % land | Tuvalu % land | Kiribati % land | Marshall Islands % land |
|---|---|---|---|---|
| 2030 | 100 | 100 | 100 | 100 |
| 2031 | 100 | 100 | 100 | 100 |
| 2032 | 100 | 100 | 100 | 100 |
| 2033 | 99.23306159 | 99.33315654 | 100 | 100 |
| 2034 | 98.53226418 | 98.71437885 | 100 | 100 |
| 2035 | 97.84682536 | 98.10720324 | 90.83338031 | 100 |
| 2036 | 97.17600196 | 97.52765163 | 82.6232981 | 100 |
| 2037 | 96.54159328 | 96.93926034 | 79.29499865 | 100 |
| 2038 | 95.90099162 | 96.3884377 | 76.26902913 | 100 |
| 2039 | 95.29209801 | 95.8586093 | 73.55073001 | 100 |
| 2040 | 94.67007528 | 95.34425034 | 70.98048058 | 100 |
| 2041 | 94.05573185 | 94.83569242 | 68.37996849 | 100 |
| 2042 | 93.56995464 | 94.45337621 | 66.05478729 | 100 |
| 2043 | 92.95784068 | 93.96443133 | 63.92690677 | 100 |
| 2044 | 92.36207618 | 93.50228174 | 61.93491154 | 100 |
| 2045 | 91.74476012 | 93.03156871 | 60.15445825 | 98.09796937 |
| 2046 | 91.1395823 | 92.5768776 | 58.41821219 | 96.02806504 |
| 2047 | 90.52523886 | 92.12052905 | 56.73329397 | 94.34125712 |
| 2048 | 89.91907016 | 91.69650059 | 55.13174642 | 92.8583727 |
| 2049 | 89.30026778 | 91.28241677 | 53.51625431 | 91.35880853 |
| 2050 | 88.69682399 | 90.84540502 | 51.98175933 | 90.03196057 |
| 2051 | 88.06860829 | 90.43325488 | 50.41729838 | 88.74654299 |
| 2052 | 86.55479671 | 89.4716633 | 46.55109494 | 85.84157457 |
| 2053 | 85.91419505 | 89.07802124 | 44.87418743 | 84.7251068 |
| 2054 | 85.15022926 | 88.59708733 | 43.08364659 | 83.63554188 |
| 2055 | 84.48188306 | 88.20620767 | 41.30794039 | 82.55512391 |
| 2056 | 83.74739585 | 87.80179225 | 39.59186943 | 81.51882661 |
| 2057 | 83.0032476 | 87.40455907 | 37.98053102 | 80.61758154 |
| 2058 | 82.2598425 | 87.00235357 | 36.65698459 | 79.62486683 |
| 2059 | 81.37969644 | 86.57086662 | 35.40642459 | 78.65152216 |
| 2060 | 80.63455731 | 86.22501409 | 34.21906014 | 77.69593337 |
| 2061 | 79.90329045 | 85.88330516 | 33.04148655 | 76.75164376 |
| 2062 | 79.15121519 | 85.54325367 | 31.91820774 | 75.81757724 |
| 2063 | 78.40458974 | 85.20182097 | 30.78691822 | 74.98789372 |
| 2064 | 77.68892918 | 84.8639794 | 29.69182522 | 74.14314462 |
| 2065 | 76.85287713 | 84.47088982 | 28.59287522 | 73.31184693 |
| 2066 | 76.1867604 | 84.13581065 | 27.51825402 | 72.46064115 |
| 2067 | 75.53947033 | 83.81122861 | 26.44808322 | 71.57984224 |
| 2068 | 74.92116339 | 83.49714368 | 25.31174992 | 70.71303281 |
| 2069 | 74.3060768 | 83.16151203 | 24.19796528 | 69.8795829 |

Table 1: RCP 2.6 Results for land percentage over time

| Year | Maldives % land | Tuvalu % land | Kiribati % land | Marshall Islands % land |
|---|---|---|---|---|
| 2070 | 73.57902116 | 82.77284229 | 23.06044522 | 69.02514877 |
| 2071 | 72.96987983 | 82.45240384 | 22.00748259 | 68.15780128 |
| 2072 | 72.36123394 | 82.13500403 | 21.03492371 | 67.30551939 |
| 2073 | 71.76001962 | 81.81788047 | 20.11843975 | 66.40642655 |
| 2074 | 71.16945722 | 81.47976265 | 19.18741785 | 65.58750417 |
| 2075 | 70.5979692 | 81.16346781 | 18.33739308 | 64.85843727 |
| 2076 | 69.9167416 | 80.76927327 | 17.47550059 | 64.06534161 |
| 2077 | 69.36061216 | 80.43778522 | 16.66879296 | 63.32174718 |
| 2078 | 68.83148411 | 80.11126949 | 15.95940056 | 62.57600052 |
| 2079 | 68.28303396 | 79.77315168 | 15.27404027 | 61.85984698 |
| 2080 | 67.73582242 | 79.43917747 | 14.6578094 | 61.18135741 |
| 2081 | 67.07961445 | 79.01542524 | 14.05581978 | 60.51631926 |
| 2082 | 66.50168573 | 78.67316383 | 13.50842162 | 59.92069043 |
| 2083 | 65.94506085 | 78.35244914 | 12.9722978 | 59.27986484 |
| 2084 | 65.4198963 | 78.02234229 | 12.47652418 | 58.64872427 |
| 2085 | 64.89572263 | 77.6850532 | 12.00122237 | 58.02350232 |
| 2086 | 64.39929351 | 77.36268108 | 11.50544876 | 57.41011762 |
| 2087 | 63.83300758 | 76.98285102 | 10.9992909 | 56.7832815 |
| 2088 | 63.35540511 | 76.67981569 | 10.52161555 | 56.24038224 |
| 2089 | 62.92164892 | 76.37595165 | 10.0561046 | 55.59040968 |
| 2090 | 62.45544152 | 76.07650744 | 9.664173458 | 54.97218247 |

Table 2: RCP 2.6 Results for land percentage over time (cont.)

| Year | Maldives % land | Tuvalu % land | Kiribati % land | Marshall Islands % land |
|---|---|---|---|---|
| 2030 | 100 | 100 | 100 | 100 |
| 2031 | 98.53226418 | 98.71437885 | 100 | 100 |
| 2032 | 97.70513002 | 97.98593386 | 89.89494109 | 100 |
| 2033 | 96.91540144 | 97.29864863 | 81.39350658 | 100 |
| 2034 | 96.28396539 | 96.7072187 | 77.55786251 | 100 |
| 2035 | 95.53065153 | 96.06578933 | 74.34022946 | 100 |
| 2036 | 94.79269625 | 95.44507795 | 71.32523758 | 100 |
| 2037 | 94.05573185 | 94.83569242 | 68.23933612 | 100 |
| 2038 | 93.31851973 | 94.26332306 | 65.54269557 | 100 |
| 2039 | 92.72225979 | 93.78238914 | 63.18161454 | 100 |
| 2040 | 91.98727715 | 93.2232793 | 60.91636528 | 99.13695697 |
| 2041 | 91.2587352 | 92.66389322 | 58.89440408 | 96.53975701 |
| 2042 | 90.52523886 | 92.12052905 | 56.94246237 | 94.4870705 |
| 2043 | 89.79966954 | 91.61915338 | 55.0136627 | 92.74322856 |
| 2044 | 89.18185804 | 91.19263876 | 53.15695937 | 91.12044939 |
| 2045 | 88.44588452 | 90.6782798 | 51.35188059 | 89.55470423 |
| 2046 | 87.6982682 | 90.19099236 | 49.51831929 | 88.01155746 |
| 2047 | 86.94817468 | 89.71088717 | 47.73222885 | 86.63574634 |
| 2048 | 86.30930706 | 89.30067071 | 45.85802064 | 85.37400325 |
| 2049 | 85.53419391 | 88.8432172 | 43.92773751 | 84.19458284 |
| 2050 | 84.74446534 | 88.35510105 | 41.89984246 | 82.90701303 |
| 2051 | 82.40822626 | 87.08163446 | 36.90650321 | 79.80134945 |
| 2052 | 81.52337354 | 86.64793759 | 35.4346104 | 78.65152216 |
| 2053 | 80.63455731 | 86.22501409 | 34.04905518 | 77.55065804 |
| 2054 | 79.59537558 | 85.74850002 | 32.68812547 | 76.42665748 |
| 2055 | 78.69764147 | 85.33579739 | 31.35508487 | 75.35915288 |
| 2056 | 77.82542242 | 84.93359189 | 30.04251607 | 74.35890538 |
| 2057 | 76.98466371 | 84.53967359 | 28.7575397 | 73.36726678 |
| 2058 | 76.1867604 | 84.13581065 | 27.46484932 | 72.3890796 |
| 2059 | 75.41139954 | 83.74299731 | 26.18907043 | 71.3613912 |
| 2060 | 74.67171023 | 83.36178606 | 24.85157944 | 70.32025138 |
| 2061 | 73.92483706 | 82.97201136 | 23.51764877 | 69.3856468 |
| 2062 | 73.08754642 | 82.51345289 | 22.2326724 | 68.37517621 |
| 2063 | 72.36123394 | 82.13500403 | 21.08298793 | 67.38515179 |
| 2064 | 71.6393804 | 81.74826797 | 19.98611478 | 66.33002249 |
| 2065 | 70.94155563 | 81.3510348 | 18.90615311 | 65.37927621 |
| 2066 | 70.24298769 | 80.96650866 | 17.90896873 | 64.46404167 |
| 2067 | 69.58479797 | 80.57231412 | 16.90199348 | 63.55795409 |
| 2068 | 68.93874649 | 80.18613054 | 16.04069438 | 62.68684021 |
| 2069 | 68.28303396 | 79.77315168 | 15.25920563 | 61.85984698 |

Table 3: RCP 4.5 Results for land percentage over time

| Year | Maldives % land | Tuvalu % land | Kiribati % land | Marshall Islands % land |
|---|---|---|---|---|
| 2070 | 67.63103722 | 79.3662501 | 14.51866049 | 61.07051772 |
| 2071 | 66.84750163 | 78.88034386 | 13.84279437 | 60.29087348 |
| 2072 | 66.16726491 | 78.47813836 | 13.1936306 | 59.55427378 |
| 2073 | 65.52369062 | 78.08477254 | 12.59846491 | 58.78431457 |
| 2074 | 64.89572263 | 77.6850532 | 12.02673795 | 58.07784605 |
| 2075 | 64.30218761 | 77.29665971 | 11.43869289 | 57.35954028 |
| 2076 | 63.73813116 | 76.92787925 | 10.85658168 | 56.62724504 |
| 2077 | 63.17506558 | 76.56517608 | 10.29019519 | 55.93046155 |
| 2078 | 62.63801052 | 76.19584314 | 9.797091818 | 55.19278574 |
| 2079 | 62.02441024 | 75.77098596 | 9.300131435 | 54.4567241 |
| 2080 | 61.51980638 | 75.4201611 | 8.798720661 | 53.77339202 |
| 2081 | 61.03898356 | 75.07099369 | 8.270014152 | 53.08091297 |
| 2082 | 60.56584003 | 74.72072132 | 7.857611208 | 52.41641288 |
| 2083 | 60.09244878 | 74.36381918 | 7.463603215 | 51.76213587 |
| 2084 | 59.60865332 | 74.01299433 | 7.141691564 | 51.12023416 |
| 2085 | 59.14517084 | 73.67432404 | 6.863097057 | 50.46595715 |
| 2086 | 58.68540414 | 73.35167567 | 6.665499675 | 49.79231009 |
| 2087 | 58.20458132 | 73.00941426 | 6.503802118 | 49.16655009 |
| 2088 | 57.66059012 | 72.63041292 | 6.327566615 | 48.53540951 |
| 2089 | 57.19388728 | 72.32433896 | 6.165572365 | 47.91180174 |
| 2090 | 56.75393811 | 72.00224307 | 6.002688036 | 47.28496562 |

Table 4: RCP 4.5 Results for land percentage over time (cont.)

| Year | Maldives % land | Tuvalu % land | Kiribati % land | Marshall Islands % land |
|---|---|---|---|---|
| 2030 | 99.10449536 | 99.20083756 | 100 | 100 |
| 2031 | 95.65327249 | 96.17131302 | 74.76271996 | 100 |
| 2032 | 94.67007528 | 95.34425034 | 70.70633647 | 100 |
| 2033 | 93.69356649 | 94.54729782 | 66.84488012 | 100 |
| 2034 | 92.84438532 | 93.88294052 | 63.53052524 | 100 |
| 2035 | 91.86440846 | 93.11996553 | 60.59386024 | 98.71512047 |
| 2036 | 90.89037686 | 92.39980774 | 57.94380046 | 95.53628117 |
| 2037 | 90.03896622 | 91.77771516 | 55.41419794 | 93.12686302 |
| 2038 | 89.06146655 | 91.1108717 | 52.917825 | 90.88047607 |
| 2039 | 88.06860829 | 90.43325488 | 50.5353821 | 88.85523045 |
| 2040 | 87.18350785 | 89.87221136 | 48.16955398 | 86.9397484 |
| 2041 | 86.17603417 | 89.22912454 | 45.66339019 | 85.27661498 |
| 2042 | 85.15022926 | 88.59708733 | 43.08364659 | 83.63554188 |
| 2043 | 84.18511555 | 88.04654092 | 40.47364033 | 82.12790685 |
| 2044 | 83.0032476 | 87.40455907 | 38.05440752 | 80.61758154 |
| 2045 | 81.8246 | 86.78246649 | 36.07813701 | 79.20625868 |
| 2046 | 80.78740001 | 86.29904642 | 34.29976057 | 77.77341354 |
| 2047 | 79.59537558 | 85.74850002 | 32.60712834 | 76.42665748 |
| 2048 | 78.40458974 | 85.20182097 | 30.95751656 | 75.05837916 |
| 2049 | 77.40529079 | 84.72558314 | 29.30019077 | 73.84559923 |
| 2050 | 76.32176733 | 84.20542314 | 27.69359945 | 72.60537842 |
| 2051 | 68.28303396 | 79.77315168 | 15.35800433 | 61.99113282 |
| 2052 | 67.30181851 | 79.15050662 | 14.2273082 | 60.73369419 |
| 2053 | 66.16726491 | 78.47813836 | 13.20371815 | 59.55427378 |
| 2054 | 65.21032592 | 77.89140451 | 12.27625657 | 58.38346229 |
| 2055 | 64.21077925 | 77.2345057 | 11.37787087 | 57.24762448 |
| 2056 | 63.35540511 | 76.67981569 | 10.48749588 | 56.18442433 |
| 2057 | 62.45544152 | 76.07650744 | 9.700666669 | 55.0189934 |
| 2058 | 61.6897417 | 75.5353532 | 8.913837454 | 53.92942848 |
| 2059 | 60.87449806 | 74.94861935 | 8.132645402 | 52.83555909 |
| 2060 | 60.16725995 | 74.42514447 | 7.510777365 | 51.81217515 |
| 2061 | 59.36787033 | 73.84725031 | 6.998685651 | 50.83344991 |
| 2062 | 58.68540414 | 73.35167567 | 6.661345976 | 49.79231009 |
| 2063 | 57.89369381 | 72.78151623 | 6.396992722 | 48.7931387 |
| 2064 | 57.19388728 | 72.32433896 | 6.145397257 | 47.81333735 |
| 2065 | 56.43338957 | 71.80390272 | 5.894395177 | 46.90832589 |
| 2066 | 55.68825043 | 71.27296936 | 5.633305543 | 45.961346 |
| 2067 | 55.06176876 | 70.80916233 | 5.38734724 | 45.02405114 |
| 2068 | 54.37236644 | 70.30419553 | 5.139905474 | 44.11419717 |
| 2069 | 53.77115212 | 69.81193578 | 4.900474412 | 43.21725656 |

Table 5: RCP 8.5 Results for land percentage over time

| Year | Maldives % land | Tuvalu % land | Kiribati % land | Marshall Islands % land |
|---|---|---|---|---|
| 2070 | 53.09983329 | 69.2912233 | 4.660153271 | 42.40909531 |
| 2071 | 52.50406879 | 68.79067635 | 4.420425517 | 41.571879 |
| 2072 | 51.84587907 | 68.27106883 | 4.165566431 | 40.74434771 |
| 2073 | 51.25903246 | 67.81803516 | 3.909223881 | 39.9345723 |
| 2074 | 50.63428482 | 67.3202506 | 3.657331723 | 39.16730337 |
| 2075 | 50.05982417 | 66.86113966 | 3.421757667 | 38.48773769 |
| 2076 | 49.42566321 | 66.37523342 | 3.169272124 | 37.81086229 |
| 2077 | 48.86185447 | 65.94954752 | 2.91352296 | 37.16465613 |
| 2078 | 48.23240018 | 65.47579585 | 2.735210607 | 36.4969277 |
| 2079 | 47.67354583 | 65.04127026 | 2.582710526 | 35.83511789 |
| 2080 | 47.08397431 | 64.57912067 | 2.435847607 | 35.2427174 |
| 2081 | 46.46665824 | 64.12304836 | 2.295808621 | 34.57391286 |
| 2082 | 45.90458355 | 63.7225003 | 2.172384431 | 33.95299536 |
| 2083 | 45.27958819 | 63.26477056 | 2.05756433 | 33.30571309 |
| 2084 | 44.70933876 | 62.87471962 | 1.933843447 | 32.71976928 |
| 2085 | 44.09573849 | 62.42389587 | 1.786980528 | 32.10961292 |
| 2086 | 43.53366379 | 62.01312693 | 1.631513519 | 31.49891851 |
| 2087 | 42.89207125 | 61.56893294 | 1.562384104 | 30.93342086 |
| 2088 | 42.29804079 | 61.19518016 | 1.507495943 | 30.36899932 |
| 2089 | 41.63167634 | 60.75789218 | 1.45142101 | 29.78359357 |
| 2090 | 41.00469923 | 60.36314516 | 1.397126234 | 29.20948702 |

Table 6: RCP 8.5 Results for land percentage over time (cont.)

## A.3 Alternative Island Submersion Results

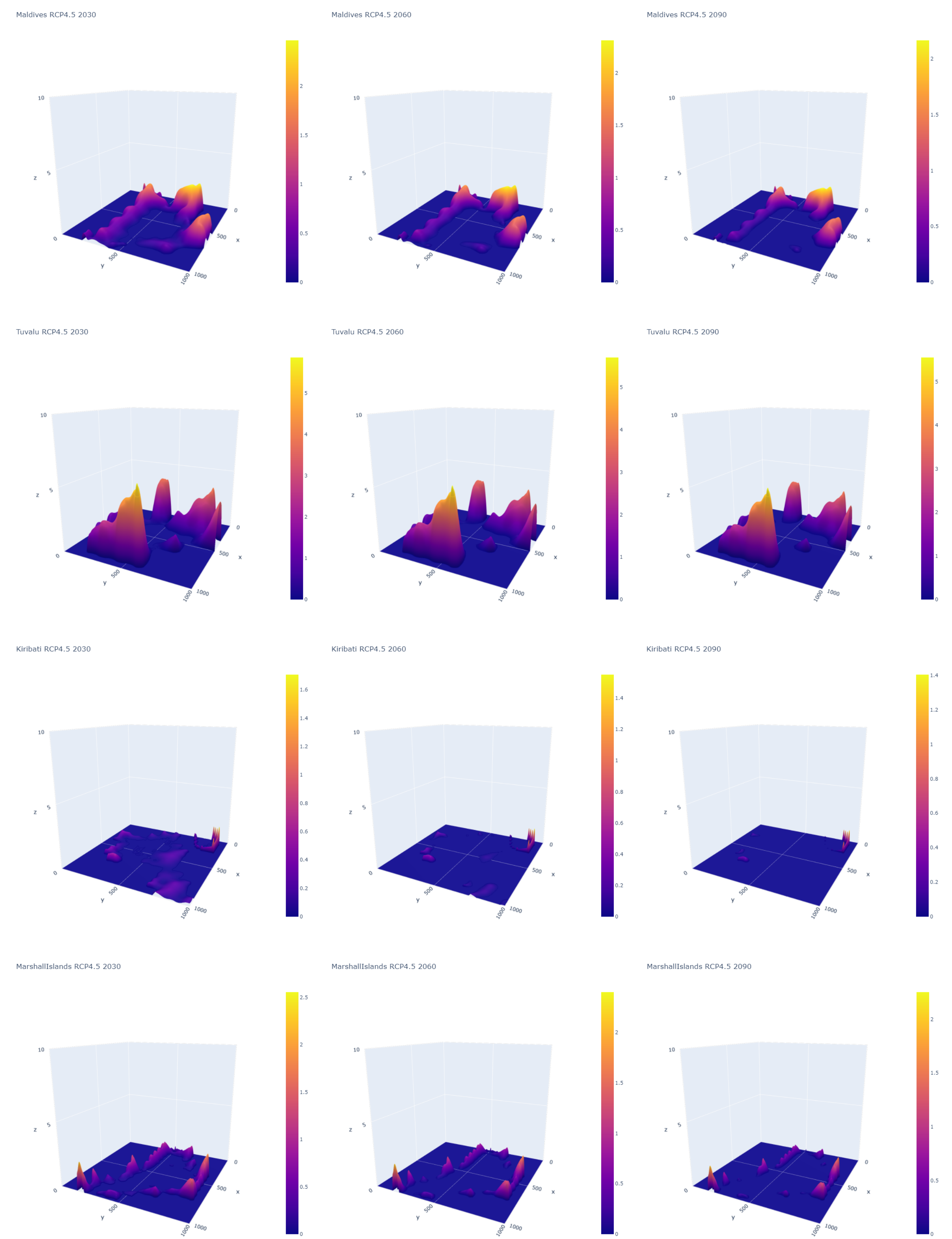


Figure 17: Island submersion results for RCP4.5

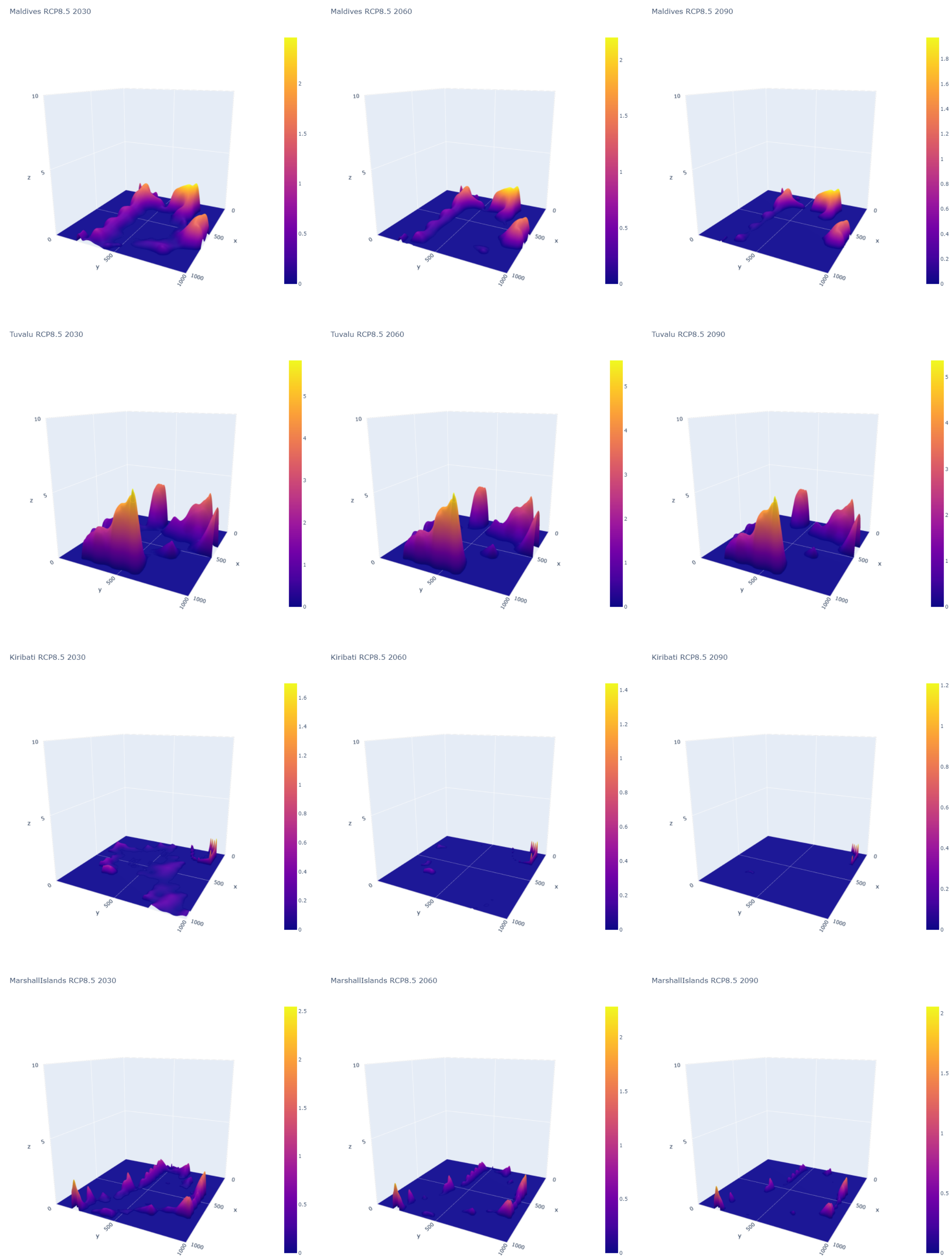


Figure 18: Island submersion results for RCP8.5