Socially Adjusted Benefit-Cost analysis for Flood Mitigation in Louisiana

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Abstract

Federal agencies select the best flood mitigation project based on Benefit-Costs analysis (BCA). These BCAs' calculations of costs and benefits often focus on property values and ignore the distribution of damages across different populations and how this might lead to different outcomes on total social welfare. For effective flood risk management that considers social vulnerability, assessing the property's value at risk and the social factors that influence an affected community's ability to respond to or recover from it is essential. A major driver of this is the income and wealth of at-risk populations. Thus, to address the distributional impacts (i.e., equity), it is important that BCAs are based on social welfare, where individual social vulnerability is considered through relative impacts on income. One of the ways to address equity is through diminishing marginal utility of income, which explains that welfare increases more when $100 goes to low-income people compared to high-income people. But to understand the vulnerability we need to identify the flood risk and how it will impact the benefit-cost analysis (BCA) of a flood mitigation project. This project aims to run a Monte Carlo simulation based on sea level rise, carbon sequestration in Louisiana. We present a methodology to calculate BCAs with a case study based on Terrebonne Parish in Louisiana. This approach will help federal agencies decide who to target while investing and how to put different weightage for low-income communities.

1. Introduction

Floods are the most common hazard causing human suffering, property damage, and loss every year all over the world. Economic flood losses are high and increasing due to many reasons (e.g., population growth, climate change, and soil subsidence) (Rahim et al., 2024; Tate et al., 2015). It is estimated that due to socioeconomic development average annual flood damages of US $6 billion for the 136 largest coastal cities will increase to US $52 billion by 2050 (Kind et al., 2017). The increasing number of disaster events, high mitigation costs, and finite resources make flood risk management (FRM) approaches more difficult to implement, where each investment must prioritize maximum social welfare.

1.1 Case study in Terrebonne Parish

Terrebonne Parish is in the coastal-southern part in Louisiana with a population of approximately 104,786 (ACS, 2022). The name Terrebonne means ‘Good Earth’, which really justifies its low flat land with varying topography from prairies and wooded areas in the northern part to bayous, lakes, and salt marshes in the southern part. The largest town, Houma, is the parish seat. Terrebonne is well known for its seafood, wildlife, and natural resources: oysters, shrimp, crabs and fisheries. For example, in 2020, almost 34% of total statewide shrimp landings were from the

Terrebonne basin (Coastal Master Plan, 2023). The Terrebonne Basin area includes about 155,000 acres of swamp and almost 574,000 acres of marsh, grading from fresh marsh inland to brackish and saline marsh near the bays and the gulf. It also includes about 728,700 acres of wetlands among which 96% of the wetlands in the Terrebonne Basin are privately owned.

The primary source of revenue for this parish is from oil and gas, and it is estimated that 7,796 wells have been drilled from January 1977 to September 2023. Other major economic activities include fisheries, navigation, and tourism. Sugarcane, cattle, citrus and vegetables are the major agronomic crops in the parish. There are four major wildlife refuges in this parish, i.e., Pointe-aux-chenes Wildlife Refuge, Elm Hall Wildlife Management Area, Isles Dernieres Barrier Islands Refuge and Mandaley National Wildlife Refuge. All of them are managed by the Louisiana Department of Wildlife and Fisheries (LDWF). Major recreational activities in those places include hunting, trapping, fishing, boating, bird watching and camping.

Terrebonne parish is considered to be home for half of the Indian people living in Louisiana, illustrating its 'Cajun French' history. Some of them are federally recognized and others are state recognized tribes. Some of them are known as Grand Caillou/Dulac Band of BCCM, Pointe-aux-chenes Tribe, United Houma Nation and Isle de Jean Charles Band of BCCM. These tribes have contributed to the culture and the history of the Terrebonne parish.

As part of the coastal Louisiana, Terrebonne parish experiences frequent natural disasters like flood and storm surges. Several towns are at risk zones which include Dulac, Cocodrie, and Chauvin. These towns could experience over 15 feet of coastal flooding (Parish Fact Sheet CPRA, 2017). Moreover, Terrebonne Parish faces severe wetland loss across the parish due to sea level rise (SLR), natural deterioration of barrier islands, historic oil and gas activities and deltaic subsidence. It is predicted by Coastal Protection and Restoration Authority (CPRA) that over the next 50 years under the medium environmental scenario with no action the wetland loss will increase, the parish could lose an additional 409 square miles, or 41% of the parish land area, which will impact many coastal towns (Parish Fact Sheet CPRA, 2017). The current wetland loss rates range from approximately 4,500 to 6,500 acres/year. According to the current wetland loss, it is predicted that one-third of the Terrebonne Basin's remaining wetlands would be lost to open water by the year 2040 (CWPPRA, 2023).

In the 2023 Coastal Master Plan, 16 projects are described for the Terrebonne region. These include various restoration measures, such as marsh creation, riverine diversions, ridge restoration, and land-bridge projects. NOAA also declared 'Island Road Project' which will support restoration of approximately 295 acres of marsh habitat in Terrebonne Parish in 2023.

The geography of Terrebonne parish, the natural resources and its recreation value, the indigenous people and culture, has significant impact on prioritizing the types of restoration projects. And these attributes should be included while implementing restoration measures in this region. In our assignment, we will investigate Sea Level Rise (SLR) and carbon sequestration and how it will impact the Benefit-Cost Analysis (BCA) of a wetland restoration project.

2. Methodology

To calculate the benefit-cost ratio (BCR) for the wetland restoration project, we assume that the project will be completed in 2024 and we start getting benefits from 2025. Later we calculated benefits for the year 2100 (75 years). In my model, I accounted for four uncertainties, which are Sea Level Rise (SLR) Scenarios, Discount rate (DR), Carbon value (CV), and Wetland Restoration costs (WRC).

In the Executive Order 12866, it is stated that, "to assess both the costs and the benefits of the intended regulation and recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs"(*Circular A4: Regulatory Analysis*, 2003). Three major factors for the benefit cost analysis calculation for this project were the sea level rise, social cost of carbon and discount rate.

2.1 Data and Assumption

I obtained the wetland restoration cost data from the United States Department of Agriculture (USDA). According to USDA's estimates, the costs of restoring and preserving new wetlands across the contiguous United States vary from approximately $170 to $6,100 per acre. The lowest costs are observed in western North Dakota and eastern Montana, while the highest costs are found in major corn-producing areas and western Washington and Oregon. I used the uniform distribution for this dataset. By converting the range, I choose it as $500 to $8000 per hectare.

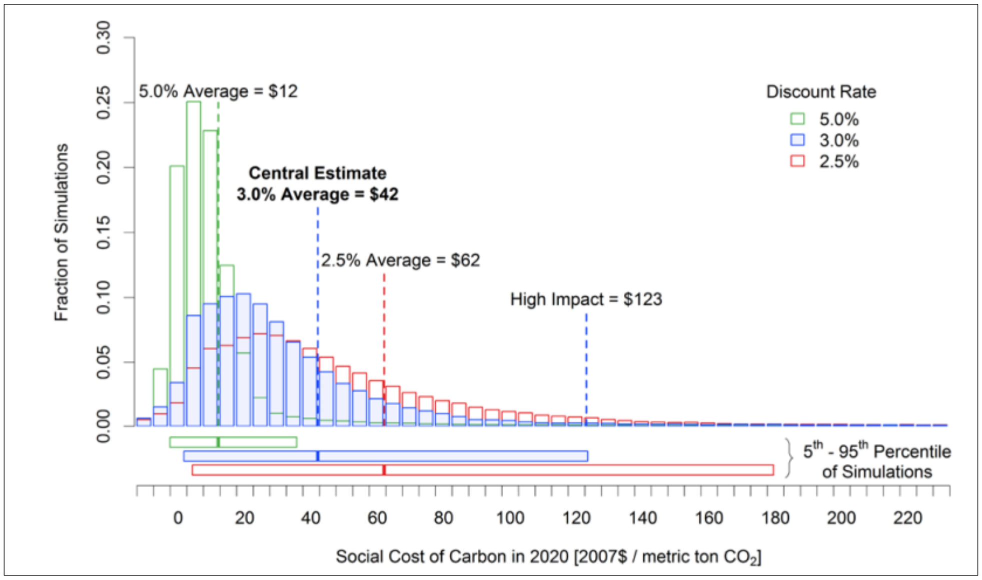
2.2 Sea Level Rise (SLR)

I utilized data from the NOAA Technical Report titled '2022 Sea Level Rise Technical Report Data Files' for estimating sea level rise (SLR) projections. In modeling SLR, I chose to use a normal distribution, as it is often considered appropriate when the mean and standard deviation of sea level rise are known. This choice is particularly suitable when SLR is influenced by intricate interactions among climate variables. However, it's important to note that a normal distribution may not fully capture long-term trends, seasonal fluctuations, and extreme events associated with SLR.

2.3 Social Cost of Carbon (SCC)

The social cost of carbon (SCC) helps agencies to incorporate the social benefits of reducing carbon dioxide (CO_2) emissions into cost-benefit analyses of regulatory actions. The SCC can be defined as an estimate of the cost, in dollars ($), of the damage occurred by each additional ton of carbon emissions. In other words, SCC can be defined as an estimate of the benefit of any measures taken to reduce a ton of carbon emissions. An SCC of $51/ton means that economists and climate scientists expect the total damage from an extra ton of carbon emissions to equal $51 a ton. Different values (estimates) have been suggested by different governments for SCC. Such as the Obama administration has suggested SCC to be $43/ton globally whereas Trump administration estimated SCC to be only between $3 to $5 per ton. Recently Biden administration has suggested the value of SCC to be $51/ton.

The SCC value is highly dependent on the discount rate (figure 01). For example, EPA's $190/ton estimate is based on a 2% discount rate. When EPA used a higher discount rate of 2.5%, thus valuing the future less, the SCC goes down to $120. When they use a 1.5% discount rate, valuing the future more, the SCC goes up to $340.



Source: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866

Figure 01: SCC estimates based on different discount rate

I set the Social Carbon Cost (SCC) range from $50 to $123. I chose $50 based on the Obama administration's suggestion of a global SCC of $43/ton. Additionally, I selected $123 because the Environmental Protection Agency (EPA) reduced the SCC to $120 when using a higher discount rate of 2.5%. I utilized a uniform distribution for SCC to cover the range of values and ensure inclusivity across the entire spectrum.

2.4 Discount Rate

According to the OMB Circular No. A-94, in 1972, it is stated that "Discount Rates to be Used in Evaluating Time-Distributed Costs and Benefits", a real rate of 10 percent was recommended by OMB for use from March 27, 1972, until October 29, 1992 (Office of Management and Budget, 2003). For the base case of public investment and regulatory analyses, OMB now suggests a real discount rate of 7 percent. For Example, FEMA has been using a seven percent (7%) discount rate for any flood mitigation project and recently they added a three percent (3%) discount rate to address the disadvantaged community. For the discount rate, I considered a range of values from 2% to 7%. Specifically, I included the 7% rate because FEMA currently utilizes it for Benefit-Cost Ratio (BCR) calculations in flood mitigation projects. Therefore, I explored discount rates ranging from 2% to 7%. In this context, I opted for uniform distribution. Figure 02 shows a simpler flowchart for the calculation of BCR.

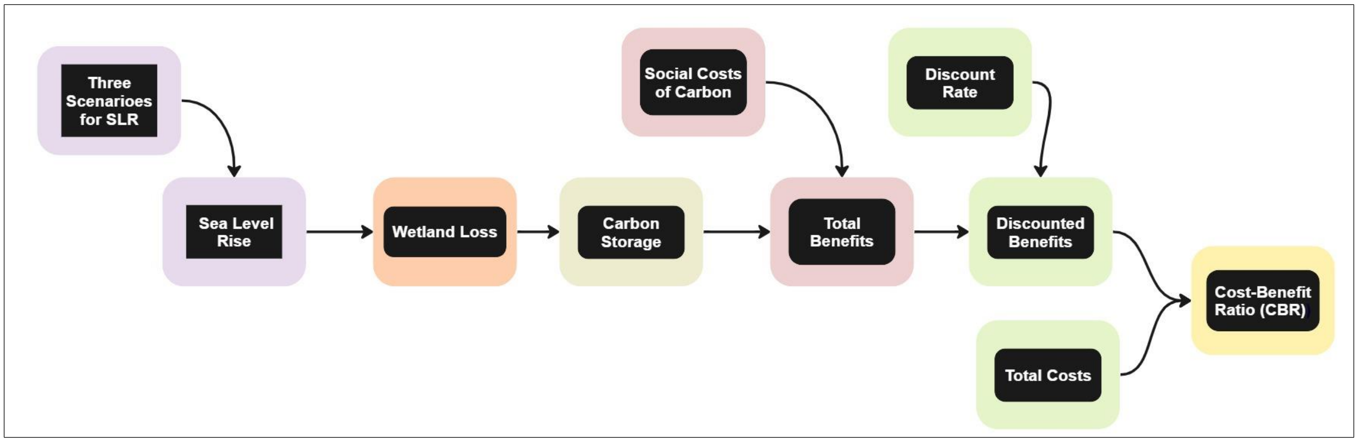


Figure 02: Flow chart for the calculation of BCR

2.5 Monte Carlo Simulation

A Monte Carlo simulation in benefit-cost analysis is a statistical method that uses repeated random sampling of uncertain input variables to generate a range of possible outcomes, providing a more comprehensive understanding of the potential risks and uncertainties associated with a project or policy by calculating the probability distribution of its net benefits, rather than just a single expected value.

3. **Results and Discussion**

The analysis focused on the relationship between the Benefit-Cost Ratio (BCR) and key variables: discount rate (dr), sea level rise (cc), and restoration cost for wetlands (rc). Key findings are as follows:

BCR Across Scenarios:

The comparison of average BCR values across scenarios revealed significant variations. Scenarios with higher BCRs suggest that the benefits of wetland restoration outweigh the costs, making them more efficient for flood mitigation. Lower BCRs may reflect higher costs, lower benefits, or the influence of higher discount rates.

Scatter Plot of BCR:

The scatter plot showed the distribution of BCR values (fig 03), with some variability and a few outliers. These outliers may correspond to specific combinations of high sea level rise (cc) or restoration costs (rc), which disproportionately affect benefits and costs.

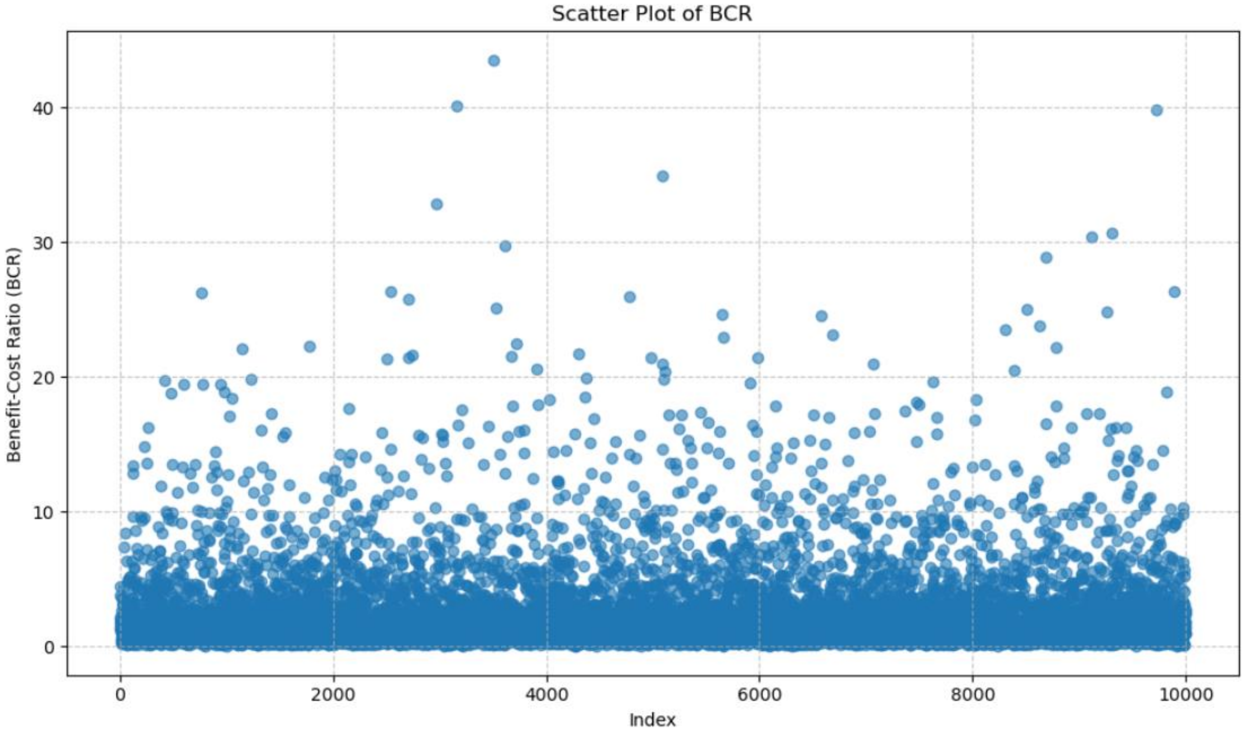


Figure 03: Scatter plot for BCA for different scenarios at the year 2100.

Discount Rate (dr): The histogram (fig 04) indicated the spread of discount rates, which affect the valuation of long-term benefits. Higher discount rates may reduce the BCR by undervaluing future benefits of wetland restoration.

Sea Level Rise (cc): The distribution of sea level rise showed its variability across scenarios. Scenarios with higher sea level rise are likely to necessitate greater investment in wetland restoration, impacting overall costs.

Restoration Cost (rc): The restoration costs varied significantly, suggesting that economic feasibility depends heavily on cost management.

The analysis highlights that scenarios with low restoration costs and moderate discount rates are more likely to achieve higher BCRs, making them efficient choices for flood mitigation programs. As sea level rise increases, strategic investments in wetlands become even more critical for long-term resilience. Prioritize scenarios with the highest BCR for cost-effective flood mitigation. Investigate scenarios with extreme BCR values to identify key drivers. Evaluate the sensitivity of BCR to varying discount rates to better balance short-term costs and long-term benefits.

This summary provides a clear understanding of how discount rates, sea level rise, and restoration costs influence the efficiency of wetland restoration as a flood mitigation strategy.

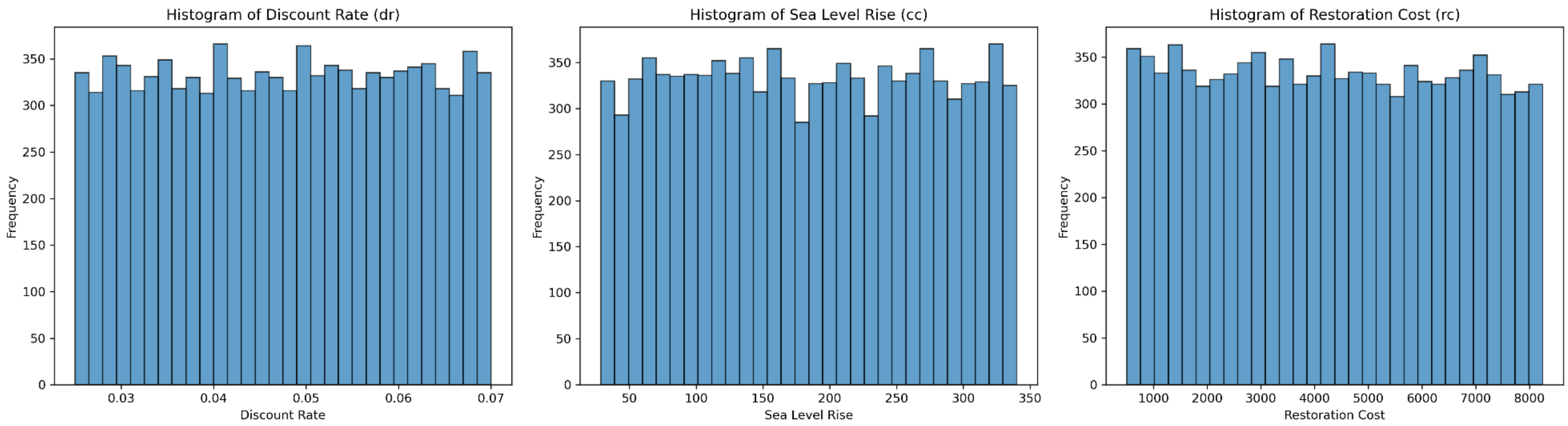


Figure 04: Histogram for Discount Rate, Sea Level Rise and Restoration Cost.

In conclusion, we can say that the wetland restoration project in the Terrebonne parish will help to decrease the impact of storm surges, while introducing habitat for species as well as recreational opportunities for the local community. In our calculation of BCR, we only included carbon sequestration which does not capture the wide range of benefits of the restoration project. We need to include other attributes such as recreation values, cultural values, nutrient or sediment transport and habitat facilities to calculate the full range of benefits.

Both the SCC estimate and Discount rate have created uncertainty in the BCR calculations. Initially we calculated BCR using SCC $123/ton and discount rate 7% which provides BCR more than one. However, when we use SCC estimate $51/ton with the same discount rate, then the BCR is less than one. This illustrates the importance of SCC estimates and why we need higher estimates of SCC for cost-effectiveness. On the other hand, for the same SCC $123/ton the discount rate 7% and –1% will provide different BCR values. With the decrease of the discounted rate, the BCR will increase which means that there will be more chances to get a higher than one benefit-cost ratio.

The timeline of the project will also impact the BCR. For example, from table 01, we can conclude that, in 2050 the BCR value is low, whereas in 2100 the BCR value is high. While we calculated the discounted benefits, we noticed the yearly benefits are significantly higher in recent years compared to the year 2100. This explains the benefits will be high for the near future compared to the distant future.

From the calculation we understand that the higher the discount rate, the chances of BCR being less than one is also higher. Sometimes, it is difficult to include the benefits of a low-income community with a higher value discount rate. Though we might choose a descriptive discount rate considering future generations will have better technology or resources to tackle SLR, but it is important to also consider the prescriptive approach to ensure distributional impacts (i.e., equity) of the benefits. Hence, we must be careful while selecting discount rate for any restoration project and consider not only descriptive approaches but also prescriptive approaches.

Wetlands restoration projects will not only bring several environmental co-benefits, such as habitat for species, barrier to storm surges, nutrient (i.e., N, P) and sediment transport, preserving mangrove forest, water quality as well as carbon sequestration but also it will include the community such as recreation for the local community, livelihood for local community, cultural ties with local community. As Terrebonne parish has natural resources like oysters, shrimps, birds and fishes, the habitat co-benefits will definitely increase the total benefits. Moreover, if we consider the tribal population the recreational and cultural co-benefits will also have a positive impact on the total benefits.

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Github Link:
https://github.com/chsharrison/Sci_comp_F24/blob/main/Fahmida_Akhter/Final%20Project_MC.ipynb