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Resiliency Assessment of Sarasota Bay Watershed, Florida

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ABSTRACT: As population in Sarasota and Manatee Counties, Florida in the United States is projected to increase, land use changes from land development happen continuously. The more land development means the more impervious surfaces and stormwater runoff to Sarasota Bay, which causes critical impact on the resiliency of the ecosystem. In order to decrease its impact on water quality and the ecosystem function of Sarasota Bay, it is important to assess the resilient status of communities that create negative impacts on the ecosystem. Three types of guiding principles of resiliency for Sarasota Bay watershed are suggested. To assess resiliency status, three indexes - vulnerability index, socio-economic index, and ecological index are developed and analyzed by using geographic information system for each census tract in the two counties. Since each indicator for vulnerability index, socio-economic index, and ecological index is measured with different metrics, statistical standardizing method - distance from the best and worst performers is used for this study to directly compare and combine them all to show total resilience score for each census tract. Also, the ten most and the ten least scores for the total resilience index scores are spatially distributed for better understanding which census tracts are most or least resilient. As Sarasota Watershed boundary is also overlaid, it is easy to understand how each census tract attains its resilience and how each census tract impacts to Sarasota Bay ecosystem. Based on results of the resiliency assessment several recommendations, guidelines, or policies for attaining or enhancing resiliency are suggested.

KEYWORDS: Resiliency Assessment, GIS, Environmental Management, Spatial Analysis
키 워 드: 도시 리질리언스 평가, 지리정보시스템, 환경관리, 공간분석

1. Introduction

Sarasota Bay is located on the southwestern coast of Florida in the United States between Anna Maria Sound to the north and the area just north of Venice Inlet to the south. Sarasota Bay is bordered by coastal barrier islands on the west and two mainland counties on the east. Two counties along Sarasota Bay are Manatee and Sarasota. Sarasota Bay is one of 28 estuaries in the United States, named by the U.S. Congress as an estuary of national significance in 1987 and officially designated as a National Estuary Program in 1989. Channelization of the Gulf Intracoastal Waterway started in late 1800s, dredging and filling for land development, loading nitrogen to Sarasota Bay from the land development are the most significant disturbances on Sarasota Bay from late 1800s to today. More than seven decades of channelization of the Intracoastal Waterway caused harmful impact such as wetland loss, habitat loss, the bay bottom modification, turbidity, and salinity change. The channelization on Sarasota Bay created a commercial waterway for people, goods and services. However, at the same time it started to slowly create disturbances on the Sarasota Bay ecosystem.

Dredging and filling activities were also applied to coastal land development on both barrier islands and coastal main land in Sarasota Bay. Dredging and filling for land development for residential and commercial uses caused wetland and habitat loss to a large extent. Population

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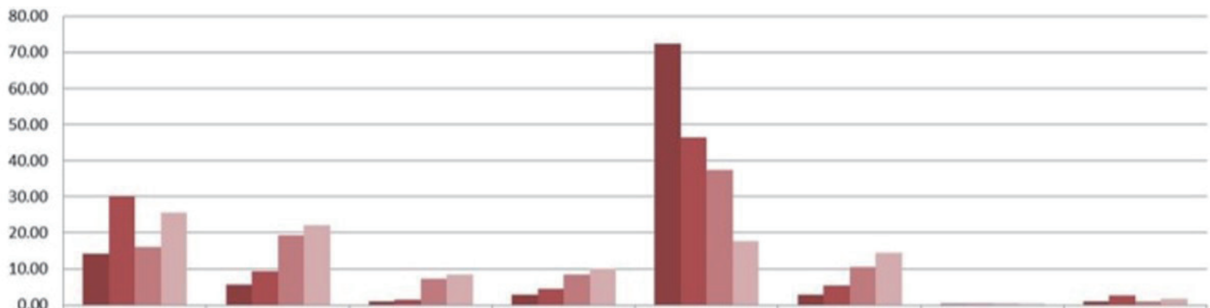
increases and the extensive development around Sarasota Bay due to rapid land development caused detrimental impacts on seagrass habitats and wetlands. Intensified waterfront development created concrete sea walls, changed shorelines, and destroyed seagrass beds and wetlands. Ignorance about degraded quality of Sarasota Bay ecosystem continued until the early 1970s when public started to concern about its impact on ecosystem from dredging and filling activities.

In addition to channelization of the Intracoastal Waterway and dredging and filling activities, the increased land development created nitrogen pollution from wastewater and stormwater runoff directly to Sarasota Bay. The degraded ecosystem, affected by the disturbance on freshwater wetlands, salt marsh, and mangrove, lost its function to filter stormwater and to prevent extensive runoff. Water quality was also impacted by wastewater and stormwater from the Sarasota Bay watershed which includes Manatee and Sarasota Counties with increased impervious surface from intensified land development. Excessive wastewater and stormwater runoff to Sarasota Bay from increased land development is the largest source of nitrogen loading in the bay. Overabundance of nitrogen caused algae blooms, which reduced oxygen levels in the bay. Eventually, it resulted in turbid water and loss of seagrass from opaque water status that sunlight cannot reach underwater grasses. Extensive nitrogen loads also affected redundancy of marine and bird species that obtained nutrients from wetlands and the seagrass beds. By 1990 nitrogen loading in Sarasota Bay was estimated 480 percent above the level prior to disturbances, even though there was significant reduction compared to 1988 due to improvements in the wastewater discharge treatment (Tomasko et al., 2005).

The rapid population growth and the intensive urban development patterns are going on today and are also projected to increase in the future. Based on the US Census data, population in both Sarasota and Manatee Counties in 2010 is 702,281. Between 2000 and 2010, more than 110,000 people moved into the two counties. In addition to the population change, Figure 1 shows the land use/ land cover percentage changes of 8 different types of classifications in Sarasota Bay watershed boundary as well as Sarasota and Manatee Counties boundary between 1999 and 2009. Urban and built-up areas increased by 16.1 and 9.4 percentage in the Sarasota Bay watershed and the county boundary, respectively. In contrast, significant level of water classification reduction is presented between 1999 and 2009. It can be interpreted that dredging and filling activities for intensive urban and built-up development has been occurring. Although urban and built-up areas significantly increased, it is meaningful that small amounts of urban forest and wetlands percentages increased between the ten years in terms of resiliency perspective.



	Urban and Built-up	Agriculture	Rangeland	Urban Forest	Water	Wetlands	Barren Land	Transportation, Communication, and Utilities
a	14.22	5.60	1.04	2.84	72.43	2.76	0.11	1.00
b	30.29	9.24	1.48	4.40	46.52	5.37	0.04	2.67
c	16.15	19.40	7.25	8.32	37.40	10.39	0.11	0.98
d	25.51	22.13	8.48	10.07	17.65	14.47	0.06	1.65

Figure 1. Land use/ Land Cover Change between 1999 and 2009 (a: LULC 1999 Watershed Boundary Percent, b: LULC 2009 Watershed Boundary Percent, c: LULC1999 County Boundary Percent, d: LULC 2009 Watershed Boundary Percent)

As population in Sarasota and Manatee Counties is projected to increase, land use changes from land development happen continuously. The more land development means the more impervious surfaces and stormwater runoff to Sarasota Bay, which causes critical impact on the resiliency of the ecosystem. In order to decrease its impact on water quality and the ecosystem function of Sarasota Bay, it is important to assess the resilient status of communities that create negative impacts on the ecosystem. It is important to understand community's resilience level for pre-disaster prepatation, post-disaster recovery and estimation of potential losses (Klein et al., 2004; Rose, 2007). Although Sarasota Bay ecosystem is currently in the reorganization phase of the adaptive cycle and social-ecological components of the system is also considered to understand the ecosystem, the ecosystem still confronts and deals with disturbances. In order to attain resiliency in the system or to enhance to some desired state, different types of resilience indicators should be considered for a resiliency assessment of Sarasota Bay ecosystem.

Frazier et al.(2013) explain that it is difficult to quantify resilience because of resilience indicators have the qualitative nature. Therefore, before establishing different types of indicators for resiliency assessment, it is better to think about a definition or guiding principles of resiliency concept and corresponding sustainable approaches to development. This study has its novelty since it proposes guiding principles to develop resilience indicators and enhance resilience status of Sarasota Bay area. Considering the geographical location of Sarasota Bay along coastal areas, one of guiding principles of resiliency is that the Sarasota Bay watershed and the two counties of Sarasota and Manatee should actively prepare and respond to natural disasters and changes in climate, such as hurricanes, storm surges, extreme heat events, or increases in sea level, in order to bounce back from unpredicted events. Considering the rapid population growth and the intensive urban development patterns, another guiding principle of resiliency is that Sarasota Bay watershed and the two counties should create minimum impacts on the Sarasota Bay ecosystem with non-structural approaches such as low impact development or green infrastructure implementation.

Another guiding principle of resiliency is that Sarasota Bay watershed and the two counties should attain and enhance the social-economic and ecological system. Gunderson and Holling (2002) stated that the ecosystem and the social system should be analyzed simultaneously as a linked system. Beatley (2009) mentioned that a resilient community refers to one with strong social systems and networks. Especially, resilience in recovery and reconstruction depends on how this social system works well with ecological system. Also, different spatial and temporal scales should be considered to understand how the ecosystem functions and sustains its resiliency without crossing carrying capacity.

2. Resiliency Assessment

2.1 Unit of Analysis

In order to analyze the resilient status of Sarasota Bay watershed, census tract is used as a unit of analysis for this study. Ecological quality in Sarasota Bay is impacted by wastewater and stormwater from the Sarasota Bay watershed which includes Manatee and Sarasota Counties with increased population, urban development, and impervious surface. Since the resilient status of Sarasota Bay is directly related to the Sarasota Bay watershed area, it is meaningful to conduct a resiliency assessment for each census tract and to represent spatial distribution of the resilient status in Sarasota and Manatee boundary. One advantage of using census tract as a unit of analysis is that it will represent detailed spatial distribution than a study with county as a unit of analysis. Sarasota watershed boundary from the United States Environmental Protection Agency (U.S. EPA) datasets do not coincide with the census tract boundary from the U.S. Census Bureau. If Sarasota watershed boundary is used as a unit of analysis, it is required to conduct additional process to allocate proportional the US census data. Therefore, another advantage of using census tract as a unit of analysis is that it will minimize the US Census data loss for census tract level. Figure 2 shows study area of Sarasota Bay Watershed and census tracts for this study.

2.2 Resiliency Indexes

Three types of guiding principles of resiliency for Sarasota Bay watershed are suggested previously. One of guiding principles of resiliency is that the study area should actively prepare and respond to natural disaster and climate change. In order to implement this guideline, a vulnerability index is suggested for the resiliency assessment. Based the results on the vulnerability index for each census tract, areas with high vulnerability should prepare and respond to natural disaster and climate change. Another guiding principle of resiliency is that the study area should create minimum impacts on Sarasota Bay ecosystem with non-structural approaches such as low impact development or green infrastructure implementation. Additional guiding principle of resiliency is that Sarasota Bay watershed and the two counties should attain and enhance social-economic and ecological system.

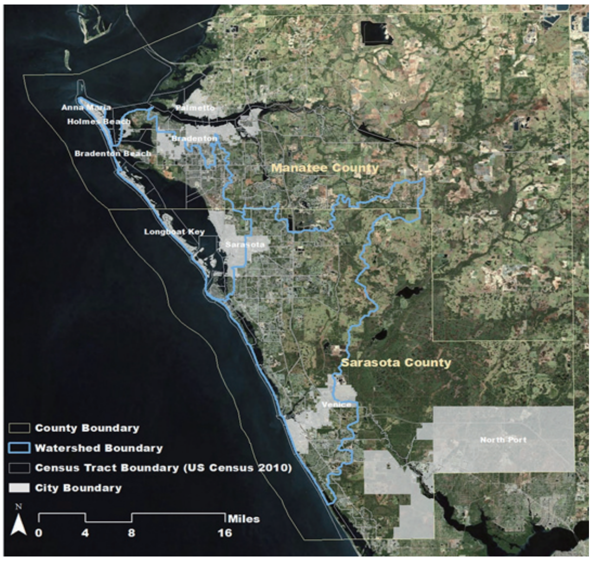


Figure 2. Study Area of Sarasota Bay Watershed

2.2.1 Vulnerability Index

The first meaningful assessment is to analyze census tracts with high vulnerability in the study area. As the Sarasota Bay Watershed is located in coastal areas, the likelihood to be vulnerable to storm surge and flood is expected to be higher than inland areas. Also, as human-induced environmental issues from rapid population change and urban development in Sarasota Bay Watershed are strongly related to climate change, climate change aspects such as extreme heat event, sea level rise, or CO2 emission should be considered for the vulnerability assessment. As each census tract has its own geographical characteristics or development patterns, the likelihood of being vulnerable to natural hazards and climate change is not equally distributed for both Manatee and Sarasota County. In order to analyze how resilient Sarasota Bay Watershed is, it is important to investigate which census tracts have more risks of being impacted from unexpected events. For this vulnerability assessment, six indicators are included and summarized in Table 1.

- Flood Insurance Rate Maps

Percentage of areas within special flood hazard areas is calculated for each census tract to investigate the likelihood to be vulnerable to flood.

- Storm Surge

Due to the geographical location of Sarasota Bay Watershed, it is important to consider storm surge as an indicator for vulnerability index. Storm surge data by Florida Regional Planning Council and Florida Division of Emergency Management for this study represents that all different storm simulations for each category of storm from 1 to 5. The percentage of areas within the storm surge projection for all storm categories is calculated for each census tract to indicate higher likelihood to be vulnerable to a storm surge.

- Urban Heat

As Sarasota Bay Watershed is located in the southern part of the United States, it is exposed to more extreme heat events compared to other areas in the northern part. Extreme heat events are critical factors to increase cooling energy demands as well as CO2 emission. Therefore, heat-related vulnerability indicator is a meaningful way to analyze census tracts with higher surface temperatures and to show thermal distribution throughout the study area.

- Sea Level Rise

As Sarasota Bay Watershed is located in the Gulf coastal area, sea level rise should be considered as one of vulnerability indicators. It is critical to investigate what extent of our communities will be impacted by the sea level rise up to 10ft. Percentage of areas within sea level rise projection (0–10ft) will be calculated for the likelihood to be vulnerable to sea level rise.

– CO2 Emission

Although there are diverse and complicated methods to calculate CO2 emission, percentage of population commuting to work by car is considered as an indicator to measure CO2 emission from each census tract for this study. The higher percentage of population commuting to work by car indicates more vulnerability status of each census tract.

– Impervious Surface

According to Florida Land Use, Cover and Forms Classification System by Florida Department of Transportation, Urban and Built–up classification is designated to areas of intensive use with much of the land occupied by man–made structure (Florida Department of Transportation 1999). As one of critical human disturbance on Sarasota Bay is from rapid urban development and impervious surfaces, consideration of impervious surface indicator for vulnerability index is important. Although there are diverse methods to calculate impervious surface, a percentage of urban and built–up land use class is considered for representing impervious surfaces in each census tract. The higher percentage of urban and built–up areas indicates higher disturbance on Sarasota Bay.

Table 1. Vulnerability Indicators

Indocator	Data	Scale (for each census tract level)
Flood	FEMA Flood Insurance Rate Maps 1996	Percentage of areas located within special flood hazard area
Storm Surge	Storm surge zones 2012	Percentage of areas within all categories of storm (1-5)
Urban Heat	Landsat 5 (April, 17 2010)	Mean Temperature (° F)
Sea Level Rise	Sea Level Rise projection	Percentage of areas within sea level rise projection (0-10ft)
CO_2 Emission	2010 ACS 5-year estimates	Percentage of Population commuting by car
Impervious Surface	2009 Land Use/Land Cover	Percentage of Urban and Built-Up classification

2.2.2 Socio–Economic Index

The second meaningful assessment is to analyze socio–economic resilience status of each census tract. Six indicators of socio–economic index are included for this study and summarized in Table 2.

– Education Attainment

Education attainment is one of the socio–economic indicators that explains how each census tract is resilient or not. People with higher education such as bachelor's degree or graduate degree have more chances to get better job opportunities and to sustain financial stability. They are also more exposed to knowledge for attaining and enhancing resiliency and sustainability of their communities. Since education and public outreach are emphasized to respond to natural or human disturbance, the higher education attainment will be an indicator for assessing resilience status of each census tract in the study area.

– Employment Status

Employment status of percentage of population in labor force or not in labor force is an indicator to assess economic resiliency status of the study area. Communities with a higher percentage of people in the labor force indicate financial stability than communities with a higher percentage of people not in the labor force.

– Poverty Level

Poverty level of the percentage of population below the poverty level is an economic resiliency indicator of the study area. In order to assess the resilience status of each census tract, a reversed poverty level is considered for socio–economic index.

– Year Householder Moved into Unit

The longer people have lived in one community, the better they understand their community. More knowledge and understanding of their community is a good aspect to respond to unexpected events and to attain resilient status. This socio–economic resilience indicator is measured by the percentage of householder who moved into a unit in 1989 or earlier. It presents the percentage of householder who has lived in each census tract for more than 20 years.

– Commuting to Work by Public Transportation

The percentage of the population commuting to work by public transportation explains how each census tract is socially resilient. People who prefer commuting to work by public transportation will be more likelihood to consider human disturbance on surrounding environment than people who drive alone to their work. One of the responses to reduce human disturbance on the study area is to reduce auto dependency and to use public transportation. The higher percentage of the population commuting to work by public transportation indicates the social resilient status of each census tract.

– Facilities

The percentage of numbers of facilities with different social functions indicates how each census tract is resilient to respond to unexpected events. These different types of facilities are places for people in each census tract to prepare and respond to natural disasters or climate change. Also, the facilities are places for education and public outreach programs for knowledge of enhancing resiliency and sustainability of their communities.

Table 2. Socio-Economic Indicators

Indocator	Data	Scale (for each census tract level)
Education Attainment	2010 ACS 5-year estimates	Percentage of Population with Bachelor's Degree, Graduate or Professional Degree
Employment Status	2010 ACS 5-year estimates	Percentage of Population in labor force
Poverty Level	2010 ACS 5-year estimates	Percentage of Population below poverty level (Reversed scale was considered for the analysis)
Year Householder Moved into Unit	2010 ACS 5-year estimates	Percentage of householder who moved into unit in 1989 or earlier
Commuting to Work by Public Transportation	2010 ACS 5-year estimates	Percentage of Population commuting to work by public transportation
Facilities	Florida Religious Center 2009 Florida Civic Centers 2011 Florida Cultural Centers 2011 Florida Social Service Center 2008 Florida Community Center 2008 Florida Hospitals 2011 Florida Fire Stations 2008	Percentage of numbers of facilities

2.2.3 Ecological Index

The third meaningful assessment is to analyze ecological resilience status of each census tract. Four indicators of ecological index are included for this study and summarized in Table 3.

– Conservation Lands

Conservation Lands represent public and private lands that identified as areas having natural resource value and being managed for conservation purposes. The percentage of conservation lands indicates that how much conservation lands exist in each census tract.

– Wetlands

Wetlands provide ecological benefits as green infrastructure such as flood mitigation or stormwater management. Therefore, the percentage of wetlands in each census tract is a good ecological indicator to shows how resilient each census tract is in the study area.

– Strategic Habitat

In order to attain and enhance ecological resilience in the study area, it is important to consider the habitats for species. According to the Florida Fish and Wildlife Conservation commission, strategic habitat identifies the particular species of wildlife predicted to occur for that location. The percentage of areas designated to strategic habitat area in each census tract is one of the indicators to measure ecological resilience level. The higher percentage of areas indicates diverse wildlife in the study area.

– Normalized Difference Vegetation Index (NDVI)

Normalized difference vegetation index is one of standardized vegetation indexes to display greenness (Jensen, 2009). Low values of NDVI indicate barren areas of rock, sand, or snow. Moderate values of NDVI and high values of NDVI represent shrub and grassland, and temperate and tropical rain forests, respectively. The mean normalized difference vegetation index in each census tract is a good indicator for ecological index to respond to climate change. The higher vegetation index shows better performance to respond to natural disturbance such as climate change by mitigating urban heat island and flood.

Table 3. Ecological Indicators

Indocator	Data	Scale (for each census tract level)
Conservation Lands	Florida conservation lands By Florida Natural Areas Inventory	Percentage of areas designated to public and private conservation lands
Wetlands	Florida Wetlands by the National Wetlands Inventory	Percentage of areas designated to wetlands
Strategic Habitat	Strategic Habitat Area determined by to the Florida Fish and Wildlife Conservation commission	Percentage of areas designated to strategic habitat area
Normalized Difference Vegetation Index	Landsat 5 (April, 17 2010)	Mean Normalized Difference Vegetation Index

2.3 Statistical Method

Since each indicator for vulnerability index, socio-economic index, and ecological index is measured with different metrics, it is important to standardize the scores of each indicator in order to directly compare and combine them all to show total resilience score for each census tract. Although there are different methods of standardizing indicators, the same statistical standardizing method, distance from the best and worst performers is used for this study. Each indicator for the three indexes is normalized into a 1 to 10 scale, then scores of each indicator are summed within each index. As there are six indicators for both vulnerability index and socio-economic index, the summed scores within the corresponding index are divided by 6 in order to present the total scores into a 1 to 10 scale. The same process is applied to the ecological index, but the corresponding total score is divided by 4 due to the number of ecological indicators. These three total scores for vulnerability index, socio-economic index, and ecological index are summed together in order to show total resilience score into a 1 to 30 scale. One thing to consider is that the reversed vulnerability index score is used for this statistical process. The reason why the reversed vulnerability index score is considered is that the higher vulnerability index represents the less resilient status. The reversed vulnerability index, the value of subtraction each vulnerability score of each census tract from the available maximum vulnerability score value of 60, is considered to combine three total index scores.

2.4 Results

Vulnerability index (6 indicators), socio-economic index (6 indicators), and ecological index (4 indicators) with 16

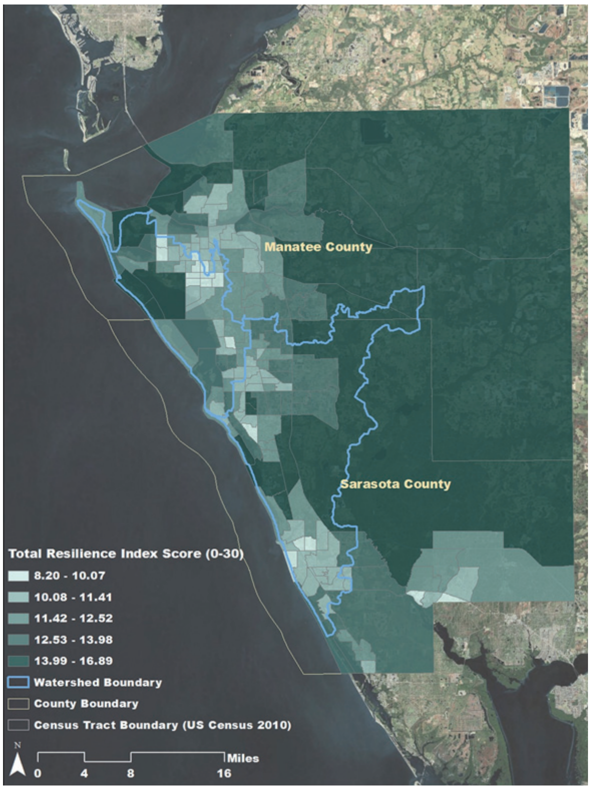


Figure 3. Total Resilience Index Score (0-30)

Figure 4. The Most and Least Resilient Census Tracts

different indicators were analyzed for resilience assessment for each census tract in Sarasota and Manatee county to represent the resilient status of Sarasota Bay watershed. Below images from Figure 3 shows spatial distribution of total resilience index score for all census tracts in Sarasota and Manatee counties. In addition to the image, the ten most and the ten least scores for the total resilience index scores are spatially distributed for better understanding which census tracts are most or least resilient (Figure 4). As Sarasota Watershed boundary is also overlaid, it is easy to understand how each census tract attains its resilience and how each census tract impacts to Sarasota Bay ecosystem.

Total resilience index score ranges from 8.20 to 16.89 out of 30. Census tracts with the least resilience index score are located mostly in Manatee County. It is interesting that census tracts such as 11.04, 12.04 and 19.07 in Manatee County and 21 in Sarasota County show the most resilience index score (Table 4). Although these census tracts are located in coastal hazard prone areas, high scores from socio-economic and ecological index increased overall resiliency status of the census tracts. It can be interpreted that in order to attain and enhance the resilient status of communities, combinations of socio-economic and ecological resiliency level are very important. In order to recommend guidelines or policies, it is suggested to consider total resiliency scores of all census tracts to enhance the least resilient census tract to desired status.

Total vulnerability index score ranges from 1.21 to 6.66 out of 10. Most of the least vulnerable census tracts are located in Manatee County, whereas the most vulnerable census tracts are represented in Sarasota County. Total socio-economic resiliency index score ranges from 1.84 to 6.18 out of 10. Total ecological resiliency index score ranges from 1.24 to 6.02 out of 10. In addition to the resiliency assessment, correlation analysis of the total resiliency index score and population density in each census tract is conducted (Figure 5). It indicates that there is statistically significant negative correlation between the resiliency index score and the population density. As population is projected to increase in the study area, it is important to consider ways to attain and enhance resilient status of Sarasota Bay watershed.

Table 4. The Most and Least Resilient Score

County	Census Tract	The most resilient Score	County	Census Tract	The least resilient Score
Sarasota	27.13	16.89	Manatee	2.01	8.20
Manatee	12.04	15.79	Manatee	3.10	8.53
Manatee	17.04	15.16	Manatee	3.06	8.79
Manatee	20.10	15.11	Sarasota	27.10	8.85
Sarasota	19.07	15.02	Manatee	3.05	9.03
Manatee	19.07	14.92	Sarasota	27.24	9.08
Sarasota	21	14.85	Manatee	3.07	9.09
Manatee	20.15	14.75	Manatee	3.08	9.19
Manatee	11.04	14.58	Manatee	3.04	9.50
Manatee	19.08	14.47	Sarasota	23.02	9.72

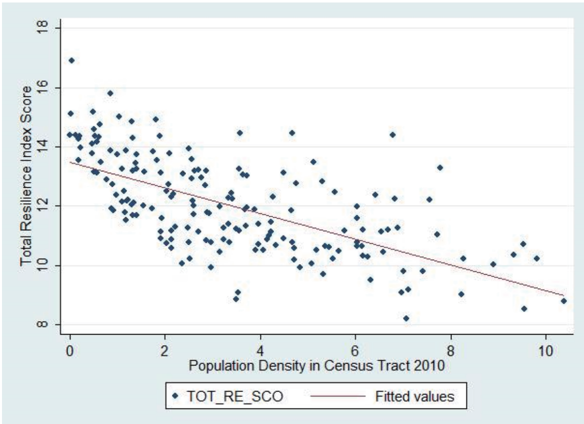


Figure 5. Correlation between Total Resilience Index Score and Population Density

3. Recommendations, Guidelines, or Policies for Attaining or Enhancing Resiliency

The Sarasota Bay ecosystem is currently in the reorganization phase of the adaptive cycle. The Sarasota Bay comprehensive conservation and management plan for the Bay and the Sarasota Bay Watershed Management Plan are good examples of the reorganization phase to restore the degraded Sarasota Bay ecosystem. However, it is important to implement more detailed guidelines and policies to attain and to enhance the resiliency of the ecosystem based on the results from the resiliency assessment for Sarasota Bay watershed and the two counties.

First, as climate changes, it is inevitable that Sarasota Bay will confront another disturbance in the future. Sea level rise will be another slow variable for adaptive cycle that Sarasota Bay ecosystem will change through the new adaptive cycle. A policy for preparedness for sea level rise disturbance should be recommended. Sea level rise will cause detrimental impacts on the existing ecosystem as well as social resiliency in Sarasota Bay. Therefore, management plans and tools for minimizing its impacts from sea level rise for waterfront communities are important to enhance resiliency of Sarasota Bay. One of the guidelines for the management plan is to limit new developments to areas within coastal high hazard areas (Brody et al., 2011) or to enforce new developments with elevated foundation up to 10ft or the freeboard regulation.

Second, it is highly recommended to implement low-impact-development strategies with green infrastructure for new developments to reduce human disturbance on the Sarasota Bay ecosystem. Green infrastructure refers to interconnected green space that mimics ecosystem function such as filtering stormwater runoffs or preventing flood damages. To reduce stormwater runoff from land development, green infrastructure implementation for the area helps maintain resiliency in the ecosystem. Setback regulations for development near natural resources, water bodies, or coastal areas that require a minimum of 10ft will be an effective guideline to protect coastal resources and runoff from impervious surfaces (Brody et al., 2011). Low impact development to avoid sprawling developments will reduce impervious surfaces. Low impact development allows new land developments to maintain existing ecosystem function, so that people will create less impacts. In result, people will have benefits from the ecosystem function. In order to encourage people to implement low impact development and green infrastructure, financial incentives or density bonuses are effective tools.

Third, it is recommended to make a guideline for conducting the resiliency assessment continuously to monitor how each census tract attains the resiliency level and to set a goal to enhance its resiliency status. Since the resiliency assessment output can be compared to other census tract or county level in the same scale, it will increase interconnection between different levels of communities, census tracts, or counties. As there is no boundary for ecosystems, guidelines and policies with interconnection of different spatial scales is important to attain and enhance the resiliency of the Sarasota Bay watershed.

These three recommendations will contribute to enhance resiliency status of Sarasota Watershed Bay area and these can be implemented in other neighborhood with urban issues. However, in order to improve resiliency assessment, additional resilience indicators are recommended to be included for further analysis. To analyze more complete resilience assessment, differential weighting and spatial autocorrelation of indicators in this study should be considered (Frazier et al., 2013). Also, analysis for the relationship between land use and land cover changes and resilience status of the study area are suggested for further research.

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