Perspective on Planning for Seal Level Rise

A study of development change and sea level rise risk in Pinellas, Hillsborough, Manatee, and Sarasota Counties

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Literature Review

Climate Change & Sea-Level Rise

The Intergovernmental Panel on Climate Change (IPCC) upholds that there is international scientific consensus supporting that anthropogenic carbon dioxide emissions are causing and will continue to cause global warming (Higgins 2008). The IPCC consists of various international parties including the National Academy of Science of the United States, the National Scientific Academies of Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, and the United Kingdom. The leaders which compose the IPCC support the consensus that warming is happening and has led to changes in the Earth's climate.

Since the mid-1800s and the onset of industrialization, humanity has significantly increased carbon dioxide emissions and other greenhouse gases – contributing to about 0.8°C to 1.2°C degrees warming above pre-industrial levels (Deyle et al 2007; IPCC 2018). The IPCC (2018) maintains high confidence that between 2030 and 2052 global warming will likely reach 1.5°C if current warming rates continue. Even if current warming levels were capped at an increase of 1.5°C, the marine ice sheet volume in Antarctica and Greenland is expected to experience irreversible losses causing multiple meters of sea level rise (SLR) over hundreds or thousands of years (IPCC 2018).

SLR poses numerous challenges for coastal communities – rates of present and future SLR are uncertain, however many effects are predicted (Pendleton 2010). SLR is expected to displace coastal communities, threaten infrastructure, cause saltwater intrusion into groundwater aquifers, intensify existing coastal flooding, and lead to the loss of recreation areas and public areas (Higgins 2008; Pendleton 2010). Beaches will experience erosion, loss of shorefront, permanent wetland inundation, and storm surge.

Florida and Sea Level Rise

The southeastern region of the United States has experienced faster population growth than the rest of the country since 1960 (Reynolds 2001). Florida's population doubled every 20 years in the 1900s. In 1900 the population was 500,000 Floridians and by 1980 there were over eight million people. In the 2010 census the total population for Florida was 18,801,310 (U.S. Census 2019). Population projections predict an average of 234,000 per year in 2020-2030 and 198,000 per year from 2030 to 2040 (Smith & Rayer 2013). Projected population growth ensures more development for planners to influence in the coming years.

Of America's 50 states, Florida is arguably the most vulnerable state to SLR (Grosso 2015). The state is highly at risk of SLR damages with 1,200 miles of coastline and 2,200 miles of tidal shoreline, a maximum elevation of 400 feet above sea level, and three-fourths of the population residing in coastal counties which generate 79% of the state's annual economy (Grosso 2015; Noss 2011). Florida's internal land at any one point is no more than 75 miles from the coast (Noss 2011). Thus, planning adaptation methods for SLR are critical to Florida's viability.

SLR increases the risk of erosion, flooding, increased storm intensity and aquifer inundation. Erosion issues have already been recorded in over 60% of the state's beaches in 2014 (Grosso 2015). Today's beach erosion issues are a result of a variety of factors including inlet migration, storms, armoring, and SLR. Due to Florida's flat topography, the coastal communities are very susceptible to damage from small amounts of SLR. Small increments of SLR can cause shoreline recession and tidal flooding (Grosso 2015.

There is great uncertainty ahead for government officials and planners to respond to the consequences to SLR. IPCC researchers have developed numerous scenarios to help predict how climate change and the resulting SLR will present itself (IPCC 2018). However, the height of SLR predictions vary greatly by expected greenhouse gas reductions occur, climate change related

changes to weather patterns and resulting increased flooding, and geospatial variability (Hsiang et al 2017). The uncertainty involved in predicting impacts of SLR on a local level presents challenges for government officials and planners to prepare for these events; however, it is important for local leaders to utilize the available information and adaptation tools available to protect their communities from harm.

Methods for Adaptation and Management

This paper breaks down the tools for addressing the expected damages from SLR into three categories: planned retreat, shore protection, and accommodation. Researchers have developed tools and models to estimate the areas which will need adaptation strategies or will experience abandonment based on expected SLR levels, and socio-demographic factors (Woodruff et al 2018). Utilizing such models will be increasingly necessary for policymakers to decide which SLR adaptation and management strategies to employ.

Planned Retreat

Retreat, or abandonment, often involves public land buyouts or construction setbacks which ban construction in hazard areas (Woodruff et al 2018). Such buyouts are based on the legal concept of Public Trust Doctrine which states that intertidal zones should be treated as public land, as SLR encroaches on land, the boundaries blur (Deyle 2007).

Numerous tools can be utilized by regulatory agencies to prepare their communities for planned retreat including rolling easements, setbacks, and limited armoring. Rolling easements are a form of property restriction that allows the landowner to develop on their waterfront property under two conditions: there must be a natural shoreline and no sea wall and if the property experiences advancing shoreline they must move or remove the structure (Higgins 2008). Setbacks are rules that define how far a structure must be built from a shoreline erosion or flood hazard (Butler et al 2016). Shoreline armoring is installed along coastal land to protect coastal

development using seawalls, breakwaters, and riprap (loose stone to break up incoming waves). Armoring, setbacks, and rolling easements are limited as SLR management measures as the rise increases the height of inundation (Grannis 2011). As such, planned retreat may become more desirable as SLR increases.

Planned retreat is capable of reducing costs from damages and is economically efficient when SLR is imminent. Despite the benefits of planned retreat many communities forgo this method because the economic benefits of development are high (Woodruff 2018). As politicians and developers prefer taking advantage of economic opportunism within coastal communities, passing retreat policy and legislation proves difficult (Woodruff et al 2018). It is important to consider that most new buildings come with a 30 to 75-year design life and the investments made on the coast today are likely to face financial consequences in high risk SLR areas (Parkingson 2009). As SLR intensifies, more vulnerable areas will be unable to prevent water from causing damages to property with engineered solutions and will be forced to retreat (Parkingson 2009).

Shore Protection

In order to protect land from inundation, erosion, and flooding shore protection, shore protection methods install various engineering structures (Parkingson 2009). Structures such as seawalls, bulkheads, and revetments, coastal hardening methods, attempt to keep shorelines in the same position. Alternatively, topographical obstacles such as dikes, dunes, or beach nourishment may be utilized to protect from flooding or permanent inundation (Deyle 2007; Parkingson 2009).

All such shore protection methods only are effective as a short-term solution or to prevent SLR impacts from lower rates of rise – as SLR elevation increases, shore protection will no longer be able to hold water from encroaching on developed land. Dunes and beach nourishment are limited as a technology for shore protection because when employed beaches will need continued

sediment supplies and management (Deyle 2007). A study in Sandbridge, Virginia showed that sea walls do not reduce sand losses (Leatherman 2018). Additionally, sea walls do not preserve the economic functionality and attractiveness of beaches so many coastal communities will laud this solution. Despite their disadvantages, coastal hardening methods, such as sea walls, are likely to be common as their installations serve as quick fixes to the incremental changes that SLR brings.

Accommodation

Accommodation measures are developed to reduce negative impacts of flooding but do not prevent floodwaters from approaching (Woodruff et al 2018). Strategies of accommodation include advancing new development away from at-risk areas, building new above ground infrastructure to accommodate higher coastal flooding elevations, or raising existing infrastructure (Deyle 2007). Directing new development away from areas determined to be affected by inundation, shoreline recession, and advancing coastal flood boundaries help accommodate for SLR. However, similar to planned retreat, directing development away from the coast proves politically difficult despite future potential financial losses.

Another accommodation measure involves enforce building code restrictions that require buildings be elevated higher than ground level. Currently, regulations exist for waterfront property that residential developments must be habitant free for resident safety and flood damage reduction ("Coastal Construction" n.d.). Coastal communities would be better protected if similar restrictions were required in SLR zones delineated using SLR area estimates.

Accommodating for existing infrastructure, such as bridges, roads, or stormwater drainage systems, involves either elevating or flood proofing to make facilities above ground – all are quite costly solutions. Existing infrastructure, such as bridges, can be rebuilt with a higher elevation with relative ease when funds are allocated to the task (Deyle 2007). However, raising roads presents more logistical issues. Roads are typically lower lying than surrounding land for drainage

purposes – just raising the road presents stormwater and flooding management challenges Stormwater drainage systems can be accommodated by enhancing gravity drainage with large diameter pipes or widening drainage ditches, installation of forced drainage systems where gravity drainage is not possible, delaying peak discharges by enhancing water detention, or improving infiltration rates (Deyle 2007).

Land Use Methods for Management

Adaptation methods such as planned retreat, shore protection, and accommodation all have their appropriate setting according to relevant needs. These adaptation tools are most effective when planned at local scales and strategically placed using data and community feedback. Land use policy provides the support needed to make a concerted effort to use these aforementioned tools. Numerous types of land managers, planners, and legislators are critical to prepare Florida communities for SLR (Deyle 2007; Mitsova & Esnard 2012). For the purpose of this paper, tools used by state policy makers, local policy makers, land use planners, transportation planners, environmental planners, watershed/water resource managers, coastal resource managers will be considered.

Comprehensive Planning in Florida

As result of numerous environmental crises occurring in the state of Florida during the late 1960s and the leadership of governor Reubin Askew, in 1972 Florida legislature adopted the Environmental Land and Water Management Acts (Catlin 1997). This included four acts which laid a foundation for statewide long-term planning for social, economic and physical growth in Florida. One of the four acts included the Florida Comprehensive Planning Act. This act drastically shifted development management from a locally driven process to a state interest protecting process (Stroud 2012).

The Florida Comprehensive Planning Act (FCPA) required all cities, towns, and counties produce a comprehensive plan through a local government agency (Catlin 1997). Under the act large-scale development activities, "developments of regional impacts" ("DRI") were regulated by regional planning agencies and required approved permits before development (Shroud 2012). Additionally, state control was extended by requiring that development in "areas of critical state concern" be approved through a state administrative appeal process. Over the years many new versions of the FCPA have been passed, modifying the methods of oversight by the state of Florida. State influence on development was recently reduced in 2011 when Governor Rick Scott and a Republican legislature rewrote the state planning act and passed the Community Planning Act (CPA) of 2011 (Stroud 2011).

In Florida, as required by the CPA, all local governments are still required to adopt and maintain a comprehensive plan that follows state standards and governs the locality's zoning and development decisions (Grosso 2015). This state-required comprehensive plans necessitate consideration of projected growth, infrastructure and service needs, and environmental protection needs. FCPA comprehensive plans aim to consider the "big picture needs" from a land use policy perspective. Despite aiming to serve "big picture needs" the FCPA is only required to consider two planning horizons – a 5-year period after plan adoption and a second 10-year period (Deyle 2007). There is no mention of the phrase "climate change" throughout the FCPA or CPA(Grosso 2015).

The CPA restricts state and regional review abilities – comprehensive plans do not need to comply with state plans and state agency reviews as previously required (Stroud 2012). State agencies may only review instances related to important state resources and facilities. Additionally, state review process has been expedited and compliance with state plans is not reviewed. Third parties are able to challenge a plan if noncompliance with state plans exists, but

the state planning agency may not be involved. Reversing the 2011 Act is necessary to empower state level legislators and agencies, once again, to direct local development towards SLR safe practices.

The greatest potential option for addressing SLR in future comprehensive plans is in the Future Land Use Element section. This section directly addresses how land use will be assigned, population densities and structure intensities per parcel of land, allowable land uses based on relevant data and survey studies. Since the ruling of the Future Land Use Element is based upon data and acts as a legal mandate, it has the greatest potential to address land vulnerable to SLR effects (Grosso 2015).

Consider further that FCPA requires plans to include criteria aimed to "C. Encourage preservation of recreational and commercial working waterfronts for water-dependent uses in coastal communities. E. Coordinate future land uses with the topography and soil conditions, and the availability of facilities and services. F. Ensure the protection of natural and historic resources. G. Provide for the compatibility of adjacent land uses (Grosso 2015)." If this legislation was written to protect waterfronts, preserve natural and historic resources, and ensure logical land uses then the FCPA must necessitate consideration of making SLR -elated land use policy. Today this legislation does not regard any consideration of SLR, failing the citizens of Florida.

Coastal Construction Control Line Program

In 1965, Florida legislators recognized the importance of protecting the ecological and economic functions of Florida's beaches and passed the Beach and Shore Protection Act (BSPA) (Ruppert 2008). The BSPA established the Coastal Construction Control Line (CCCL) which on a county-by-county basis regulated construction from a 50 ft setback. The CCCL prohibits construction seaward of the construction setback line but does not prohibit all construction. By 1985 the law was amended to include a thirty-year erosion projection line (EPL), prohibiting

construction of habitable structures seaward of the line (Ruppert 2008). The EPL currently does not account for shoreline migration or projected SLR (Misova & Esnard 2012).

The CCCL program is designed to protect the shoreline from problematic development that could accelerate erosion or interfere with public beach access (Marshall et al 2011). CCCL considers if proposed developments will have significant adverse impacts on beaches and dunes – if the assessment shows no significant adverse impacts, a permit will be granted for development. The main flaw is with the CCCL's ability to protect beaches from erosion is that the permit system only considers individual site impacts and does not assess the cumulative impact from clusters of development (Marshall et al 2011).

The National Flood Insurance Program

The National Flood Insurance Act of 1968 initiated the National Flood Insurance Program (NFIP). Originally, NFIP was enacted to provide disaster recovery to properties experiencing river flooding from the Mississippi River as many private insurers were unwilling to insure properties with repeated flooding (Leatherman 2018). Later, Congress extended the NFIP coverage to states experiencing coastal flooding.

However, lawmakers neglected to consider the significantly higher levels of soil/land erosion experienced by coastal properties, which increases the exposure of buildings to waves and flooding (Leatherman 2018). In the decades since the initiation of the NFIP, coastal flooding and land erosion have significantly increased, concurrently increasing the risk of flood damage.

While NFIP was designed to reduce risk and damage related to flooding an unintended effect has been encouraging beachfront development – increasing flood related losses (Leatherman 2018). NFIP has historically been a costly program that unfairly burdens the average taxpayer since coastal homes are frequently purchased by wealthy homeowners as a second home investment (Kriesel & Landry 2004). These homes often exceed the $250,000 claim

limit held by the NFIP. Many policies did not financially reflect the flood risk until provisions added to the act in 2016.

Since the 2016 provision to NFIP, rates are required to match the true flood risk. The majority of participants in the program, 80%, were estimated to experience no rate increases (Leatherman 2018). However, the remainder of participants, mainly beachfront property owners experienced 25% annual rate increases. The 2016 legislation neglected to mention coastal erosion in the provision. While rate increases are a significant improvement to this federal program – by better reflecting the cost burden of coastal development – SLR and land erosion need to be considered in depth by this program. Only after SLR and land erosion have been built into the pricing and conditions for qualification will the bias toward coastal development be extinguished.

Land Use Planning and Zoning

As discussed previously, the Florida state legislature has the power to influence development by setting standards of zoning in the approved comprehensive plans that are currently required. Despite recent setbacks in the oversight states have in comprehensive plans, more local governing bodies have the ability to prepare for SLR by employing one of the strongest planning tools: zoning (Grosso 2015).

Comprehensive plans or zoning ordinances empower city or county governments to implement intentional land use planning for their communities. Zoning ordinances define zones that will comply with specific requirements in that zone – including how far structures should be set back from the street, density allowances for development, and structure sizes (Grannis 2011). Overlay zones can be implemented to superimpose new regulations on existing zones.

In Grannis' (2011) *Adaptation Tool Kit: Sea Level Rise and Coastal Land Use,* the author details four potential SLR overlay zones that could be employed: protection zones,

accommodation zones, retreat zones, and preservation zones. Protection zones could designate critical infrastructure and dense urban development in which local governments see soft-armoring techniques to be most useful. Accommodation zones are areas that local governments would maintain some new development but would limit density of new development, require flood resistant structures, and limit hard shore armoring. Retreat zones could be areas where hard armoring is prohibited, damaged structures would be prohibited from rebuilding, and inundated structures must be moved or removed. Preservation zones would be areas where local governments preserve land to enhance natural resources, habitats, and flood buffers. Utilizing Grannis' (2011) overlay zoning, a local government would greatly strengthen their climate change resilience.

Today, areas in floodplains, that are prone to frequent flooding, receive their own zoning designations which prohibit future development of buildings which house occupants. As climate change related SLR approaches, governments will need to down-zone areas which are predicted to become floodplains (Grosso 2015). Recommended zoning designations for high risk areas include large lot, low-density, agricultural, or passive recreational uses. After passing a comprehensive land-use plan with down-zoning, local governments will be enabled to deny requests to intensify predicted SLR floodplain areas (Grosso 2015).

Down-zoning will be politically difficult due to the influence property owners and developers have on local politics and economic development (Grosso 2015). Legal battles on the grounds of "takings" will likely follow suit. Florida courts have already rejected "takings" claims in cases making zoning changes, such as a commercial to agricultural/rural down zoning, to preserve archaeological and environmental resources – a promising result for future SLR zoning changes (Grosso 2015). It is recommended that down-zoning be performed in a comprehensive plan to increase feasibility. Marmet (2013) describes how comprehensive down-zoning, especially when

supported by a community Master Plan, following specified criteria, such as low-density residential land in close proximity to a flood plain, is more likely to maintain validity. Piecemeal down-zoning, or case-by-case parcel down-zoning, holds less strength in court (Marmet 2013). Despite the political challenges of down-zoning in preparation for SLR, this responsible planning strategy will have great potential to reduce storm and flood damages.

Four-County Area Research

This research aims to define tools ideal for planners in Florida who anticipate long term inhabitance of their community and want to prepare for SLR. As such, the commonly studied south Florida region was not studied as their challenges have been studied extensively and the anticipated damage and adaptation measures will be very costly. SLR in Hillsborough, Pinellas, Manatee, and Sarasota Counties will occur closer to the coast (Figure 1). Higher elevations in this area leave a great deal of land protected from 2100 estimates – while still costly, adaptation measures will be on a smaller scale to that of south Florida.

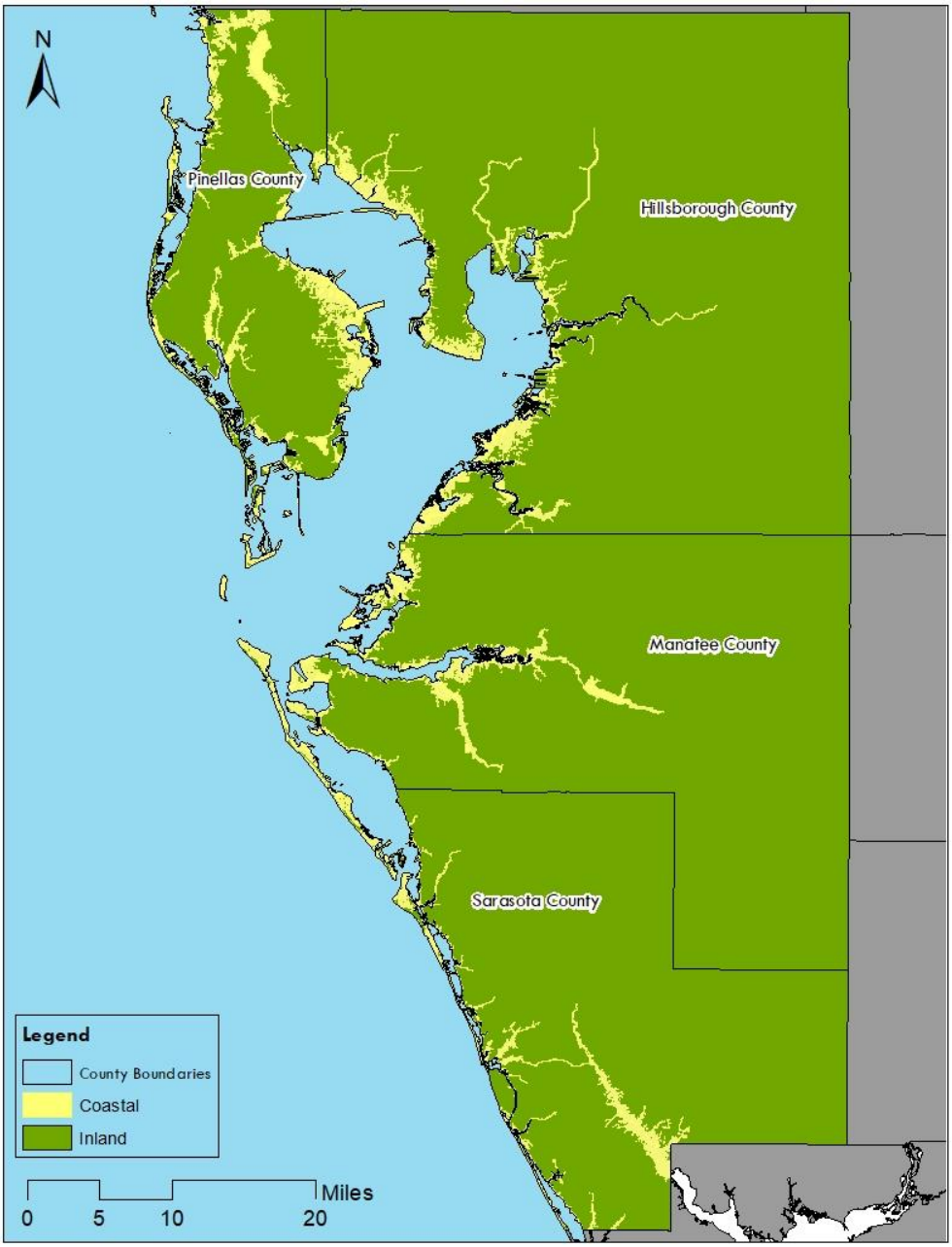

Figure 1 – Four-county focus area inland and coastal regions

Methods

Data

NOAA's SLR maps show how inundation from SLR would flood coastal regions (NOAA 2019). This map considers elevation by subtracting VDATUM from the digital elevation model (DEM) to determine where inundation will occur (NOAA 2017). NOAA's VDATUM model considers tidal, orthometric, and ellipsoidal vertical elevation to create a common reference system for elevation data.

The National Land Cover Database (NLCD) products are produced by the United States Geological Survey (USGS). This dataset provides spatial categorization of land cover and includes 28 land classifications (Homer et al 2020). The dataset extends from 2001 to 2016 - both sets are used to determine how much new development has occurred recently.

The following study explores the rates of development in the Hillsborough, Pinellas, Manatee, and Sarasota four-county area comparing inland and coastal land use classifications. Inland area includes the National Oceanic Atmospheric Administration (NOAA) five feet SLR area. Five feet was selected through a visual investigation of Climate Central's Surging Seas tool which utilizes updated DEM files and considers various additional factors in estimating rise levels such as year, pollution scenario, flood level, and global warming sea level outlook ("luck") (Climate Central 2019). For this investigation SLR with moderate flood, moderate cuts in pollution, and medium luck were evaluated. Five feet of SLR was closest upon visual investigation.

GIS Analysis

In order to ascertain the change in development change from 2001 to 2016 in sea level rise threatened areas versus inland areas, the two areas had to be delineated. The coastal area is derived from NOAA's SLR 5ft inundation map. The inland area was derived by subtracting

coastal boundaries from the county boundaries of Hillsborough, Pinellas, Manatee, and Sarasota counties.

By characterizing the 28 NLCD land classifications as developed or undeveloped and comparing the 2001 to 2016 changes, the rate of development for both coastal and inland areas will be elucidated. The distribution of land use types is displayed in Figures 2 and 3 for the four-county region.

- NLCD 2001, NLCD 2016, and SLR 5ft were reprojected into the FL_NLCD to NAD_1983_StatePlane_Florida_West_FIPS_0902 projection
- SLR 5ft data was clipped to the four-county focus area
- Tabulate Area was performed on the inland and coastal areas for both years 2001 and 2016
- The resulting tabulate area attribute tables provided the total area of each 28 land classifications in the specified coastal or inland areas. The percent development was calculated by totaling the 2001 and 2016 developed versus undeveloped in the inland and coastal areas
- Join all the tables to respective inland or coastal shapefiles for visuals

Percent change calculation

Of the 28 NLCD classifications, 15 NLCD classifications were displayed in either undeveloped or developed. Developed classifications included developed - low intensity, developed - medium intensity, and developed - high intensity. The undeveloped classification is composed of barren land, deciduous forest, evergreen forest, mixed forest, shrub scrub, herbaceous, hay pasture, cultivated crops, woody wetlands, and emergent herbaceous. Developed – open space is considered undeveloped for this analysis because impervious surfaces compose less than 20% and are often settings for recreation or erosion control – in planning for SLR, this would functionally be an undeveloped space. Open water was excluded from analysis as it is exempt from being developed.

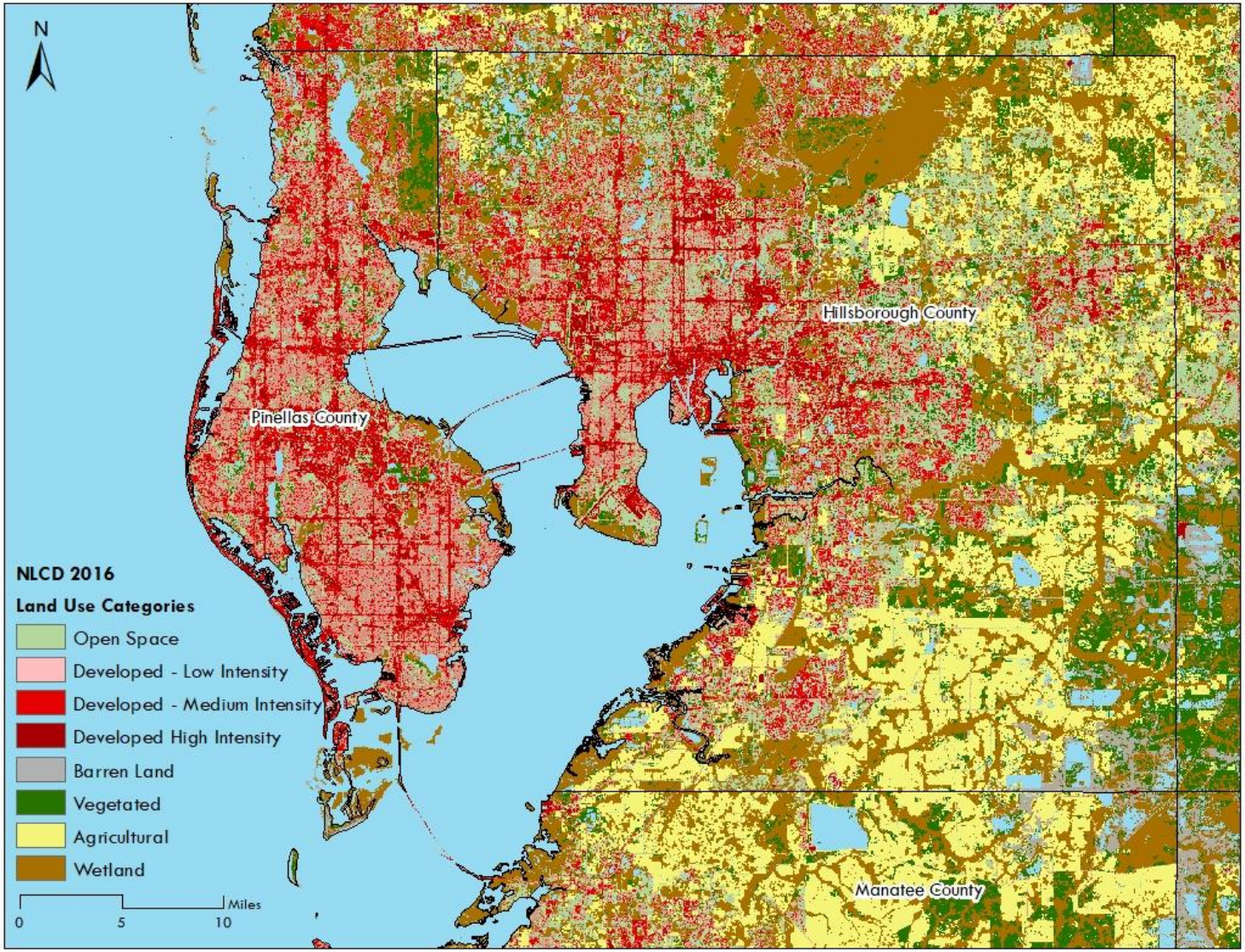

Figure 2 - Pinellas and Hillsborough County land use distribution in 2016

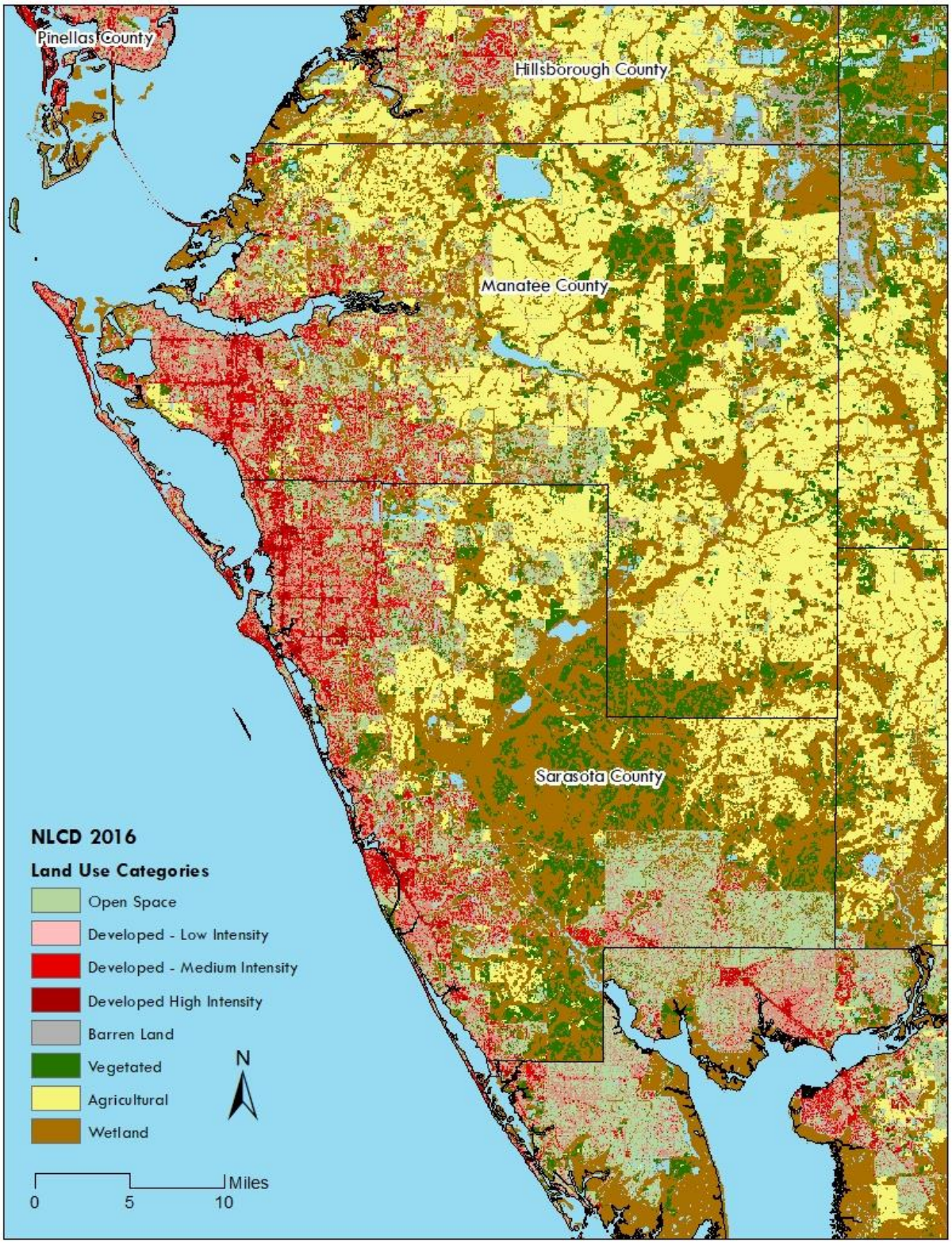

Figure 3 - Manatee and Sarasota County land use distribution in 2016

Results

For the purpose of displaying results, some land use classifications were categorized together: developed - low, medium, and high became 'Developed', developed - open space became 'Open Space', barren land remained as 'Barren Land', deciduous forest and evergreen forest became 'Forest', Shrub Scrub and Herbaceous became 'Vegetated', hay pasture and cultivated crops became 'Agricultural Land', and woody wetland and emergent herbaceous wetland became 'Wetland'.

Table 1 shows the percentage of land cover for each of the six land use types in 2001 and 2016, distinguished by inland or coastal areas. Figure 4 makes the distribution by year and coastal versus inland breakdown clearer. It is apparent that developed land area percentage was higher in 2001 than in 2016. It also appears, as expected, that the inland area had higher percentages of agricultural land than the coast areas of counties. There is a consistent level of open space from 2001 to 2016 in inland and coastal areas with 3-4% more open space in inland areas.

Table 1 - Four-county study area land use type percentage.

	Open Space	Developed	Barren Land	Vegetated	Agricultural Land	Wetland
2001 Inland	13.4%	21.9%	1.1%	9.8%	25.6%	28.0%
2001 Coastal	8.8%	13.7%	1.1%	2.6%	1.2%	72.7%
2016 Inland	14.1%	24.9%	1.0%	9.5%	23.1%	27.3%
2016 Coastal	8.6%	16.2%	1.1%	1.9%	0.5%	71.6%

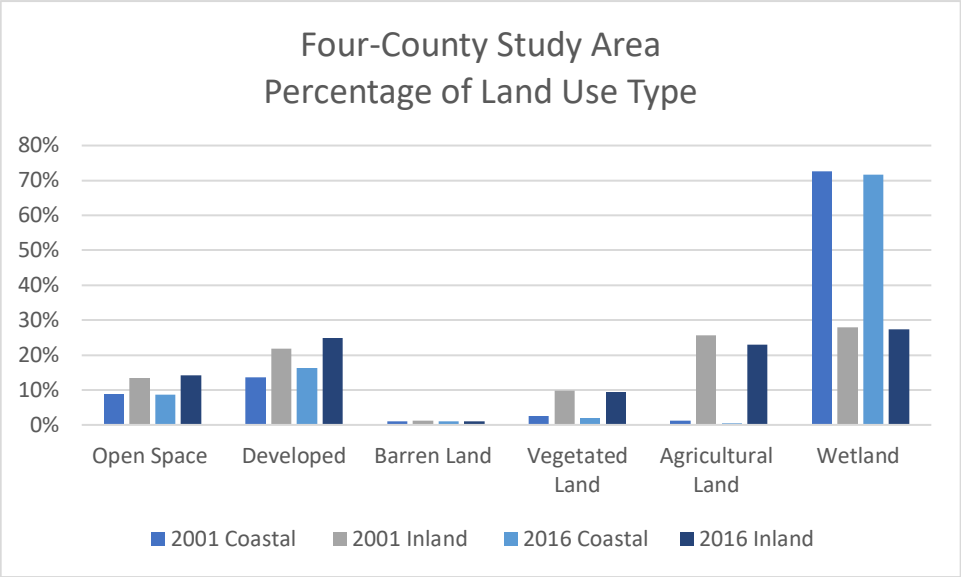

Figure 4 – Percentage of land cover by land use type in four-county study area

Table 2 shows the rate of change from 2001 to 2016 for both inland and coastal areas by developed or undeveloped lands. In coastal areas a 15% increase is observed in developed land use and a 3% decrease is observed in undeveloped land. Inland areas experienced a 12% increase in developed land use and a 4% decrease in undeveloped land use (Table 2).

Four-County Study Area Percent Change				
	Coastal		Inland	
	Developed	Undeveloped	Developed	Undeveloped
2001	14%	86%	22%	78%
2016	16%	84%	25%	75%
Percent change	15%	-3%	12%	-4%

Table 2 - Percent change calculations for four-county study area

In Manatee County, as seen in Figure 5, the highest percentage of land use type is observed as wetlands for the coastal area and as agricultural land for the inland area. There is a significantly smaller percentage of developed land use found in this county. Additionally, Table 3 illustrates that the percentage change from coastal to inland areas differs more than the four-

county study area – coastal development increased 16.6% and inland developed land use area increased 20.5%.

Manatee County				
	Coastal		Inland	
	Developed	Undeveloped	Developed	Undeveloped
2001	11%	89%	10%	90%
2016	13%	87%	13%	87%
Percent Change	16.6%	-2.5%	20.5%	-3.0%

Table 3 - Percentage calculation for Manatee County

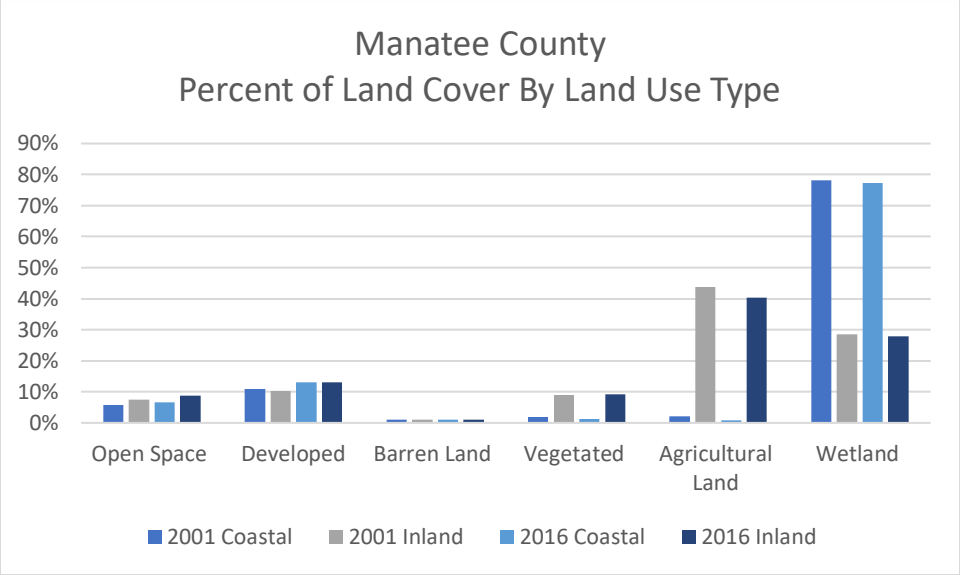

Figure 5 – Manatee County percent of land cover by land use type

As seen in Figure 6, Sarasota County's highest percentage land use type, for coastal areas, is observed as wetland. The highest percentage land use type in inland areas are observed as wetland land. Developed land use percentage is lower than the four-county area percentages in Sarasota County. The percentage of change is more similar to the four-county area in Sarasota County. As seen in Table 4, the developed land use percentage change increased approximately 12-13% and decreased approximately 3-4% in coastal and inland areas.

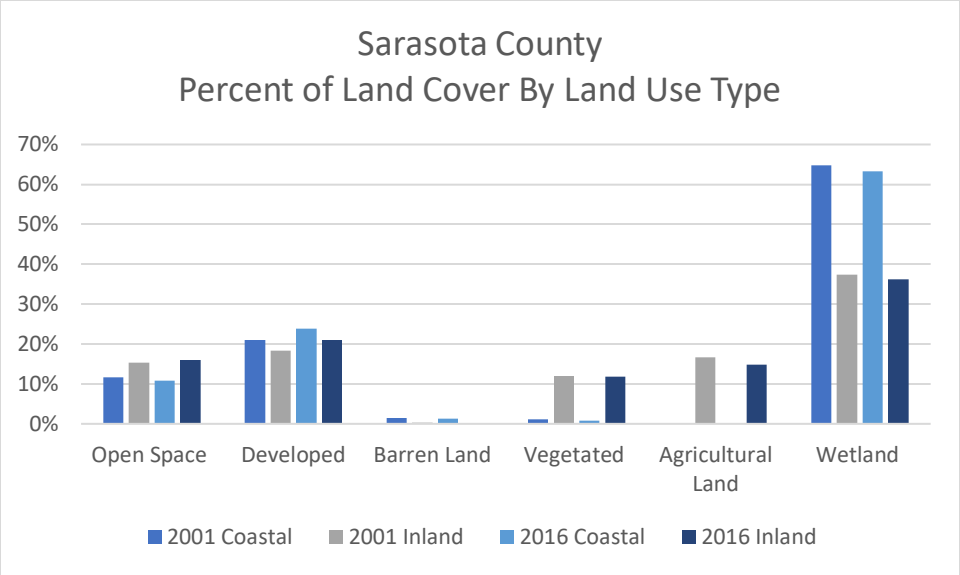

Figure 6 – Sarasota County percent of land cover by land use type

Sarasota County				
	Coastal		Inland	
	Developed	Undeveloped	Developed	Undeveloped
2001	21%	79%	18%	82%
2016	24%	76%	21%	79%
Percent Change	11.8%	-3.7%	12.9%	-3.4%

Table 4 – Percentage change calculations for Sarasota County

As seen in Figure 7, Hillsborough County's wetland is the highest percentage of land use in coastal and inland areas – representing a significantly greater portion of land use in coastal areas. The proportion of developed land use and agricultural land use fall in the 21-24% range and place them as tied for the second highest land use category for inland Hillsborough County. Shown in Table 5, Hillsborough County experienced a high rate of development with an increase of 27.8% in coastal areas. Inland development was also high with an increase of 14.8%. Small, under 5%, decreases in undeveloped land uses were observed in both coastal and inland.

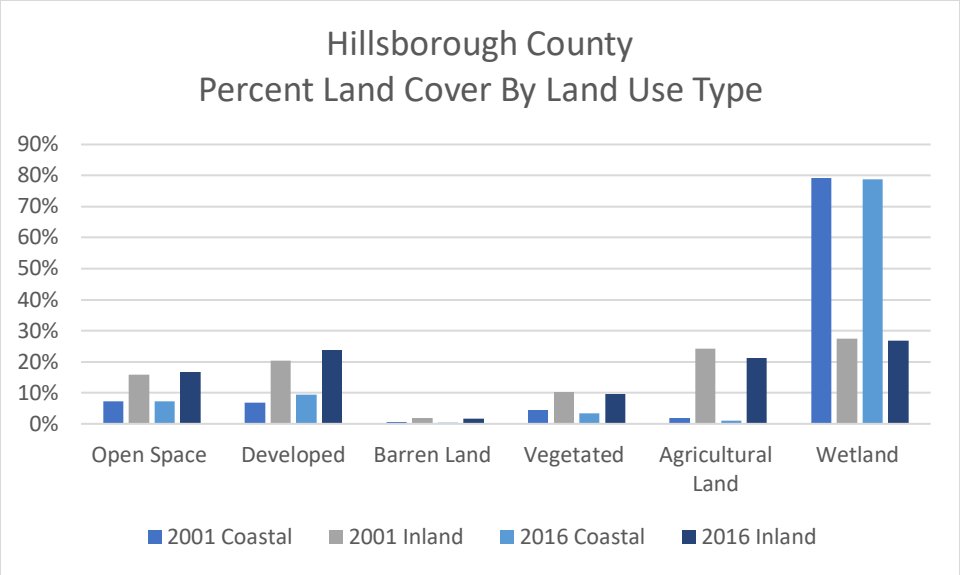

Figure 7 – Hillsborough County percent of land cover by land use type

Hillsborough County				
	Coastal		Inland	
	Developed	Undeveloped	Developed	Undeveloped
2001	7%	93%	20%	80%
2016	9%	91%	24%	76%
Percent Change	27.8%	-2.9%	14.8%	-4.7%

Table 5 – Percentage change calculations for Hillsborough County

In Pinellas County, as seen in Figure 8, inland areas are majority developed and coastal areas are majority wetland. Open space comprises 11-15% of land use for Pinellas County for both inland and coastal areas. Table 6 shows that the percentage change of land use types differs greatly between coastal and inland areas. Development increased by 10.4% in coastal areas and 2.9% in inland areas while undeveloped land decreased by 3.2% in coastal areas and 6.8% in inland areas.

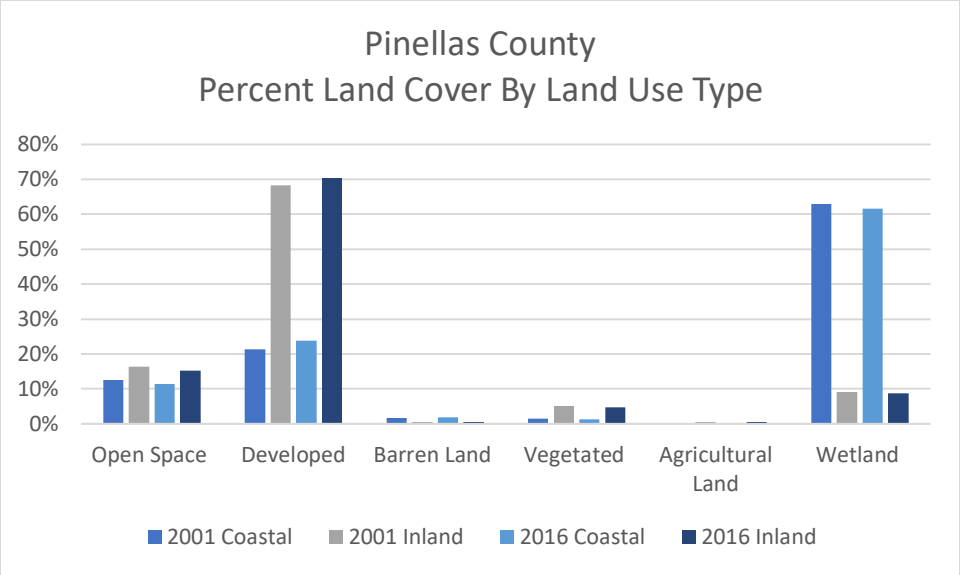

Figure 8 – Pinellas County percent of land cover by land use type

Pinellas County				
	Coastal		Inland	
	Developed	Undeveloped	Developed	Undeveloped
2001	21%	79%	68%	32%
2016	24%	76%	70%	30%
Percent Change	10.4%	-3.2%	2.9%	-6.8%

Table 6 – Pinellas County percent of land cover by land use type

Discussion and Conclusions

Climate change is going to increase erosion, flooding, aquifer inundation, and storm intensity in coastal areas. City and county planners are increasingly challenged with the task to prepare their coastal development for future hardship. Planned retreat, shore protection, accommodation, and policy should be utilized to best prepare communities for SLR challenges. By studying the development patterns in Sarasota, Manatee, Hillsborough, and Pinellas counties, this paper provides support for requirements on how planners should prepare their communities. It is the ethical responsibility leaders and planners to prepare their communities with adaptation policies and infrastructure that will protect the lives and livelihoods of their citizens.

The literature review of this paper lays out the types of adaptation tools that can be taken to prepare for SLR and emphasizes how policy and planning is necessary to appropriate investments efficiently. Planned retreat should be implemented in areas with existing deficit in built environment investments. Contrarily, shore protection will be a preferred short-term solution for areas with higher investments in coastal areas but will be an expensive temporary solution. Similarly, accommodation techniques are costly and not likely to be a permanent solution for SLR as rise depths increase but will aid in short term management of SLR.

The results show that from 2001 to 2016 in the four-county study area coastal and inland areas development increased at a similar rate of 12-17%. Concurrently, in inland areas developed land was 25% of land use in 2016 and 22% of land use in 2001. This is compared with values of 16% and 14% in 2016 and 2001 for coastal areas. This data shows us that development is more prevalent in the inland areas of the four-county study area. Communities with higher development inland will be economically prepared for SLR adaptation expenses because inland development will remain largely unaffected. Adaptive techniques will be necessary for preparing the local, largely tourism based, economies of these areas.

Percent change increases can be compared by viewing Table 7. Manatee County experienced the highest percent of development change for inland areas (Figure 9). This could be due to Manatee County being one of the least developed counties in the study area – giving way to more possibility of development in the recent years. However, more research is necessary to draw definite conclusions.

Percent Change from 2001 to 2016				
	Coastal		Inland	
	Developed	Undeveloped	Developed	Undeveloped
Manatee	16.6%	-2.5%	20.5%	-3.0%
Sarasota	11.8%	-3.7%	12.9%	-3.4%
Hillsborough	27.8%	-2.9%	14.8%	-4.7%
Pinellas	10.4%	-3.2%	2.9%	-6.8%

Table 7- Percent change for coastal and inland areas, comparing the developed and undeveloped values.

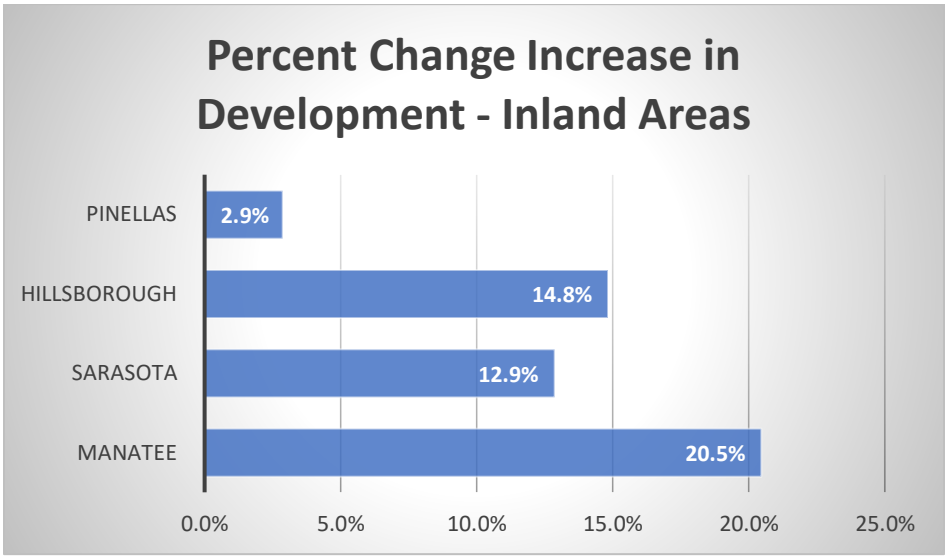

Figure 9 - Percent change increase in development for inland areas

The highest increases in development change were observed in Hillsborough county coastal areas with an increase of 28% (Figure 10). Currently, it is not understood why Hillsborough County is experiencing significantly higher coastal development change. Perhaps,

Hillsborough County's 2001 NOAA 5ft SLR areas contained disproportionately higher area of undeveloped when compared to the other study areas. If so, this may have given rise to a greater opportunity for newly developed land in 2016. Future research is needed to understand the reason for Hillsborough's higher rate of development.

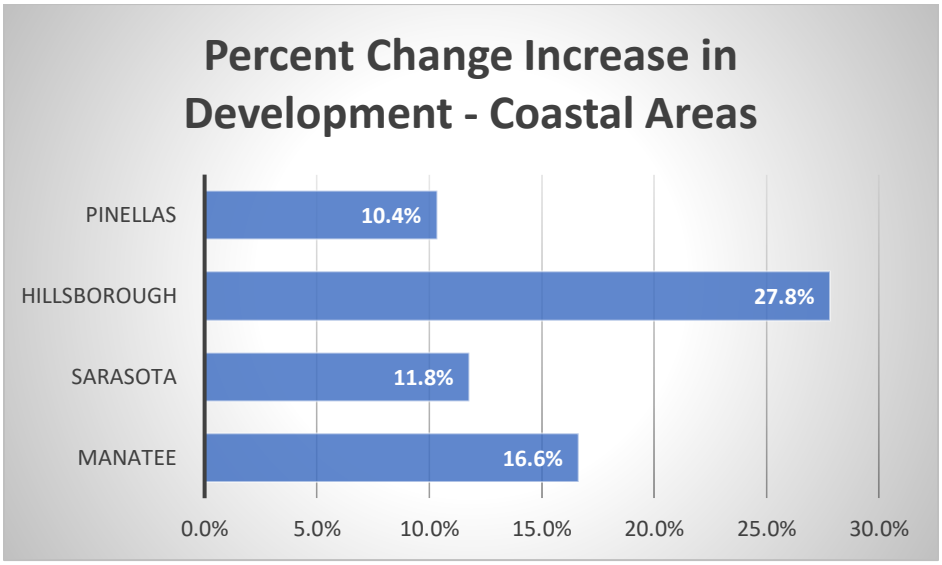

Figure 10 - Percent change increase in development for coastal areas

Pinellas County has the highest proportion of coastal land in comparison to the other three counties and therefore planners have the greatest responsibility to focus on planned retreat. However, Hillsborough has the greatest percent of development increase found in coastal areas, lending equal responsibility to their planners need to consider threats to the built environment from SLR. Pinellas County's major metropolis, the City of Saint Petersburg and Sarasota County's major city, the City of Sarasota, are the only two public municipality/county jurisdictions in the four-county study area with a plan explicitly addressing SLR (City of Sarasota 2017; Wright 2019).

The St. Petersburg Integrated Sustainability Action Plan directly names SLR as a challenge being addressed by city officials (Wright 2019). This plan points exclusively to investments in ecological and natural resource groups as their intended method of addressing SLR. The plan

lacks any timelines or objectives for natural resource maintenance or improvements, indicating that these guidelines will not guarantee any measurable actions. Additionally, the plan does not consider areas for planned retreat or shore protection. Considering all other counties and cities in the four-county study area do not have even this level of planning, this plan is a step forward for Florida SLR planning. However, greater steps are necessary for all of these government leaders to protect their citizen's investments and lives.

The City of Sarasota has a much more specific target of SLR and adaptation measures in their *2017 Climate Adaptation Plan* (City of Sarasota 2017). This document clearly documents the estimated local risks associated with SLR, including a likelihood index, risks to infrastructure, and an adaptation plan with concerted priories for planned adaptation measures. City of Sarasota's adaptation measures prioritize 56 of 80 assessed assets, increasing climate resilience using shore protection and increasing green stormwater infrastructure to reduce flood risk. More government leaders and planners should take this approach in Florida – allocating the resources necessary to get expert advice about localized risk assessment and determining the best course of action to address their specified issues.

Currently, state policies in Florida do not directly address SLR. Acceptance by state lawmakers is necessary to advance the state's preparation for impending climate change issues. Once lawmakers accept SLR as an issue that the state faces, they can nudge county level government toward useful policies to prepare for SLR. For example, the Florida Comprehensive Planning Act should have a section that requires all counties to assess their risks associated with SLR so they can prepare their bridges, water management facilities, stormwater and sewage infrastructure, and other impacted government regulated built infrastructure that citizens depend on. Additionally, the aims of the CCCL Act, to prevent erosion through designating setbacks for

coastal development, need to be updated, for the purpose of protecting communities and their investments, to reduce property damage as result of SLR related erosion.

It is imperative that government leaders and planners understand their responsibility in addressing SLR. First and foremost, the role of leaders in state and local roles is to invest in the best information to projecting SLR for their jurisdiction; by understanding SLR projections for their jurisdiction they can then assess which critical infrastructure are most threatened by SLR. After clarifying the threats that their communities face, planners and government leaders can develop specialized and actionable goals on how to prioritize adaptive policies and infrastructure.

The research limitations include a consistency issue with the inland and coastal areas. By utilizing NOAA's 5ft SLR data to delineate what is coastal versus inland, there are inconsistently large or small areas allocated as "coastal." For instance, Hillsborough County likely has higher elevation and more sea walls, so there is less "coastal" area caught by the NOAA 5ft SLR area. Additionally, there are large differences in coastal versus inland percentages per county. For example, Pinellas County is surrounded by water on three sides, so Pinellas has a greater portion of "coastal" area; while Hillsborough County is only touching water on one of four sides, resulting in less "coastal" area. This discrepancy likely had an influence on how land use types were distributed. Future research should consider more consistent ways to develop a coastal and inland study area.

By having a better understanding of which areas under threat from SLR serve the greatest economic benefit to their community, planners can make better overlay zoning recommendations for protection zones, accommodation zones, retreat zones, and preservation zones. Future recommended research would greatly improve SLR planning recommendations for this area of Florida. It is recommended that change in land use type be calculated in ArcGIS at a cell by cell

basis so targeted land use recommendations can be made based on where development change is occurring.

Additional future research should overlay more factors to determine the areas that would benefit most from shore protection in the coming century. By overlaying multiple factors, a climate risk site assessment could be created. First, economic vitality hotspots should be identified by analyzing overlays such as revenue or employment. Second, geographic analysis which considers the degrees of SLR risk based on flooding depths would greatly assist overlay zoning recommendations. Plus, population density should be considered in order to protect the highest number of resident's lifestyles. After considering these factors, planners will be better equipped to protect their community from the detriment associated with climate change by employing known adaptation best practices.

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