SUITABILITY OF MANAGED RETREAT FOR HONOLULU

Feasible development areas based on
7-foot sea level rise in the Primary Urban Center

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The Issue Examined

Coastlines across the world have become increasingly vulnerable due to climate change, with the main consequence manifesting in rising sea levels. According to NOAA, “About 2 feet of sea level rise along the U.S. coastline is increasingly likely between 2020 and 2100 because of emissions to date. Failing to curb future emissions could cause an additional 1.5 - 5 feet of rising for a total of 3.5 - 7 feet by the end of this century” (Sweet, et al., 2022). There is increased pressure placed on coastal regions and governing bodies to make crucial decisions regarding how to adequately plan for this impending threat. Continuing to pour money and resources into combating sea level rise is often a futile and expensive endeavor. Managed retreat is an alternative approach that works more collaboratively rather than combatively to adapt to these climate related issues.

Managed retreat is the “application of coastal zone management and mitigation tools designed to move existing and planned development out of the path of both short- and long-term coastal hazards” (Neal, et al., 2017). These are not solely limited to issues of sea level rise but include natural disasters such as hurricanes, tsunamis, erosion, etc. This strategy is intriguing because it is “proactive in recognizing that the coastal zone dynamics should dictate the type of management employed” (Neal, et al., 2017). This allows for an adaptive framework that can be applied to any coastal zone based on specific area characteristics relative to the degree of prevalence with which their coastal hazards occur. In the United States, “only a few plans or studies have proposed larger scale, strategic relocation of coastal neighborhoods, infrastructure, communities, or ecosystems” (Peterson, 2019). State and localities often only prepare for temporary coastal hazards and form plans that address the preparations for sea level rise. In vulnerable areas, the absence of managed retreat analysis in coastal planning illustrates the need for a study of this nature.

Hawaii has approximately 750 miles of oceanic coastline (U.S. Department of Commerce, 2006). Millions of people travel to its islands, contributing to the state's thriving tourism industry. In 2019, tourism generated an estimated $2.07 billion in tax revenue (Hawaii Tourism Authority, 2020). The threat of sea level rise endangers an island economy that relies heavily on its tourism industry. On the island of O'ahu, the capital city of Honolulu and its surrounding Primary Urban Center (PUC) provide the largest access to tourism activities. The PUC comprises about 22% (84,000 acres) of total land on O'ahu, but about 47% (450,000) of O'ahu's total population. In February of 2019, the State of Hawaii conducted a feasibility study assessing the various retreat strategies for vulnerable coastal areas. They found that of the three adaptation options – retreat, accommodation, and protection – retreat was viewed as a last resort, only necessitated by a catastrophic event, due to difficulties relating to funding, political will, and essential resources. It should be noted that experts involved in the study acknowledged the validity of a managed retreat scheme. The recently proposed Primary Urban Center Development Plan (PUCDP) includes a chapter dedicated to sea level rise resiliency but has development strategies in conflict with executing adaptation goals. A reactive approach to these climatic crises may prove too late and insufficient as the threat of sea level rise increases.

Much of the available land in this area is comprised of the Ko'olau mountain range and is either preserved or the slope creates an environment unfit for large scale development. Should catastrophic trends occur along this coastline, there is limited land available to merely supplant existing coastal activity. If timely climate action is not implemented in this metropolitan area, the people, infrastructure, and main economic source will be at increased risk.

The goal of this project is to illuminate the question that if, under a projected 7-foot sea level rise, what land would theoretically be available and where would that distribution occur? This project utilizes a 7-foot sea level rise- a worst-case scenario- as a means of illustrating the severity of the issue. Our group outlines several variables, including slope, FEMA flood zones, current zoning classifications, streams, and road infrastructure. Due to Hawaii's remote location, the ability to access resources rebuild infrastructure in an adequate timeframe becomes difficult, lending more credence for proactive adaptation.

Purpose of Work

The purpose of this project is to provide evidence for the importance of early mitigation and adaptation. Our team aims to utilize a suitability modeler through ESRI's ArcGIS Pro software to visualize the availability of buildable space, with consideration to existing infrastructure, as well as municipal and environmental constraints. This type of analysis can be implemented in strategic coastal planning. This project provides an exploratory approach in which planners may better understand and prepare spaces for future coastal conditions, protecting economic, environmental, and social stability.

Hypothesis

As previously mentioned, the PUC is comprised mostly of dense urban development along the coast, medium-intensity residential up to the foothills of the Ko'olau Mountains, and natural/agricultural preserves otherwise undevelopable in the mountain range itself. Based on our selected variables and their relative weighted importance in the model, our group expects to find that not only is the overall amount of available land limited, but that such land will be oriented deeper towards the foothills of the Ko'olau mountains. Additionally, we hypothesize that this sea level rise will have a significant financial impact on businesses across industries.

Deliverables

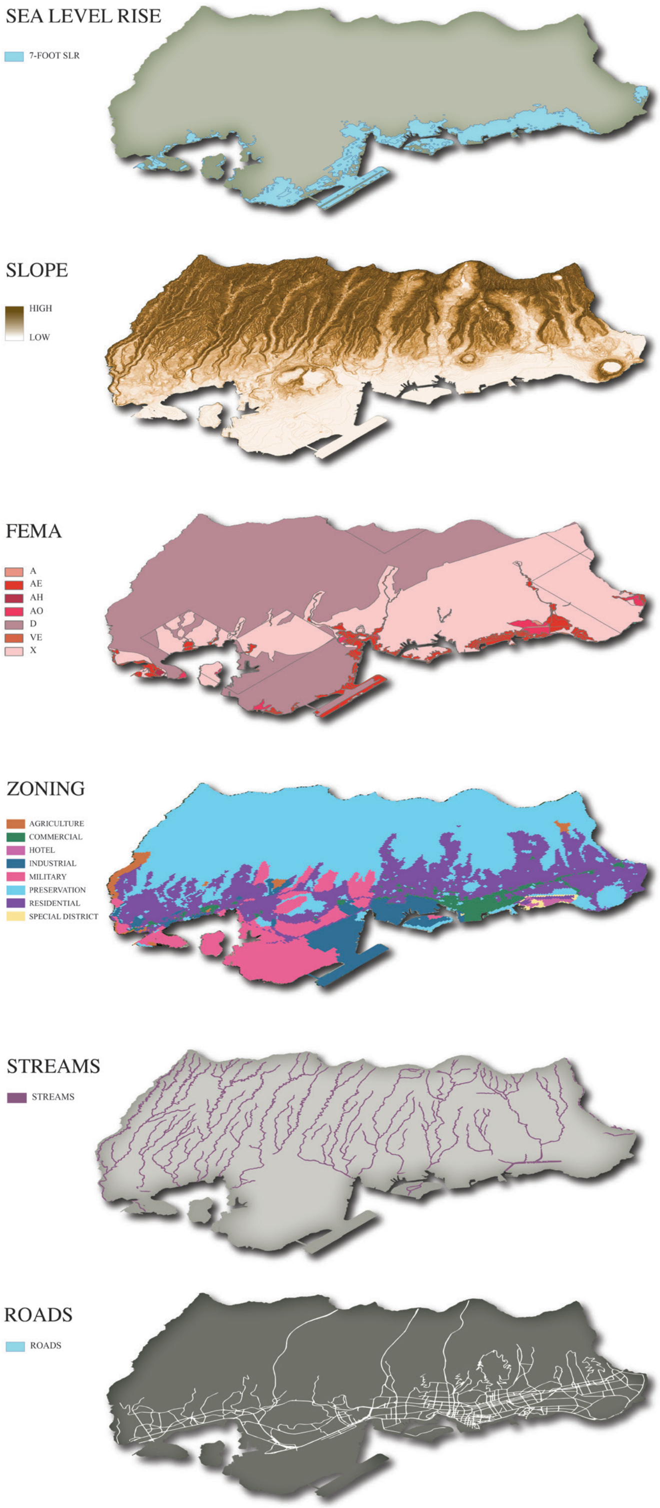


Figure 1

Our group created several deliverables, displayed through an ArcGIS Story Map.

This analysis utilized ArcPro's Suitability Modeler in order to locate feasible areas for future development within the PUC. Our criteria included slope, existing road infrastructure, future flooding, stream network, FEMA insurance designation, and zoning classification, which were individually ranked then collectively weighted with respect to their overall impact on potential development. Figure 1 highlights each criterion and its respective suitability independently, allowing for a more segmented suitability analysis as it fits into a broader context.

Figure 2 combines the abovementioned criteria overlaid into a comprehensive suitability model. The combined criteria visualize the lack of available infrastructure sites post-sea-level rise.

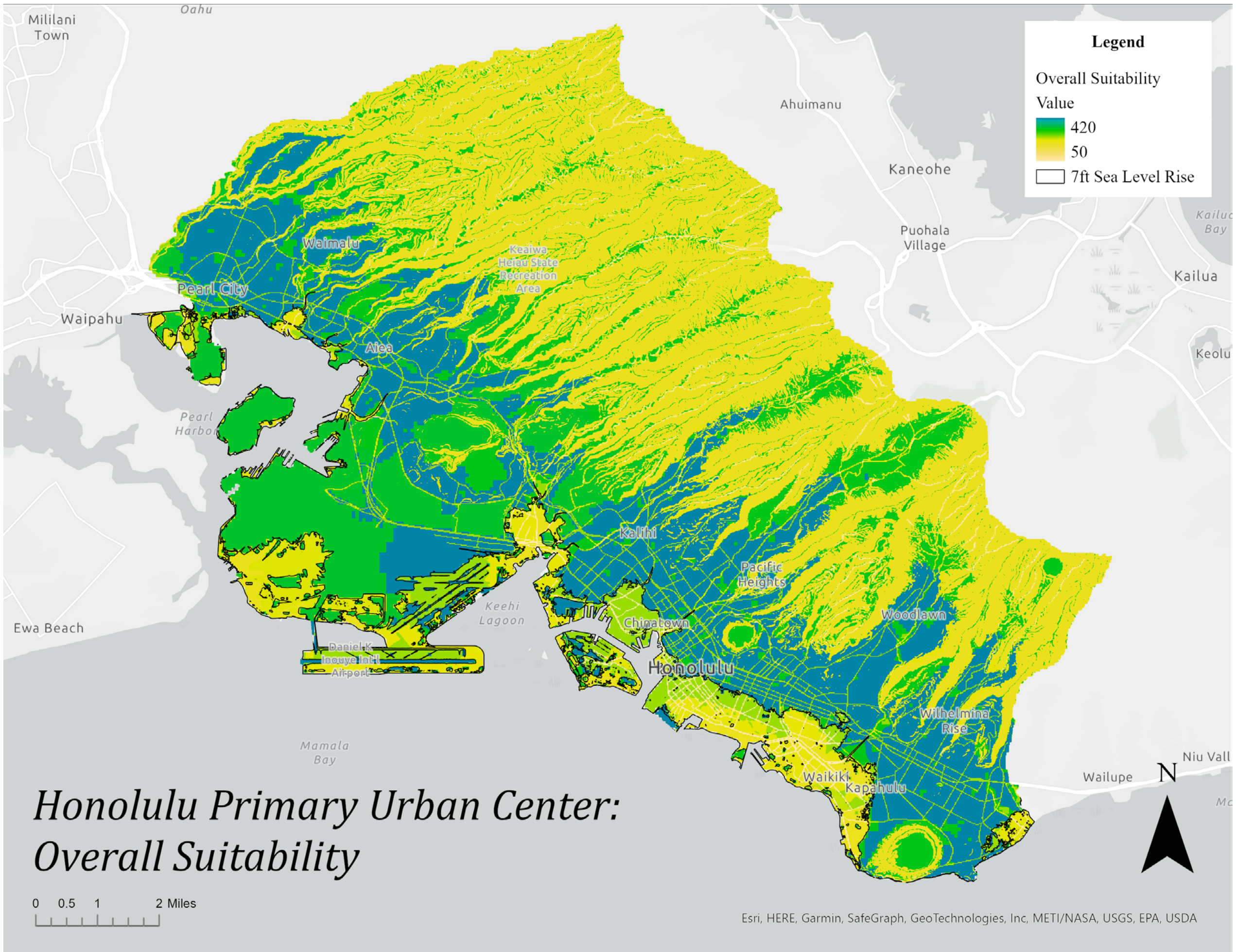
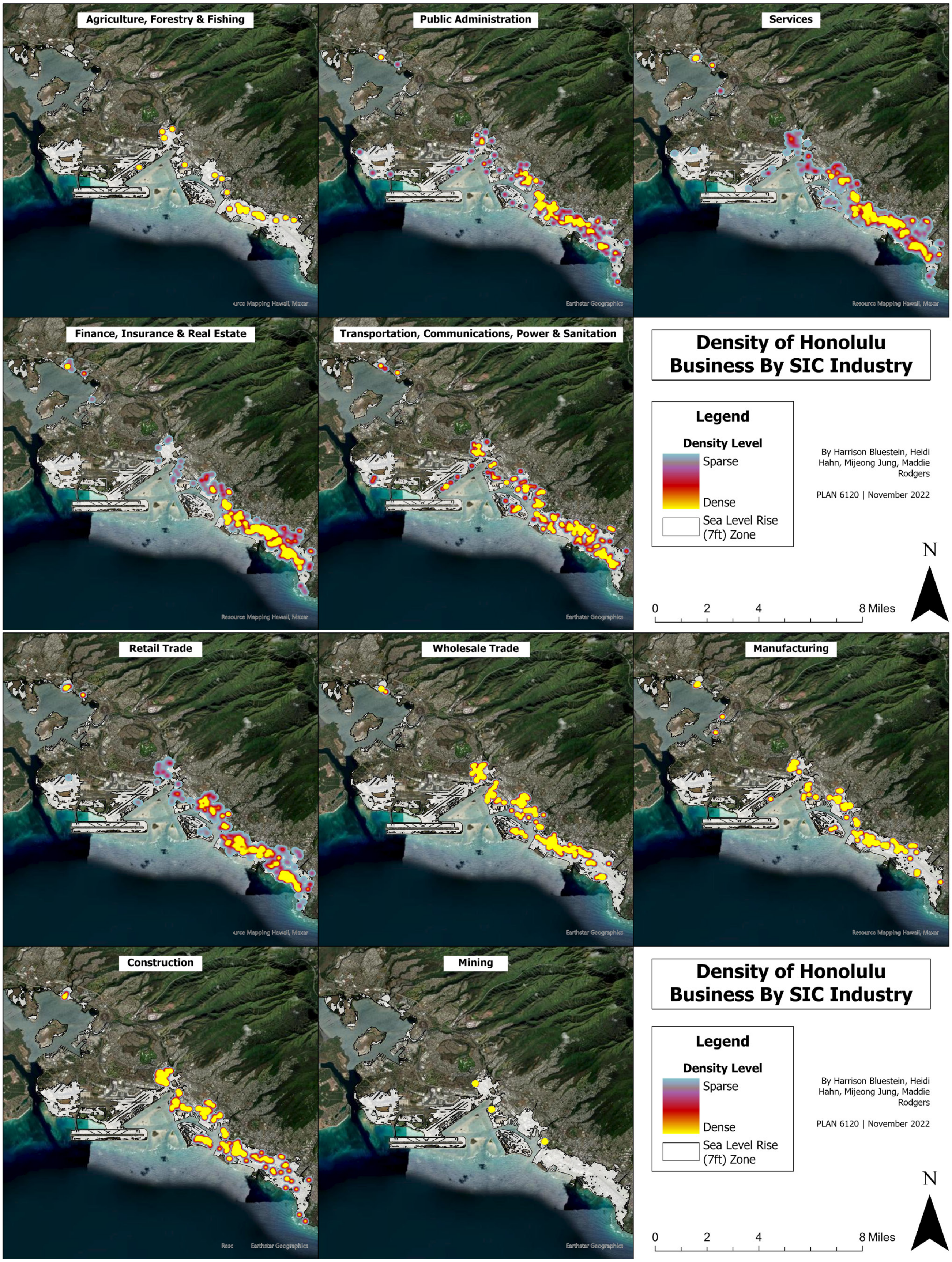


Figure 2

After completion of the suitability model, an economic analysis was conducted using ArcPro's Business Analyst, calculating the estimated sales volume/assets by Standard Industry Classification (SIC) code for businesses within the 7ft sea level rise zone. Figure 3 represents the industry density of the business analysis to better understand what sectors are most affected and where in the PUC they are distributed.


Agriculture, Forestry & Fishing
Public Administration
Services
Finance, Insurance & Real Estate
Transportation, Communications, Power & Sanitation
Density of Honolulu Business By SIC Industry
Legend
Density Level
Sparse
Dense
Sea Level Rise (7ft) Zone
By Harrison Bluestein, Heidi Hahn, Mijeong Jung, Maddie Rodgers
PLAN 6120 | November 2022
N
0 2 4 8 Miles
Retail Trade
Wholesale Trade
Manufacturing
Construction Trade
Mining
Density of Honolulu Business By SIC Industry
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Sea Level Rise (7ft) Zone
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Figure 3

Figure 4 charts the annual financial impact on businesses by sector within the 7ft sea level rise zone based on data from Business Analyst (via Data Axle).

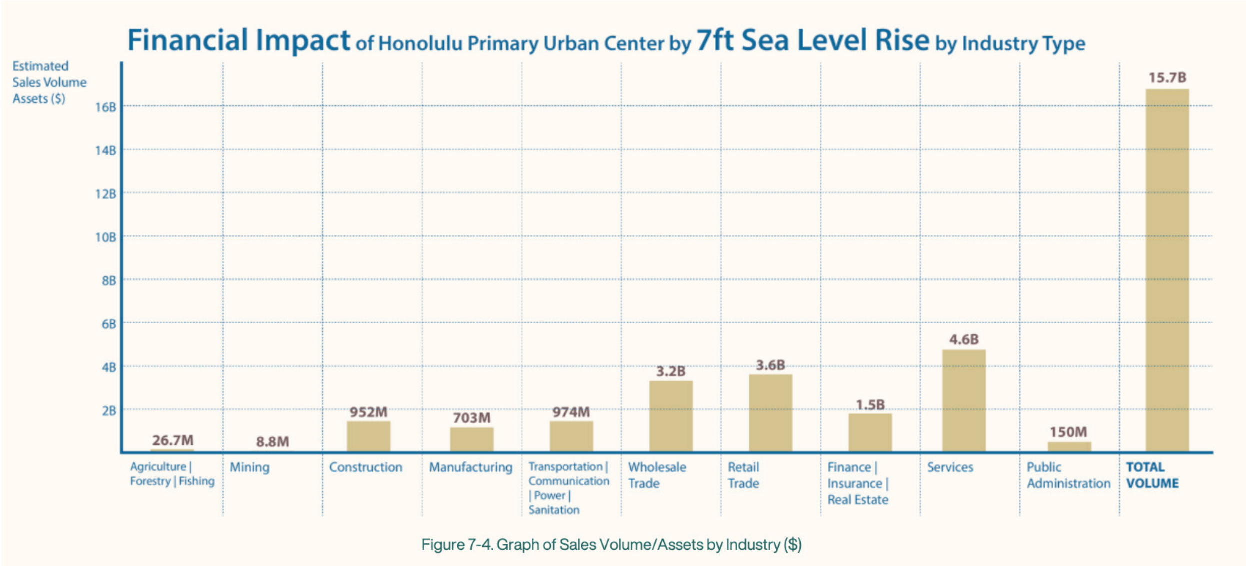

Figure 4

Data Sources and Methods

We acquired data from multiple different open data sources that were later manipulated in ArcPro to the PUC boundary and rasterized to input into the suitability modeler. The data and their sources are as follows:

- NOAA Sea Level Rise map - https://coast.noaa.gov/slr/
- FEMA Flood Insurance Maps - FEMA Flood Map Service Center
- Streets - State of Hawaii (Open data)
- Streams - State of Hawaii (Open data)
- Zones - State of Hawaii (Open data) from 2004 Master Plan
- Slope - derived from US Landsat images and then calculated using DEM

Our data was broken down in three ways: creating a PUC boundary layer, acquiring sea level rise information, and getting appropriate data for the suitability modeler. Our first task was to gather the correct information to show the PUC area we were analyzing. We obtained this information from the State of Hawaii Open Data, where we inserted it into our map. Next, we used NOAA's Sea Level Rise map to obtain the 7-foot sea level rise. We also used this data as a short clip in our story map to show this sea level rise development (1-7-feet). The final and most time-consuming part of our data collection was to figure out which datasets should be used in our suitability modeler. We decided on FEMA Flood Insurance maps, streets, streams, slope, and zoning. These were all obtained from the State of Hawaii Open Data. In all these layers, we added a field of either one or zero so that this data could be more easily manipulated in our suitability modeler. For example, the FEMA layer's attribute table showed zones A, AE, X, and more. We researched which zones of these zones were high-risk and which were low. In this newly created field, zones with low-risk were given a value of one, and zones with high-risk were given a value of zero (meaning zero suitability). In zoning, our main objective was to show preservation and military areas of lesser suitability. We took a similar approach in creating a field where these two zones were deemed "zero". As for streets and streams, we needed to "erase" these layers from the PUC boundary, then "join" them, so it included data across the whole PUC area, rather than just accounting for these roads or streams. Similarly, these fields gave streams and streets zero and any other areas one. Lastly, we needed to rasterize these layers to be used and inputted in the suitability modeler.

Results of the Analysis

ArcPro's Suitability Modeler and Business Analyst tools helped us to visualize the magnitude of impact that sea level rise will have on the area. Our group estimated the worst-case scenario of sea level rise in order to stress the importance of early mitigation and adaptation. If early intervention is not taken, we found that a large area of the PUC will be significantly impacted.

The Business Analyst tool helped our team discover the total estimated loss of sales volume and assets is over 15.7 billion dollars. Broken down this is 26.7 million for the agricultural, forestry, and fishing industries, 8.8 million for the mining industry, 952 million for the construction industry, 703 million for the manufacturing industry, 974 million for the transportation, communication, power, and sanitation industries, 3.2 billion for the wholesale trade industry, 3.6 billion for the retail trade industry, 1.5 billion for the finance, insurance, and real estate industry, 4.6 billion for the services industry, and 150 million for the public administration industry. These numbers represent the projected loss from sales volume and assets; however, they do not account for the externalities. For example, if hotels are inundated, individuals may decide not to visit Hawaii, therefore impacting car rental businesses, restaurants, and other tourist attractions located in other areas of the island. Sea level rise, if adaptation measures are not taken, can have a cascading effect on the environment, society, and economy.

Based on these findings, strict coastal land use policies and measures must be implemented early to prevent these impacts. As documented in Hawaii's Managed Retreat Final Report, "managed retreat is a "wicked problem" that will need to be approached through a combination of planning, policy, regulatory and financing tools, with critical underpinnings of political will and community acceptance," (Office of Planning Coastal Zone Management Program, 2019). The findings from these deliverables may pose further questions such as how retreat may be funded, how retreat is to be accomplished, how open space and public access will be implemented, and how social equity may be ensured. Once these questions are discussed, stakeholders may recognize that there is not enough feasible land to protect the stability of the economy, environment, and society.

Conclusions

This project demonstrates the need for proactive and long-term planning for coastal areas. As climate-related hazards grow in volatility, cities have begun to implement planning strategies and plans that look at both current and future developments. While this project presents a worst-case scenario sea level rise of 7-feet, it is still a viable threat. As global emissions continue to rise and mitigation thresholds are not achieved, a worst-case scenario is conceivable. More importantly, it illustrates both the physical and economic impacts that this disaster could have on an area. Honolulu's Primary Urban Center is a hub for tourism, which is a major contribution to Oahu's economic success. With this being said, most of the areas that would be inundated by this sea level rise are their hotel and tourism spaces.

The suitability modeler also illustrates the multitude of constraints for further development in the PUC area. Slope is a major issue for building development, and the mountainous terrain of Hawaii is a huge constraint when expanding in this region. Additionally, this area contains military and preservation zoning, not fit for development.

Though people are aware of this concern, the suitability model from this project is a persuasive and powerful tool for informing people and planners of the importance of strategic planning for future concerns. In addition, the Business Analyst aspect of this project exhibits the financial impact associated with this issue. There is a blatant fragmentation in agency when it comes to addressing climate related issues, and this project produces a compelling argument and planning analysis for policy makers and urban planners alike. Moreover, the economic impact analysis of the project is most likely the strongest justification for implementing early mitigation and adaptation strategies in planning.

In all, this project generates a strong analysis technique for planners and policy makers by addressing sea level rise and the availability for future development and mitigation practices in the PUC area. The combination of suitability and economic impact models illustrates the importance of long-term planning, not only in the PUC area, but all areas susceptible to sea level rise, for the protection of economic, environmental, and social stability.

Limitations and Caveats

While the location and general issue of our project has remained the same, the final products shifted throughout our investigation. In our original proposal, we planned to propose a rezoning of the PUC area. However, as we began our project and collected appropriate data, we focused on creating an in-depth suitability modeler that included information that showed feasible areas for future development with regards to a 7-foot sea level rise. While we did take zoning into consideration, it focused more heavily on areas like preservation and military, where development wouldn't be ideal because of the necessity of these zones. We also relied more heavily on slope, FEMA, roads, and streams as a tool to dictate appropriate areas. Rather than focusing on a complete redevelopment plan, our project shifted to be more of an investigation into the criteria and factors that need to be considered in long-term, purposeful planning.

Moving forward, there are a few aspects of our project that could be improved. The criteria used in the suitability modeler was for the entire island of Oahu but was clipped by the PUC boundary. Our final map and suitability data would have been strengthened by also clipping the 7-foot sea level rise and merging it. By doing this, we would have been able to weigh this area in each dataset as a suitability of zero. Instead, certain layers displayed this area of sea level rise as a feasible area for development, so our final suitability modeler map didn't quite show this area as 100% undevelopable. By clipping sea level rise and merging with criteria layers, our team would have been able to rank this section in all datasets as unfeasible locations, showing the 7-foot layer as red.

Another element to strengthen this project would be additional data within the suitability modeler. Soil type and current population and building density would be useful in narrowing down feasible areas for future development. There were also areas like the Punchbowl, an extinct volcanic crater, that showed up as a developable location, however this is obviously not the case. Certain areas like these could be edited in our model to increase the accuracy of our plan.

In all, this project and analysis is suitable to use in other circumstances. This is a great way to illustrate and plan for sea level rise or other climate crisis impacts. While this project is set up for worst case scenario sea level rise, it still holds importance in showing the need for proactive planning. This approach is applicable to coastal areas, not only for showing the physical impact, but the economic impacts associated with this climatic disaster.

Though this study centers on sea level rise, other factors could be utilized in this modeler. For example, climate change brings other impacts, such as wildfires, threatening homes, businesses, and agricultural land. This loss of land could substitute sea level rise, where areas subject to or affected by wildfires could be the guiding principle.

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