Coastal Housing Markets and Climate Resilience: Financial Value of Nature-Based Solutions

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Abstract

Valuing benefits of preserving nature is a difficult task, often resulting in insufficient funding directed to nature preservation. As extreme weather events intensify due to the climate change, one of the tangible benefits of nature is the protection it offers to people and property against such events. Measuring financial value of nature's climate adaptation benefits is key to attracting private investments. We propose a methodology for such valuation, by assessing how mangroves, a common coastal wetland in Florida, mitigate the effects of hurricanes on home prices by reducing flood risks and their perception by the housing market participants. Using property-level housing transaction data from Zillow, we measure how the presence of mangroves and their abundance affect home price changes in the aftermath of hurricanes. We find that proximity to mangroves reduces home price decline and dispersion following major hurricanes in 2004, 2012, and 2017. Wider forests provide larger price stability benefits. We show that the probability of a 25% value loss following the hurricane is substantially lower for properties protected by the mangroves (by as much as 7 percentage points). These results demonstrate a sizable private financial value of mangrove protection or restoration and suggest that private funding needs to be a part of financing such projects. More generally, the results point to the importance of measuring private value of nature, commonly thought to be only providing public benefits.

Keywords: climate adaptation, hurricanes, nature-based adaptation, housing, property values

JEL codes: Q54, G12, R31

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1 Introduction

The effects of climate change are no longer a future risk. The frequency and severity of climate-related disasters have increased in recent years and are expected to increase further (Hsiang and Kopp, 2018). This means that we need to think not only about climate change mitigation efforts, designed to reduce greenhouse gas (GHG) emissions, but also about adaptation efforts that would help protect nature, infrastructure, and people from the consequences of climate change. Nature-based solutions (NbS) such as protecting and restoring coastal wetlands are effective at reducing flood risks following hurricanes (Arkema et al., 2013; Menéndez et al., 2020; Beck et al., 2022). However, the benefits of such solutions are difficult to evaluate, which is a barrier to attracting private investments in such projects. Attracting private investment is key to preserving and restoring nature and biodiversity, because financial needs in this area exceed the means of governments and non-profit companies (Flammer et al., 2025).

In this paper we propose a methodology to evaluate private benefits of nature as protection against climate-related extreme weather events using market-based evidence. In particular, we measure the reduction of hurricane-related market value losses of properties as a result of protection provided by mangrove forests, account for the effects of mangroves on price dispersion, and compute the dollar value of private benefits from such protection. In prior studies, such as del Valle et al. (2019); Hochard et al. (2019); Menéndez et al. (2020); Sun and Carson (2020), the financial benefits of mangroves are derived from damage avoidance analysis based on construction costs data. Our analysis of market values of properties is designed to incorporate forward-looking differences between expected values of properties protected by nature and those that are not.

The state of Florida provides a relevant setting for our analysis. Multiple counties in the state have been hit by severe hurricanes in recent decades with substantial impacts on housing prices.[1] At the same time, parts of Florida's coastline are covered with mangroves, which are shown to be a natural protection against hurricane-induced flood damages (Thomas et al., 2020). In terms of the physical storm impact, studies such as Gijsman et al. (2021) and Mazda et al. (2006) find a linear effect of mangroves on flood risk reduction: wave energy and storm surge decay along a transect through mangroves, and wave and surge attenuation is a function of the distance inland of the mangrove forest. This impact translates into physical property damages, and Beck et al. (2022) and Menéndez et al. (2020) demonstrate that mangroves effectively reduce property damages from hurricane and flooding. Similar findings in economics studies are reported in del Valle et al. (2019), Hochard et al. (2019), and Sun and Carson (2020).[2]

We combine geographic variation in flood protection provided by mangroves with over-time variation in the impact hurricanes on housing prices. Property-level data allow us to analyze the

[1] See the list of continental U.S. hurricanes collected by NOAA at https://www.aoml.noaa.gov/hrd/hurdat/UShurrs_detailed.html.

[2] In particular, Sun and Carson (2020) finds that coastal wetlands' protection is especially effective in areas with weaker disaster prevention building codes, and in general the average value of these protections (damage avoidance) is around $1.8 million per square kilometer annually.

full distribution of the effects, rather than focusing only on the average value losses. We choose to summarize the effects using the measure of probability value at risk (pVaR), frequently used in pricing the value of extreme events, which measures the probability of housing price values dropping by more than a threshold amount following a hurricane (we choose a 25% threshold as an example). We then translate this measured pVaR into the willingness to pay for mangrove protection, as a share of pre-hurricane house value.

In addition to computing average effects across all the hurricane years, we allow for the effects to differ across counties that were on the path of hurricanes and those that were off path. We find that on the hurricane path proximity to mangroves reduces the probability of the 25% value loss of residential properties by as much as 7 percentage points, which is a sizeable decline in risk. When translated to willingness to pay, this corresponds to 40-80 thousand dollars value of mangrove protection per 1-million dollar property, depending on the initial risk of value loss, likely exceeding estimated direct damages or insurance premium differences. This reduction is also observed in off-path counties, but the effect is about half as large and is only apparent with about 1-year lag. This is likely due to the fact that perception of flood risk protection from mangroves increases following hurricanes as housing market participants learn from the experience of their neighbors.

Our reduced-form approach is supported by related works in coastal engineering. More specifically, studies such as Gijsman et al. (2021) and Mazda et al. (2006) find a linear effect of mangroves on flood risk reduction. Wave energy and surge decay along a transect through mangroves, and wave and surge attenuation is a function of the distance inland of the mangrove forest. Moreover, Beck et al. (2022) and Menéndez et al. (2020) demonstrate that mangroves effectively reduce property damages from hurricane and flooding. Our approach is also supported by studies that use distance to value the amenities of ecosystem services (Atreya et al., 2016).

We combine multiple data sets to conduct our analysis. Transaction prices of residential property sales, as well as property locations and characteristics, are sourced from Zillow's Transaction and Assessment Database. For data on mangrove locations relative to properties, we rely on Global Mangrove Watch maps. The elevation of the properties is measured using the Topologically Integrated Geographic Encoding and Referencing database. The National Flood Hazard Layer from the Federal Emergency Management Agency (FEMA) is used to identify flood risk designation. All these data are merged using the geo-coordinates of the properties. We estimate the effects of a generalized hurricane variable (based on three major hurricane years: Ivan and Jeanne in 2004, Sandy in 2012, and Irma in 2017). Our analysis focuses on seven coastal counties affected either direclty or indirectly by these hurricanes: Pinellas, Miami, Manatee, Lee, Hillsborough, Collier, and Charlotte.[3]

The statistical analysis is conducted at two levels of granularity. At the property level, we are able to evaluate property-specific price changes using repeated sales information and controlling

[3]The benchmark results focus on FEMA medium risk regions. In the estimations that include all FEMA flood zones, the sample also includes Broward County

for property fixed effects. Property fixed effects absorb any differences in flood exposures and amenities associated with specific properties.[4] This analysis provides us with estimates of the average housing price effect of hurricanes depending on the properties' proximity to the mangroves. To address the dispersion of the price effects, we also conduct the zip code-level analysis of the coefficient of variation of housing prices, controlling for aggregated values of properties' attributes in each zip code.

We apply the results of our statistical analysis to the observed distribution of housing price changes for the properties with repeated sales before and after hurricanes to evaluate the effect of proximity to mangroves on the pVaR of property values. We find that the effect varies by hurricane and county and can be as large as 7 percentage point reduction (from over 36% to nearly 29%[5]) of the probability of 25% housing value loss, which is what we estimate for Collier County following Hurricane Irma. The willingness to pay for this risk reduction, and therefore for mangrove protection and restoration, corresponds to 60 thousand dollars per 1-million dollar house, under standard assumptions.

We have to make a few important specification decisions for our analysis. First, we want to control for properties' inherent exposure to flood risk following a hurricane. This depends on the property elevation as well as their proximity to the coast. In property-level analysis both elevation and proximity to the coast are captured by the property fixed effects, in the zip-code level analysis, we control for the average elevation and distance to the coast of properties in the zip code.

Not surprisingly, proximity to the coast is highly correlated with proximity to mangroves. We address this issue in three ways: first, in the regressions with property fixed effects, this issue does not arise as the distance to the coast is absorbed by property fixed effects; second, in our benchmark regressions, we discretisize the distance to mangroves into five categories which reduces the multicollinearity problem; third we we rely on FEMA flood maps to control for the properties' exposure to flood risk.[6] Importantly, properties in high flood-risk areas (floodplains) are subject to a number of financial and regulatory requirements as well as subsidized insurance premia, which distorts the response of their values to disasters such as hurricanes (Morgan, 2007).[7] In addition, property values in floodplains are shown to be lower in general (David Harrison and Schwartz, 2001; Zhang, 2016), suggesting that some of the flood effects might be priced in. For this reason, and because of regulatory distortions in housing markets in high flood risk areas, our analysis is limited to properties in the medium flood risk area, which is subject to hazard, but not affected by

[4]Daniel et al. (2009) show that not controlling for amenity values may create biased results when measuring the effects of floods on property prices. Doss and Taff (1996a) show that properties with open access to the coastline are generally valued higher than those with forested wetlands, such as mangroves.

[5]This is the case for Collier County after Hurricane Irma

[6]FEMA flood maps is a common source for such analysis. For example, Faticaa et al. (2023) use flood risk maps to simulated the gains for firms for adaptation in terms of reduced negative post-disaster performance.

[7]A similar distortion is found in the aftermath of wildfires in California that received FEMA rescue funds, as shown by (Issler et al., 2020).

distortions.[8]

Second, housing sales are affected by hurricanes. As we are relying on actual transaction data, we allow for up to three years for the measured effects of the hurricanes, not counting the hurricane year. Other studies have demonstrated that housing price effects of hurricanes might be even more persistent, up to 5-6 years (Bin and Landry, 2013; Ortega and Taşpınar, 2018), however, the high frequency of major hurricanes in Florida makes it impractical to include more than three years in the estimation without overfitting the model. In addition, we verify that there are no pre-trends due to differences in distance to mangroves in our data.

Third, in the zip code level analysis, we have to control for property characteristics because we cannot control for property fixed effects. We include the following controls in our regressions, taking the median of them at the zip code level: distance to coast, elevation, property age, building area square footage, share of property types (single family house or condominium). In addition, we include county and time fixed effects.

In addition to our benchmark specification, we extend our analysis by allowing the effect of mangroves to vary as a function of the width of the mangrove forest at each location. We define "width" to be the cross-shore distance from water edge to back of the mangrove (belt, band or forest). Studies have shown that mangrove flood protection effects are larger when mangrove forests are wider (Gijsman et al., 2021; Maza et al., 2021). Our results are consistent with this finding — the decline in property prices following hurricanes is substantially smaller when mangrove forest is wider in proximity to the properties in question: an additional 10 meters of mangrove (up to 30 meters) have as much protection effect as increasing proximity to mangroves by 2 km.

We are not the first to estimate the effect of flood risks on housing prices. The negative effect has been found in a number of studies, including Bin and Landry (2013), Daniel et al. (2009), Graff Zivin et al. (2022), Bernstein et al. (2019), Baldauf et al. (2020), Hino and Burke (2021), and Keys and Mulder (2020). Bernstein et al. (2019) and Baldauf et al. (2020) that speak to the climate effects on housing prices by measuring the climate belief effects, while Ortega and Taşpınar (2018) attribute long-term reduction in New York property values following hurricane Sandy to change in climate beliefs. Our paper is also related to Benetton et al. (2022) and Kelly and Molina (2023). Benetton et al. (2022)estimates the value of "gray" infrastructure (sea wall) using house listing prices in Venice. To our knowledge, ours is the first study to measure the mitigating effect of mangroves or NBS more generally on flood risk-related housing value loss. Additionally, our identification of flooding risks through hurricane events is echoed by studies such as Gete et al. (2024) showing that riskiest Florida counties could experience mortgage rate spread increase as high as 13% compared to before the landfall. Our paper is also broadly related to studies that look broadly at the financial value of wetlands preservation and conversely of wetland loss, as seen in Taylor and Druckenmiller (2022) and Rizzi (2022).

Our analysis contributes to the literature on valuing conservation and the ecosystem. In par-

[8]In the Appendix we document the differences in the effects of mangroves by flood risk level.

ticular, Nolte (2020) uses housing data to estimate the costs of conservation in the United States. Most related studies focus on the amenity values of the ecosystem rather than climate risk reduction (Atreya et al., 2016; Belcher and Chisholm, 2018; Cho et al., 2006; Doss and Taff, 1996b; Mahan et al., 2000). More specifically, our analysis contributes to the literature on the costs and benefits of flood risk reduction measures, which includes studies by Brouwer and Schaafsma (2013); Corderi-Novoa et al. (2021); Lind (1967); Zhu et al. (2007), although very few of these studies focus on NbS. More recently, analytical models from Giglio et al. (2025) shows that as climate extreme event become more frequent, the marginal value of nature's adaptation effect increases as climate change intensifies.

To summarize, we find that the protection effects of mangroves can have large effects in terms of reducing potential residential property value losses after hurricanes, especially in the areas that are not currently designated as high flood risk. While we only measure the effects on the housing values, other benefits of NbS are many and need to be taken into consideration in a broader cost-benefit analysis.[9] Specifically to mangroves, in addition to flood protection of non-housing assets such as agricultural areas, public infrastructure, open spaces, and other properties, co-benefits include biodiversity protection through preservation and restoration of the habitats, and other ecological benefits. Moreover, further private benefits can be generated through carbon offset markets due to the potential of mangroves to sequester carbon.[10]

There are two main takeaways from our analysis. First, to the extent that residential property values reflect actual costs of hurricane-related damages, protection and restoration of mangroves could be an important part of the adaptation to climate change and an associated increase in hurricane frequency. Second, given that mangroves provide benefits to residential property owners as well as developers, insurance companies, and financial institutions, these private agents need to be contributing to the expenses associated with protection and restoration of mangroves. Designing financial instruments that would allow for such contributions will help alleviate climate adaptation costs for federal, state, and local governments while reaping the co-benefits in terms of ecosystem and biodiversity protection. Our analysis provides actual estimates as well as the methodology to quantify private benefits of nature that can be incorporated in such financial instruments.

2 Data Sources

To help answer the research question, we develop a novel dataset that combines high-resolution geospatial dataset with housing financial transactions. One key distinguishing feature of the dataset is that we are able to identify property-level variations of flood risks and the benefits provided by coastal wetlands.

[9] Allaire (2018) surveys the literature on the broad impacts of extreme flooding that NbS may help reduce.

[10] Globally, mangroves are among the most carbon-rich tropical ecosystems, comprising 14% of global ocean carbon sequestration as both above ground biomass and soil organic matter, despite only covering about 0.5% of global coastal areas (Alongi (2012); Alongi (2014)).

We combine the datasets of Global Mangrove Watch and Zillow's Transaction and Assessment Database (ZTRAX) to assess the value of mangroves in flood risk reduction. The data merging process is based on the geo-coordinates of the properties. We supplement the data with additional geographic information system (GIS) data such as house elevation from U.S. Geological Survey and the U.S. Census.[11] We use the National Flood Hazard Layer (NFHL) from FEMA to identify the perceived flood risks.

Housing Data

ZTRAX is a dataset of house final sales that provides a rich set of information on sale price, date of sale, square footage, and other key properties characteristics.[12] The scope of analysis is Florida due to mangroves mainly growing in tropical environments and the high frequencies of hurricanes in the state. Our study includes eight coastal counties: Pinellas, Hillsborough, Manatee, Charlotte,Lee, Collier, Broward, and Miami-Dade.[13] The time coverage of our data is 1993 to 2019. There are over 6.4 million records of transactions in our sample, in which there around 2.04 million unique properties. The majority, 68%, of these properties are single-family houses. All the sale price data have been converted to real terms (in terms of 2015 dollar).

Mangrove Data

We collected mangrove data from Global Mangrove Watch, which is an online platform established by the Japan Aerospace Exploration Agency's Kyoto and Carbon Initiative. The initiative is an international collaboration among Aberystwyth University, solo Earth Observation, and the International Water Management Institute. The platform provides remote sensing data and tools for monitoring mangroves (Bunting et al., 2018). Remotely sensed data was created from satellite radars that were able to detect mangrove extent across the entire world at 30-meter resolution (Bunting et al., 2022). This dataset additionally displays the change in mangrove coverage between select years during 1996 and 2020.[14] Unfortunately, there are no sufficient changes in mangrove coverage in the counties we consider in proximity of the properties in our data in order for us to use mangrove dynamics as a source of identification (see Table A.2). For this reason we use a time-invariant measure of the distance to mangroves and mangrove width as described next.

Figure 1 shows the distribution of mangroves in our sample. While all eight counties in the sample have mangrove coverage, the southwestern Florida counties have higher density. To measure the

[11] From the U.S. Census, we use TIGER (Topologically Integrated Geographic Encoding and Referencing database).

[12] Importantly, these data are collected from county assessors' offices and not from the Zillow website. As far as we know, ZTRAX does not provide information of the properties' listing dates.

[13] We are precluded from considering remaining coastal counties due to the limitations of the GIS data.

[14] Specifically, we use data from years 1996, 2007, 2008, 2009, 2010, 2015, 2016, 2017, 2018, 2019, and 2020. The average of these years' data is used as the mangrove distance measure.

effect of mangrove on flood risk reduction, we devise measures of property-specific distance to mangrove and the width of the mangrove forest. Property-specific distance is calculated as a geodesic (shortest distance) to the closest mangrove forest. We bin the distance measure into 2km groups: 0-2km, 2-4km, 4-8km, 8-16km, and more than 16km, to allow for non-linear decay of the effect of mangroves with distance.

For each property we also record the width of the mangrove forest that is closest to the property. We calculate the width of mangrove forest using the GIS data by generating transects between the boundaries of mangroves and location of properties and calculating the geodesic distances from the properties to the boundaries. Additional details are described in Appendix A.2.

Hurricane Data

The dates and paths of hurricane lending are obtained from National Hurricane Center, National Oceanic and Atmospheric Administration (NOAA) and North Carolina Institute for Climate Studies. We selected three main hurricane years during which major hurricanes affected Florida in our sample. While hurricanes Ivan and Jeanne as well as Irma passed through Florida (see Figure 4, Sandy did not. The choice of Sandy as a hurricane to include in the analysis is to illustrate that the benefits of mangroves materialize not only in terms of flood risk reduction for those counties in the hurricane paths, but also in terms of the perception of risks for those not directly on the hurricane path (but are indirectly affected through weather events and proximity to the hurricanes).

FEMA Data

Using National Flood Hazard Layer (NFHL), we categorize properties into three flood risk categories: low, medium, and high. More specifically, in line with the taxonomy of FEMA, an area is a medium (or moderate) risk zone if it is located in a 500-year floodplain, meaning that the damages to this areas are not likely unless the flood is of a size that only occurs once in 500 years.[15] When an area is designated as a high risk zone, also known as Special Flood Hazard Area (SFHA), or 100-year floodplain, it means that properties are likely to experience damages from a smaller-scale event, such as occurs once in a 100 years. Figure 2 shows that substantial areas of the coastal counties are either in medium or high flood risk zones.

3 Empirical strategy

Following real estate economics literature including Mueller et al. (2009) and Graff Zivin et al. (2023), we use a hedonic regression model to estimate how housing prices, both in terms of level

[15]Data were obtained from FEMA "Flood Zones" at https://www.fema.gov/glossary/flood-zones in 2021-2024.

and dispersion, reflect the value of mangroves. To uncover the level effect, we rely on the variation arising from the repeated sales of properties. In other words, if a house is sold after a recent hurricane, its price should reflect how buyers and sellers perceive the risk exposure of the property and the potential value of mangroves in alleviating the risks.

We focus on three major hurricane years that fall in the time frame of the sample: Hurricanes Ivan and Jeanne in the year 2004; Hurricane Sandy in 2012; and Hurricane Irma in 2017. Given that perception of the flood risk in Florida can be affected by the hurricanes that land in neighboring states along the Gulf of Mexico and eastern seaboard, some of the effects we find for Irma in 2017 could also be affected by hurricanes Harvey and Maria. Figure 4 shows the paths of these hurricanes across the six counties in our sample. We allow for differential effects of hurricanes on counties that are directly in the paths of hurricanes and those that are not. As the paths of hurricanes show, different hurricanes landed in different counties in our sample (and Sandy did not land in Florida) providing sufficient variation for identification of separate effects. To generalize the effects of these hurricanes, we combine three hurricanes into a single hurricane variable in the benchmark estimations.

3.1 Identification and measurement of the mangrove effect

A major source of flood risk comes from buildings close to the coast, as ocean waters can travel inland during storms Gijsman et al. (2021). However, the risk is mitigated by natural barriers like mangroves when they are in between homes and their coastline (Das and Vincent (2009)). Everything else equal, even when faced with identical flood risks, properties closer to mangroves are less likely to be damaged by hurricanes and floods or, if affected, are likely to have smaller damages.

It is not straightforward to identify how housing prices would reflect the presence of mangroves. There are at least two mechanisms at work. On the one hand, if people perceive that mangroves can reduce the impact of flooding, therefore protecting their home value, they would be willing to pay more for houses in closer proximity to mangroves. On the other hand, the presence of mangroves can potentially reduce the amenities that one would value when living by the ocean, such as view and access to the waterfront, therefore pushing down the house price. Our identification strategy relies on the assumption that risk reduction can be affected by the flooding events, such as those associated with major hurricanes, while the amenity value is not.

Our benchmark specification relies on differential changes in house prices in the aftermath of the hurricanes depending on the proximity of the property to mangroves. We include year-month fixed effects to absorb any price trends common to our sample, as well as average impact of hurricanes on housing prices. We include property fixed effects to account for distance to the coast, elevation, amenity values resulting from mangroves as well as all other property characteristics. The variable of interest is an interaction of a post-hurricane indicator, which only varies over time but not across properties, and our measure of property proximity to mangroves, which only varies across properties

but not over time. Main effects of these variables are absorbed by fixed effects. We also include 1 and 2 years before the hurricane to capture any pre-trends.

One important identification issue remains — since mangroves grow at the water edge, proximity to mangroves is highly correlated with proximity to water edge and therefore with the exposure to flood damages. Even though we can measure proximity to water edge directly, we cannot control for its interaction with post-hurricane indicator because of resulting near-multicollinearity. In the robustness tests we make sure that our results of distance to mangroves are not spuriously driven by the distance to the coast. In addition, we focus our benchmark specification on NFHL "medium flood risk" areas, thus excluding properties that are not at the risk of flooding at all, or those that are at an extreme risk of flooding. Importantly, NFHL risk designations combine information on proximity to the water edge, elevation, and any existing flood protection measures, thus these measures are not highly correlated with distance to mangroves. In our pre-testing we find that the properties in the medium flood risk are most likely to benefit from proximity to mangroves.

3.2 Baseline Econometric Specification

We estimate the effect of mangroves on flood risk reduction on the level and the coefficient of variation of properties' sale prices. The baseline specification of the hedonic regression is the following:

$$log(P_{it}) = \beta'(m_i \times H_t) + \delta_i + \delta_t + \epsilon_{it}, \tag{1}$$

where $log(P_{it})$ is the logarithm of sale price of property i in month t. H_t is a vector of indicators of whether house i is sold after 1 or 2 years before, the year of, or 1 or 2 years after a hurricane. For example, Hurricane Irma occurred in August-September of 2017, if a property is sold in October 2017, the "year of hurricane" indicator for that particular observation is 1. m_i indicates mangrove distance group in which the property is located. The baseline group is within 2km of mangrove presence, and there are 4 additional groups: 2-4km, 4-8km, 8-16km, and more than 16km. The specification includes property fixed effects δ_i to obtain estimates of within-property variation, identified by repeated sales. We also control for year-month fixed effects δ_t to account for common housing price dynamics and seasonality. Note that in this specification the main effect of mangrove distance group is absorbed by property fixed effects since it does not vary over time, while main effect of the components of H_t is absorbed by the time fixed effects.

3.3 Price dispersion

To examine the probability value at risk (pVaR) impact of mangroves we need to also obtain a measure of price dispersion as a function of proximity to the mangroves in the aftermath of the hurricanes. To do so, we aggregate the property data to the zip code level and estimate the following regression of the price dispersion measure σ_{zt}/μ_{zt}, measured as the coefficient of variation of the

sales price within a particular zip code (where σ_{zt} is the standard deviation and μ_{zt} is the average sales price of properties in zip code z in month t).

$$\frac{\sigma_{zt}}{\mu_{zt}} = \xi m_z + \beta'(m_z \times H_t) + \gamma' X_z + \delta_c + \delta_t + \epsilon_{zt}, \tag{2}$$

where m_z now represents median distance of properties in zip code z to mangroves. In this regression, since we cannot include property fixed effects, we include county fixed effects δ_c and a vector of zip-code level control variables X_z that includes average distance to coast, elevation, property age, building area square footage, dummy variables whether the property is a family house or a condominium. We continue to include time fixed effects δ_t which absorb the main effect of the hurricane indicators.

3.4 Distinguising between Direct and Indirect Effects (learning)

After establishing average effects of the mangrove distance, we allow for heterogeneous effects depending on whether a given county is in the path of hurricane or not. To do so, we create an indicator θ_{ct} for whether a hurricane that landed in a given year t, moved through county c. We extend this definition to indicators of of "before" and "after" the hurricane. We also create an "off path" indicator for counties that were not hit by a given hurricane, $1 - \theta_{ct}$. We then split the interaction term in our regression 1 into two separate variables: one for "on path" properties and one for "off path" properties.

For the property-level regression with thus estimate

$$log(P_{it}) = \beta_1'(\theta_{ct} m_i \times H_t) + \beta_2'((1 - \theta_{ct}) m_i \times H_t) + \delta_i + \delta_t + \epsilon_{it}, \tag{3}$$

similarly, for zipcode level coefficient of variation equations we estimate

$$\frac{\sigma_{zt}}{\mu_{zt}} = \xi m_z + \beta_1'(\theta_{ct} m_z \times H_t) + \beta_1'((1 - \theta_{ct}) m_z \times H_t) + \gamma' X_z + \delta_c + \delta_t + \epsilon_{zt}. \tag{4}$$

3.5 Price Level and Width of the Mangrove Forest

So far in the estimation, we have not allowed for the heterogenetiy of the effects across the width of the mangrove forest. As Gijsman et al. (2021) point out, forest width is an important factor in mangroves' functionality in reducing flood risks. The importance of examining the width of the mangrove forest is supported by additional studies: del Valle et al. (2019) examines the impact of the width of the mangrove forest on economic activities; while Maza et al. (2021) shows that in conditions characterized by short waves, mangrove forest widths exceeding 300 meters are necessary to diminish incoming waves and surge by over 50%. Thus, we estimate

$$log(P_{it}) = \beta'(m_i \times H_{it}) + \gamma'(\omega_i \times H_{it}) + \rho'(\omega_i \times H_{it} \times m_i) + \delta_i + \delta_t + \epsilon_{it}, \tag{5}$$

where as before the main effects of the width of the mangrove forest ω_i and distance group as well as their interaction are absorbed by the property fixed effects δ_i.

We measure forest width by discretizing it in three ways: 1) whether the observed width falls in the threshold value of 300 meters; 2) 4 bins of mangrove widths ranging from less than 100 meters to greater than 500 meters;[16]; and 3) the inverse of the mangrove width in meters. In the main results, we use measure of inverse of the width.[17]

4 Results

In this section, we first show the estimation results of mangrove effects on the level and dispersion of property sale prices. We use point estimates to calculate the probability of losing 25% or more of property value following a hurricane as a function of property distance to the mangroves. We then extend our analysis to account for the intensive margin of the effect as measured by the width of the mangrove forest.

Throughout our analysis we focus exclusively on properties located in medium flood risk zone shown on Figure 2. As described in Appendix Appendix A.4, the effects of mangroves on prices of high flood risk properties in the aftermath of hurricanes is less clear. This is likely due to the effect of special policies and insurance rules that apply to such properties.

4.1 Benchmark Results: price levels, hurricane paths and price dispersion

We begin by reporting our benchmark results which will contribute to our calculations of the pVaR and willingness to pay (WTP) for mangrove protection.

Effect on the price level: property-level analysis

Table 1 reports the results of our benchmark estimation of the effects of mangroves on the level of property prices following hurricanes (equation 1). All regressions include monthly time fixed effects as well as property fixed effects. To test for the pre-trends we include separately an indicator of 1-24 months before each hurricane, an indicator of 0-12 months following hurricane, and 12-36 months after the hurricane. We first include these indicator individually and then together, all interacted with the index of distance to mangroves (the main effect of the time period indicator is absorbed by the time fixed effects). The main effect of distance to mangroves as well as all property-specific characteristics are absorbed by property fixed effects. The identification comes from price changes

[16]More specifically, there 4 bins are: less than 100m; between 100m and 200m; between 200m and 500m; and greater than or equal to 500m. The choices for these bin sizes are based on the empirical distribution of the width data in our data, and with support from experimental results in Figure 3 of Maza et al. (2021)

[17]The main reason for this choice is the ease of interpretation. The results for the other 2 measurements are in the Appendix

between repeated sales of the same property, relative to monthly trend. In the last column we also allow for annual trend to vary by distance to mangroves.[18] The mangrove distance groups are labeled so that the larger the number, the more distant an individual property is from mangrove presence. Therefore, a negative coefficient of this measure means that the further the mangrove, the lower the house sale price is.

We find that there are no pre-trends, except when we include mangrove distance-specific trends when we observe a positive pre-trend: that is, in pre-hurricane years prices are higher for properties that are further away from mangroves. In the year of the hurricane and the two years that follow we observe that the price decline increases with distance to mangroves. We illustrate this effect in Figure 3 using our benchmark specification in column (4). When allowing for trends to vary with mangrove distance, we find that prices grow slower for properties that are further away from mangroves. It is possible that persistent negative effects of hurricanes, which are more substantial for properties further away from the mangroves contribute to these differential trends. Thus, while our results show that trends in house prices differ with distance to mangroves, these differences might be reflecting actual effects we are trying to measure, and therefore we do not include them as controls in the rest of our analysis.

Properties in counties on and off the hurricane path: preperty-level analysis

We separate the properties into two groups: those located in counties through which the hurricanes in question (Ivan, Jeanne, or Irma) passed directly, and the rest, as shown in Figure 4. We allow for the effect of the distance to mangroves following the hurricanes to be different for these sets of counties. Note that, as before, the effect main effect of hurricanes on property prices are absorbed by time fixed effects.[19] The results are reported in Table 2. We find positive pre-trends for properties on the hurricane path and negative pre-trends for properties off the hurricane path (or all properties preceding 2012, hurricane Sandy year). Following the hurricanes, we find that the effects of mangrove protection are substantially larger for the properties located in hurricane-path counties, both immediately following hurricanes and in the following two years. In the year of a hurricane there is in fact a positive effect on prices of the properties with high distance to mangroves in counties not directly hit by the hurricane, which can reflect demand for relocation from affected areas. In the two years that follow, however, we find that prices drop for properties that are further away from mangroves, even for properties in the counties not directly hit by the hurricanes. The effects are illustrated in Figure 5. The magnitude of the effect on prices of properties in off-path counties is about three times smaller than that for properties in on-path counties. These findings indicate that housing market participants learn about the protective nature of mangroves

[18]The results are similar if we allow for different trends for different mangrove distance bins rather than an interaction of trend with the categorical mangrove distance measure. These results are available upon request.

[19]Including a separate set of time fixed effects for counties on and off hurricane paths for specific hurricanes does not make any difference in the estimates. These results are available upon request.

when their neighbors are affected by the hurricanes and the damages are much more contained and prices hold up much better for the properties that benefit from mangrove protection.

We will use the estimated coefficients for the years 2-3 after the hurricane from column (4) in Table 2 to predict the shift of the empirical distribution of price changes due to the presence of mangroves for our pVaR and WTP analysis.

Effect on price dispersion: zipcode level analysis

Next, we estimate our zipcode level regressions in equation 2 to obtain estimates of the effect of mangroves on price dispersion following hurricanes. We aggregate our data to zip code level for each month taking mean, standard deviation, and median of sale prices for each month and zip code, separately for single-family homes and condos. We calculate median distances to mangroves and to the coasline, median elevation, median property size and mean values of Building Code Indicators in each zip code. We include these values as controls in the regressions along with time fixed effects and zip code fixed effects. We continue to cluster standard errors on time.

Our dependent variable is the unit-free coefficient of variation of house sale prices in a given month in a given zip code. The results are reported in Table 3. In all specifications, we find a positive and significant effect of higher distance to mangroves on the coefficient of variation in the aftermath of the hurricanes. That is, the proximity to mangroves attenuates price dispersion after hurricanes (shorter distance to mangroves means lower price dispersion).

When we break down the effect of hurricanes by counties that are on and off the hurricane path, we find that the increase in price dispersion for properties further away from mangroves is larger for the counties that are on the hurricane path but are also positive and significant in the year following hurricanes in the counties off the hurricane path. We find that without controls or zip code fixed effects, higher distance to mangroves on average is associated with lower price dispersion, but the sign flips once we include controls, and the coefficient becomes essentially zero once we also include zip code fixed effects. Note that the effects of controls also drop when we include zip code fixed effects, suggesting these don't vary much over time.

We will use the estimates for the years 2-3 after the hurricane from this last regression (column(5)) to predict the increase in dispersion of the price changes due to the presence of mangroves for our pVaR and WTP analysis.

To help interpret the results, we visualize the mangrove effects across space in Figure 6 of southern Florida, on which our data sample is based. The results from the regressions of the price level and dispersion reported in Tables 1 and 3, without differentiation by the hurricane path, provide the *relative* effects across mangrove distance groups: 0-2km, 2-4km, and so on.[20] When an individual

[20]Each hexagon represents an area with 5km of diameter, in which there are housing transactions as reported by the ZTRAX dataset. We intrapolate the effects of distance to mangrove into 1km grid to calculate average effect on

property is located between 2 and 4km to mangroves, the reduction of house sale price is higher on average by 3.25 percentage points (relative to properties right next to mangroves), but this reduction becomes greater if the property is further from mangrove. Similarly, there is an increase in price dispersion as the distance to mangroves increases. Thus the map shows that mangrove proximity has a price level as well as stabilization effects.

4.2 Heterogenity across the width of the mangrove forest

We have shown that the overall effect of mangrove is to stabilize housing price following hurricanes. We now explore it further by focusing on one dimension of heterogeneity: conditional on the same distance of properties from mangroves, how does the width of the mangrove forest affect price declines following hurricanes? This dimension of heterogeneity is of particular interest because it has been demonstrated that mangrove width is important in providing protection from flooding and wind damage. To evaluate the effect, we are focusing on the interaction terms between the width of the mangrove forest and other key variables.

Estimating Equation 5 with additional interaction terms for the flood risk indicators, we compute marginal effect of different groups of mangrove forest width on the price level properties in medium flood risk areas 2 years following hurricanes, controlling for distance to the mangroves. Table 4 reports the results.[21] We select width groups of mangrove forest to report based on the empirical distribution of the width of Florida mangroves in the sample. As shown by the table, houses near thinner banks of mangroves, such as those less than 20 meters wide do experience higher reduction of sale price after a hurricane. Such relative reduction of sale prices dwindle as the width of mangrove forest increases.

To get a sense of the importance of the width of the mangrove forest, it is useful to look at the effects of mangrove distance and width together. Figure 7 is a heat map that shows the effects of both mangrove distance and width 2 years after hurricane Ivan for properties in the medium flood risk areas.[22] In general, the closer properties were to mangroves and the wider are the belts of mangroves, the more sale price benefits a property experiences. In terms of magnitudes, when a property is located within 0-2km from mangroves, and such mangrove forest is between 20-30 meters wide, this property could be sold up to 10% higher in the aftermath of a hurricane than if the distance were 2-4km and the forest width were 10-20 meters. In fact, properties in close proximity to mangroves that are 30 or more meters wide did not experience decline in housing prices 2 years following hurricane Ivan. As the heatmap shows, the effect of every 10 meters of reduction in mangrove forest width is equivalent in magnitude to the effect of an increase in distance to mangroves by 2km.

price level and dispersion for each hexagon.

[21] Full regression results are available upon request. Tables A.8-A.11 report the results for alternative measures of width.

[22] The results for other hurricane years are available upon request.

4.3 Probability Value at Risk

To make further sense of magnitudes and to account for potential effect of mangrove protection on the dispersion of housing prices, which is essential to evaluating a private financial benefit of mangrove protection, we turn to the concept of value at risk, which is quite standard in evaluating risk properties of assets.

To illustrate the concept, we compute changes in sale price of each property from the last transaction before a given hurricane year to the first transaction in the 2nd year following the hurricane. Figure 8 shows the distribution of percentage price changes from repeated sales of each property before and after each hurricane by county. Given important housing market dynamics during our sample, including rapid increase prior to 2007 followed by the price collapse in 2008-09, we adjust these price changes by Florida-specific Case-Shiller U.S. National Home Price Index. For illustrative purposes, we select a 25% property loss value as a threshold for the value at risk. Red areas indicate the probability of a loss exceeding this 25% threshold, which is known as probability value at risk, or pVaR. For instance, for Charlotte county following hurricane Sandy, which did not even pass through Florida, there was a 41% probability of losing more than 25% of house value relative to trend.

Next, we ask how this measure varies with the distance to mangroves. We already have the estimates for how the mean of distribution is affected by the distance to mangroves for counties on and off the hurricane path (column (4) Table 2) and also the effect on the second moment, measured by the coefficient of variation (column (5) of Table 3). Thus we can adjust this empirical distribution of price changes for each hurricane and each county. We calibrate the distribution of price changes based for properties that are are more than 16km from mangroves and for properties that are closer than 2km to mangroves. We then compare the difference in the probability of 25% value loss between properties with and without close mangrove protection.

Figure 9 shows the results by counties and hurricanes. It is evident that the presence of mangroves makes a difference in reducing the probability value at risk of property sale prices. In general, because of the flood risk reduction benefits of mangroves, the regions of significant property value losses (25% or more) are smaller for properties near mangroves than for those far away. In the most prominent cases of Collier or Hillsborough counties after Irma, the decline in pVaR is 7 percentage points. Notably, the effects are observed not only in the counties directly hit by the hurricanes but also in counties where perceived flood risk and perceived benefits of mangroves are affected by experience in the neighboring regions. Not surprisingly, these effects are smaller in magnitude.

4.4 Willingness to Pay

How do we translate pVaR estimated in the previous section to the amount of money those who benefit from mangrove protection should be willing to invest in it? We have to make some parametric assumptions.

Assume a Constant Relative Risk Aversion (CRRA) utility function

$$u(x) = \begin{cases} \frac{x^{1-\gamma}}{1-\gamma}, & \text{if } \gamma \neq 1, \\ \ln(x), & \text{if } \gamma = 1. \end{cases}$$

A homeowner that faces a choice of protecting and not protecting mangrove is essentially facing potential hurricane effects that the same losses but with different probabilities (lower probability in case of mangroves). We can simplify our analysis by assuming binary lottery (no loss vs. 50% loss of value) and use our empirical estimates to calculate willingness to pay for the reduction in the probability of a 50% loss.

Thus, without mangroves, the expected utility will be

$$\mathbb{E}[u(W_N)] = (1 - p_N)u(W) + p_N\, u(0.5\, W)$$

W is the value of the property before the hurricane, and p_N is a probability of loosing half of this value as a result of the hurricane in the absence of mangroves.

Certainty equivalent of this lottery is

$$CE_N = \begin{cases} \left((1 - p_N)W^{1-\gamma} + p_N(0.5\, W)^{1-\gamma}\right)^{\frac{1}{1-\gamma}}, & \text{if } \gamma \neq 1, \\ W^{1-p_N}(0.5\, W)^{p_N}, & \text{if } \gamma = 1. \end{cases}$$

Similarly for the case with mangrove protection,

$$\mathbb{E}[u(W_M)] = (1 - p_M)u(W) + p_M\, u(0.5\, W)$$

where $p_M < p_N$ is the pVaR with mangrove protection.

$$CE_M = \begin{cases} \left((1 - p_M)W^{1-\gamma} + p_M(0.5\, W)^{1-\gamma}\right)^{\frac{1}{1-\gamma}}, & \text{if } \gamma \neq 1, \\ W^{1-p_M}(0.5\, W)^{p_M}, & \text{if } \gamma = 1. \end{cases}$$

The willingness to pay for mangrove protection will then be

$$WTP = CE_M - CE_N.$$

The results of these calculations are reported in Figure 10. We can see that for cases such as Collier or Hillsborough counties following hurricane Irma, where the probability of losing 25% of house value was 31-32 percent without mangroves and drops by 7 percentage points due to mangrove protection, the owner (or the insurer) of the 1-million-dollar property should be willing to pay about 60 thousand dollars for mangrove protection.

5 Robustness Tests

We have conducted analysis of alternative specifications to check for robustness of the headline estimation that exploits property-level fixed effects. In the benchmark we use the measure of generalized major hurricane events. As robustness check, we redo the estimation in Equation 1, but with indicator variables of Ivan, Sandy, and Irma included (instead of the aggregate hurricane variable). The results are highly consistent with Table 1.

One potential concern of the baseline specification is that we do not explicitly account for distance to coast, and the mangrove distance measure used potentially captures coastal distance–in other words, the price benefit shown in the baseline regression could in fact be showing amenity value of proximity to the coast.[23] To assuage such concerns, we use an alternative specification: instead of linear measure, we use an indicator variable of mangrove presence. Additionally, we include the linear distance of properties to coast, in addition to property-level co-variates such as property age and square footage to account for property characteristics.

In this specification, the mangrove indicator variable is equal to 1 if a property is located within 500 meters of mangroves. Table A.6 shows the results of the estimation. Similar to what results in Table 1 suggest, the results here show that mangrove proximity by itself increases the property sale price. Additionally, in majority of the cases, when taking into account hurricane shocks, the price stabilizing effect of mangroves continue to be true, which are consistent with results in our main specification. In terms of magnitude of effects, the coefficients in Table A.6 are larger, which makes sense as here we are comparing properties close to mangrove with all other properties (as opposed to effects of relative mangrove distance in Table 1).

Another concern is with potential heterogeneity of property sizes. So far we have only considered the effects of mangroves on the overall sale prices of properties. In our benchmark specification, the direct effect of property size on price is absorbed by the property fixed effects and in the aggregate regressions we control for the property square footage. That said, it is worth verifying property heterogeneity is not affecting our results. Table A.7 shows the results of mangrove effect on the price per square foot. The signs of coefficients are fully consistent with the specification in which the dependent variable is the overall price.

6 Conclusion

Preserving nature and biodiversity has risen to list of the foremost concerns of the policymakers worldwide. The problem with financing the preservation and restoration of nature and biodiversity, however, is their quintessential public good nature. Unfortunately, governmental and non-profit resources are not sufficient for the needed investments. Thus, it is key to attract private capital to

[23] Potential multicollinearity is the main reason of not including both mangrove distance and coast distance interactions with hurricane indicators in the same regression.

finance preservation of these resources. Attracting private capital requires quantification of private benefits of natural resources so that a case can be made for structured financial instruments and public-private partnerships. One such benefit of nature is its contribution to reducing climate-related risks.

While nature-based climate adaptation solutions have been shown in natural sciences and engineering literature to have flood risk reduction benefits, there are limited studies that explicitly measure the financial value of such benefits. In this paper, we help fill the gap by demonstrating the financial benefits of mangroves in stabilizing property values following hurricane disasters. Using the Florida housing market as an example, we identify the mangrove effect by comparing the effect of hurricanes on sale prices of properties close to mangrove versus those that are not. We find that on average, after a major hurricane, properties 2-4km away from mangroves experience a loss of around 3.3% of value relative to properties near mangroves. The price effect difference increases even more (to over 15%) when properties are further than 16km away from mangroves. Moreover, mangrove protection reduces prices dispersion following hurricanes. These changes result in as much as 7 percentage points reduction in the probability of losing more than 25% of the property value following a hurricane. This is a substantial benefit of mangroves presence to property owners and insurers. An owner or insurer of a 1-million dollar property in this case would be willing to pay 40-80 thousand dollars, depending on the initial risk of value loss, for preserving or restoring mangroves nearby.

Additionally, we take into consideration how the mangrove effect can vary by the width of the mangrove forest. In coastal engineering studies, wider belts of mangroves have been found to be important in reducing wave and surge impact. Perhaps unsurprisingly, our analysis finds that properties close to wider mangrove forest experience greater price stabilization benefits after hurricanes.

These private financial benefits of mangroves are only one component of their overall benefits to flood reduction, ecosystem services, and biodiversity. We do not conduct a full cost-benefit analysis of mangrove protection and restoration, but our results are important in demonstrating private benefits that may help secure private funding of mangroves protection and restoration efforts as well as inform policy decisions on how funding of such efforts can be structured.

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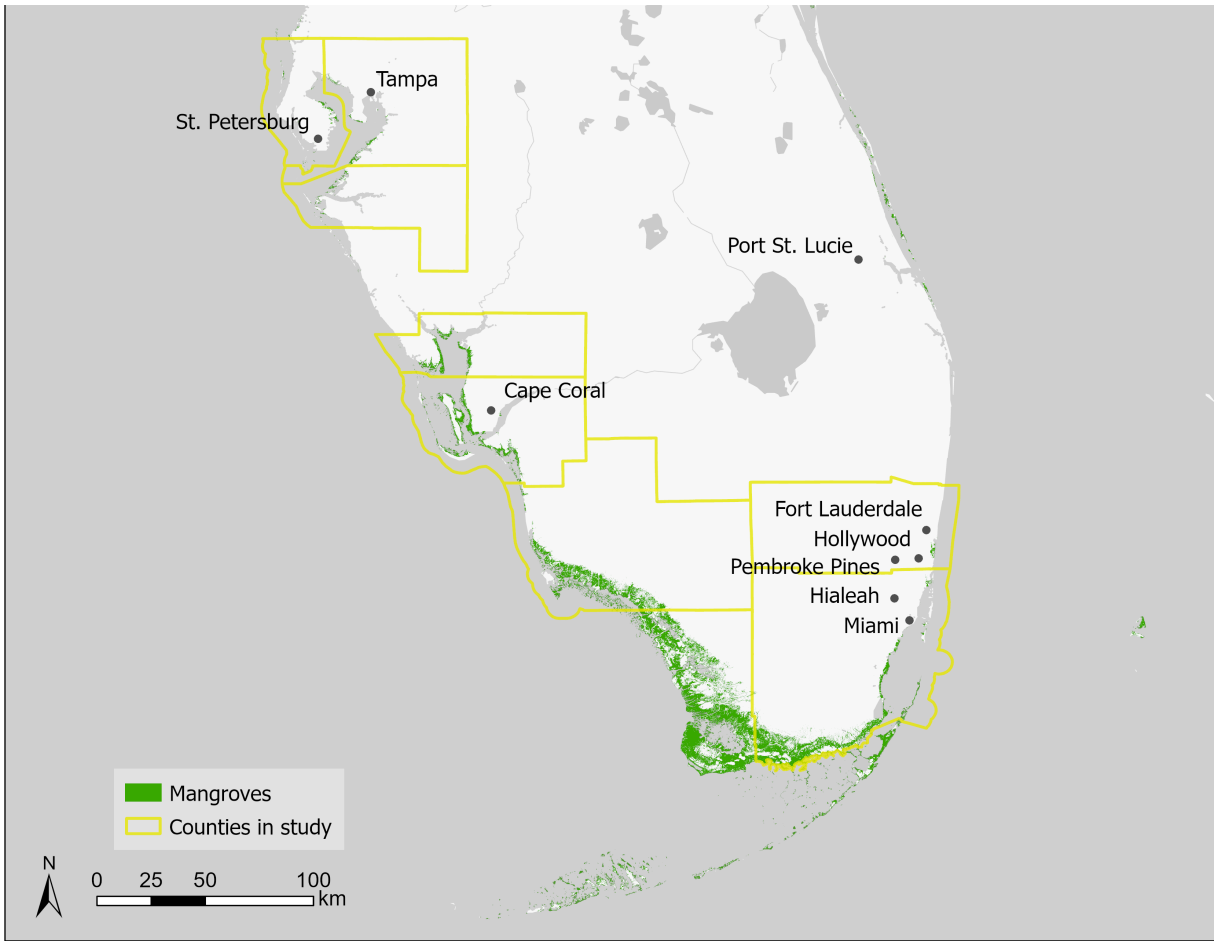
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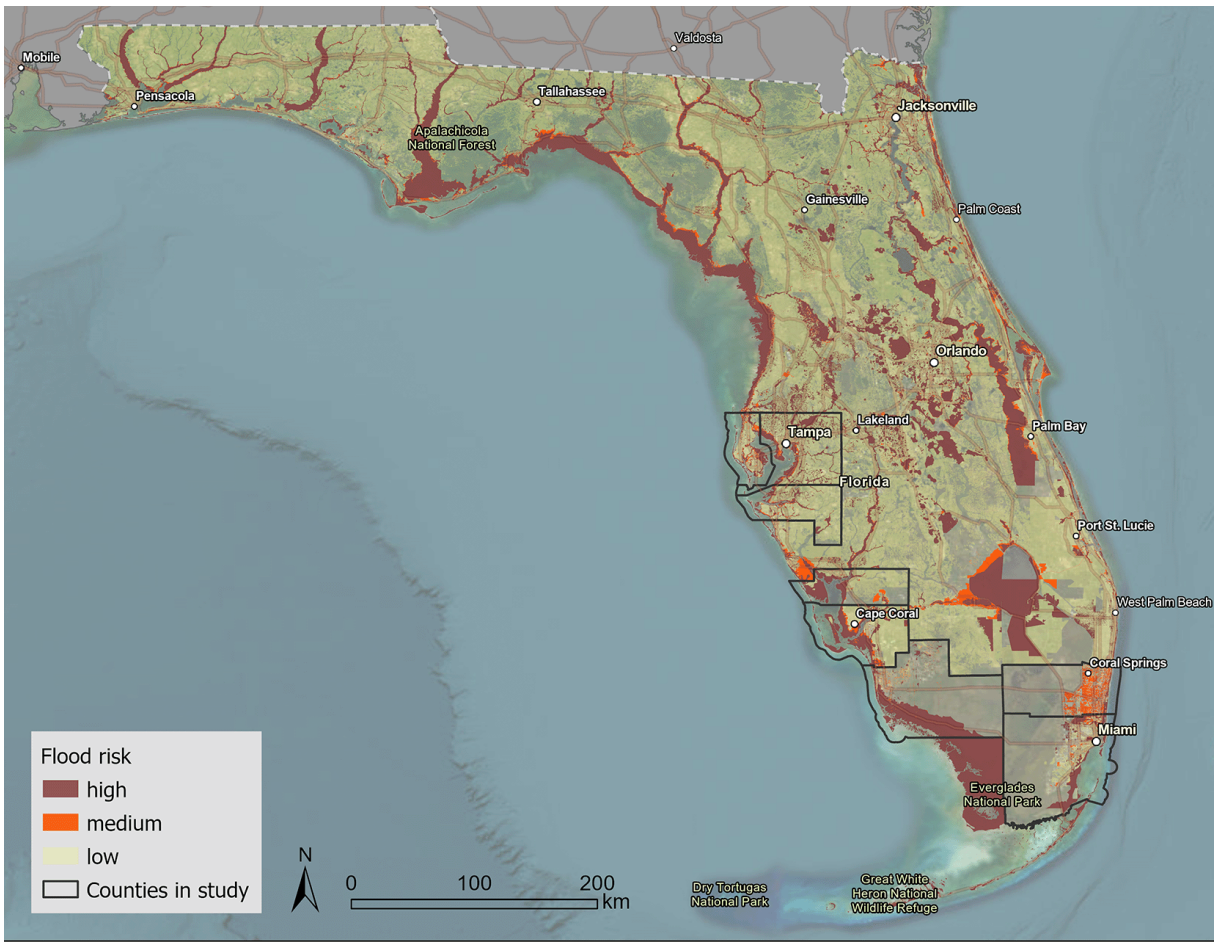
Zivin, Joshua S Graff, Yanjun Liao, and Yann Panassie, "How Hurricanes Sweep Up Housing Markets: Evidence from Florida," Working Paper 27542, National Bureau of Economic Research July 2022.

Figure 1: Mangroves Distribution in Florida



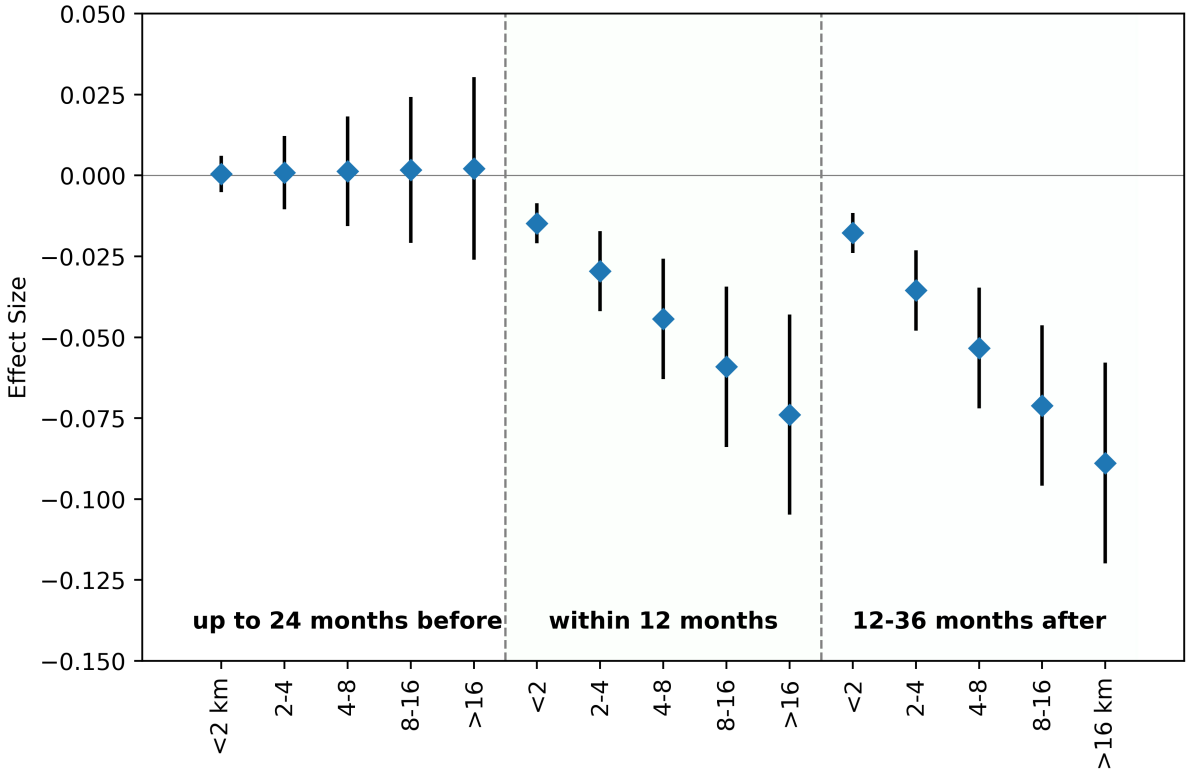
Notes: Details the eight counties studied and mangrove distribution in 2020. Source: Global Mangrove Watch.

Figure 2: Flood Risk Map



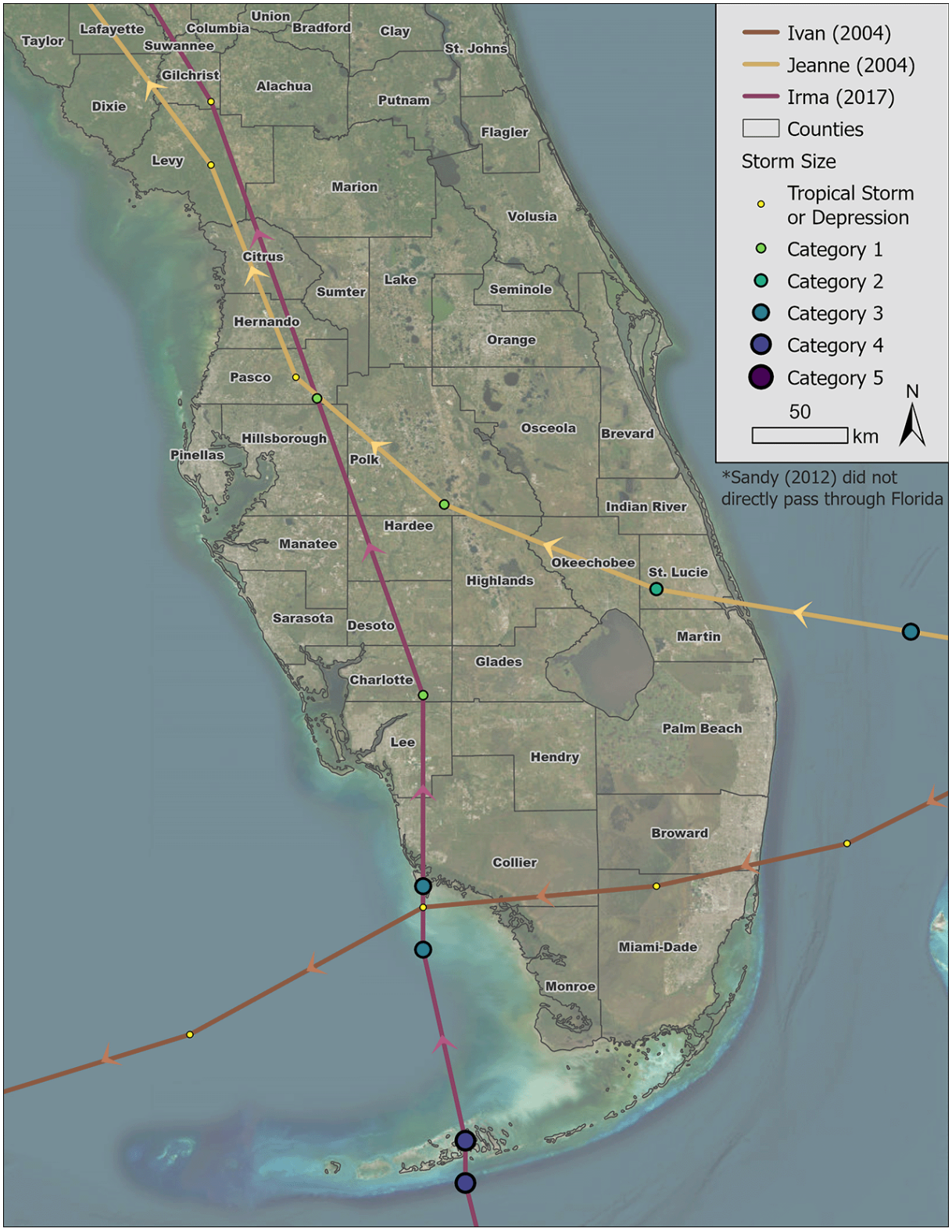
Notes: Risk from the associated flood zones from FEMA Flood Hazard Layer for all of Florida in 2020.

Figure 3: Benchmark coefficient estimate



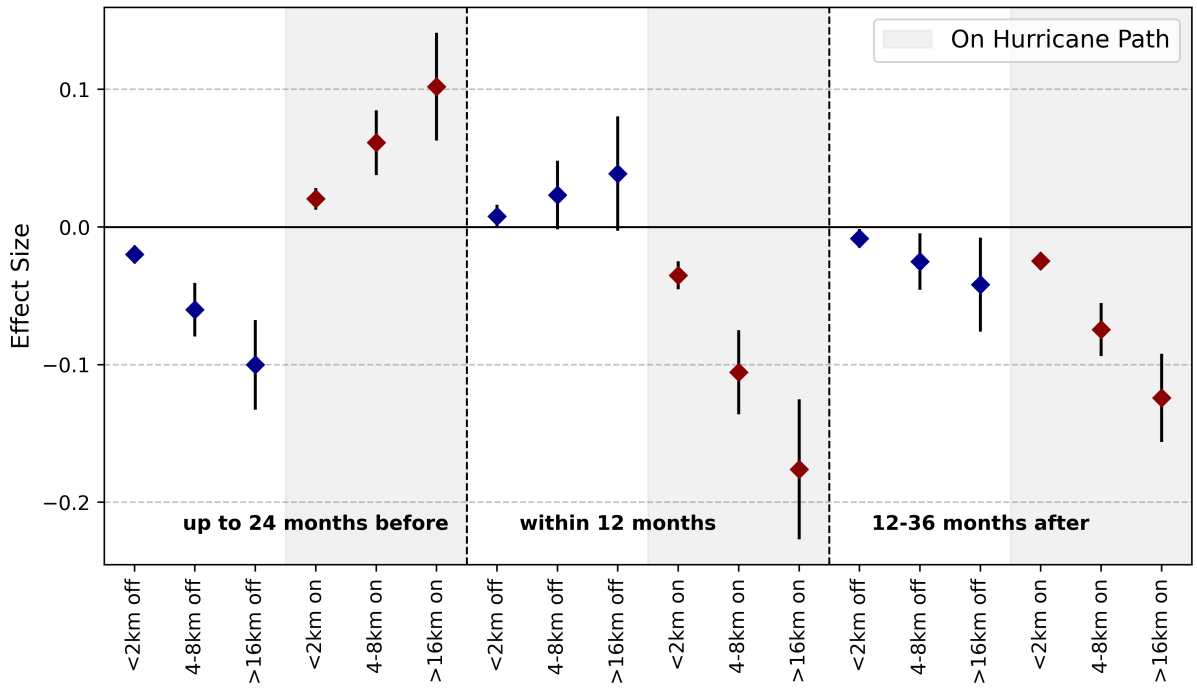
Notes: Plotted are coefficients and standard errors from column (4) of Table 1 that estimates equation 1.

Figure 4: Hurricane Paths



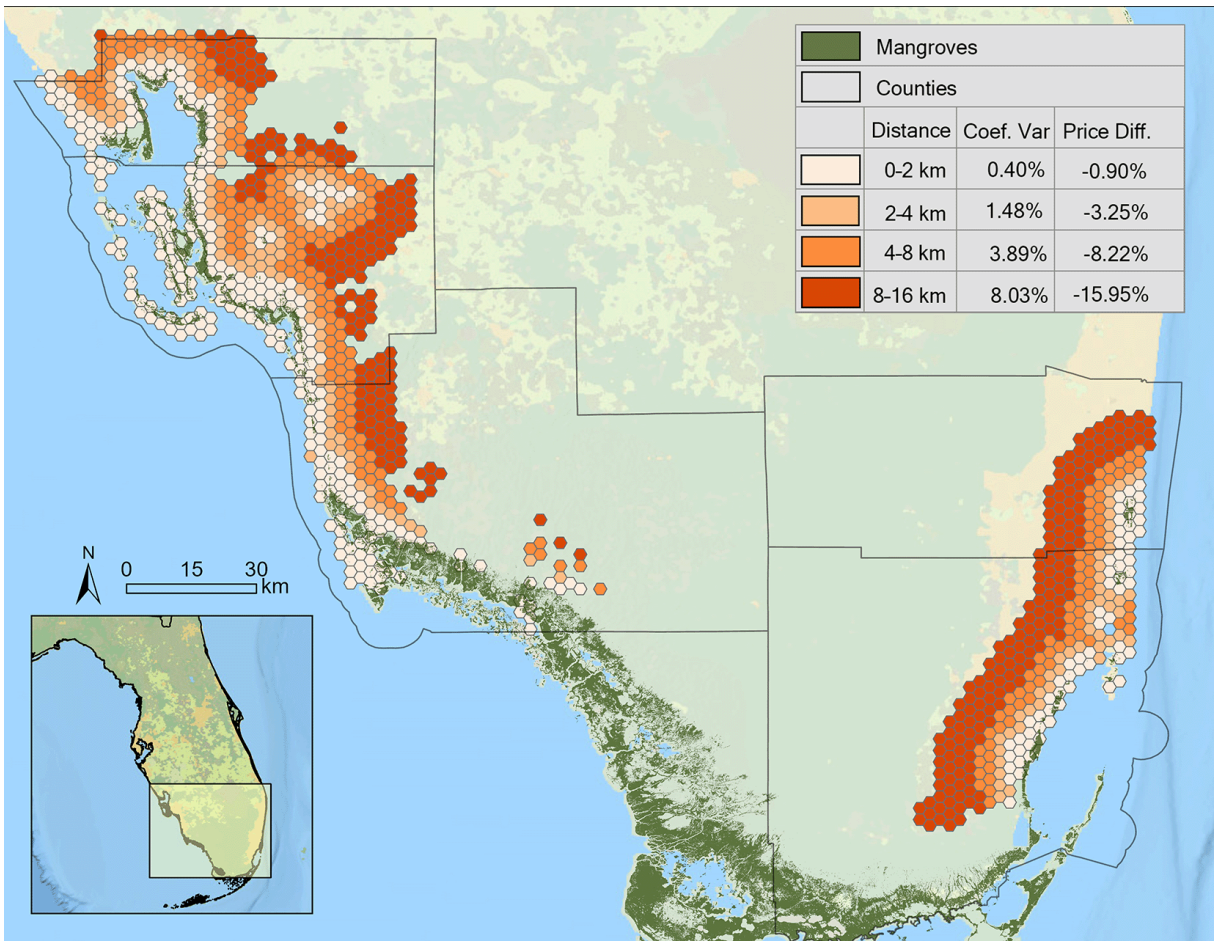
Notes: The graph illustrates the paths of hurricanes examined in this paper. Sources: National Hurricane Center, NOAA; North Carolina Institute for Climate Studies.

Figure 5: Benchmark: With Path



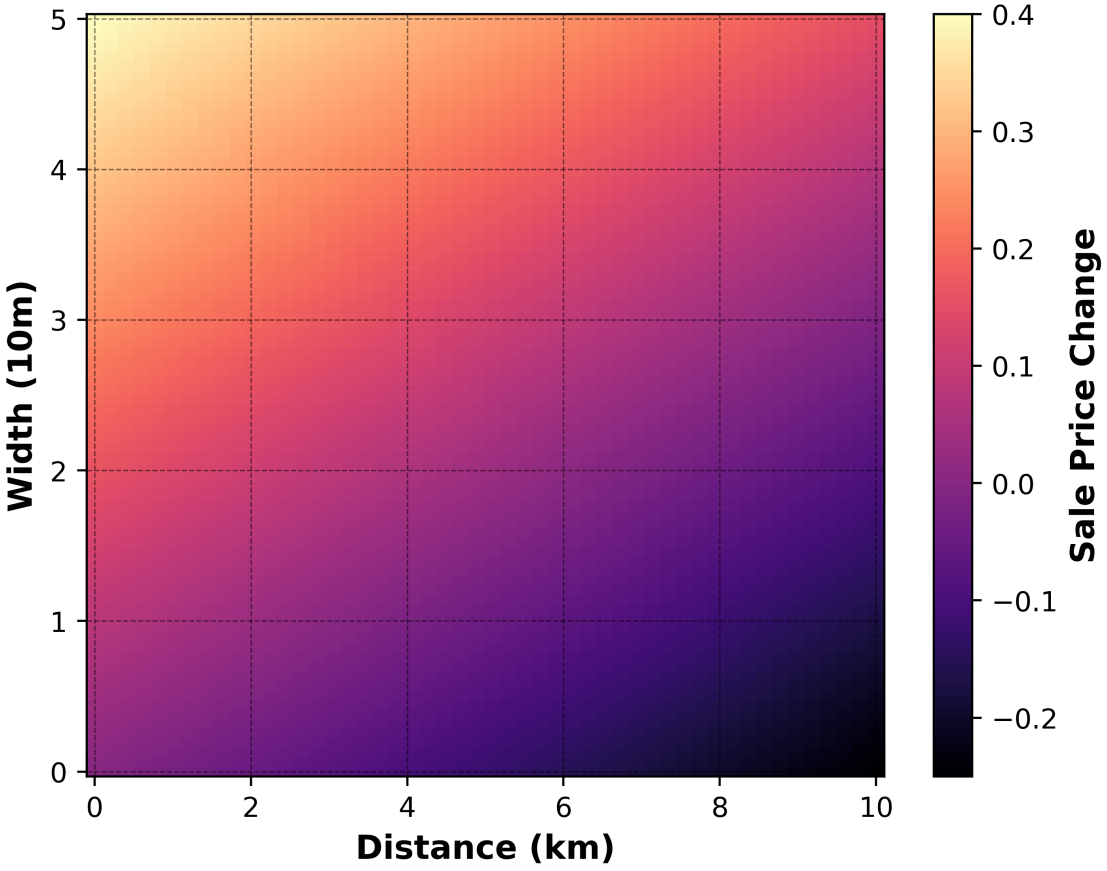
Notes: Plotted are coefficients and standard errors from column (4) of Table 2 that is estimates equation 3 and differentiates between counties on and off the hurricane paths.

Figure 6: Distribution of Distance to Mangroves and its Effect



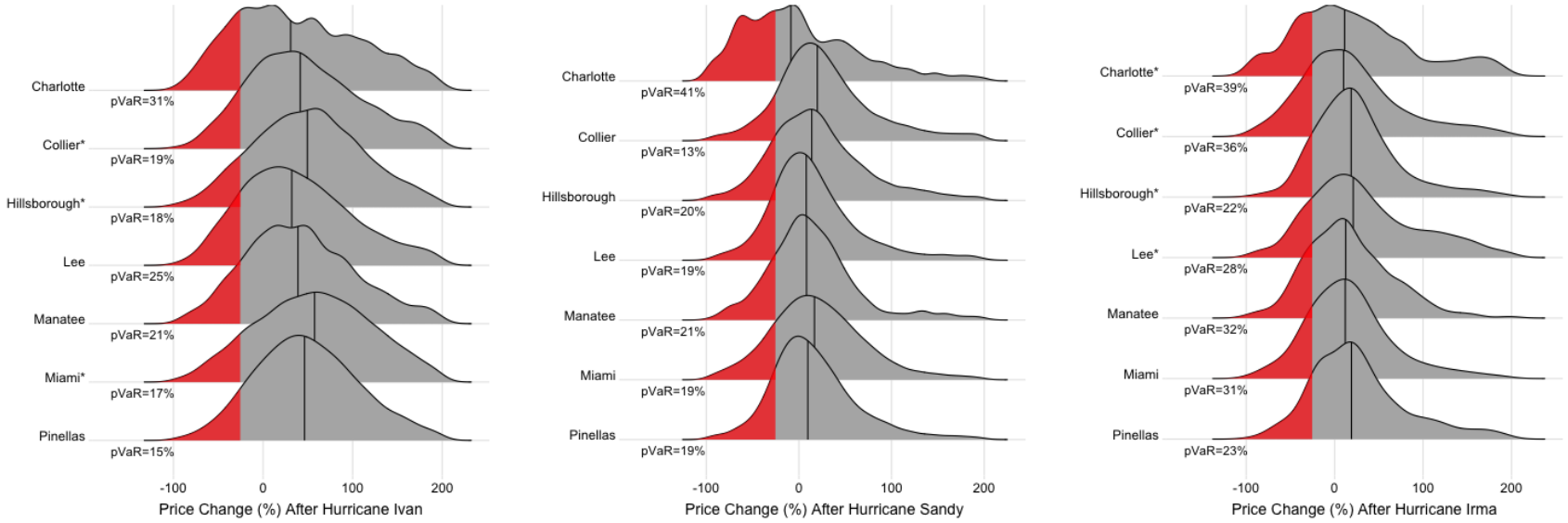
Notes: The numbers are computed from estimates reported in Table 1 column (4) and Table 3 column (4). "Price Diff." refers to the relative difference of prices between properties by mangrove proximity after a hurricane hit. Closer proximity to mangroves results in smaller sale price reductions following a hurricane. "Coef. Var" refers the price dispersion reduction effect of mangroves. Closer proximity to mangroves results in smaller sale price volatility following a hurricane. The results reported are relative percentage differences between distances. The reference baseline case is a property with nearly 0km distance to mangroves.

Figure 7: Effect of Mangrove Distance and Width on Sale Price, Medium Risk Areas



Notes: Proximity to mangrove in combination with greater mangrove width generally result in more positive sale price changes following hurricanes. Results are based on estimation for Hurricane (year 2) for counties on the path in medium risk areas, and a linear combination of mangrove distance (interact with hurricane) coefficient and mangrove width 10m coefficient. We choose coefficient for mangroves with 10 meter width because it is at the lower end of mangrove width empirical distribution, namely a lower threshold to meet for the width benefits to take effect. The unit of measurement of effect here is the log of sale price.

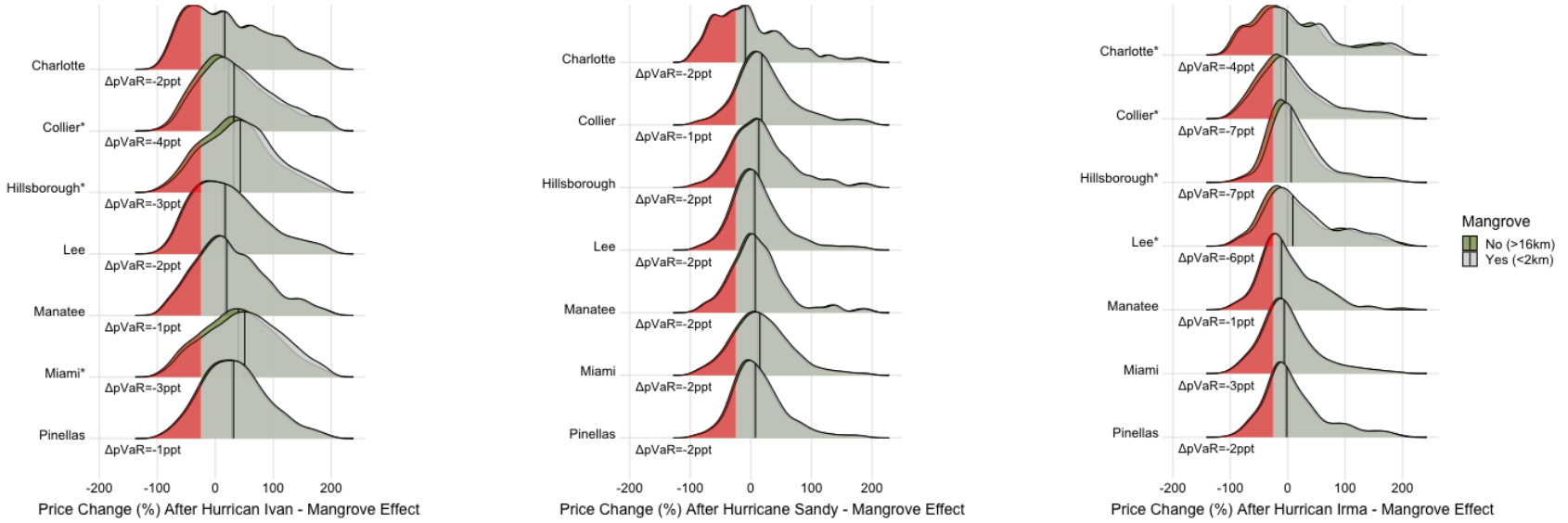
Figure 8: Probability Value at Risk after Hurricanes



Ivan (2004) Sandy (2012) Irma (2017)

Notes: County names with asterisks refer to those on the hurricane path. Price changes of properties in FEMA-designated medium flood risk zones, adjusted using Florida-specific Case-Shiller U.S. National Home Price Index. The effect refers to the 2nd year after the hurricanes, in this case Sandy. The red region refers to a loss of 25% or more, and $pVaR$ refers to the cumulative density of this region.

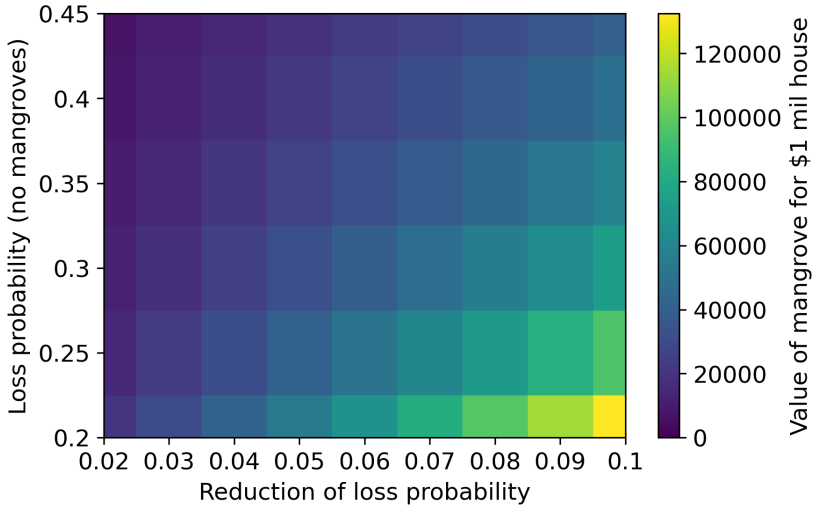
Figure 9: Mangroves Reduce Probability Value at Risk after Hurricanes



Ivan (2004) Sandy (2012) Irma (2017)

Notes: County names with asterisks refer to those on the hurricane path. Price changes of properties in FEMA-designated medium flood risk zones, adjusted using Florida-specific Case-Shiller U.S. National Home Price Index. The red region refers to a loss of 25% or more. ΔpVaR represents the differential of the cumulative density between mangrove and no mangrove case–a negative value means pVaR is reduced because of mangrove presence.

Figure 10: Willingness to pay for mangrove risk reduction



Notes: Willingness to pay for reducing the probability of losing 25% of housing value following hurricanes. Calculations assume CRRA untility function with $\gamma = 3$.

Table 1: Effect of Mangroves on Prices after Hurricanes

	Dependent variable is Log(Sale Price)				
	(1)	(2)	(3)	(4)	(5)
Mangrove Distance ×	0.001			0.000	0.013***
I(2 years before hurricane)	(0.002)			(0.003)	(0.003)
Mangrove Distance ×		-0.009***		-0.015***	-0.013***
I(1 year after hurricane)		(0.002)		(0.003)	(0.003)
Mangrove Distance ×			-0.014***	-0.018***	-0.003
I(2-3 years after hurricane)			(0.003)	(0.003)	(0.003)
Trend × Mangrove Distance					-0.002***
					(0.000)
R^2	0.714	0.714	0.714	0.714	0.714

Note: The negative coefficients of the interaction variables means that closer proximity to mangrove results in smaller sale price reduction following a hurricane. Results estimated from Equation (1) $log(P_{it}) = \beta'(m_i \times H_t) + \delta_i + \delta_t + \epsilon_{it}$ for medium flood risk properties in the data. Thus, time and property fixed effects are included in all regressions. Standard errors are in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Number of observations in all regressions is 1171460.

Table 2: Effect of Mangroves on Prices after Hurricanes: hurricane path effects

	Dependent variable is Log(Sale Price)			
	(1)	(2)	(3)	(4)
Mangrove Distance × I(2 years before hurricane)				
On hurricane path	0.013***			0.020***
	(0.003)			(0.004)
Off path	-0.013***			-0.020***
	(0.002)			(0.003)
Mangrove Distance × I(1 year after hurricane)				
On hurricane path		-0.011***		-0.035***
		(0.003)		(0.005)
Off path		-0.006		0.008
		(0.003)		(0.004)
Mangrove Distance × I(2-3 years after hurricane)				
On hurricane path			-0.021***	-0.025***
			(0.003)	(0.003)
Off path			-0.007*	-0.008*
			(0.003)	(0.003)
R^2	0.714	0.714	0.714	0.714

Note: The negative coefficients of the interaction variables means that closer proximity to mangrove results in smaller sale price reduction following a hurricane. Results estimated from Equation (3) $log(P_{it}) = \beta_1'(\theta_{ct} m_i \times H_t) + \beta_2'((1 - \theta_{ct}) m_i \times H_t) + \delta_i + \delta_t + \epsilon_{it}$ for medium flood risk properties in the data. Thus, time and property fixed effects are included in all regressions. Standard errors are in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Number of observations in all regressions is 1171676.

Table 3: Effect of Mangroves on Price Dispersion after Hurricanes

	Dependent variable is coef. of variation of sales price				
	(1)	(2)	(3)	(4)	(5)
Mangrove Distance ×	0.009***	0.003	-0.001	-0.001	
I(2 years before hurricane)	(0.002)	(0.003)	(0.003)	(0.003)	
Mangrove Distance	0.006*	0.010**	0.010**	0.010**	
I(1 year after hurricane)	(0.002)	(0.003)	(0.003)	(0.003)	
Mangrove Distance	0.011***	0.009**	0.008*	0.008*	
I(2-3 years after hurricane)	(0.003)	(0.003)	(0.003)	(0.003)	
Mangrove Distance × I(2 years before hurricane)					
On hurricane path					-0.012***
					(0.003)
Off path					0.004
					(0.003)
Mangrove Distance × I(1 year after hurricane)					
On hurricane path					0.016***
					(0.004)
Off path					0.008*
					(0.004)
Mangrove Distance × I(2-3 years after hurricane)					
On hurricane path					0.008*
					(0.003)
Off path					0.005
					(0.003)
Mangrove Distance	-0.010***	0.005*	0.002	0.002	0.003
	(0.002)	(0.002)	(0.005)	(0.005)	(0.005)
Median distance to the coast		-0.004***	0.002	0.002	0.002
Median elevation		0.022***	-0.002	-0.002	-0.001
Median property age		0.001***	0.000	0.000	0.000
Median property size		0.000	0.000	0.000	0.000
Residence type indicators	YES	YES	YES	YES	YES
Zipcode Fixed Effect	No	No	YES	YES	YES
R^2	0.023	0.139	0.226	0.226	0.227
Observations	76559	45063	45060	45060	45060

Note: Dependent variables: Coefficient of variation of sale prices at zip-code level. Results estimated from Equation (2) and include controls for zip-code level averages of property characteristics: $\sigma_{zt}/\mu_{zt} = \xi m_z + \beta'(m_z \times H_{zt}) + \gamma' X_z + \delta_c + \delta_t + \epsilon_{zt}$. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4: Marginal Impact of Mangrove Width, 2nd Year after Hurricanes–Medium Risk Areas

Dependent variable: log of sales price	
10m	-0.08***
	(0.01)
20m	-0.04***
	(0.00)
30m	-0.03***
	(0.00)
70m	-0.01***
	(0.00)
150m	-0.01***
	(0.00)
N	1164057

Note: Dependent variables: log of sale prices. It is clear that as mangrove widths (from 10m to 150m), the negative effects of hurricane become smaller. Results are based on the interaction terms between hurricane variable, mangrove distance, and mangrove width estimated from Equation (5): $log(P_{it}) = \beta'(m_i \times H_{it}) + \gamma'(\omega_i \times H_{it}) + \rho'(\omega_i \times H_{it} \times m_i) + \delta_i + \delta_t + \epsilon_{it}$. The choice of width measure is the inverse width, and specific width value is based on empirical distribution: 10 meters (10th percentile), 20 meters (<20th percentile), 30 meters (25th), 70 meters (median), and 150 meters (95th). Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

A Appendix

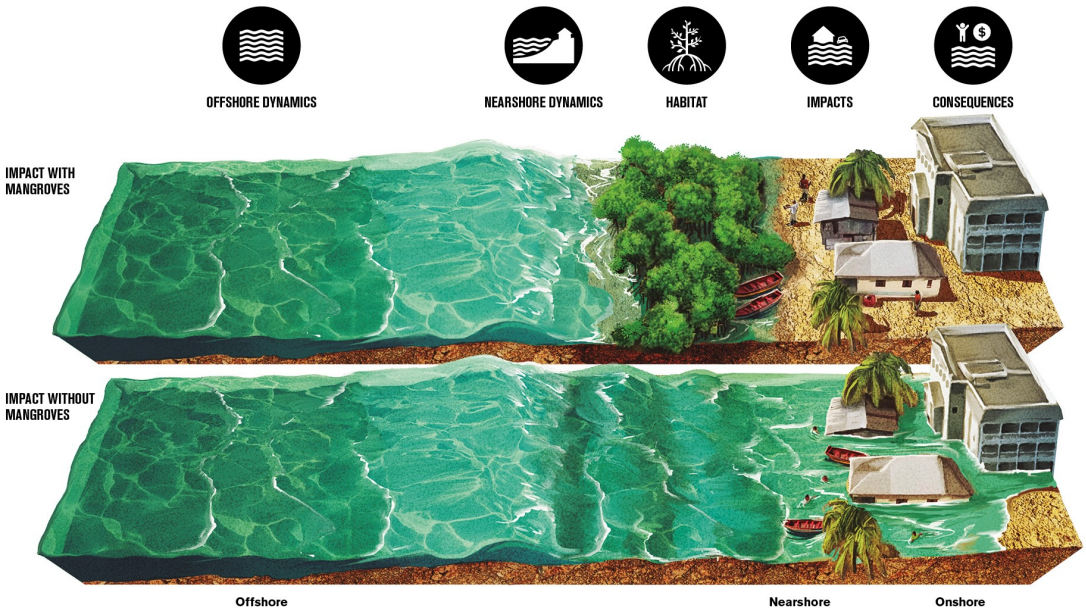
Appendix A.1 Mangrove Illustrations

Figure A.1: Mangrove Forest



Notes: The photo illustrates a typical coastal mangrove forest. Photo used is under Creative Commons License and sourced from wikimedia

Figure A.2: Illustration of the protective effect of mangroves



Notes: The graph illustrates how mangroves reduce flood risks. Photo used is under Creative Commons License and published in “”Forces of Nature: Coastal Resilience Benefits of Mangroves in Jamaica” (source link)

Appendix A.2 Data Details

Table A.1: Data source table

Data type	Scale or Resolution	Coverage	Years	Source
Houses	Interpolated property address	Florida	1993-2022	ZTRAX
County lines	7.6 foot accuracy	National	2016	TIGER
Elevation map	10 meter cells	Florida	2022	USGS
Coastline	167 foot accuracy	National	2018	USGS
Mangroves	30 meter cells	Global	1996-2020	GMW
Flood risk zones	60 foot accuracy	National	2020	FEMA
Mangrove width	2.22e-4 degree cells	National	2020	GMW

Note: The six datasets used in this analysis and their characteristics. Some data provided a time series while other data was used to characterize the most recent state of that resource.

We have used a variety of GIS data to evaluate the effect the mangrove distance and width on housing transaction prices. More specifically, as shown by Table A.1, there are 3 types of data: 1. housing; 2. mangrove distance and width; 3. flood risk zones. We have gathered the most detailed, recent data in these fields.

All geoprocesses were completed in ArcGIS Pro (v3.1.0) using a python notebook to batch run spatial analysis that added landscape attributes to each Zillow housing transaction in this study Environmental Systems Research Institute (2023). The attributes gathered included housing elevation, distance to mangroves, and distance to coastlines. The ArcPy library (v3.1) provided functions to convert a table of the transaction data into spatially explicit points based on their latitude and longitude, spatially join these points to landscape attributes, and export the tabulated results. This supplemental material outlines one way to reproduce this analysis for housing transactions in other locations.

Housing. Zillow transactions had CSV tables with the sale details and locations for the sold homes in the study area from 1993 to present day (Zillow, 2022). County data was provided by the 2020 year census, and enabled us to group transactions by county U.S. Census Bureau (2022). Elevation data from the USGS 3D Digital Elevation Program was from U.S. Geological Survey (2020).

Housing data was converted into mapped points using the display X, Y data function using their latitude and longitude fields (WGS84). These houses were intersected with county linework using a spatial join between houses that are within a county polygon U.S. Census Bureau (2022). Elevation data was joined with the transactions using the raster to points function.

Mangroves Distance. Global Mangrove Watch data included 30-meter resolution mangrove coverage for select years between 1996 and 2020 Bunting et al. (2022). This mangrove feature

describes presence and absence to help researchers identify coverage changes. The National Hydrography Dataset had a detailed coastline for all records where the parent feature was coastline ($PARENT_FEA$ = Coastline) U.S. Geological Survey (2018).

The distances between each housing transaction and landscape level attributes was calculated with a spatial join. These spatial joins recorded the geodetic distance between a housing feature and the closest mangrove and coastline feature. All this information was exported as a table for subsequent analysis outside ArcGIS Pro using the export table function. For an overview of the complete workflow, see Figure A.3.

Mangrove Width. Our approach focuses on the mangrove closest to a property, rather than calculating what is between houses and the coastlines. Engineering studies use mangrove width measures between communities and coastline because it predicts storm surge and inundation mitigation De Dominicis et al. (2023). In the literature, these widths have been calculated as either the length of mangroves covering the shortest distance from a community to the coastline Del Valle et al. (2020); Das and Vincent (2009), the mangrove area normalized by coastline length Hochard et al. (2021), or the mean cross-shore mangrove width Heatherington and Bishop (2012); Montgomery et al. (2018). For an overview of the workflow, see Figure A.4.

Flood Zones Flood zones were used to evaluate the awareness and risk of houses Federal Emergency Management Agency (2020). These houses were classified into three categories of flood risk, low, medium, high, based on their flood zone and its subtly (flood zone data table). High risk category had a flood zone of AE or VE, medium had all other flood zones except those with a zone subty of "Area of Minimal FLood Hazard" where were classified as low. Zones in the high or medium category required added flood insurance requirements for mortgages

Figure A.3: Mangrove Concept Map. This concept map shows the steps used to create the data for this study. The ordering of analyses are in series with an interchangeable order, after the Zillow transactions are projected into points.

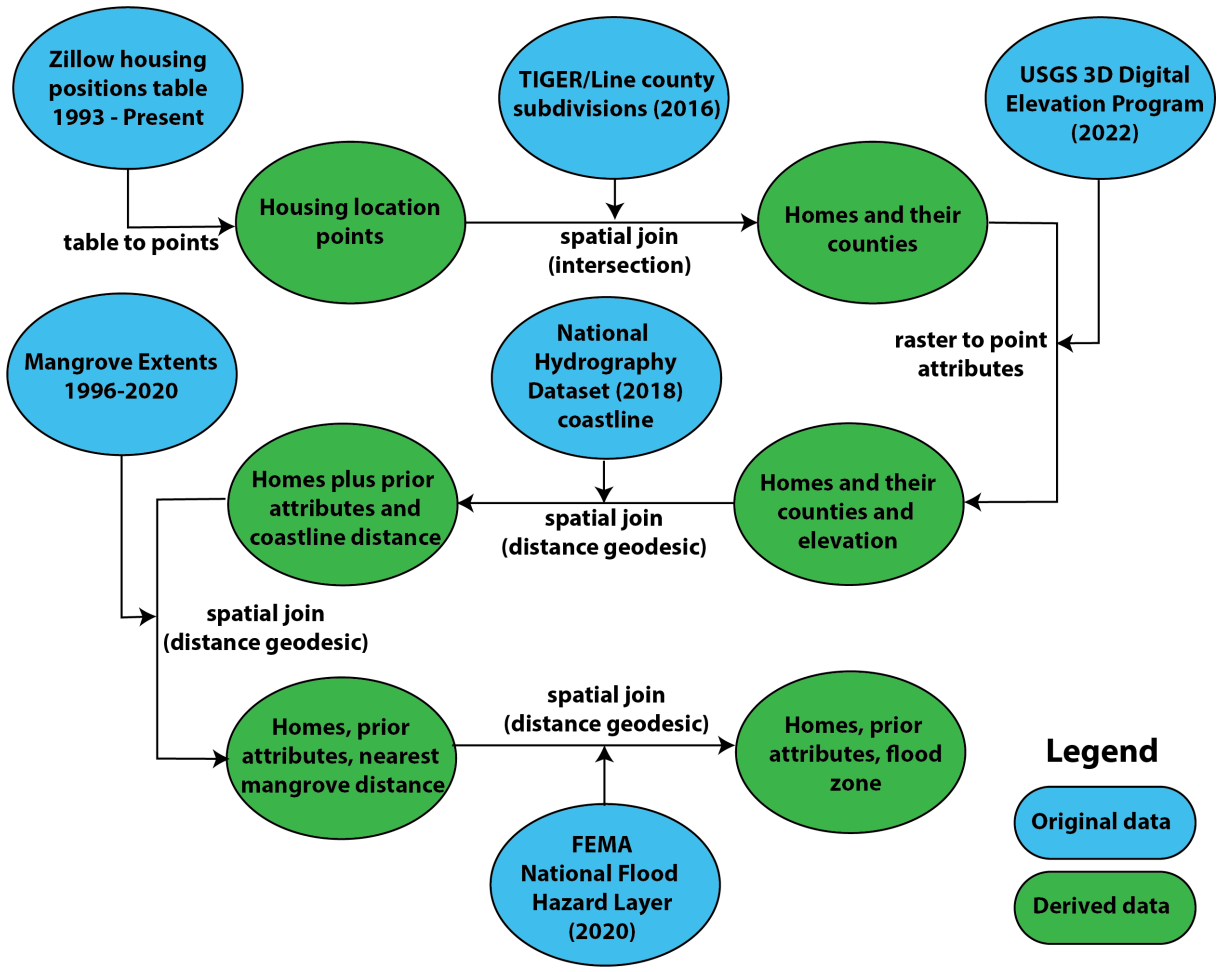
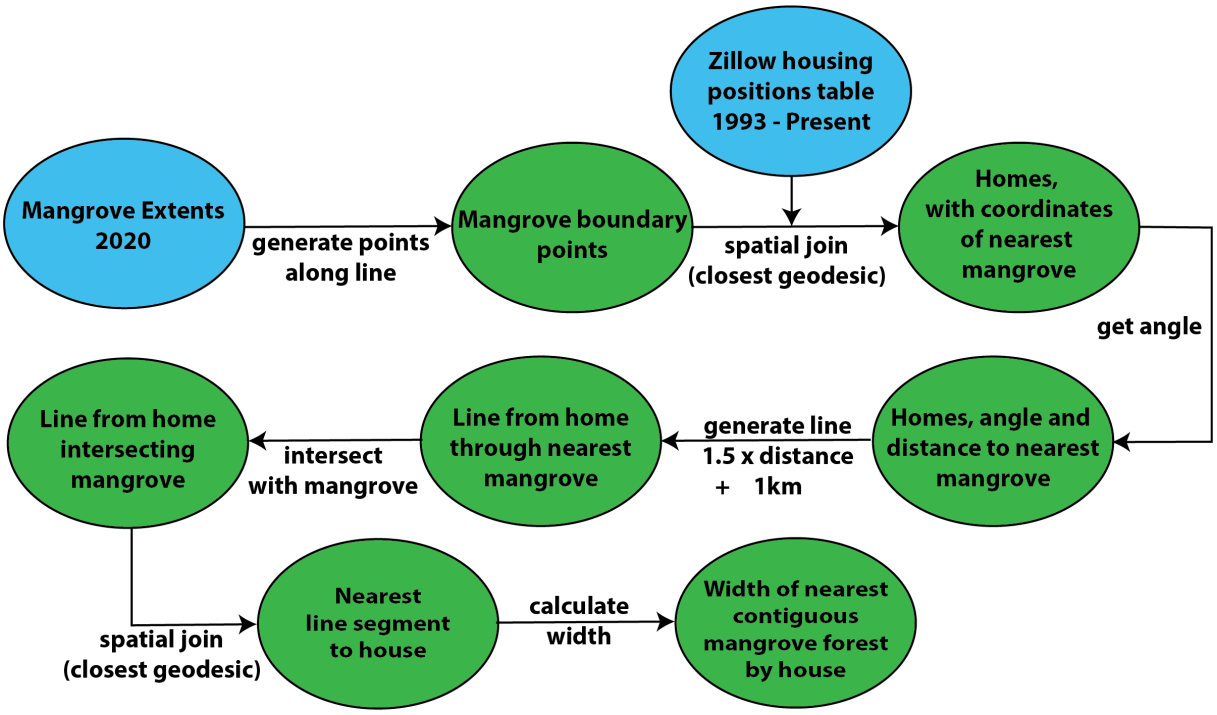


Figure A.4: Width Calculations



Appendix A.3 Temporal Variation of Mangrove

Table A.2: Summary Statistics: Change (%) in Property-Mangrove Distance (1996 through 2020)

Percentile	Max year to year change (%)	Longitudinal Change (1996 vs. 2020) (%)
5th Percentile	0	0
25th Percentile	0	0
50th Percentile (Median)	0	0
75th Percentile	0.08	0.02
95th Percentile	2.5	1.9
Mean	1.1	1

Appendix A.4 Effect of Flood Risk

We account for the *ex ante* flood risk using National Flood Hazard Layer (NFHL) data.[24] The NFHL flood risk data not only provides information on the underlying flood risks, but it is likely to affect housing sale prices due to variety of regulatory implications. For instance, one key pricing mechanism that arise would be the insurance requirement: if properties are located in the high risk zone and if they have federally-backed mortgages or are financed by federally regulated lenders, they are required to have at least federal flood insurance.[25]

While such mandatory insurance policy has potentials of protecting homeowners against losses, it is also likely to distort property prices. There is a small but growing literature that document such unintended consequences on housing affordability, when areas become designated as high flood risk zones. For example, Blickle and Santos (2022) show that becoming designated as high risk potentially reduce mortgage originations, especially for lower-income borrowers. Additionally, Sastry (2022) documents that banks are incentivized to shift the burden of risks to federal agencies. More importantly, banks optimize their risk exposure by rationing credit through reducing loan-to-value (LTV) ratio of mortgage, which results in the composition of borrowers shifting towards groups with higher credit scores or higher income.

With this institutional context, we show the results of estimation from Equation (1), disaggregated by the flood risk zones and by the major hurricane events we examine. The results are reported in Table A.3. It helps to visualize them as shown in Figures A.5 and A.6. We can see evidence of reduction in price of the medium flood risk properties that are further away from compared to similar properties with proximity to mangroves. For instance, after Hurricane Ivan, the averted value loss of properties near mangroves is almost 10 percentage points compared to those over 2 kilometers away from mangroves. This pattern is consistent across different hurricane incidents.

In contrast, for high-risk flood zones there is no discernible effect of the distance to mangroves. One possible explanation is that in high flood-risk areas, the insurance requirement and the actual insurance coverage already cover potential losses or rebuilding costs and therefore hurricanes realizations have little effect on property prices. While mangroves protects these properties in the first place from damages, financial support from insurance payouts may have aided the reconstruction of these properties—both may have resulted in almost equivalent outcomes and potentially housing valuation after a natural disaster. Another potential mechanism at work is that because of the additional financing and insurance burden, the bidding intensity for properties is lower than it otherwise would be in high-risk areas. So the closing or final sale prices of such properties are lower than they otherwise would be. In this case, the expected financial benefits of mangrove presence in flood risk reduction is outweighed or crowded out by the overall financial costs.

For these reasons, in our benchmark analysis, we rely on the estimates for medium flood risk properties. Table A.4 presents our benchmark results disaggregated by hurricanes and interacted

[24] See Appendix A.2 for the detailed discussion of the floodzone definitions we use.

[25] https://www.benefits.gov/benefit/435

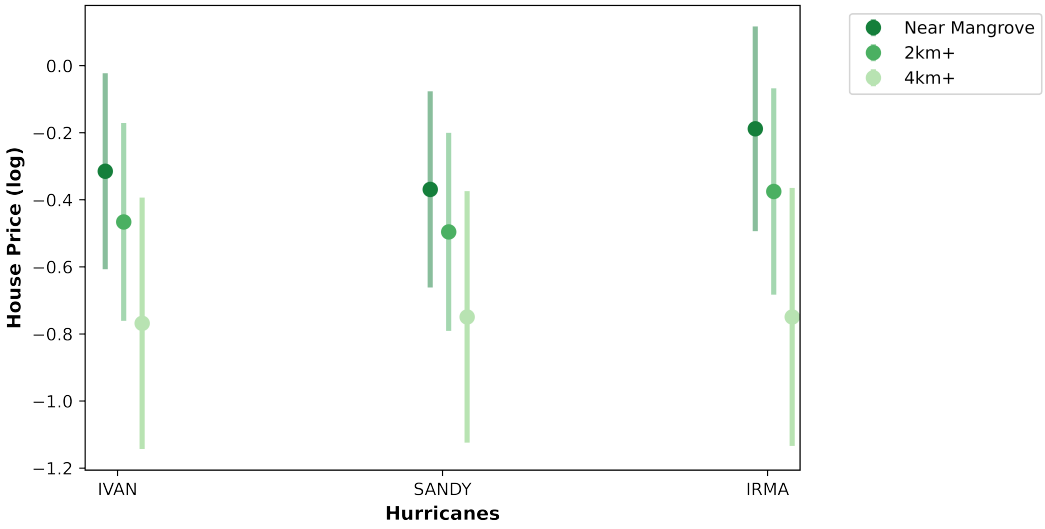
with each flood risk level, estimated on the full sample of our data.

Table A.3: Level Effect of Mangroves by Flood Risk

	Low flood risk			Medium flood risk			High flood risk		
	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Ivan*Distance	-0.01***	0.02***	0.01***	-0.01**	-0.04***	-0.04***	-0.02***	-0.04***	-0.02*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Sandy*Distance	0.01**	0.01***	-0.02***	-0.01*	-0.01*	0.00	-0.04***	-0.04***	-0.02**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Irma*Distance	-0.05***	-0.04***	-0.03***	0.01***	-0.03***	-0.04*	0.02***	0.01	-0.04
	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Flood risk			–			-0.26			-0.52*
			–			(0.16)			(0.21)
Property FE									Yes
Year-Month FE									Yes
R-squared									0.79
N									4048657

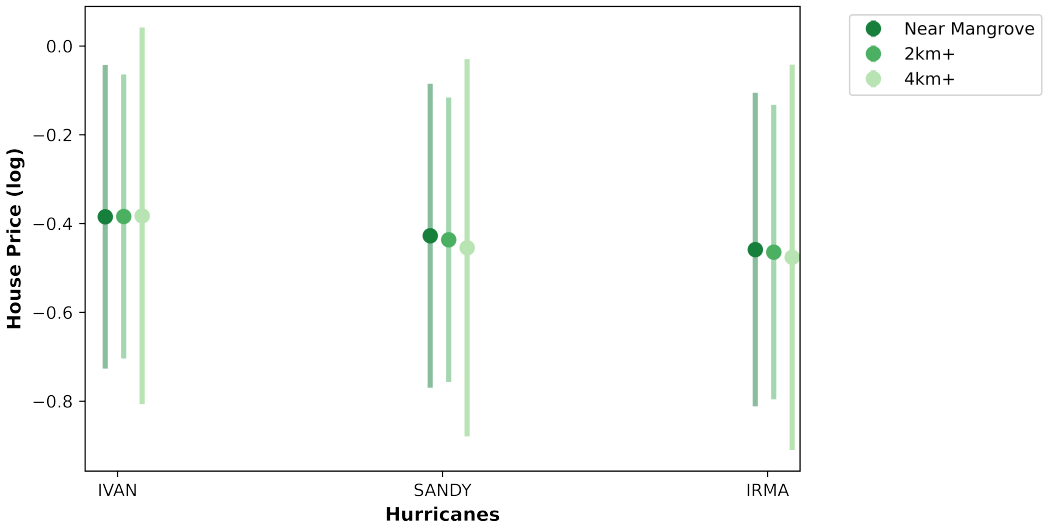
Note: Dependent variables: log of sale prices. Closer proximity to mangrove results in smaller sale price reduction following a hurricane. A larger value in variable "distance" indicates further distance from mangrove. Results estimated from the following equation for all properties in the data:
$log(P_{it}) = \beta'(m_i \times H_{it}) + \lambda_1'(H_{it} \times High_i) + \lambda_2'(H_{it} \times Med_i) + \eta_1'(m_i \times H_{it} \times High_i) + \eta_2'(m_i \times H_{it} \times Med_i) + \delta_i + \delta_t + \epsilon_{it}$,
where $High_i$ and Med_i are indicator variables of whether a property is located in a high or medium risk area, respectively. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure A.5: Mangrove and Price, Moderate Flood Risk Zone



Notes: Results are a linear combination of hurricane effect, mangrove distance effect, and their interaction terms. The results are from coefficients in Table A.3 estimated through $log(P_{it}) = \beta'(m_i \times H_{it}) + \lambda_1'(H_{it} \times High_i) + \lambda_2'(H_{it} \times Med_i) + \eta_1'(m_i \times H_{it} \times High_i) + \eta_2'(m_i \times H_{it} \times Med_i) + \delta_i + \delta_t + \epsilon_{it}$. Specifically, when calculating the medium-risk results, we estimate the linear combination of the triple interaction term of mangrove distance (adjusted for the distance examined), hurricane, and flood risk zone variables, plus the double interaction terms among these variables, and their main effect terms.

Figure A.6: Mangrove and Price, High Flood Risk Zone



Notes: Results are a linear combination of hurricane effect, mangrove distance effect, and their interaction terms. The results are from coefficients in Table A.3 estimated through $log(P_{it}) = \beta'(m_i \times H_{it}) + \lambda_1'(H_{it} \times High_i) + \lambda_2'(H_{it} \times Med_i) + \eta_1'(m_i \times H_{it} \times High_i) + \eta_2'(m_i \times H_{it} \times Med_i) + \delta_i + \delta_t + \epsilon_{it}$. Specifically, when calculating the high-risk results, we estimate the linear combination of the triple interaction term of mangrove distance (adjusted for the distance examined), hurricane, and flood risk zone variables, plus the double interaction terms among these variables, and their main effect terms.

Table A.4: Level Effect of Mangroves by Flood Risk, Hurricane, and Year

	Low flood risk			Medium flood risk			High flood risk		
	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Ivan*Distance	-0.01***	0.01***	0.01***	-0.01***	-0.04***	-0.04***	-0.02***	-0.04***	-0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Sandy*Distance	0.00	0.00	-0.01***	-0.01**	-0.00	0.00	-0.04***	-0.04***	-0.02**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Irma*Distance	-0.05***	-0.04***	-0.04***	0.00	-0.03***	-0.03*	0.01**	0.01	-0.04
	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Ivan			–	0.07***	0.11***	0.11	0.22***	0.15***	0.06***
			–	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Sandy			–	0.07***	0.06***	0.07***	0.15***	0.15***	0.12***
			–	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Irma			–	0.02	0.15***	0.14*	-0.06***	-0.06**	-0.02
			–	(0.02)	(0.02)	(0.06)	(0.01)	(0.02)	(0.05)
Flood risk			–			0.11			-0.04
			–			(0.14)			(0.18)
Property FE									Yes
Year-Month FE									Yes
R-squared									0.79
N									4048657

Note: Dependent variables: log of sale prices. Closer proximity to mangrove results in smaller sale price reduction following a hurricane. A larger value in variable "distance" indicates further distance from mangrove. Results estimated for all properties in the data from equation: $log(P_{it}) = \beta'(m_i \times H_{it}) + \lambda_1'(H_{it} \times High_i) + \lambda_2'(H_{it} \times Med_i) + \eta_1'(m_i \times H_{it} \times High_i) + \eta_2'(m_i \times H_{it} \times Med_i) + \delta_i + \delta_t + \epsilon_{it}$. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix A.5 Robustness test tables and analysis disaggregated by hurricanes and years

Table A.5: Marginal Impact of Mangrove Width, 2nd Year after Hurricanes–Medium Risk Areas

	(1) Ivan	(2) Sandy	(3) Irma
10m	-0.05***	-0.08***	-0.07***
	(0.01)	(0.01)	(0.01)
20m	-0.03***	-0.04***	-0.04***
	(0.00)	(0.00)	(0.01)
30m	-0.02***	-0.03***	-0.02***
	(0.00)	(0.00)	(0.00)
70m	-0.01***	-0.01***	-0.01***
	(0.00)	(0.00)	(0.00)
150m	-0.00***	-0.01***	-0.00***
	(0.00)	(0.00)	(0.00)
N	1164273	1164273	1164273

Note: Dependent variables: log of sale prices. It is clear that as mangrove widths (from 10m to 150m), the negative effects of hurricane become smaller. Results are based on the interaction terms between hurricane variable, mangrove distance, and mangrove width estimated from Equation (5): $log(P_{it}) = \beta'(m_i \times H_{it}) + \gamma'(\omega_i \times H_{it}) + \rho'(\omega_i \times H_{it} \times m_i) + \delta_i + \delta_t + \epsilon_{it}$. The choice of width measure is the inverse width, and specific width value is based on empirical distribution: 10 meters (10th percentile), 20 meters (<20th percentile), 30 meters (25th), 70 meters (median), and 150 meters (95th). Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A.6: Level Effect of Mangrove: proximity indicator

	(1) 1st Year	(2) 2nd Year	(3) 3rd Year
Mangrove Proximity (<0.5km)			0.29***
			(0.00)
Distance to Coast (km)			-0.02***
			(0.00)
Ivan*Mangrove	0.12***	0.01	-0.04
	(0.01)	(0.02)	(0.02)
Sandy*Mangrove	0.01	0.04***	0.03*
	(0.01)	(0.01)	(0.01)
Irma*Mangrove	-0.06**	-0.14***	0.06
	(0.02)	(0.03)	(0.07)
Zipcode FE			Yes
Year-Month FE			Yes
R-squared			0.35
N			2050807

Note: Dependent variables: log of sale prices. Results estimated from Equation (1) and include property data in high, medium, and low flood risk areas designated by FEMA. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A.7: Level Effect of Mangrove on Price per Square Foot

	(1) 1st Year	(2) 2nd Year	(3) 3rd Year
Mangrove Distance			-0.12
			(0.10)
Ivan*Mangrove	-0.05***	-0.02***	-0.03***
	(0.00)	(0.00)	(0.00)
Sandy*Mangrove	-0.03***	-0.02***	-0.03***
	(0.00)	(0.00)	(0.00)
Irma*Mangrove	-0.05***	-0.08***	-0.05***
	(0.00)	(0.00)	(0.00)
Property FE			Yes
Year-Month FE			Yes
R-squared			0.69
N			1803920

Note: Dependent variables: log of sale price per square foot. Results estimated from Equation (1) and include property data in high, medium, and low flood risk areas designated by FEMA. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A.8: Level Effect of Mangrove Distance and Width Bins

	(1) 1st Year	(2) 2nd Year	(3) 3rd Year
Mangrove Distance			-0.23
			(0.38)
Ivan $*$ Mangrove Distance	-0.02**	0.01	0.00
	(0.01)	(0.01)	(0.01)
Sandy $*$ Mangrove Distance	0.02**	0.04***	0.00
	(0.01)	(0.01)	(0.01)
Irma $*$ Mangrove Distance	-0.04***	-0.06***	0.02
	(0.01)	(0.02)	(0.04)
Ivan $*$ Distance $*$ Width Bins	-0.00*	-0.01***	-0.00
	(0.00)	(0.00)	(0.00)
Sandy $*$ Distance $*$ Width Bins	-0.01***	-0.01***	-0.01***
	(0.00)	(0.00)	(0.00)
Irma $*$ Distance $*$ Width Bins	0.00	0.01	-0.02
	(0.00)	(0.00)	(0.01)
Property FE			Yes
Year-Month FE			Yes
R-squared			0.79
N			3941834

Note: Dependent variables: log of sale prices. Results estimated from Equation (5). There are 4 width bins: 1. less than 100 meters; 2. between 100 and 200 meters; 3. between 200 and 500 meters; over 500 meters. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A.9: Level Effect of Mangrove Distance and Width Threshold

	(1)	(2)	(3)
	1st Year	2nd Year	3rd Year
Mangrove Distance			0.01
			(0.26)
Ivan $*$ Mangrove Distance	-0.02***	0.00	0.01
	(0.01)	(0.01)	(0.01)
Sandy Ivan $*$ Mangrove Distance	-0.01	-0.00	-0.01
	(0.01)	(0.01)	(0.01)
Irma Ivan $*$ Mangrove Distance	-0.01	-0.04**	-0.02
	(0.01)	(0.01)	(0.02)
Ivan $*$ Distance $*$ Width Threshold	-0.01	-0.02**	-0.03***
	(0.01)	(0.01)	(0.01)
Sandy $*$ Distance $*$ Width Threshold	-0.00	-0.01	-0.02*
	(0.01)	(0.01)	(0.01)
Irma $*$ Distance $*$ Width Threshold	-0.03***	-0.00	-0.02
	(0.01)	(0.01)	(0.02)
Property FE			Yes
Year-Month FE			Yes
R-squared			0.79
N			4023282

Note: Dependent variables: log of sale prices. Results estimated from Equation (5). Threshold is based on >= 300 meters. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A.10: Level Effect of Mangrove Distance and Inverse Width

	(1) 1st Year	(2) 2nd Year	(3) 3rd Year
Mangrove Distance			-0.14
			(0.10)
Ivan ∗ Mangrove Distance	-0.03***	0.00	0.01*
	(0.00)	(0.00)	(0.00)
Sandy ∗ Mangrove Distance	-0.00	-0.00	-0.02***
	(0.00)	(0.00)	(0.00)
Irma ∗ Mangrove Distance	-0.03***	-0.03***	-0.03
	(0.00)	(0.00)	(0.01)
Ivan ∗ Distance ∗ Width (Inverse)	-0.23**	-0.61***	-0.65***
	(0.08)	(0.07)	(0.07)
Sandy ∗ Distance ∗ Width (Inverse)	-0.32***	-0.34***	-0.24***
	(0.07)	(0.06)	(0.06)
Irma ∗ Distance ∗ Width (Inverse)	-0.30***	-0.31**	-0.34
	(0.06)	(0.10)	(0.29)
Property FE			Yes
Year-Month FE			Yes
R-squared			0.79
N			4023282

Note: Results estimated from Equation (5). There are 4 width bins: 1. less than 100 meters; 2. between 100 and 200 meters; 3. between 200 and 500 meters; over 500 meters. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A.11: Level Effect of Mangrove Distance and Forest Width

	(1) 1st Year	(2) 2nd Year	(3) 3rd Year
Mangrove Distance | Width			0.06
			(0.13)
Ivan ∗ Mangrove Distance | Width	-0.01	0.03***	0.03***
	(0.01)	(0.00)	(0.00)
Sandy ∗ Mangrove Distance | Width	-0.00	-0.01*	-0.02***
	(0.00)	(0.00)	(0.00)
Irma ∗ Mangrove Distance | Width	-0.04***	-0.04***	-0.04**
	(0.00)	(0.00)	(0.01)
Property FE			Yes
Year-Month FE			Yes
R-squared			0.80
N			3002912

Note: Results estimated from Equation (5). Dependent variables: log of sale prices. The results show the mangrove distance effect, given that the mangrove forest width is at least 30m. Additional estimates have been done for 70 meters, 100 meters, and 300 meters. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A.12: Price Level Effect of Mangroves, by hurricane and year

	High Risk	Medium Risk	Low Risk
	(1)	(2)	(3)
Ivan (1st year) X mangrove	-0.03***	-0.02***	-0.01
	(0.01)	(0.00)	(0.01)
Ivan (2nd year) X mangrove	-0.03***	-0.02***	0.01*
	(0.00)	(0.00)	(0.00)
Ivan (3rd year) X mangrove	-0.01*	-0.03***	0.01
	(0.00)	(0.00)	(0.00)
Sandy (1st year) X mangrove	-0.04***	-0.01	0.00
	(0.00)	(0.00)	(0.00)
Sandy (2nd year) X mangrove	-0.04***	-0.00	0.00
	(0.00)	(0.00)	(0.00)
Sandy (3rd year) X mangrove	-0.03***	-0.01*	-0.01***
	(0.00)	(0.00)	(0.00)
Irma (1st year) X mangrove	-0.03***	-0.04***	-0.05***
	(0.01)	(0.01)	(0.00)
Irma (2nd year) X mangrove	-0.03***	-0.07***	-0.04***
	(0.01)	(0.00)	(0.00)
Irma (3rd year) X mangrove	-0.08***	-0.07***	-0.04***
	(0.01)	(0.01)	(0.01)
Property FE	Yes	Yes	Yes
Year-Month FE	Yes	Yes	Yes
R-squared	0.83	0.74	0.80
N	798326.00	1171676.00	2078400.00

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$