Research on the Ecological and Economic Impacts of Rising Sea Levels on Mangroves in Southern Florida in the Context of Climate Change

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Abstract. The decline in mangrove ecosystems is a major contributor to the loss of biodiversity, extra carbon release, and local economic instability, particularly in tropical coastal regions that are constantly influenced by climate changes. Despite the importance of the mangroves, there is limited research investigating the consequences. Under the context, this research examines the correlation between mangrove density, sea level rise, and economic impacts in Southern Florida. The work aims to address three main questions: (i) what are the ecological impacts of sea level rising on mangroves density; (ii) what are the economic implications of mangrove loss; (iii) what extent of government intervention should be imposed on the environmental problem. The research presents a two-variable graph that examines the relationship between mangrove density in Southern Florida and sea level rise, analyzing its overall correlation in the Caribbean region. Another correlation study of the impacts of mangrove loss on local tourism is created and set as the focus. The conventional hedonic method is applied as the tool of evaluating mangroves value. The results demonstrate a close negative correlation between sea level and mangrove density, and a positive correlation of mangroves density and local tourism.

1 Introduction

Under the context of climate change, even the minor change of environment will dramatically influence people's well-being and society's sustainability. As global temperatures continue to increase, the polar ice caps of the earth are melting at an alarming rate, resulting in the expansion of ocean waters. This phenomenon has caused the rise of sea levels, which has emerged as one of the most pressing environmental issues confronting the world nowadays. According to the report by Intergovernmental Panel on Climate Change (IPCC), the increase in sea level had reached approximately 15cm since the late nineteenth century, and are projected to show a further increase of 30-110cm by the end of this century with devastating consequences [1].

Mangrove forests, consisting of bushes and rooted trees that thrive in the littoral areas of tropical and subtropical coastlines, are among the most vulnerable ecosystems affected by sea level-related factors. The distribution of mangroves along the coastline varies over time and involves a delicate balance between accretion and sedimentation, erosion and vegetation stabilization, productivity and decomposition, and tidal flushing. Based on these effects, the biomass of mangroves and relative sea level (RSL) are closely intertwined and mutually impacted. Mangroves have the function of storing and sequestering large area-specific quantities of blue carbon (Corg), providing potential effect of greenhouse gas offsets. Its average carbon stock in mangroves is 738.9 Mg Corg per hectare, with a total stock around the world of 6.17 Pg Corg, which means mangroves can store approximately 17% of total tropical marine carbon [2]. Mangrove ecotourism contributes to the local economy worldwide. Based on the report from Florida Department of Economic Opportunity, ecotourism in Southern Florida had brought $95 million to the host communities alone [3]. In 2011, there were 19,347 jobs in all Florida state parks with mangroves. Due to the mangroves' significant potential for carbon sequestration, biodiversity conservation, and support of local economic development, mangrove ecosystems have garnered global attention for their preservation. There have been detailed case studies of sea level changes in southern Florida and their sediment impacts, but only a few studies of the economic impacts of mangroves. This study creates three regression models between the three variables to examine their correlation. The mangrove attractions serve as an intermediate factor that influences the relationship between sea level rise and the quantity of tourists. By determining the correlation coefficient through heatmap analysis, the study aims to enhance the comprehension of the importance of the factors at play. It is hoped that the findings may serve as a potential reference for local policymakers.

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2 Literature review

Regarding the difficulty to collect tourists' information of a specific area of mangroves, an alternative method could be taken based on the social media data. Some researches investigate the potential usage of social media data to evaluate the social value of mangroves protected areas [4]. The authors collected social media data from TripAdvisor and Instagram to analyze the visitors' posts and extract information related to the natural features of the protected areas. It could be applied in this study to research the Florida mangroves keywords on TripAdvisor. A potential setback is the variation and inaccuracy caused by language differences and repetition of posts. Except for the social value, the actual economic value should also be taken into consideration. Studies conducted in Africa, which is famous for its mangrove protection and tourism. Sarhan and Tawfik discuss the economic value of mangrove ecosystems estimates the monetary value of these services. The researchers find that the numerical value of mangrove ecosystem related services is significant, with estimates ranging from $2000 to $9000 per hectare each year [5]. The study could apply the value as well in Southern Florida to calculate the loss in capital every year as the mangroves disappear. To sustain the profit from ecotourism, appropriate government interventions are significant. Fistiningrum and Harini investigate how managing mangroves tourism affects the economic situation of people in Kulonprogo Regency suggests the potential of promoting sustainable development and improve the socio-economic conditions of local communities [6]. However, it requires careful planning and management to ensure long-term benefits. Some studies have provided insights about the management of mangroves protection. The research on the Volta estuary catchment in Ghana stated that community-based forest management can help conserve mangroves, improve local livelihoods through income generation, and increase the resilience of coastal communities to climate change impacts [7]. However, challenges and limitations in management practices remain, such as lack of community participation in decision-making and poor enforcement of regulations. This study highlights the need for a more inclusive and collaborative approach to forest management that engages local communities, government agencies, and other stakeholders.

3 Methodology and discussion

3.1 Data source

3.1.1 Historical area of Florida mangroves

The study utilized Forest Inventory and Analysis (FIA) data from the U.S. Agriculture Department Forest Service section as shown in Table 1 [8]. The data set is the only open resource time series data of mangrove concentration in Florida. FIA data, usually collected by trained professionals using rigorous quality control measures, minimized the difficulty involved in measurement, accessibility, and working conditions and its reliability has been proven by the U.S. Forest Service department.

Table 1. Change in the number of mangroves in different Florida regions by year.

Surveyed Region	2007	2009	2010	2011	2012
Northwest	0	0	0		
Northeast	0	0	9,118	9,118	9,406
Central	13,109	20,146	20,088	26,091	25,561
South	76,750	128,865	147,676	183,309	194,820
State	89,859	149,011	176,882	218,518	229,787

www.sciencedirect.com/science/article/pii/S0308597X18306602?via%3Dihub

3.1.2 Metadata of mangrove habitat

A metadata of mangrove habitats distribution in the Southern Florida region could help visualize the mangrove colonizing area effectively.

3.1.3 Florida historical sea level uprising data

The study utilized sea level uprising data from seven different regions in Florida to examine how the impacts on mangroves vary across different geographic regions and the general trend of sea level.

3.1.4 Florida sea level rise impacts data

Graph-based data is being used to determine the affected area by a 1m/ 3m sea level rise in Southern Florida.

3.1.5 Keyword search frequency data on ecotourism in Florida

Collecting data on how people value mangroves and its potential economic effects is considerably difficult because of the absence of an explicit market. The data from Spalding and Parrett's research quantified the mangrove ecotourism in Southern Florida by collecting the frequency of keyword searches related to mangrove-based recreation on reliable travel websites. The Hedonics approach reflects accurate results indicating a demand for mangrove ecotourism and thus emphasizes the necessity of preservation.

3.2 Hypothesis

The research hypothesizes that there exists a moderately negative relationship between the sea level rise and

mangroves density, a relatively strong connection between the mangrove density and value of ecotourism, and a corresponding negative correlation between the sea level and tourists.

3.3 Correlation analysis

The study uses SPSS and Excel to analyze the correlation among the sea level rise, the local tourism and the number of mangrove attractions. Correlation coefficient and regression coefficient had been calculated based on the data sources above.

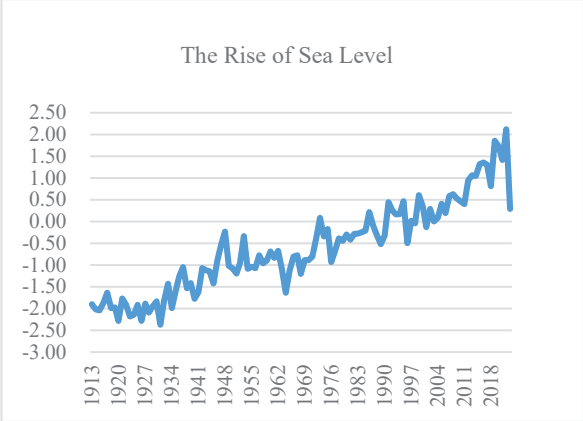

Fig. 1. Florida historical sea level rise record. https://sealevelrise.org/states/florida/

According to Figure 1, the sea level rise is fluctuating and increasing from 1931 to 2021. The study created a hot picture as shown in Figure 2.

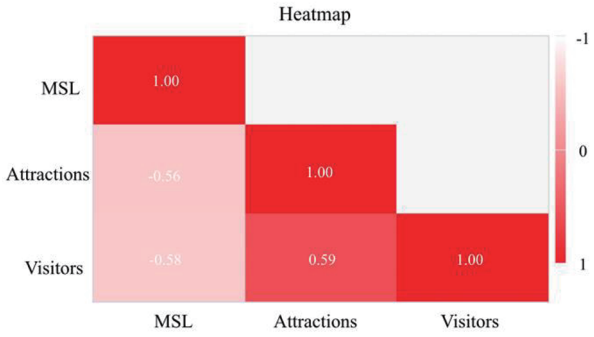

Fig. 2. Heatmap Analysis for the Three Variables (Photo credit: Original).
Note: * p<0.05; ** p<0.01.

Drawing from the information presented in Figure 2, it is evident that there exists a negative correlation between rise in sea level and the number of mangroves, as indicated by the Pearson correlation analysis. At the 1% level of significance, the correlation coefficient value of -0.560 holds statistical significance. Additionally, a negative correlation exists between the rise in sea level and the number of tourists with a correlation coefficient of -0.583. The data implies that as sea levels rise, the number of tourists visiting the area is expected to decrease. There is a positive correlation between mangrove attractions and the total visitors, with a correlation coefficient value of 0.592. The correlation is in a positive direction, suggesting that an increase of the mangroves would result in a corresponding increase in the number of tourists. Conversely, if the mangrove density decreases, the visitors to southern Florida is also expected to decrease.

The study uses three regression models to examine the correlation in detail. From Table 2, it can be seen that using sea level rise as an independent variable and the number of tourist attractions as a dependent variable in regression line analysis, the adj- R-squared numerical value of the model is 0.307, indicating that regression model can explain the 30.7% change in the number of attractions in the mangrove forests. The value of regression coefficient if sea level rise is -0.190 (t=-7.059, p=0.000<0.01), indicating that sea level rise will demonstrate a substantial negative impact on the number of mangroves. Even though the natural process of falling leaves will add biomass to the soil and raise its elevation to offset the effects of sea level, the mangroves are still vulnerable to sea elevation.

Table 2. Regression Model 1.

	B	Se	Beta	t	p	VIF
Constant	6.77	0.032	-	210.466	0.00 **	-
The Rise of Sea Level	-0.19	0.027	-0.56	-7.059	0.00 **	1

Note: R2=0.314; adj-R2=0.307.

From the data of Table 3, it can be seen that taking the number of mangroves scenic spots as the independent variable and the number of visitors as the dependent variable for linear regression analysis. The adj-R squared is 0.344, which indicates that the second model of regression is able to explain 34.4% of the dependent variable visitors. The regression coefficient value of the number of mangroves is 0.542 (t=7.627, p=0.000<0.01), indicating that the mangroves will demonstrate a positive effect on the tourism in southern Florida. In other words, if the number of mangrove attractions increases, the number of visitors will increase.

Table 3. Regression Model 2.

	B	SE	Beta	t	p
Constant	8.618	0.49	-	17.5	0.00**
Attractions	0.542	0.071	0.592	7.62	0.00**

Note: R2=0.350; adj-R2=0.344.

Based on Table 4, the number of scenic spots in the mangroves forest and sea level rise were used as independent variables, and the number of visitors was the dependent variable. The adjusted R-squared value is 0.433, meaning that this regression model is able to predict 43.3% of the variance in the number of visitors.

This indicates that other factors not shown in the model might play a role of influencing the number of visitors as well.

The regression coefficient for the number of scenic spots in the mangroves forest is 0.354 (t=4.461, p=0.000<0.01), suggesting a noteworthy positive impact on the number of visitors. The linear regression coefficient for sea level rise is -0.114 (t=-4.241, p=0.000<0.01), showing a potential negative impact on the number of visitors.

Table 4. Regression Model 3.

	B	SE	Beta	t	p
Constant	9.839	0.539	-	18.259	0.00**
Attractions	0.354	0.079	0.387	4.461	0.00**
The rise of Sea level	-0.114	0.027	-0.368	-4.241	0.00**

Note: R^2=0.444; adj-R^2=0.433.

In summary, the number of mangroves has a positive impact on the number of visitors, while sea level rise has a negative impact on the number of visitors. Furthermore, models 1, 2, and 3 show that the mangrove attractions act as a mediator variable. The impact of sea level rising on the number of visitors are mediated by the mangrove attractions. However, it is important to note that this does not imply causation.

3.4 Insufficient areas

Although the study indicates some insights to the relationship between sea level rise, mangrove attractions, and tourism in Southern Florida, it is important to note that the absence of actual data limits the accuracy of estimates. As such, the findings should be interpreted with caution and further research is needed to obtain more precise results. Additionally, while efforts were made to control for potential confounding variables, it is possible that other factors not accounted for in this study could have influenced the observed trends. Therefore, future research should consider a more comprehensive range of variables to better understand the complex dynamics at play.

4 Feasible solution

Mangrove loss is driven by large-scale factors, and optimizing the utility of mangroves as a valuable natural resource requires policy interventions. The government can establish linkages between mangroves and the local economic community, and promote the development of mangrove scenic spots to enhance the climate change resilience of coastal regions while protecting mangroves. Moreover, a moderate level of regulatory intensity can effectively promote mangrove protection without hindering the normal livelihoods of local residents. Governments can learn from the experience of Southeast Asian countries in addressing the preservation of mangroves ecosystem. Moderate intensity of management, purchases for environmental services, and the establishment of protected areas are all viable approaches [9]. However, it is important to integrate scientific research, local knowledge, and community involvement in the development and implementation of policies to ensure their effectiveness [10].

5 Conclusion

Under the environment of constant global warming effects, mangroves preservation could be a “double dividend” that both establish the social resistance to sea level rising and benefiting local residents by stabilizing the ecotourism economy. The study examines the correlation between sea level rise, the number of tourists, and the attraction of mangrove forests, using three regression models. By providing a better understanding of the significance of these factors, the study’s findings may serve as a potential reference for policymakers seeking to preserve mangrove ecosystems. The results of all three observational studies indicate that the presence of mangroves has a significant impact on Southern Florida’s tourism, especially ecotourism. Moreover, the findings suggest that despite numerous determinants, coastal mangroves areas continue to be affected by sea level rise. These findings underscore the importance of preserving and protecting mangrove ecosystems, which play a critical role in supporting the region's tourism sector and overall coastal resilience.

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