A Cost-Benefit Analysis of Adaptations to Climate Change

Comparing ecosystem-based adaptation versus engineered approaches to tropical storm variability

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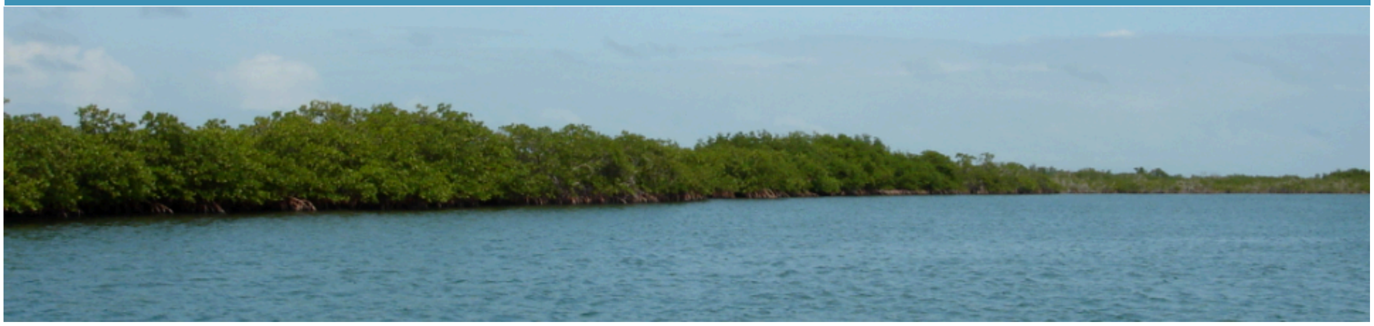


INTRODUCTION:

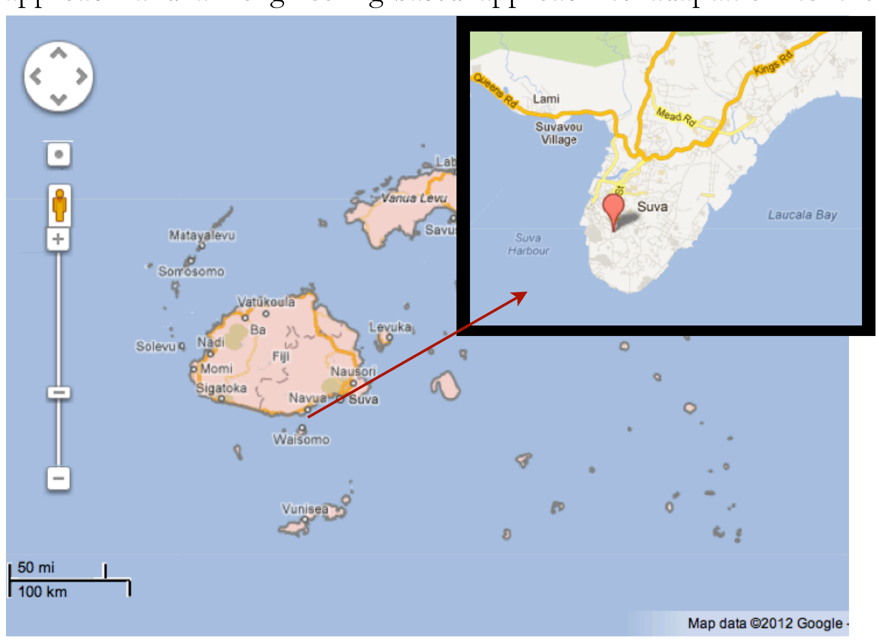
The global climate is changing rapidly due to the accumulation of anthropogenic greenhouse gas emissions (GHGs) in the atmosphere. According to the Intergovernmental Panel on Climate Change (IPCC), "These changes in atmospheric composition [greenhouse gases and aerosols] are likely to alter temperatures, precipitation patterns, sea level, extreme events, and other aspects of climate on which the natural environment and human systems depend" (2007). Planned adaptation is society's a priori defense against risks caused by climate variability, whether those risks are to agricultural crops, flood plain communities, coastline integrity or any other number of resources. This project addresses planned adaptation to climate-driven threats to coastal communities in the South Pacific islands.

PROJECT SIGNIFICANCE:

One potential impact of climate change is the increased risk of coastal flooding due to sea level rise and changes in tropical storm frequency and intensity. In the South Pacific islands, high coastal population density and low lying coastlines coupled with their location in the cyclone belt increase their vulnerability. Conservation and development organizations are seeking a way to aid communities in their planned adaptation efforts, while trying to conserve ecosystems. These organizations are interested in the use of Ecosystem-based Adaptation (EbA), which is defined as reducing the impacts of climate change through the conservation and restoration of natural ecosystems. Our project provides a framework for comparing the effectiveness and costs of an EbA approach and an engineering-based approach to adaptation to the increased risk of coastal flooding.

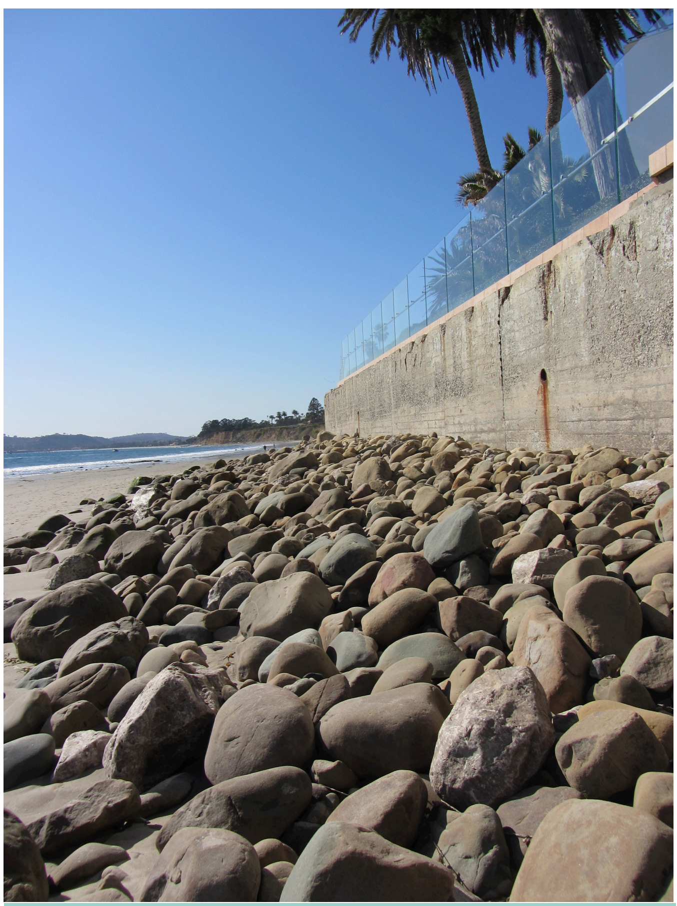
Case Study:

We focused our analysis on the island of Viti Levu, Fiji and answered the question: What is the most economically efficient form of adaptation to climate driven threats to coastal communities of the Suva Peninsula?



Mangroves vs Seawalls

The nation of Fiji has the third most extensive mangrove forest cover of all the South Pacific islands. One of the largest mangrove areas is on the southeast coast of Viti Levu and serves as our model of an EbA option.



We used the construction of a seawall as our engineered-based adaptation approach to storm surge inundation. Seawalls protected 51% of the 11.8 miles of coastline surveyed on the Suva Peninsula in 1996.

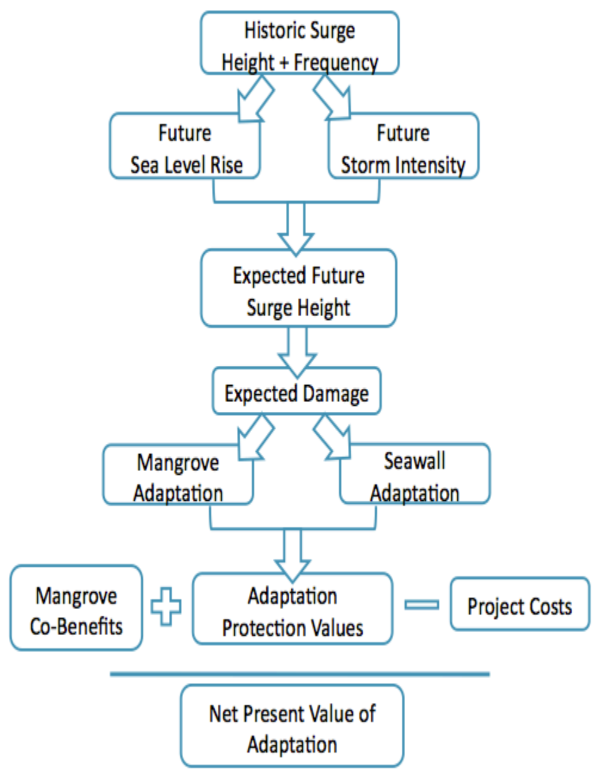
Project Objectives and Methodology:

1) Develop a model of the physical impacts and the associated economic damages of a storm surge on the coast of Fiji under a range of climate scenarios.

2) Incorporate adaptation approaches (seawalls and mangroves) into the model and project economic damages avoided with the presence of each.

3) Conduct a Cost-Benefit Analysis comparing adaptation measures to determine the Net Present Value of each adaptation.

Conceptual Framework:

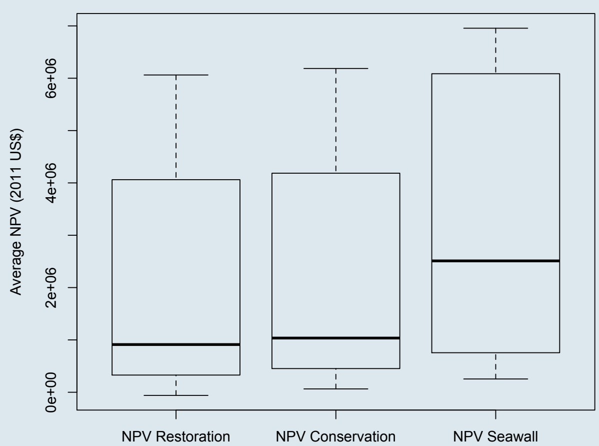


RESULTS SUMMARY:

After averaging across uncertainty in climate scenarios, adaptation effectiveness, and flood impact costs (among other variables) our model finds that the mean Net Present Value (NPV) over 40 years for constructing seawalls is generally higher than it is for conserving or restoring mangrove systems. Within the range of uncertainty, there are scenarios in which mangroves outperform seawalls. In these scenarios, the mangrove forests would need to be mature and provide high surge reduction capacities.

A key project question is the value of ecosystem service co-benefits (timber, fisheries, tourism, etc.). In this particular case, coastal protection is the most valuable ecosystem service that mangroves provide and the other co-benefits do not contribute significantly to the final economic analysis. These results are locally specific as co-benefit values vary by location and system.

It is important to note the difference between the physical and economic components of disaster modeling. The large disparity between the costs of seawall construction (high) and mangrove conservation/ restoration (low) has a significant impact on the final NPV. The availability of investment and maintenance capital for these projects is an important consideration. While a high quality seawall may provide the greatest protection value, the costs for such a project may be out of reach for poorer communities. One of the key advantages to the ecosystem approach is the relative affordability and overall flexibility given a range of possible future climate scenarios. The trade-offs become difficult from a policy perspective.



This chart displays the Net Present Value of restoring a mangrove forest, conserving a mangrove forest and building a seawall. The spread in the plot is due to the model uncertainties, listed on the right. The thick line represents the mean value.

Restoration & Conservation - Sources of Variability:

1) Surge to damage equation
2) Tides
3) Climate change scenario
4) Changes in storm intensity
5) Land cost for conservation
6) Level of protection

Seawall - Sources of Variability:

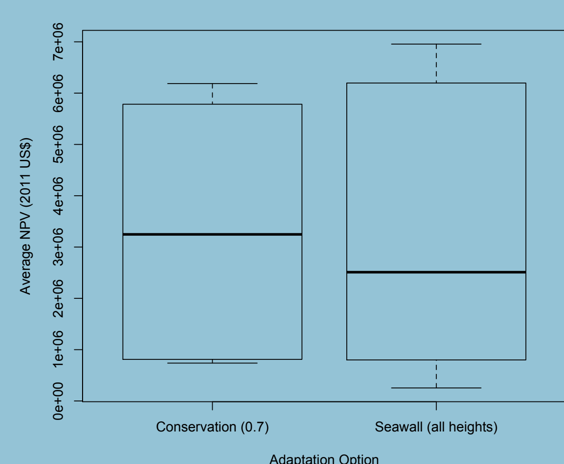
1) Surge to damage equation
2) Tides
3) Climate change scenario
4) Changes in storm intensity
5) Construction costs
6) Seawall height

The Case for Mangroves:

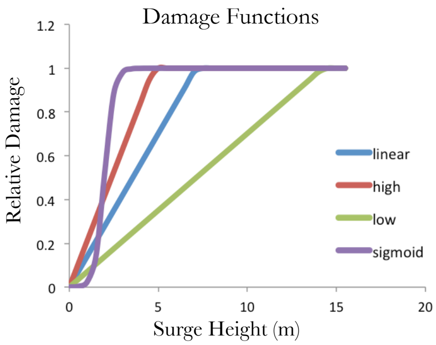
Given the uncertainty surrounding climate change and storm surge intensity, we project that there are instances where mangroves can out compete seawalls. Our analysis has shown that if EbA using mangrove forests were to be implemented, it must be ensured that the forest offers a level of protection at or above a wave reduction capacity of 70% (See chart to right - 'Conservation (0.7)' represents this). Mangroves of this quality are mature and dense.

This figure shows the average NPV of mangrove conservation given a high attenuation coefficient and the average NPV for all seawall heights. As you can see, a mangrove forest with a high surge reduction capacity has a higher NPV.

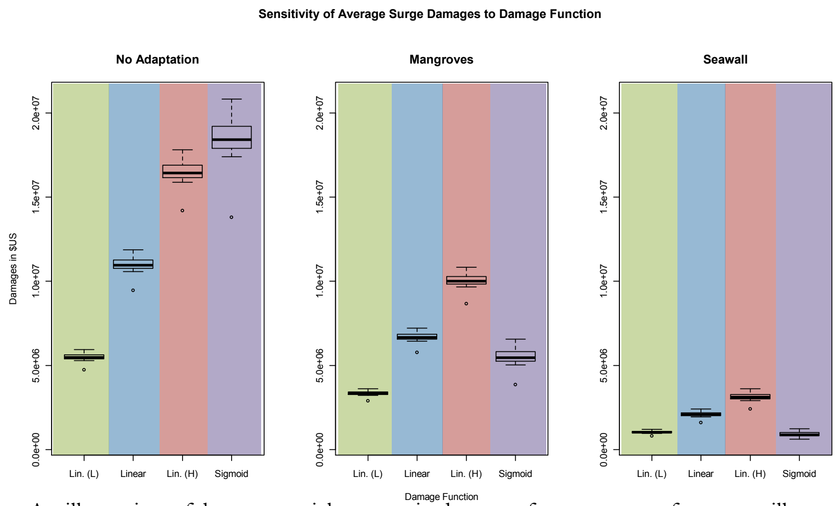
This makes a case for determining the option value associated with the conservation of mangrove forests for protection from storm surge. As the uncertainties surrounding climate change impacts are reduced via better information, the optimal adaptation strategy could then be chosen.



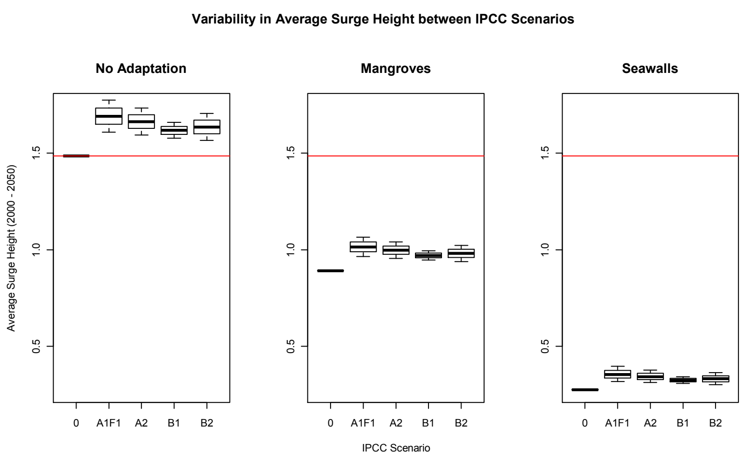
Exploring Model Uncertainties:



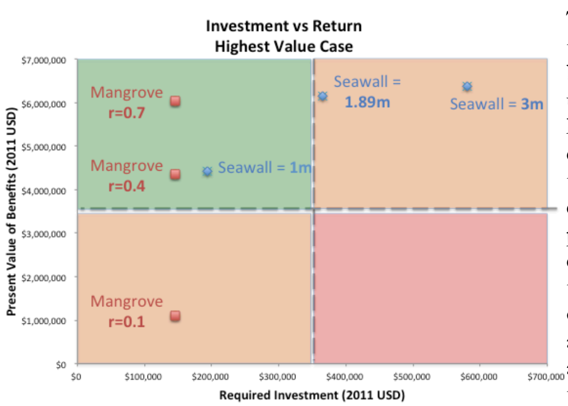
Four potential functions describe the relationship between surge height and economic damages incurred in an area. These functions are specific to Fiji and vary in shape and slope to encompass the uncertainty between storm surge height and physical economic damage. It is currently unclear what the true relationship is.



An illustration of how potential economic damages from a range of surges will vary depending on the assumed damage function for a given location. The spread of each box-plot encompasses the model uncertainties in tide, storm intensity, climate change scenario and sea level rise.



This chart demonstrates how mangroves and seawalls reduce incoming surge compared to when there is no adaptation. Variability across the IPCC scenarios has little impact on our estimates of the effectiveness of different adaptation options. The red line represents 1990 historical baseline surge levels.



This chart describes the investment vs. benefit of the projects under analysis. The location of the different projects on the chart may make a difference from the perspective of a decision maker trying to choose the best course of action with a given risk appetite and level of resources to spend.

Implications for Decision Makers:

Our model identified several key sources of uncertainty in estimating the value of different adaptation options. The greatest uncertainty was the surge to damage relationship. More spatially explicit flood modeling coupled with site specific socio-economic data could reduce this data gap. Additionally, we had to rely on an overly simplistic model of seawall effectiveness and additional data as well as improved models of seawall effectiveness are needed. Once these limitations are quantified, decision makers can use our methodology to conduct an economic comparison of different adaptation approaches for coastal protection. Our methodology can be employed worldwide to compare different adaptation options, with site specific data. Our conceptual model (indicated on page 2) can be employed in comparing adaptation options to any climate change threat with the installation of site specific data.

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IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.