CLIMATE-SENSITIVE HAZARDS IN FLORIDA

Identifying and Prioritizing Threats to Build Resilience against Climate Effects

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This report was produced under contract for the Florida Department of Health. This project was supported by an award from the Centers for Disease Control and Prevention (grant number U5UE1EH001047-02, Building Community Resilience in Florida through Adaptation and Mitigation). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the Centers for Disease Control and Prevention.

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IDENTIFYING AND PRIORITIZING THREATS TO BUILD RESILIENCE AGAINST CLIMATE EFFECTS

1. PROJECT INTRODUCTION

An uncertain climate future, and perhaps more importantly, impacts from a changing climate, loom before us. Today's climate was influenced by millions of years' worth of shifts in weather patterns, warming and cooling trends, and more recently by human influences on land and technology growth. Climate futures are also clouded by rhetoric and incomplete science. Fortunately, a focus on climate-sensitive hazards[1] does not require a connection between the reasons behind climate change and the effects of such change. Therefore, we do not focus on changing climate from the standpoint of "who is responsible" for "what portion" of "what pollution" that is causing the earth to change. Rather, this report will focus on the possible outcomes from a changing climate and the likely consequences of those outcomes as they manifest themselves across the state of Florida.

Simply put, hazard losses (even when controlling for population and inflation) have been increasing at a steady pace in this country since 1960, and Florida is no exception to this trend. Since many hazards are dynamically linked to the earth's weather processes, we can connect any subsequent aberrations in local, regional, or national weather to a variety of disaster consequences for which we are currently often ill-prepared. Included here are the devastating impacts from flooding, drought, and hurricanes that continue to affect the lives and livelihoods across the nation every year. Impacts and outcomes from these current incidents coupled with the fact that considerably more people are living within "hazard zones," especially within the state of Florida, mean that impacts from future expanded, and possibly more devastating, events might be seen as disasters waiting to happen. These must be assessed and adapted to if public health resilience is to be achieved.

The goal of this project is twofold. First, we will provide an expert overview of climate-sensitive threats[2] to lives and livelihoods within the state of Florida that is grounded in science and supported by pre-existing studies at the state and regional level. Second, we will assess and analyze priority climate-sensitive hazards for spatial and population impacts across the state. To that end, this report will focus on identifying, describing, and detailing multiple climate-sensitive events that will be influenced either positively or negatively by changes in Florida's climate. This review provides the scientific justification for identifying priority climate hazard threats to health for Florida's populations. The following sections will discuss a general background of hazards and losses for Florida, including an overview of hazards related to an overabundance of water (rain, flooding, and severe storms), severe and large scale events (storm surge and sea level rise), and those related to a lack of water (drought, heat, and wildfire). A short conclusion will highlight the findings and tease out those hazards that pose a threat to the most people across the state.

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[1] Climate-sensitive hazards/threats refer to those hazard events that would be influenced by changes in climate conditions. Some examples include drought, hurricanes, flooding, sea level rise, wildfires, and extreme precipitation.
[2] See climate-sensitive hazards.

PROJECT BACKGROUND

Though climatic conditions vary across geographic regions of Florida, most of the state lies within the southernmost portion of the mid-latitude humid subtropical climate zone, characterized by a long, hot, and humid summer, and a mild, wet winter. In the southernmost section of the peninsula, weather patterns are generally designated by the tropical savanna[3], sharing many characteristics observed in the Caribbean islands (subdivided further as equatorial monsoon, equatorial savanna, and equatorial rainforest in Figure 1 below). Tropical savanna precipitation follows monsoon seasonality, highly concentrated during summer months, with a distinct decrease in rainfall throughout the winter season. Geographic factors governing Florida's climate include latitude, prevailing wind and pressure systems[4], land and water distribution, ocean currents, storm prevalence, and topography (Winsberg, 2003a). While statewide relief reaches a maximum elevation of approximately 345 meters above sea level (Britton Hill, along the Florida-Alabama border), subtle topography characterizes the Florida shoreline, providing nominal natural barrier to mitigate the impacts of floods, hurricanes, and extreme coastal events.

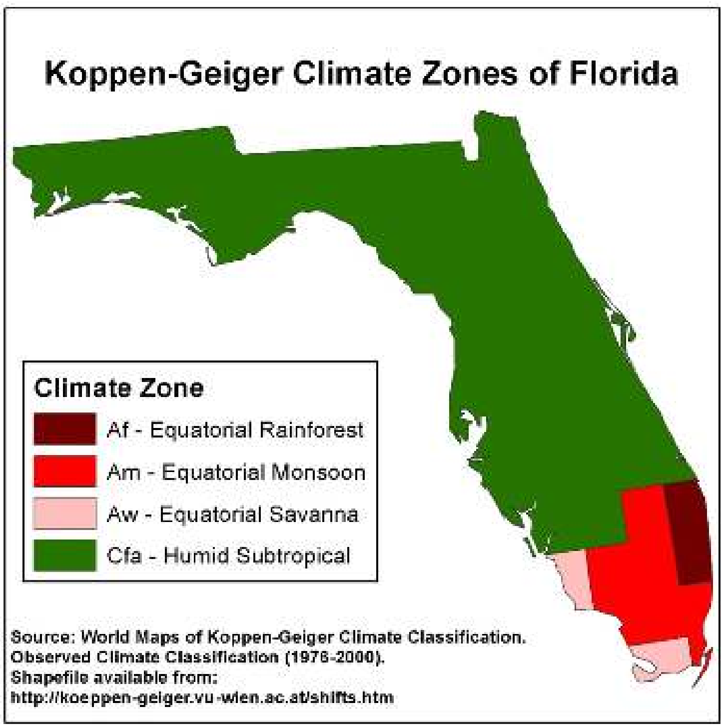

Figure 1: Koppen-Geiger climate zone map of Florida.

[3] Tropical savanna climate is a climate type that has monthly mean temperature above 18 °C (64 °F) all year and generally has a pronounced dry season, where precipitation during the driest months is less than 60 mm and where total precipitation is also less than (100 − [total annual precipitation {mm}/25]). A tropical savanna climate generally either has less rainfall than a tropical monsoon climate or more pronounced dry seasons.

[4] A pressure system is an area atmosphere where air pressure is unusually high or low. High and low pressure systems develop and dissipate continuously due to thermodynamic interactions of temperature differentials in the atmosphere and water of oceans and lakes.

Historically, Florida has been no stranger to hazards and disaster events, enduring 65 major presidential declarations and 12 declared emergencies since 1953 (FEMA, 2013). Among the most common hazards are severe thunderstorms, wind, lightning, tornadoes, tropical storms, and floods. In many cases, these hazards outnumber similar events across the country in frequency, magnitude, and impacts. From 1959 to the present, Florida has experienced more lightning fatalities than any other state (Vaisala, 2012), and has exhibited the highest annual average number of tornadoes per 10,000 square miles (NCDC, 2011). Florida is also among the wettest states in the country, consistently ranking among the top five in average annual precipitation (CoCoRaHS, 2011; Winsberg, 2003a). By comparison, Florida's shoreline is nearly as long as the combined strands of all other Gulf and Atlantic coast states from Virginia to Texas (Winsberg, 2003a). Because of the state's unique peninsular geography, it is exposed along both the Atlantic Ocean and the Gulf of Mexico, creating what Bossak (2004) refers to as the "hurricane bull's eye" (p.541). Consequently, more tropical systems make landfall in Florida than any other state (Malmstadt et al., 2009). Unsurprisingly, hurricanes and tropical storms represent the costliest hazard in Florida's history, accounting for 86% of the state's total hazard losses from 1960 to 2012 (HVRI, 2013). Disaster loss data in the United States is collected by a variety of first order data collection services including the National Climatic Data Center, the United States Geological Survey, and other government entities. Many of these data sources are compiled and combined with spatial enumeration data at the county level as the base data for the Spatial Hazard Events and Losses Database for the United States (SHELDUS). Table 1 below illustrates monetary losses and casualties by hazard type for the 53-year period. Measured by injuries, impacts from hurricanes and tropical storms are second only to tornadoes. Examining total fatalities, however, lightning and combined coastal hazards (including storm surge, rip currents, etc.) represent the deadliest hazards in the state.

Table 1: Florida hazard profile, 1960 to 2012.

Hazard Type	Monetary Losses (2012 adjusted)	Fatalities	Injuries
Hurricane/Tropical Storm	$ 87,373,452,167	148	2,940
Wind	$ 3,932,003,179	86	473
Flooding	$ 3,436,397,989	19	5
Winter Weather	$ 2,354,049,615	36	2
Tornado	$ 2,044,959,759	168	3,070
Wildfire	$ 834,628,358	0	255
Severe Storm	$ 740,811,980	47	228
Hail	$ 592,629,556	10	31
Coastal	$ 555,793,597	296	349
Lightning	$ 119,672,074	458	1,564
Fog	$ 2,350,860	6	47
Heat and Drought*	$ 129,666,151	12	10
TOTAL	**$102,116,415,285**	**1,288**	**8,974**

Source: The Spatial Hazard Events and Losses Database for the United States. (HVRI 2013)

* Impacts for heat and drought are combined. Casualties represent fatalities and injuries resulting directly from exposure to the hazard and may not represent the total medical impact from extreme heat events.

Temporal trends[5] for all hazard losses in Florida are generally concurrent with those tabulated throughout the United States (Cutter and Emrich, 2005; Gall et al., 2011), representing an increasing and unsustainable pattern of damage. Figure 2 illustrates the long-term trend of hazard losses for Florida, which, when smoothed, suggests an overall increase in annual total costs over time. This tendency relates to both an increase in hazard frequency and an ever-inflating coastal population, leaving more people and infrastructure exposed to future disasters (Malmstadt et al., 2009).

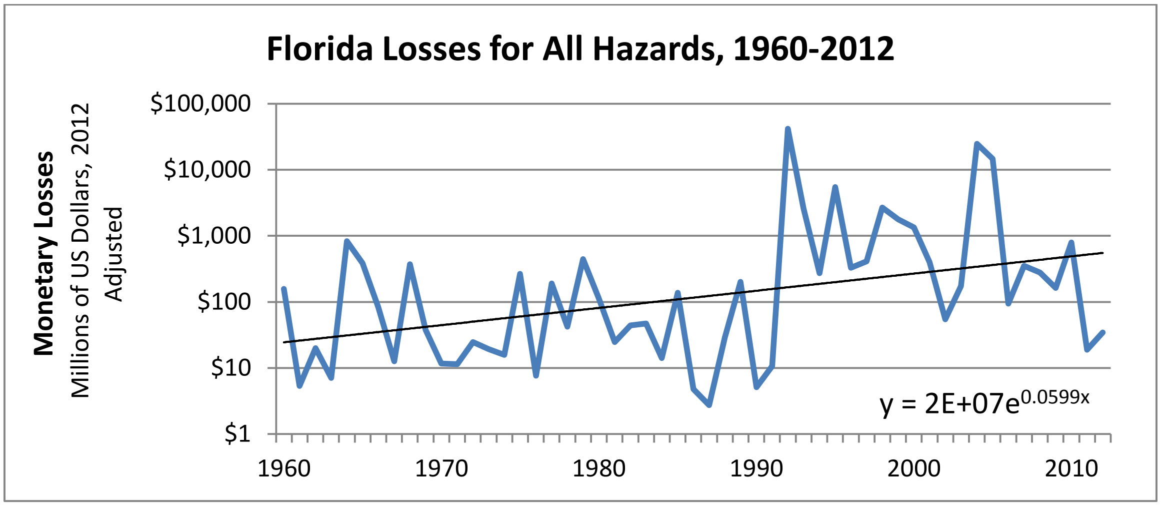

Figure 2: Long-term pattern of hazard losses in Florida plotted on a logarithmic scale.

Source: The Spatial Hazard Events and Losses Database for the United States (HVRI 2013).

The threat of future losses from hazards and disasters is compounded when taking into account the projected scenarios of global environmental change. Florida currently has frequent loss-causing flood and wind events in relation to seasonal rain, thunderstorms, and tornadoes; periods of chronic drought; and storm surge from hurricanes, tropical storms, and other coastal storms. While a new hazard regime may manifest itself in the years to come, the incidence of climate-sensitive hazards is generally expected to increase in severity and impact in the Southeastern United States (Emrich and Cutter, 2011; Ingram et al., 2012). In simplest terms, these events are likely to include increases in wind, rain, and storm surges linked with rising atmospheric and sea surface temperatures, and an overall rise in sea level (Ingram et al., 2012).

However, with considerable uncertainty surrounding the interpretation of long-term climatological trends, it is difficult to anticipate where and how future climate hazards will have the greatest impacts, and which populations are at greatest risk. The following subsections review the prevalent literature on climatological trends, future projections, and implications for extreme events, focusing particularly on the Southeast United States and Florida. While most of the extant climate analyses occur in the context of larger oceanic and atmospheric systems rather than by state, this review will extrapolate from

[5] Trends over a specific time period. For Florida, the temporal trends in hazard losses from 1960 – 2012 do not generally deviate from those of the nation.

those pertinent projections for climate-sensitive hazards made in regards to the North Atlantic and Caribbean Ocean Basins where local climate predictions are limited or unavailable.

Precipitation, Floods, and Severe Storms

In general, researchers discern no long-term trends in the time series of annual or summer season precipitation across the Southeast during the last 100 years, with the exception of the northern Gulf Coast (Ingram et al., 2012; Kunkel et al., 2012). However, some researchers note that inter-annual variability has increased in recent decades across much of the region, with noticeable increases in the incidence of exceptionally wet and dry summers in comparison to the middle twentieth century, likely in relation to the positioning of the Bermuda High[6] (Groisman and Knight, 2008; Wang et al., 2010). When the system shifts southwest, precipitation tends to increase in the Southeastern United States, and similarly during northwest shifts, precipitation tends to decrease. At the local scale, this relationship is tempered by variations related to the strength of sea breeze circulation[7] (Ingram et al., 2012). Along the Florida panhandle, increased precipitation is linked to stronger sea breeze circulation, corresponding to the westward expansion of the Bermuda High (Misra et al., 2011). Additionally, Marshall et al. (2004) note the influence of anthropogenic land cover change across the Florida Peninsula on the increasing frequency and intensity of sea breeze precipitation.

Sea surface temperature anomalies in the equatorial Pacific produced by the El Nino-Southern Oscillation (ENSO)[8] correlate with precipitation variations throughout all seasons in south Florida (Jury et al., 2007; Winsberg, 2003b). It is important to note that ENSO is a natural, inter-annual climate variation that amplifies climate-sensitive hazard events. The exact timing of this oscillation, however, does not occur on an absolute schedule. Specifically, this can be explained in terms of a warm anomaly (El Niño) and a cold anomaly (La Niña). El Niño is associated with above average precipitation across all seasons, increased severe weather events, and cooler temperatures. Pervasive El Niño events can yield significant hazards, as was the case in June 1998, following the strong 1997-98 El Niño event, when numerous wildfires broke out during dry summer conditions, fueled by a dense vegetation growth triggered by heavy winter precipitation (Changnon, 1999; Ingram et al., 2012). In contrast, La Niña is tied to unseasonably dry conditions in late fall, winter, and early spring; above average temperatures; and warmer water in the Atlantic Ocean, substantially increasing hurricane activity (Winsberg, 2003a).

In terms of extreme precipitation, Ingram et al. (2012) note that frequency of heavy rain events has been increasing across the Southeastern United States, particularly over the

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[6] A semi-permanent area of high pressure located over Bermuda in summer and fall that steers many storm systems westward across the Atlantic. This is important for Florida because this steering guides hurricanes, tropical storms, and other systems towards the state.
[7] A pattern of wind occurring in coastal areas where winds blow from the ocean/gulf towards land. This type of breeze occurs most often in the spring and summer months because of the greater temperature differences between the ocean and nearby land, particularly in the afternoon when the land is at maximum heating from the sun.
[8] A band of warm ocean water temperatures that periodically develops off the western coast of South America. ENSO also causes extreme weather (such as floods and droughts) in many regions of the world.

past two decades. In Florida, the incidence of torrential rain is closely linked to La Niña conditions (Winsberg, 2003b). Across the Southeastern United States, an increase in extreme precipitation, coupled with increased runoff due to the expansion of impervious surfaces and urbanization, has led to an increased risk of flooding in urban areas of the region (Shepherd et al., 2010). Though researchers note a discernible increase in the number of severe storms and tornadoes over the last 50 years, it is likely that the upsurge is associated with improvements in storm observation and reporting (Ingram et al., 2012). Brooks and Doswell (2001) suggest that annual frequencies of strong tornadoes have remained relatively constant over the last half century.

Ingram et al. (2012) and others (Keim et al., 2011; Kunkel et al., 2012; Li et al., 2011) describe model simulations for future precipitation patterns using the A2 and B1 emissions scenarios from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

> The A2 marker scenario (A2-ASF) was developed using an Atmospheric Stabilization Framework (ASF) modeling approach applied to each of nine world regions. This integrated set of modeling tools was also used to generate the first and the second sets of IPCC emission scenarios. Overall, the A2-ASF quantification is based on the following “business as usual” assumptions (Sankovski et al. 2000):
> a. Relatively slow demographic transition and relatively slow convergence in regional fertility patterns,
> b. Relatively slow convergence in inter-regional GDP per capita differences,
> c. Relatively slow end-use and supply-side energy efficiency improvements (compared to other storylines),
> d. Delayed development of renewable energy, and
> e. No barriers to the use of nuclear energy.
>
> The B1 marker scenario (de Vries et al., 2000) was developed using the Integrated Model to Assess the Greenhouse Effect (IMAGE) 2.1, which assesses anthropogenic influences on climate change. Earlier versions of the model were used in the first IPCC scenario development effort. B1 illustrates the possible emissions implications of a scenario in which the world chooses consistently and effectively a development path that favors efficiency of resource use and "dematerialization" of economic activities. In particular, the scenario entails:
> a. Rapid demographic transition driven by rapid social development, including education;
> b. High economic growth in all regions, with significant catch-up in the presently less-developed regions that leads to a substantial reduction in present income disparities;
> c. Comparatively small increase in energy demand because of dematerialization of economic activities, saturation of material- and energy-intensive activities (e.g., car ownership), and effective innovation and implementation of measures to improve energy efficiency; and
> d. Timely and effective development of non-fossil energy supply options in response to the desire for a clean local and regional environment and to the gradual depletion of conventional oil and gas supplies.

While average annual precipitation is projected to decrease between 2-4% across regions of south Florida and Louisiana, an increase in seasonal rainfall, up to 6%, is generally expected throughout every season except summer. Keim et al. (2011) note little change in the annual frequency of extreme precipitation across the southern tier of the southeast region, with more dry days expected across the northern Gulf Coast. This expected drying may point to an increase in the frequency and severity of hydrologic drought[9] (Biasutti et al., 2009; Ingram et al., 2012). Overall, however, there is much uncertainty in precipitation projections, resulting from inadequacies in climate model resolution, which is often too coarse to account for regional and local-scale processes and inter-annual variability in the climate system (Ting et al., 2009; Stefanova et al., 2012).

Similarly, future projections for the frequency and intensity of severe storms and tornadoes are highly indefinite, as they cannot be resolved simply by global or regional climate models (Diffenbaugh et al., 2008). Generally, severe thunderstorms, including those that produce tornadoes, require large amounts of convective available potential energy (CAPE)[10], which is tied to atmospheric warming and moistening (Ingram et al., 2012). Though CAPE is generally projected to increase throughout the twenty-first century (see Trapp et al., 2007), global climate model simulations indicate significant inter-annual variability due to internal climate dynamics, such as ENSO (Marsh et al., 2007). In addition to CAPE, tornadoes also require strong vertical wind shear, which Diffenbaugh et al. (2008) suggest may decrease over much of the mid-latitudes due to a weakening of the pole-to-equator temperature gradient[11] (see also Ingram et al., 2012). Cloud-to-ground lightning represents a significant hazard across the Florida peninsula, both as a leading cause of hazard-related fatality in the state, and as a source of wildfire ignition (Ashley and Gilson, 2009; Ingram et al., 2012). While some research generally suggests that warmer temperature and increased convective[12] activity could result in increased lightning activity (Price and Rind 1994), Ingram et al.'s (2012) Southeast Region Technical Report to the National Climate Assessment does not mention definitive projections for lightning frequency.

With all of the uncertainty surrounding future scenarios of precipitation, flooding, and severe storms, there is a high degree of difficulty in drawing concrete conclusions about the frequency and intensity of extreme weather events in Florida. In regards to future precipitation, however, there is some consensus throughout the research that suggests a decrease in average annual precipitation and an increase in the number of dry days, which could heighten the severity and duration of drought (Ingram et al., 2012).

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[9] One of the four main types of drought where periods of precipitation shortfalls decrease the surface or subsurface water supply. Hydrologic droughts can impact water supply for farming, power production, and human consumption.

[10] The amount of energy a parcel of air would have if lifted a certain distance vertically through the atmosphere. This energy indicates atmospheric instability. Such indication is valuable in predicting severe weather.

[11] Describes how changes to temperatures in the higher latitudes (even minute) impact temperatures, weather, and possibly climate in the lower latitudes.

[12] Manifestations of upward air and moisture movement in the atmosphere including the development of convective clouds and resulting weather phenomena, such as rain showers, thunderstorms, squalls, hail, and tornadoes.

Hurricane Storm Surge, Winds, and Rising Sea Level

While recent events such as Hurricanes Katrina, Isaac, and Sandy highlight the vulnerability of the greater Gulf Coast and Mid-Atlantic regions to climate-sensitive hazards, Florida has experienced the largest number of hurricane landfalls in comparison to any other state (Malmstadt et al., 2009). Although the potential for hurricanes under current climatic conditions continue to threaten communities, there is growing concern that climate change could influence the likelihood and/or impacts of future hurricanes. Understanding if and how climate change may influence future hurricanes are critical questions as coastal communities develop long-term comprehensive land use plans to accommodate the continual increase in populations (Frazier et al., 2010).

Analyses of hurricanes and tropical cyclones over the entire Atlantic basin provide differing perspectives regarding long-term trends (Ingram et al., 2012). Holland and Webster (2007) and Mann and Emmanuel (2006) noted increasing trends in tropical cyclone activity in the Atlantic basin extending back to 1900 and 1880, respectively. Landsea (2007), however, warns that hurricane monitoring has improved drastically since the 1940s, with the arrival of airplane reconnaissance, and even more since the 1960s thanks to satellite imagery. Still, after adjusting for reporting biases, Landsea et al. (2009) identified a slight upward trend in tropical cyclone frequency between 1878 and 2008. Some research posits that the higher frequency of Atlantic hurricanes since 1995 is evidence of long-term climate change (Anthes et al., 2006; Emanuel, 2005; Pielke et al., 2005; Webster et al., 2005), while other studies suggest that the increased activity simply represents multi-decadal variability (Emanuel et al., 2008; Goldenberg et al., 2001; Gray et al., 1996; Landsea et al., 1999).

Though some researchers warn against linking climate change to hurricane impacts (Pielke et al., 2005), current climate projections suggest a fundamental shift in hurricane regimes. Recent work by Knutson et al. (2010) projects an overall reduction in hurricane event frequency given the current climate trajectory. At the same time, many researchers suggest increased sea surface temperatures could heighten hurricane intensity (Emanuel, 2000; Emanuel, 2005; Knutson and Tuleya, 2004; Pielke et al., 2005; Webster et al., 2005). Concurrent with this view, a recent study by Bender et al. (2010) anticipates a decrease in hurricane formation in the North Atlantic basin, coinciding with an increase in storm severity correlating with warming sea surface temperatures. The projected result is an upsurge in the number of hurricanes reaching category 4 or 5 on the Saffir-Simpson scale[13]. Although research on the frequency and intensity of future hurricanes is still under debate (Shepherd and Knutson, 2007), Frazier et al. (2010) note an emerging consensus in support of Bender et al.'s (2010) conclusions. Climate change may result in fewer tropical cyclones but with increasing intensities and precipitation totals (Bengtsson et al., 2007; Edwards, 2008; Landsea et al., 2006). However, recent research utilizing downscaled climate models and scenarios points to more frequent tropical cyclone activity (Emanuel, 2013; Strazzo et al., 2013). Even if future hurricane frequency or intensity remains constant, numerous researchers suggest that the rise in sea level could result in coastal populations previously outside of

[13] A hurricane wind scale ranging from 1 to 5 based on a hurricane's sustained wind speed. This scale estimates potential property damage. Hurricanes reaching Category 3 and higher are considered major hurricanes because of their potential for significant loss of life and damage. Category 1 and 2 storms are still dangerous and require mitigation and preventative measures.

contemporary storm-surge zones to be exposed to future land-falling hurricanes (Emrich and Cutter, 2011; Frazier et al., 2010; Kleinosky et al., 2007; Wu et al., 2002).

Long-term records suggest that sea levels have exhibited a rising trend across the coastline of the Southeastern United States (Konrad and Fuhrmann, 2012). Satellite altimetry records, however, reveal spatial and temporal variations in the rates of sea level rise due to both land subsidence and short-term climate variability, including ENSO (Mitchum et al., 2010). Trends in global sea level dating back nearly 500,000 years have been assessed using coastal sediment cores (Rohling et al., 2008). These records indicate variations in global sea level of as much as 100 meters that correspond with glacial and inter-glacial cycles (Church et al., 2010; Ingram et al., 2012).

For most of the twentieth century, tidal gauge records indicate an average increase of 1.7 mm per year (Kunkel et al., 2012). Examining more advanced satellite altimetry data, the rate of sea level rise is estimated to have increased to a rate of 3.0 to 3.5 mm per year since the early 1990s (Prandi et al., 2009). Variations in sea level rise are driven primarily by thermal expansion[14] from warming of ocean waters and glacial melt (Domingues et al., 2008; Pritchard et al., 2009). Mote's (2007) recent analysis of glacial melting on Greenland shows that the melt rate from 1996 to 2007 was above the long-term average (1973 to 2007), with 2007 exhibiting the highest melt rate on record by more than 60%.

In Ingram et al.'s (2012) technical review, the authors note that the southeastern region displays an extensive and complex coastline that is especially vulnerable to sea level rise. As the sea level rises, storm surge and coastal erosion is likely to increase in magnitude. Sea level rise models from the IPCC AR4 project a mean rise of between 18 and 59 cm by the end of the twenty-first century, with the potential of an additional rise of between 10 and 20 cm from a rapid dynamic melting episode of the Greenland or West Antarctic ice sheets (Mitchum et al., 2010). Other recently modified projections suggest global sea level will rise by 80 to 200 cm by 2100 (Overpeck et al., 2006; Pfeffer et al., 2008). Such an event could result in complete inundation of various low-lying areas in south Florida (Milliken et al., 2008).

Climate Central's (2013) Surging Seas project presents a contemporary analysis of sea level rise impacts combined with tidal maximum and storm surge from hurricanes for all exposed coasts in the United States. From this study, projected new sea level rise by the year 2050 is expected to reach 33 cm in Florida. With this projection, Climate Central estimates over a 1 in 6 chance that sea level rise, in combination with hurricane storm surge and high tide, could overtop areas lying 2.4 meters above sea level. In this scenario, approximately 25% of the state's total population and housing stock is exposed. The study takes into account special considerations specific to Florida geography, including the porous limestone bedrock underlying much of the state, and a unique concentration of development within the first few feet above high tide[15] that make Florida especially vulnerable to sea level rise. Of particular importance in the discussion of sea level rise are coastal communities that are currently experiencing land subsidence from natural or anthropogenic processes (e.g., groundwater extraction, sediment

[14] As water heats, it also expands, meaning that as the oceans warm the volume of water also increases influencing sea level rise.

[15] Higher porosity of underlying bedrock allows more saltwater intrusion at a faster rate and increases the possible land subsidence related to sinkhole development. As the study notes, the reverse is true for almost all other coastal states (Climate Central 2013).

redistribution). Ericson et al. (2006) warn that these areas of the coast will be most affected by sea level rise. Some impacts of sea level rise are already visible in Florida. In simple terms, these include saltwater contamination of freshwater aquifers, flooding at extreme high tide, and an observed diminishment in the effectiveness of the Southeast Florida canal system (Climate Central, 2013).

In addition to increases in storm surge inundation zones due to sea level rise, the potential for future hurricane impacts is exacerbated by the continuing growth of populations migrating to coastal Florida, increasing the number of people, homes, and infrastructure in storm surge hazard zones (Cutter et al., 2007; Frazier et al., 2010; Whitehead et al., 2000). As Frazier et al. (2010) and others note (Cutter et al., 2007; Emrich and Cutter, 2011), the combined factors of hurricane storm surge inundation, the potential of sea level rise to extend inundation zones, and the continuing development of the coast indicate a pressing need for coastal communities to conduct comprehensive vulnerability assessments[16] for new threats presented by climate-sensitive hazards (Cutter et al., 2007; Frazier et al., 2010).

Heat, Drought, and Wildfires

Most climate scientists agree that climate change will bring an overall increase in global temperatures (IPCC, 2007). While there is no consistent agreement on its extent, future climate scenarios indicate less cold weather and more hot weather (IPCC, 2012; McMichael et al., 2006). These assessments also anticipate an increase in extreme heat events and with them the increased potential for drought and wildfires (IPCC, 2012).

As climate change persists, heat events will likely become more dangerous (Meehl and Tebaldi, 2004). Over the past two decades, extreme heat events in the United States and Europe have caused thousands of fatalities in older adults and other vulnerable populations (McMichael et al., 2006). While studies predict more intense extreme heat events (IPCC, 2007, Meehl and Tebaldi, 2004), the impact of these events in Florida is historically minimal, due to the population's acclimation to hot weather (Luber and McGeehin, 2008). Therefore, it is reasonable to expect that, in general, extreme heat events pose a relatively small risk to the state's residents, but may be problematic for certain population segments, such as older adults and homeless who may be effected more quickly or do not have adequate access to air conditioning.

Historically, Florida droughts are shorter in duration than those experienced in other parts of the country, owing in part to tropical cyclone activity during potential drought months (Maxwell et al., 2011; Seager et al., 2009). Climate change projections suggest a fundamental change in drought potential in Florida. A study by Strzepek et al. (2010) projects increases in drought risk throughout the United States, including the southeast region. Other factors could compound drought risk, including increased water demand and projected decreases in tropical cyclone frequency (Knutson et al., 2010; IPCC, 2012). Beyond the more obvious ramifications of drought, the potential exists for the spread of diseases such as malaria (Epstein, 2001) and West Nile virus (Shaman et al., 2005) within the state. As Shaman et al. (2005) explain, periodic drought and subsequent rewetting can bring avian hosts and mosquitoes into close contact, facilitating epizootic cycling and amplification of the arboviruses, supporting higher levels

[16] An assessment of potential adverse impact/loss from a threat, risk, hazard, or disaster.

of transmission[17]. Consequently, the authors suggest that widespread spring drought followed by summertime rewetting may yield epidemic levels of West Nile virus transmission in southern Florida.

Drought and potentially drier environments may lead to other dangers (IPCC, 2007). Wildfire is another potential risk in a changing climate, endangering human lives and altering regimes of both flora and fauna (Dale et al., 2001; Williams et al., 2010). The state experiences roughly 5,000 wildfires annually, ranking second in national frequency (Wyman et al., 2012). Projections indicate that the entire United States will see an increase in frequency, size, and season severity of wildfires (Brown et al., 2004; Le Page et al., 2010; Hessl, 2011; Flannigan et al., 2000). In particular, Florida's fire season could potentially increase from four to seven months (Liu et al., 2010; Liu et al., 2013). Changes to fuel condition brought on by lengthier drought events (Gedalof et al., 2005), increased lightning activity (Hessl, 2011; Price and Rind, 1994), or climate change-induced vegetation shifts[18] could also increase the risk of wildfire (Hessl, 2011). Considering these factors, wildfires could pose a more serious risk to Florida residents living in close proximity to areas of dense vegetation.

Past impacts from wildfires indicate that, while wildfires will continue to pose a threat, the severity of impacts and the population directly at risk is disproportionately lower when compared to those currently residing in storm surge/sea level rise impact zones. However, the deleterious air quality effects of wildfire smoke and particulate matter continue to pose a threat to human health in and around wildfire areas, especially to those who have pre-existing respiratory problems.

Priority Climate-Sensitive Threats

In this review, we have identified and discussed many different hazards and disasters that impact Florida's populations and infrastructure at present, and those that will become even more disastrous for the state if current trends in temperature and climate variation continue as expected. From these main climate-sensitive threats, we focus on seven that will likely cause the largest disruptions to lives and livelihoods across the state in the coming years, namely coastal flooding from storm surges, more intense hurricane winds, sea level rise, wildfires, flooding, drought, and extreme temperature. Although the most devastating of these is related to an overabundance of water, each is also characterized by a different speed of onset, duration, and a host of divergent threats to people, health, and longer-term adaptation strategies. A hurricane's volatile nature causes vast damage within a knowable area and provides an opportunity to pre-plan and mitigate health, population, and infrastructure effects while the subtle onset of sea level rise makes long term planning, mitigation, and adaptation more nebulous and often more difficult to translate into realistic and actionable adaptation steps. Impacts from each can be modeled and analyzed with a high degree of precision, meaning that we can identify where inundation will occur, the extent of impact, the depth of water, and the people and things that will be or are in the hazard zone. However, in neither instance can we concretely estimate the amount of sea level rise that will exist in the future or the precise

[17] The process by which the population of infected vector mosquitoes could greatly increase in relation to drought extremes and subsequent heavy precipitation events.
[18] Changes to predominant land cover types related to climate changes. The types and quantities of flora have a distinct impact on fuel source for wildfires.

location of future landfalling hurricanes. This fact supports the need for comprehensive planning across all jurisdictions using the best available data and most appropriate spatial analytic methods. Such analysis will be vital for sustaining adequate adaptation planning for future climate threats.

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2. Social Vulnerability

Background

The concept of vulnerability, or the potential for harm, first introduced into the hazards and disasters literature in the 1970s, provided a means for understanding the interactions between social and ecological systems. It also provided understanding on how such interactions give rise to hazards and disasters (O'Keefe et al., 1976). Vulnerability explains the differential impacts of shocks or stressors to natural systems and the ability of those systems to absorb and withstand impacts (biophysical vulnerability). A companion construct, social vulnerability, provides the societal context within which such stressors operate and highlights the uneven capacity for preparedness, response, recovery, and adaptation to environmental threats in and across social systems. Conceptually, vulnerability is understood to be inherent in the social system, independent of the hazard (Cutter et al., 2000 and 2003). However, to fully understand and characterize the hazards of places, measures of the physical characteristics of hazards and the environment (i.e., hazard exposure) must be combined with those social, economic, and demographic characteristics that influence a community's ability to prepare for, respond to, cope with, recover from, and ultimately adapt to environmental hazards (Cutter et al., 2000). Vulnerability is widely used in the hazards, disasters, and human dimensions of global change literature to describe the differential impacts of environmental threats on people and the places where they live and work (Pelling, 2003; Wisner et al., 2004; Adger, 2006; Birkmann, 2006; Eakin and Luers, 2006; Fussell, 2007; Polsky et al., 2007).

The Social Vulnerability Index (SoVI) is a quantitative measure of social vulnerability to environmental hazards. Originally developed in 2003 and applied to counties in the United States, SoVI provides a comparative metric that facilitates the geographic examination of differences in levels of social vulnerability across states and regions (Cutter et al., 2003). Based on extensive research literature focused on post-disaster response and recovery that now spans nearly a half century (NRC, 2006), SoVI includes those population characteristics known to influence the ability of social groups and communities to prepare for, respond to, and recover from disasters, especially coastal disasters (Heinz Center, 2002). The index synthesizes these socioeconomic variables into multiple dimensions, and sums the component values to produce the overall score for the particular spatial unit (e.g., county, census tract) of interest[19]. Conceptually, SoVI relates well to indices of social well-being, but its focus is on environmental hazards and the capacity of social groups to prepare for, respond to, and recover from disasters. For example, socioeconomic status (wealth or poverty) affects the ability of a community to absorb losses. Wealth enables communities to withstand the impact of losses more readily than those communities in poverty because of their access to capital, insurance, and so forth. Age is another characteristic that influences vulnerability, and this is normally recognized at the two extremes of the age continuum—children and older adults. These age cohorts need special care, are often more susceptible to harm, and may have mobility constraints, all of which influence the ability to get out of harm's way. Special needs populations (e.g., nursing home residents, infirmed) are another example of a highly vulnerable population as they are often difficult to identify. Gender, race, and ethnicity often impose language and cultural barriers, affect access to post-disaster recovery funding, and often constrain employment opportunities and access to

[19] See methods section for more information on variables and construction of SoVI

education. Finally, housing type and tenure (e.g., manufactured housing and renters) influence vulnerability. Manufactured housing is not as reliable as a sheltering option in high wind environments, for example. Renters are more vulnerable than homeowners are because they live in temporary quarters, often do not have renters insurance to cover the loss of their personal property, and lack strong social ties to the community.

The project represents an improvement in the SoVI, which now only examines those specific social and demographic correlates of vulnerability, and is more reflective of social well-being. In the original formulation (Cutter et al., 2003), there were ten additional variables that measured aspects of the built environment (e.g., housing age) and county economic activity. We have now separated these into a companion Built Environment Index (BEVI), which is not included in this analysis. This new formulation of SoVI provides a more robust snapshot of those social group characteristics that are associated with vulnerability and known, based on the case study and empirical research literature, to either enhance or retard hazard preparedness, response, recovery, and mitigation/adaptation.

Methods

The original SoVI formulation used 42 variables (derived from the United States Census) for each county in the nation. The original computation included social and demographic characteristics as well as some measures of county economic productivity and growth. Because one could argue that economic productivity was more reflective of built environment indicators (e.g., the density of manufacturing establishments) rather than social indicators, these variables were deleted in this analysis. As a result, SoVI now reflects those characteristics of social groups that influence their differential capacity to prepare for and respond to environmental threats.

Twenty-eight variables were used in the SoVI-FL2010 computation (Table 2), based on the research literature described above. To facilitate comparisons across counties, all data were from the United States Census Decennial product (2010) and United States Census rolling 5-year American Community Survey (ACS) product (2006-2010). The Census 2010 data represent true counts of the population and their characteristics.

Table 2: Known correlates of social vulnerability and variables used to compute SoVI-FL2010.*

Population Characteristic and Specific Variables	**Influence on Social Vulnerability**
Race & ethnicity % African American % Native American % Asian or Pacific Islander % Hispanic	Imposes language and cultural barriers for disaster preparedness and response; affects access to pre and post-disaster resources; minority group tendency to occupy high hazard areas; non-white and non-Anglo populations are viewed as more vulnerable.
Socioeconomic Status Per capita income % households earning more than $200,000	Affects community ability to absorb losses; wealth enables communities to recover more quickly using insurance and personal resources; poverty makes communities less able to respond and

% poverty	recover quickly.
Gender % females in labor force % female population % female headed household, no spouse present	Women often have a more difficult time coping after disasters than men due to employment sector (personal services), lower wages, and family care responsibilities.
Age Age depended populations (% population under 5 years old and % population over 65) Median age	Age extremes increase vulnerability; parents must care for children when day care facilities are not available; older adults may have mobility or health problems.
Rural/Urban % urban population Population density	Rural residents may be more vulnerable due to lower wealth and dependence on locally based resource economy (farming); high-density urban areas complicate evacuations and sheltering.
Renters % renters Median Gross Rent	Renters are viewed as transient populations with limited ties to the community; they often lack shelter options when lodging becomes uninhabitable after disasters or too costly; lack insurance; often lack savings.
Residential property Median value of owner occupied housing % housing units that are mobile homes	The value, quality, and density of residential construction affect disaster losses and recovery; expensive coastal homes are costly to replace; mobile homes are easily damaged.
Occupation % employed in farming, fishing, forestry % employed in service occupations	Some occupations, especially those involving resource extraction (e.g.,fishing, farming), can be affected by disasters; service sector jobs suffer as disposable income declines; infrastructure employment (e.g., transportation, communications, utilities) is subject to temporary disruptions post-disaster.
Family Structure Average number of people per household % families	Families with large numbers of dependents or single parent households may be more vulnerable because of the need to rely on paid caregivers.
Employment % civilian labor force unemployed	Communities with high numbers of unemployed workers (pre-disaster) are viewed as more vulnerable. Because jobs are already difficult to obtain, this slows the recovery post-disaster.

Education % population over 25 with no high school diploma	Limited educational levels influence ability to understand warning information and likely disaster impacts; access to post recovery resources.
Population Growth % ESL (poorly or not at all)	New immigrant populations lack language skills and are unfamiliar with state and federal bureaucracies in how to obtain disaster relief; may not be permanent or legal residents; unfamiliar with range of hazards in area.
Social Dependency and Special Needs Populations % collecting social security benefits Per capita residents in nursing homes % no automobile	Residents totally dependent on social services for survival are often economically marginalized and thus more vulnerable; special needs populations (infirmed) require more time for evacuation and recovery is often difficult.

*Source: Heinz Center, 2002; Cutter et al., 2003.

The 28 variables were standardized and input into a principal components analysis (PCA) to reduce the number of variables into a smaller set of multi-dimensional attributes or components. Adjustments to the component's directionality were made to ensure that positive values were associated with increasing vulnerability, and negative values associated with decreasing vulnerability. If a factor included negative and positive values that both influenced vulnerability (such as older adults and the young), then the absolute value was used. Once the directionality was established, the components were added together to produce the final SoVI score for Florida (SoVI-FL2010).

Six distinct components explain 65.96% of the variance within the data for the SoVI-FL2010 (Table 3). This amount of explained variance falls in line with the results from most of the SoVI models ever implemented by the Hazards and Vulnerability Research Institute. Generally speaking, the more variables within the model, the more variance explained. However, it is important to also remove co-linearity in the dataset by a reduction of input variables. A by-product of this reduction is a lower variance explained. These components include class (percent living below poverty, percent with education less than 12th grade, percent employed in service industry) and race (percent Black), age (older adults), wealth (per capita income, percent rich, median house value), urban/female populations, ethnicity (percent Hispanic, percent English as a second language), and high occupancy households. These components and the level of explained variance are consistent with other SoVI studies for different regions and for the United States as a whole. There is considerable sensitivity testing of the SoVI metric to monitor its robustness at different spatial scales and in different places (Schmidtlein et al., 2008), and in different application domains (see http://sovius.org).

Table 3: Social Vulnerability Index-Florida (SoVI-FL2010)[20].

SoVI 2010 Component Read Me
28 Variables, Population > 0, Housing Units > 0
Florida Department of Health

Component	Cardinality	Name	% Variance Explained	Dominant Variables	Component Loading
1	+	Class (Poverty), Race (Black)	16.46	QBLACK	0.815
				QPOVTY	0.798
				QNOAUTO	0.706
				QFHH	0.683
				QED12LES	0.586
				QRENTER	0.577
				QSERV	0.534
				QFAM	-0.641
2	+	Older Adults	12.88	QSSBEN	0.888
				QAGEDEP	0.841
				MEDAGE	0.770
				QCVLUN	0.629
				QASIAN	-0.596
3	-	Wealth	11.82	QRICH200K	0.888
				MDHSEVAL	0.875
				PERCAP	0.813
4	+	Urban, Females	8.70	QFEMALE	0.710
				QFEMLBR	0.564
				QURBAN	0.543
				QEXTRCT	-0.557
5	+	Ethnicity (Hispanic)	8.69	QHISP	0.846
				POPDENS	0.727
				QESL	0.582
6	+	High Occupancy Households	7.41	PPUNIT	0.850
				QFHH	0.436
			65.96		

State Summary

The social vulnerability scores, ranging from 9.85 indicating the most vulnerable tract (in Miami-Dade County) to -17.01, the least vulnerable tract (in the Dry Tortugas), were mapped using a three-class standard deviation method. The standard deviations preserve the underlying distribution of the data (mean of zero and one-half standard deviation on either side) (Figure 3). The moderate category represents the mean; the elevated category is greater than one-half standard deviation above the mean; and the low category is more than one-half standard deviation below the mean. This method permits the best balance between interpretation (three classes) and the identification and visualization of the extremes (high and low vulnerability that are of the most interest).

[20] To learn more about SoVI or the variable naming conventions visit - http://webra.cas.sc.edu/hvri/products/sovi_details_2006.aspx

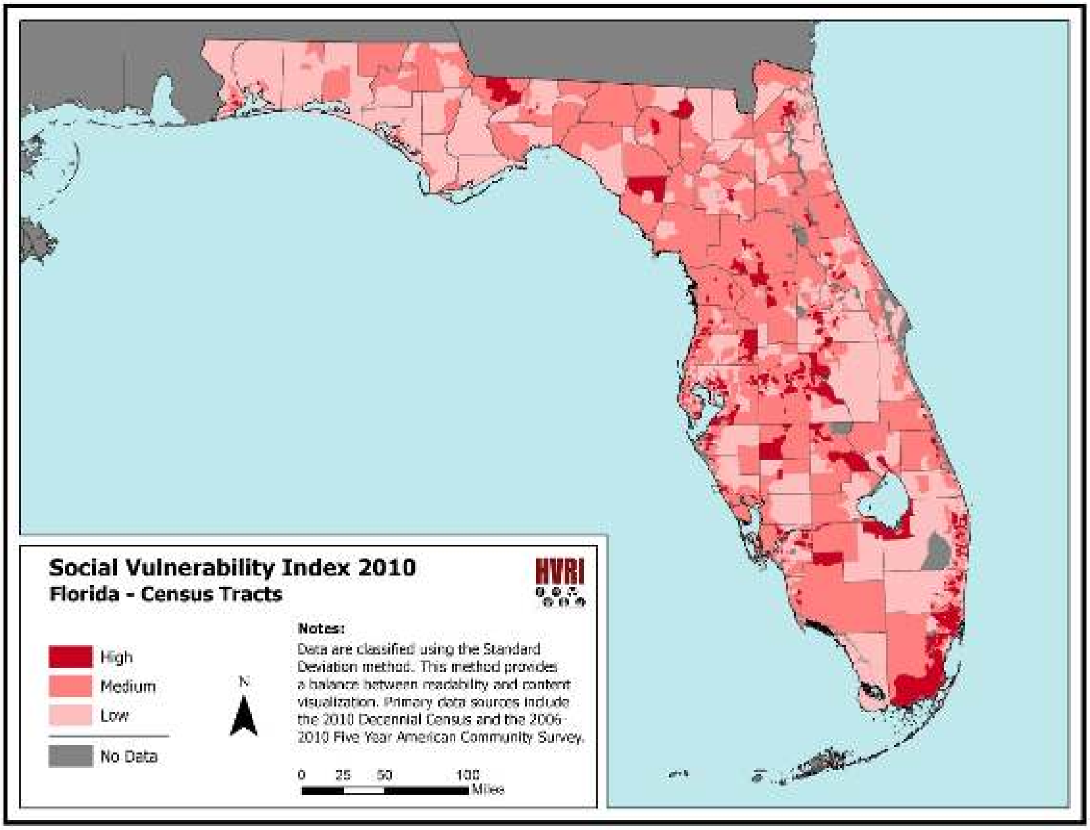

Figure 3: SoVI-FL2010 tract level social vulnerability for the state of Florida.

Overall, social vulnerability at the tract level for the state is driven by the place specific combination of underlying socioeconomic and demographic conditions present at the local level. These baseline conditions are teased out and merged into "components" through the factor analytic process. Mapping of each component provides a different view of the drivers of vulnerability across the state and may be useful for planning, exercise design, and the allocation of goods and services within the context of emergency management (Figure 3).

SoVI-FL2010 tract is comprised of the six factor components outlined above and detailed in
Table 4 and Table 5.

Table 4 shows the percentage of each county's composite census tracts in reference to their SoVI classification. For instance, 67.86% of tracts in Alachua County are classified as having low vulnerability while only 7.14% of tracts contain high social vulnerability. Table 5 provides an actual count of populations within these same zones for comparative purposes. Here, one can easily see that although Table 4 shows nearly 56% of Gadsden County populations reside in areas with elevated vulnerability, this corresponds to 25,033 people (Table 5), while Palm Beach County's 34% located in the medium SoVI class represents more than 500,000 residents.

Using these tables in combination with the map above is the only accurate way to understand where clusters of vulnerability are occurring. Identification of and discussion about these areas of higher vulnerability can be found below in the discussion section.

Table 4: Census tract summary of SoVI class by county (SoVI-FL2010).

	Social Vulnerability Index Rank				Social Vulnerability Index Rank		
County Name	High	Medium	Low	County Name	High	Medium	Low
Alachua	7.14%	25.00%	67.86%	Lee	19.39%	53.33%	27.27%
Baker	-	50.00%	50.00%	Leon	8.82%	29.41%	61.76%
Bay	6.98%	37.21%	55.81%	Levy	-	88.89%	11.11%
Bradford	-	75.00%	25.00%	Liberty	-	-	100.00%
Brevard	5.41%	54.95%	39.64%	Madison	-	100.00%	-
Broward	30.75%	39.06%	30.19%	Manatee	24.36%	50.00%	25.64%
Calhoun	-	33.33%	66.67%	Marion	24.59%	67.21%	8.20%
Charlotte	13.16%	81.58%	5.26%	Martin	5.88%	55.88%	38.24%
Citrus	18.52%	81.48%	-	Miami-Dade	70.12%	16.21%	13.67%
Clay	3.33%	60.00%	36.67%	Monroe	-	16.67%	83.33%
Collier	20.55%	52.05%	27.40%	Nassau	-	41.67%	58.33%
Columbia	8.33%	75.00%	16.67%	Okaloosa	-	17.07%	82.93%
DeSoto	33.33%	33.33%	33.33%	Okeechobee	27.27%	54.55%	18.18%
Dixie	33.33%	33.33%	33.33%	Orange	24.27%	30.10%	45.63%
Duval	21.39%	38.15%	40.46%	Osceola	34.15%	46.34%	19.51%
Escambia	16.90%	42.25%	40.85%	Palm Beach	31.33%	34.64%	34.04%
Flagler	15.00%	80.00%	5.00%	Pasco	21.05%	63.16%	15.79%
Franklin	-	25.00%	75.00%	Pinellas	15.16%	50.41%	34.43%
Gadsden	55.56%	44.44%	-	Polk	33.77%	50.65%	15.58%
Gilchrist	-	60.00%	40.00%	Putnam	18.75%	75.00%	6.25%
Glades	-	66.67%	33.33%	Santa Rosa	4.00%	16.00%	80.00%
Gulf	-	33.33%	66.67%	Sarasota	13.83%	60.64%	25.53%
Hamilton	33.33%	33.33%	33.33%	Seminole	8.14%	45.35%	46.51%
Hardee	33.33%	66.67%	-	St. Johns	2.56%	25.64%	71.79%
Hendry	50.00%	33.33%	16.67%	St. Lucie	23.26%	72.09%	4.65%
Hernando	34.09%	59.09%	6.82%	Sumter	33.33%	50.00%	16.67%
Highlands	30.77%	57.69%	11.54%	Suwannee	14.29%	71.43%	14.29%
Hillsborough	23.10%	40.19%	36.71%	Taylor	-	75.00%	25.00%
Holmes	-	100.00%	-	Union	-	33.33%	66.67%
Indian River	17.24%	68.97%	13.79%	Volusia	15.93%	59.29%	24.78%
Jackson	-	63.64%	36.36%	Wakulla	-	50.00%	50.00%
Jefferson	-	66.67%	33.33%	Walton	-	18.18%	81.82%
Lafayette	-	50.00%	50.00%	Washington	-	57.14%	42.86%
Lake	16.07%	78.57%	5.36%	**State Total**	26.56%	42.84%	30.60%

Table 5: Census tract summary of population by SoVI class by county (SoVI-FL2010).

County Name	Social Vulnerability Index Rank			County Name	Social Vulnerability Index Rank		
	High	Medium	Low		High	Medium	Low
Alachua	19,406	63,347	164,583	Lee	100,752	383,164	134,838
Baker	-	14,215	12,900	Leon	17,898	84,296	173,293
Bay	8,846	62,686	97,320	Levy	-	39,399	1,402
Bradford	-	22,193	6,327	Liberty	-	-	8,365
Brevard	20,847	319,227	203,295	Madison	-	19,224	-
Broward	549,548	731,748	466,770	Manatee	84,453	149,338	89,042
Calhoun	-	8,196	6,429	Marion	102,216	205,763	23,319
Charlotte	17,905	136,079	5,994	Martin	4,091	87,546	54,681
Citrus	23,598	117,638	-	Miami-Dade	1,900,621	367,572	224,934
Clay	5,311	86,946	98,608	Monroe	-	17,134	55,956
Collier	76,682	187,437	57,401	Nassau	-	32,436	40,878
Columbia	2,872	51,954	12,705	Okaloosa	-	34,692	146,130
DeSoto	13,900	8,849	12,113	Okeechobee	10,116	22,307	7,573
Dixie	7,331	4,101	4,990	Orange	252,348	355,711	537,897
Duval	150,426	336,831	377,006	Osceola	103,651	137,735	27,299
Escambia	39,923	132,277	125,419	Palm Beach	378,320	500,487	440,655
Flagler	15,884	76,595	3,217	Pasco	87,242	288,083	89,372
Franklin	-	2,804	8,745	Pinellas	132,662	484,182	299,698
Gadsden	25,033	21,356	-	Polk	219,460	301,041	81,594
Gilchrist	-	11,787	5,152	Putnam	10,480	60,285	3,599
Glades	-	9,136	3,748	Santa Rosa	6,115	18,226	127,031
Gulf	-	3,076	12,787	Sarasota	46,430	240,838	92,180
Hamilton	1,760	4,835	8,204	Seminole	25,901	197,548	199,269
Hardee	10,630	17,101	-	St. Johns	4,155	44,284	141,600
Hendry	21,846	11,716	5,578	St. Lucie	37,115	228,610	12,064
Hernando	62,301	101,941	8,536	Sumter	52,106	31,264	3,653
Highlands	35,116	62,607	1,063	Suwannee	7,016	32,732	1,803
Hillsborough	279,785	501,682	447,759	Taylor	-	14,693	7,877
Holmes	-	19,927	-	Union	-	4,495	11,040
Indian River	14,670	106,227	17,131	Volusia	83,236	297,516	113,841
Jackson	-	29,998	19,748	Wakulla	-	13,577	17,199
Jefferson	-	8,876	5,885	Walton	-	11,004	44,039
Lafayette	-	5,706	3,164	Washington	-	14,348	10,548
Lake	40,805	234,222	22,025	**State Total**	**5,110,809**	**8,232,846**	**5,447,271**

The pattern of elevated social vulnerability within the state of Florida (Figure 3) is concentrated in four main areas across the state. The first is within the urban areas in the southeast part of the state, north from Miami-Dade, through Broward, and into Palm Beach Counties where 76%, 31%, and 29% of the respective populations live in areas with high vulnerability (Table 5). Here, social vulnerability is a product of a diverse set of drivers particular to each enumeration unit. For example, the most vulnerable tracts (medium high and high SoVI) within these counties - while primarily driven by component four (Urban, Females) and component six (High Occupancy Households) in both cases is not solely an urban vs. rural phenomenon (Table 6). Of particular interest is the difference in overall vulnerability and its constituent parts between these areas of extreme vulnerability.

Table 6: Driving forces of the most vulnerable tracts in southeast Florida.

County	Tract	Total Population	Comp 1 - Class (Poverty), Race (Black)	Comp 2 - Age (Older Adults)	Comp 3 - Wealth	Comp 4 - Urban, Females	Comp5 - Ethnicity (Hispanic)	Comp 6 - High Occupancy Households	SoVI
Miami-Dade	12086009040	120	3.33	5.71	1.13	-1.58	1.54	-0.27	9.85
Palm Beach	12099980100	5	0.53	-0.78	1.37	3.82	-1.29	5.54	9.18
Miami-Dade	12086980800	3	0.90	-0.66	1.75	3.46	1.09	2.52	9.07
Miami-Dade	12086980700	964	4.60	0.44	1.51	0.25	-1.87	3.01	7.94
Miami-Dade	12086980100	18	0.64	-1.30	0.90	1.86	0.87	4.63	7.61
Miami-Dade	12086001501	3,479	5.02	0.23	-0.41	2.02	-0.59	1.08	7.35
Palm Beach	12099005939	1,162	1.17	4.21	0.77	2.44	-0.41	-1.34	6.85
Miami-Dade	12086001801	3,778	3.72	0.62	-0.10	1.22	-0.10	1.46	6.81
Broward	12011110335	7,569	-0.32	3.46	0.78	1.85	1.83	-1.04	6.56
Miami-Dade	12086009315	3,066	0.45	1.38	0.39	0.76	4.61	-1.07	6.53
Palm Beach	12099007747	2,792	1.07	4.33	0.08	2.52	0.22	-1.80	6.43
Miami-Dade	12086010001	6,465	1.64	0.49	0.10	1.37	0.21	2.61	6.42
Miami-Dade	12086009017	6,202	-0.35	0.97	1.38	-0.17	3.15	1.45	6.42
Miami-Dade	12086009022	2,118	-0.64	0.39	0.76	1.04	2.88	1.98	6.40
Miami-Dade	12086009021	4,729	0.44	0.65	0.49	0.10	3.62	1.06	6.36
Miami-Dade	12086008304	7,577	1.77	0.78	0.26	1.82	-0.06	1.79	6.36
Miami-Dade	12086011003	4,448	0.91	0.58	0.32	0.20	1.94	2.39	6.33
Palm Beach	12099007746	1,052	0.78	3.45	1.07	3.08	-0.34	-1.86	6.18
Miami-Dade	12086009314	3,942	0.64	0.88	0.58	0.20	4.16	-0.30	6.16
Miami-Dade	12086003100	4,416	4.30	0.34	-0.12	1.43	0.22	-0.04	6.14
Miami-Dade	12086010016	4,919	-0.44	0.35	0.31	1.12	2.21	2.52	6.07
Miami-Dade	12086000410	4,231	1.47	0.30	0.21	1.01	0.36	2.72	6.05
Palm Beach	12099005933	2,934	0.25	3.84	0.83	2.85	-0.30	-1.42	6.05
Miami-Dade	12086000901	8,227	0.06	0.75	0.53	-0.03	2.79	1.91	6.02
Broward	12011030401	3,017	2.17	0.82	-0.11	1.05	-0.21	2.23	5.96
Palm Beach	12099001403	2,863	3.69	0.23	0.09	1.84	-1.19	1.28	5.94
Miami-Dade	12086000706	7,688	-0.05	0.89	0.47	0.31	4.07	0.19	5.89
Miami-Dade	12086000601	5,412	-0.83	1.06	0.36	0.28	3.06	1.95	5.88
Miami-Dade	12086001502	3,926	4.25	0.28	-0.52	1.29	-0.56	1.11	5.85
Palm Beach	12099006802	3,069	2.40	0.65	-0.06	0.44	0.30	2.11	5.84

Vulnerability Driver | Vulnerability Detractor

The second area of elevated SoVI is comprised of tracts located on the I-4 corridor from Hillsborough County to Orange County and throughout the periphery of Orlando, FL in south-central Florida. Here, between 22% - 36% of the population resides in areas with the most extreme vulnerability scores in the state (Table 7). In Hillsborough County, nearly 280,000 individuals are situated within 73 census tracts characterized with medium high or high SoVI. Thirteen tracts in Osceola County containing nearly 97,000 people are characterized by high vulnerability. Nearly 250,000 people (more than 20%) reside within the most vulnerable tracts (49) in Orange County, while in Polk County more than 35% (213,000) of people live in the most socially vulnerable tracts. Overall, the I-4 corridor contains 837,000 people within 186 tracts characterized by high vulnerability. Again, the drivers of social vulnerability are diverse both within each county and between constituent tracts (Table 7). Component six (High Occupancy Households) serves to increase vulnerability in each of the 30 most vulnerable tracts within this zone while neither component two (Age-Older Adults) nor component three (Wealth) serve as major contributors. However, components four and five attenuate vulnerability in some of the most vulnerable places.

The third cluster of extreme social vulnerability exists in Southwest Florida, specifically in Lee and Collier Counties. Here, 46 census tracts containing 173,000 people, 24% and 15% from Lee and Collier Counties, respectively, are characterized by either medium high or high vulnerability (Table 8). Again, one of the main drivers of vulnerability in these tracts is component six (High Occupancy Households) (2.72 people per house compared to the mean of 2.47) and a mixture of components one, two, and five. Table 9 provides a breakdown of populations for the most vulnerable tracts within each county with respect to overall social vulnerability score.

Table 7: Driving forces of the most vulnerable tracts in central Florida.

County	Tract	Total Population	Comp 1- Class (Poverty), Race (Black)	Comp 2 - Age (Older Adults)	Comp 3 - Wealth	Comp 4 - Urban, Females	Comp5 - Ethnicity (Hispanic)	Comp 6 - High Occupancy Households	SoVI
Hillsborough	12057003400	3,009	3.66	0.70	0.16	1.82	-0.31	1.64	7.66
Orange	12095014605	4,305	2.31	0.81	0.26	1.71	-0.63	1.71	6.17
Hillsborough	12057001900	2,831	2.72	0.19	0.15	1.59	-1.09	1.60	5.17
Osceola	12097042601	3,074	0.12	0.37	0.35	0.56	1.67	1.87	4.93
Hillsborough	12057012900	2,942	2.06	0.72	0.01	-0.09	0.62	1.47	4.79
Hillsborough	12057001800	4,129	2.92	0.20	-0.07	0.91	-0.74	1.35	4.56
Orange	12095014601	7,597	2.67	-0.61	0.14	1.31	-0.55	1.40	4.36
Hillsborough	12057003600	4,333	2.15	-0.08	0.26	1.13	-0.91	1.64	4.19
Polk	12105980000	3	1.76	-0.45	0.25	1.78	-2.23	3.03	4.14
Orange	12095012202	4,539	1.58	-0.52	0.40	0.96	-0.19	1.31	3.55
Orange	12095017001	2,889	1.42	0.02	0.50	1.07	-1.30	1.73	3.44
Polk	12105014502	3,651	0.71	0.91	0.73	-2.51	1.77	1.76	3.38
Orange	12095014908	5,979	0.53	-0.08	0.64	1.21	-0.31	1.37	3.35
Orange	12095012304	6,295	1.35	-0.69	0.09	1.08	-0.14	1.42	3.11
Hillsborough	12057013505	3,251	0.77	-0.20	0.31	0.40	0.03	1.64	2.96
Osceola	12097041300	13,009	0.30	-0.06	0.34	0.34	0.03	1.80	2.75
Polk	12105012602	5,778	0.61	0.32	0.35	-2.03	1.55	1.94	2.74
Osceola	12097041100	16,827	0.05	-0.33	0.49	0.51	0.37	1.63	2.71
Hillsborough	12057013914	4,531	0.34	0.78	0.88	-3.58	0.84	2.98	2.24
Orange	12095016806	12,476	0.01	-0.65	0.26	0.57	0.67	1.32	2.18
Orange	12095012306	3,193	0.39	-0.78	0.27	1.30	-0.73	1.53	1.99
Hillsborough	12057013913	5,195	0.11	0.40	0.43	-1.84	0.94	1.93	1.97
Hillsborough	12057013912	3,471	-0.27	0.81	0.96	-1.69	0.02	2.00	1.82
Polk	12105014501	8,295	0.11	0.59	0.97	-1.30	-0.06	1.49	1.79
Polk	12105015401	2,526	0.12	0.69	0.75	-0.51	-0.69	1.32	1.68
Orange	12095016807	17,017	-0.67	-1.09	0.42	0.71	0.65	1.42	1.44
Orange	12095012303	6,429	0.17	-0.95	0.21	1.22	-0.76	1.47	1.36
Polk	12105014902	7,268	-0.53	0.37	0.85	-2.32	1.09	1.90	1.36
Polk	12105014103	8,341	0.03	-0.50	0.46	-0.23	-0.31	1.84	1.29
Orange	12095017701	5,186	-0.58	-0.54	0.11	0.24	0.53	1.49	1.26

Vulnerability Driver **Vulnerability Detractor**

Table 8: Driving forces of the most vulnerable tracts in southwest Florida.

County	Tract	Total Population	Comp 1- Class (Poverty), Race (Black)	Comp 2 - Age (Older Adults)	Comp 3 - Wealth	Comp 4 - Urban, Females	Comp5 - Ethnicity (Hispanic)	Comp 6 - High Occupancy Households	SoVI
Lee	12071000502	3,417	3.75	0.92	0.20	0.98	0.35	1.28	7.47
Lee	12071000600	3,783	3.63	0.69	-0.07	1.01	-0.75	1.47	5.97
Collier	12021011302	5,920	1.22	1.02	0.72	-2.31	1.47	3.24	5.36
Lee	12071000503	3,832	1.51	-0.01	0.35	-0.02	0.55	1.95	4.33
Collier	12021011103	2,225	-0.08	2.23	1.28	-0.90	0.75	0.37	3.65
Collier	12021011301	6,369	0.67	0.34	0.74	-2.24	1.80	2.12	3.42
Collier	12021010420	6,012	0.58	-0.40	0.34	-0.78	2.22	1.14	3.11
Lee	12071040305	2,953	-0.19	0.57	0.70	0.47	0.77	0.77	3.09
Collier	12021011205	2,664	2.59	1.07	-0.03	-4.64	1.86	2.10	2.95
Collier	12021011204	4,807	2.33	0.87	-0.03	-4.61	2.73	1.44	2.74
Lee	12071040122	4,897	1.55	-0.57	-0.13	-0.62	1.20	1.22	2.66
Collier	12021011400	4,657	0.89	0.91	0.03	-4.20	2.11	2.82	2.57
Lee	12071040311	3,038	0.04	0.72	0.71	-0.22	1.14	0.09	2.48
Lee	12071040301	6,000	0.36	-0.64	0.69	0.25	0.38	1.42	2.47
Lee	12071020101	3,906	-0.88	2.98	0.65	0.71	-1.00	-0.12	2.34
Lee	12071040109	4,674	0.77	-0.19	0.08	0.66	0.19	0.75	2.26
Lee	12071000700	2,207	2.18	-0.19	0.36	-0.26	0.23	-0.19	2.11
Lee	12071040314	1,913	0.22	0.22	0.45	-0.64	-0.03	1.88	2.10
Collier	12021010802	10,208	0.75	0.42	-0.61	-0.73	0.93	1.13	1.88
Lee	12071001101	3,244	1.62	-0.41	0.35	-0.03	0.36	-0.04	1.85
Lee	12071040208	1,319	0.22	0.14	0.45	-0.79	-0.02	1.82	1.82
Lee	12071040303	4,540	0.08	-0.47	0.14	0.02	0.34	1.60	1.71
Lee	12071040313	1,338	-0.39	-0.67	0.90	0.84	-0.11	1.02	1.60
Lee	12071040210	2,087	0.23	0.00	0.55	-0.43	-0.18	1.29	1.46
Collier	12021010505	6,784	-0.07	-0.06	0.46	0.79	0.22	0.07	1.41
Collier	12021010410	8,157	0.53	-0.56	0.05	-2.02	2.46	0.93	1.39
Collier	12021010419	3,160	-0.17	-0.72	0.28	-0.68	1.71	0.90	1.32
Collier	12021010411	6,632	-0.34	-0.20	0.12	-0.28	1.14	0.84	1.27
Lee	12071040125	1,965	0.05	0.01	0.33	-0.31	0.49	0.68	1.25
Lee	12071010501	3,540	-0.83	0.32	0.34	0.48	0.51	0.42	1.23

Vulnerability Driver | Vulnerability Detractor

The final area of elevated SoVI extends from western Pasco County through Hernando and into Citrus, Marion, Sumter, and Lake Counties. Here, 73 tracts containing more than 347,000 people exhibit medium high and high social vulnerability. Component two (Age-Older Adults) is considerably more influential in this area than many of the other

SoVI components. Additionally, components four (Urban, Females) and five (Ethnicity-Hispanic) generally decrease vulnerability in this area, and component six is less influential here than in the other areas of increased SoVI across the state.

Table 9: Driving forces of the most vulnerable tracts in west central Florida.

County	Tract	Total Population	Comp 1- Class (Poverty), Race (Black)	Comp 2 - Age (Older Adults)	Comp 3 - Wealth	Comp 4 - Urban, Females	Comp5 - Ethnicity (Hispanic)	Comp 6 - High Occupancy Households	SoVI
Marion	12083001800	1,750	3.36	0.54	0.23	1.84	-1.37	0.43	5.04
Sumter	12119911302	1,148	3.51	0.96	0.27	0.22	-1.87	1.24	4.33
Lake	12069030504	7,145	0.95	1.41	0.56	0.62	-0.03	0.05	3.56
Marion	12083001700	4,977	2.21	-0.16	0.45	0.95	-0.34	0.29	3.40
Marion	12083001204	5,957	0.81	-0.08	0.49	0.80	-0.15	1.20	3.08
Pasco	12101032601	3,466	1.65	0.49	0.21	-0.46	0.76	0.17	2.82
Pasco	12101032700	2,768	0.01	2.05	1.43	-0.65	-0.39	0.29	2.74
Pasco	12101031807	3,069	0.46	1.58	1.19	-0.26	-0.64	0.31	2.65
Pasco	12101031012	4,581	-0.44	1.13	0.83	0.80	0.23	-0.16	2.39
Marion	12083001004	12,236	0.14	0.65	0.52	-0.13	-0.07	1.07	2.18
Hernando	12053041204	3,147	-0.11	1.21	0.98	-0.07	0.30	-0.13	2.17
Lake	12069030206	4,024	0.71	0.17	0.81	0.14	-0.19	0.52	2.16
Marion	12083001401	5,006	1.33	-0.16	0.64	0.57	-0.77	0.43	2.04
Marion	12083001500	3,534	1.66	0.46	0.62	-0.17	-1.29	0.57	1.84
Pasco	12101033101	2,437	-0.61	2.86	1.26	-1.81	-0.69	0.80	1.79
Lake	12069030307	4,441	-0.85	1.19	1.09	0.64	-0.25	-0.09	1.74
Marion	12083001005	6,004	0.05	1.10	0.44	0.26	-0.90	0.76	1.70
Pasco	12101032500	5,289	0.12	0.44	0.68	-1.60	0.82	1.21	1.66
Pasco	12101031205	3,946	-0.30	1.50	0.94	-0.58	-0.13	0.18	1.62
Hernando	12053041006	6,310	-0.24	0.19	0.67	0.59	-0.01	0.42	1.62
Hernando	12053041103	3,959	-0.44	0.30	0.80	0.94	-0.25	0.18	1.53
Hernando	12053041402	5,269	-0.34	0.62	0.72	0.94	-0.47	0.05	1.52
Marion	12083001207	11,209	-0.14	-0.26	0.62	0.70	-0.14	0.74	1.52
Pasco	12101032402	3,409	0.53	0.70	0.89	-1.91	-0.14	1.40	1.47
Hernando	12053041004	6,378	-0.50	0.09	0.75	0.82	-0.06	0.36	1.46
Hernando	12053041401	5,779	-0.19	0.12	0.75	0.50	-0.07	0.29	1.40
Pasco	12101031007	4,915	0.39	0.30	0.50	0.36	-0.05	-0.14	1.36
Hernando	12053041203	4,029	-0.08	0.93	0.18	0.41	-0.08	-0.01	1.35
Lake	12069030503	1,492	1.08	-0.38	0.46	-0.58	-0.24	0.98	1.33
Hernando	12053040905	6,141	-0.75	1.43	0.32	0.68	-0.37	-0.09	1.23

Vulnerability Driver | Vulnerability Detractor

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3. Medical Vulnerability

Background

Research over the past two decades from epidemiology and public health has investigated the link between health and social vulnerability, drawing ties from the social science literature to identify the social characteristics of populations at highest health risk based on access to medical resources (Aday, 1994 and 2001). These commonly cited social characteristics that correlate with health care access include social status, social capital, and human capital; showing unmistakable parity with those social indicators introduced by the social vulnerability literature in the previous section. Several researchers, however, make a clear distinction between health risk and health need (Aday, 1994 and 2001; Morath, 2010). While the social indicators of health risk help to identify sensitive populations, the indicators of health need identify individuals and communities with inherent medical vulnerability, independent of ancillary factors.

While the concept of medical vulnerability is relatively new in the field of hazards research, it is tenured in a long-standing tradition combining concepts of public and environmental health, quality of life, health equity, medical surge, and other place-based models of community and family health. Based on the epidemiology and disaster surveillance literature, Morath's (2010) investigation of medical vulnerability to disasters identifies three dimensions that contribute to a potential for harm: individual medical needs, community healthcare access, and health system capability. These dimensions, described in Table 10, are derived not only from direct disaster impacts on the exposed population, but also from impacts on the healthcare system that include the interruption of key medical services.

Table 10: Medical vulnerability concepts and description.

Population Characteristic and Specific Variables	**Influence on Medical Vulnerability**
Healthcare access County level medically underserved areas Tract level medically underserved areas County level medically underserved populations Tract level medically underserved populations County level mental health practitioner shortage areas Zip code level mental health practitioner shortage areas Tract level mental health practitioner shortage areas County level primary health practitioner shortage areas Tract level primary health practitioner shortage areas Zip code level non-emergency access to geriatric medical specialists Zip code level non-emergency access to emergency medical specialists Zip code level non-emergency access to obstetric medical specialists Zip code level non-emergency access to pediatric medical specialists Zip code level non-emergency access to primary medical specialists Tract level non-emergency access to federally qualified health centers Tract level non-emergency access to Hill Burton[21] facilities	Individuals or communities with limited access to healthcare resources, either through direct local scarcity of healthcare providers or through financial proxies, such as insurance status.

[21] Free and Reduced-Cost Health Care - http://www.hrsa.gov/gethealthcare/affordable/hillburton/

Tract level non-emergency access to rural health centers Tract level access to emergency medical transport services Tract level non-emergency access to county health clinics Tract level non-emergency access to free health clinic	
Health System Capability County level community emergency response team (CERT) capacity Zip code level community emergency response team (CERT) capacity County level funding of non-profit health care organizations County level home health facility capacity County level homemaker and companion service facilities Tract level interventional cardiac capability Tract level stroke care capability Tract level pediatric trauma capability Tract level emergency maternity capability Tract level trauma level 1 or level 2 capability Tract level emergency mental health capability Tract level emergency hospital capability Tract level emergency burn service capability	Resources maintained by the local healthcare system that prepare for emergencies and help to build medical surge capacity during disasters.
Medical needs County level percentage of uninsured populations County level percentage of Medicaid recipients County level percentage of developmentally disabled populations County level percentage of seriously emotionally disturbed children County level percentage of adults with serious mental illness County level percentage of oxygen dependent populations County level percentage of adults with probably Alzheimer's Disease County level percentage of elders (age 65+) living alone County level percentage of person's reporting poor overall health County level percentage of diabetic populations Zip code level percentage of dialysis patients County level percentage of adults with chronic heart disease County level percentage of adults with hypertension County level percentage of adults with asthma County level percentage of adults with debilitating arthritis County level percentage of low birth weight babies County level per capita number of violent crimes County level per capita number of domestic crimes County level perception of access to medical care County level perception of medical care quality Zip code level of water borne communicable diseases Zip code level of OASDI beneficiaries Zip code level percentage of brain and spinal cord injuries Zip code level percentage of pregnant mothers enrolled in WIC program Zip code level percentage of children's medical service patients County level per capita number of nursing home beds County level per capita number of assisted living beds County level per capita number of hospice facilities	Individuals dependent on the public healthcare system for medication, medical treatment, equipment, or supervision from skilled medical professionals to maintain quality of health and life. Individuals with psychological or psychosomatic disorders, or having mental limitations that often require medical consideration including medication, therapy, supervision, and in some acute cases institutionalization.

Methods

Despite a well-developed understanding of public health and wellbeing indicators, quantification of community health remains a major challenge, due in part to the insufficiency and confidentiality of health incidence data. In 2010, Morath developed the Medical Vulnerability Index (MedVI), borrowing the algorithmic approach finalized by Cutter et al. (2003) for the construction of the SoVI. Morath's (2010) MedVI used principal components analysis to derive a multidimensional construct of social vulnerability, comprised by the concepts reviewed in the table above. Identifying appropriate data for quantifying medical vulnerability across that state was the first step necessary to create a spatial representation of the theoretical framework. For this project, we relied heavily on previous work undertaken by Morath (2010) as a basis from which to build the current MedVI dataset. Included in Morath's work were 36 variables identified through a detailed literature review and expert identification provided by the Florida Department of Health as indicators or representations of medically vulnerable populations across the state (FLDOH Key Indicators; FDOH 2012). These indicators provided a solid starting point for the data collection described in this work.

In the progression of this research design, our variant of the MedVI includes a number of key modifications to Morath's original work, including:

1. An expanded set of indicators, including 61 discrete variables that capture MedVI at multiple scales to comprehensively capture spatial variations.
2. Utilization of a tenured subject matter expert on the project team to guide us in sometimes unfamiliar territory
3. Departure from the principle components analysis utilized by Morath in favor of a method that is more easily dissectible and readily applicable to planning and decision analytics

The variables, selection criteria, processing steps, and analytic procedures used in this section are outlined in a detailed technical appendix following the results. Generally, however, variables were chosen for inclusion in this project if they met one or more of the following criteria.

- Previous identification of a variable as characteristic of medically vulnerable populations by the Florida Department of Health.
- Variables utilized in the previous work by Morath in the first iteration of MedVI for Florida.
- Variables related to high risk health concerns (e.g., heart disease, low birth rate).
- Crime information related to possible delays in medical response following a disaster.
- Perceptions of health quality, health care access, and indicators of areas that have historically been medically underserved or have shortages of practitioners.
- Locations with higher than average numbers of persons who will require special attention or special medical assistance during a disaster.
- Characteristics of communities that lead to higher levels of capacity to respond to a disaster.

- Indicators of decreased access to health care resources.

Results and Findings

The pattern of MedVI across the state is varied, with the highest scores generally located in rural areas and in counties that are more rural (Figure 4). However, this image can be a bit misleading because there are many urbanized areas within the state that also have high MedVI but are such small census tracts that they are not easily identifiable on the maps below. Table 11 shows the number of census tracts in each MedVI standard deviation class. This method permits the best balance between interpretation (3 classes) and the identification and visualization of the extremes (high and low vulnerability that are of the most interest). Here, one can gain a more robust understanding of the pattern of MedVI within and between counties than is comprehendible by simply looking at the maps. The table helps us to identify many instances where there are significant numbers of tracts with high MedVI classification that may be too small to identify on a map. For example, Brevard County has 27 tracts and Hillsborough County has 85 tracts with high MedVI scores that are not immediately recognizable on the map. Table 12 provides information on the total populations residing within each of these census tracts based on their assigned medical vulnerability. This table provides a higher level of aggregation for counties and the state as a whole but also supports a finer level of sub-county assessment.

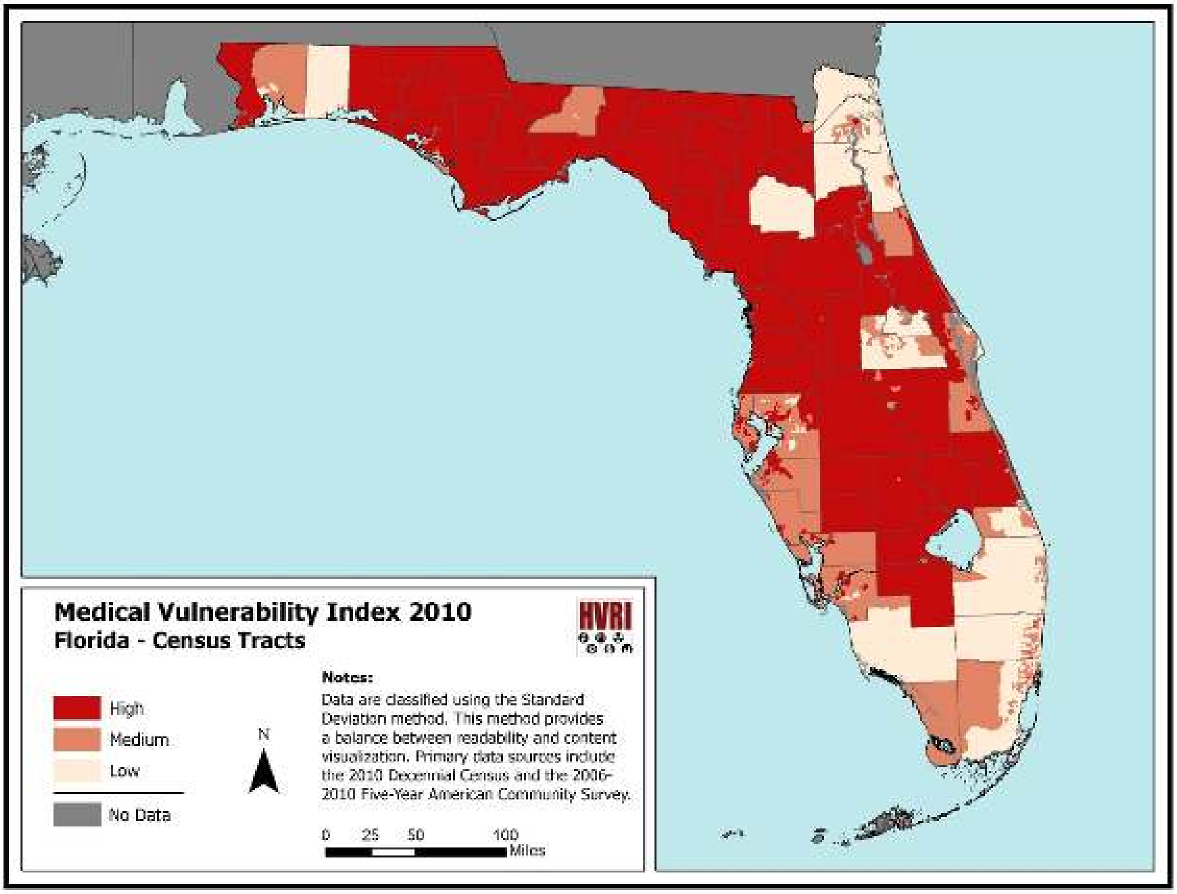

Figure 4: MedVI for census tracts within the state of Florida.

Table 11: Census tract summary of MedVI standard deviation classification by county.

County Name	Medical Vulnerability Index			County Name	Medical Vulnerability Index		
	High	Medium	Low		High	Medium	Low
Alachua	-	-	100.00%	Lee	19.28%	78.92%	1.81%
Baker	75.00%	25.00%	-	Leon	-	95.59%	4.41%
Bay	74.42%	25.58%	-	Levy	100.00%	-	-
Bradford	100.00%	-	-	Liberty	100.00%	-	-
Brevard	23.89%	74.34%	1.77%	Madison	100.00%	-	-
Broward	1.11%	28.25%	70.64%	Manatee	21.79%	78.21%	-
Calhoun	100.00%	-	-	Marion	98.41%	-	1.59%
Charlotte	18.42%	81.58%	-	Martin	-	35.29%	64.71%
Citrus	96.43%	-	3.57%	Miami-Dade	0.77%	33.78%	65.44%
Clay	-	-	100.00%	Monroe	-	96.67%	3.33%
Collier	-	6.85%	93.15%	Nassau	-	-	100.00%
Columbia	100.00%	-	-	Okaloosa	-	-	100.00%
DeSoto	100.00%	-	-	Okeechobee	100.00%	-	-
Dixie	100.00%	-	-	Orange	-	31.40%	68.60%
Duval	5.78%	34.68%	59.54%	Osceola	95.12%	4.88%	-
Escambia	98.59%	1.41%	-	Palm Beach	-	16.96%	83.04%
Flagler	30.00%	70.00%	-	Pasco	98.50%	1.50%	-
Franklin	100.00%	-	-	Pinellas	27.87%	71.72%	0.41%
Gadsden	100.00%	-	-	Polk	99.35%	0.65%	-
Gilchrist	100.00%	-	-	Putnam	100.00%	-	-
Glades	100.00%	-	-	Santa Rosa	-	52.00%	48.00%
Gulf	100.00%	-	-	Sarasota	17.02%	82.98%	-
Hamilton	100.00%	-	-	Seminole	-	13.95%	86.05%
Hardee	100.00%	-	-	St. Johns	5.13%	12.82%	82.05%
Hendry	100.00%	-	-	St. Lucie	97.73%	-	2.27%
Hernando	100.00%	-	-	Sumter	94.74%	5.26%	-
Highlands	96.30%	3.70%	-	Suwannee	100.00%	-	-
Hillsborough	26.65%	64.89%	8.46%	Taylor	100.00%	-	-
Holmes	100.00%	-	-	Union	100.00%	-	-
Indian River	96.67%	-	3.33%	Volusia	100.00%	-	-
Jackson	100.00%	-	-	Wakulla	100.00%	-	-
Jefferson	100.00%	-	-	Walton	100.00%	-	-
Lafayette	100.00%	-	-	Washington	100.00%	-	-
Lake	100.00%	-	-	**State Total**	**30.80%**	**33.35%**	**35.85%**

Table 12: Census tract summary of population by MedVI standard deviation classification by county.

County Name	Medical Vulnerability Index			County Name	Medical Vulnerability Index		
	High	Medium	Low		High	Medium	Low
Alachua	-	-	247,336	Lee	136,588	478,225	3,941
Baker	20,431	6,684	-	Leon	-	265,689	9,798
Bay	127,796	41,056	-	Levy	40,801	-	-
Bradford	28,520	-	-	Liberty	8,365	-	-
Brevard	158,238	385,131	-	Madison	19,224	-	-
Broward	27,116	530,018	1,190,932	Manatee	73,525	249,308	-
Calhoun	14,625	-	-	Marion	331,298	-	-
Charlotte	32,234	127,744	-	Martin	-	56,055	90,263
Citrus	141,236	-	-	Miami-Dade	12,514	937,344	1,543,269
Clay	-	-	190,865	Monroe	-	73,070	20
Collier	-	24,417	297,103	Nassau	-	-	73,314
Columbia	67,531	-	-	Okaloosa	-	-	180,822
DeSoto	34,862	-	-	Okeechobee	39,996	-	-
Dixie	16,422	-	-	Orange	-	371,439	774,517
Duval	34,821	264,174	565,268	Osceola	264,577	4,108	-
Escambia	294,396	3,223	-	Palm Beach	-	231,220	1,088,242
Flagler	24,521	71,175	-	Pasco	458,710	5,987	-
Franklin	11,549	-	-	Pinellas	272,992	641,881	1,669
Gadsden	46,389	-	-	Polk	602,092	3	-
Gilchrist	16,939	-	-	Putnam	74,364	-	-
Glades	12,884	-	-	Santa Rosa	-	73,996	77,376
Gulf	15,863	-	-	Sarasota	63,596	315,852	-
Hamilton	14,799	-	-	Seminole	-	33,476	389,242
Hardee	27,731	-	-	St. Johns	7,673	18,182	164,184
Hendry	39,140	-	-	St. Lucie	277,789	-	-
Hernando	172,778	-	-	Sumter	87,023	-	-
Highlands	98,785	1	-	Suwannee	41,551	-	-
Hillsborough	307,926	849,989	71,311	Taylor	22,570	-	-
Holmes	19,927	-	-	Union	15,535	-	-
Indian River	138,028	-	-	Volusia	494,593	-	-
Jackson	49,746	-	-	Wakulla	30,776	-	-
Jefferson	14,761	-	-	Walton	55,043	-	-
Lafayette	8,870	-	-	Washington	24,896	-	-
Lake	297,052	-	-	**State Total**	**5,772,007**	**6,059,447**	**6,959,472**

Overall, medical vulnerability is comprised by a multitude of factors that can be categorized into three broad categories:

1. Health Care Access
2. Health Care System Capability
3. Medical Need

Each of these broad categories was developed based upon how the component parts (variables) are seen in relation to the concept of social vulnerability described above. Every variable was appraised based on how it either added to or diminished overall

MedVI and how it characterized the populations or capacities within the state. Each of these broad categories is discussed in detail below.

Health Care Access

The first of the three categories utilized in the creation of this MedVI index centers on the identification of locations and populations within the state of Florida with less than adequate access to medical care. Lack of access or inadequate access to medical treatment facilities, physicians, emergency medical care, and primary medical treatment increases MedVI. Understanding where people are located and identifying service area gaps and medical treatment shortages linked to those locations provides a useful “picture” of areas where planning, decision-making, and resource allocation may help not only during but also in non-disaster times. To that end we identified, normalized, standardized, and mapped the following component pieces:

- County level medically underserved areas
- Tract level medically underserved areas
- County level medically underserved populations
- Tract level medically underserved populations
- County level mental health practitioner shortage areas
- Zip code level mental health practitioner shortage areas
- Tract level mental health practitioner shortage areas
- County level primary health practitioner shortage areas
- Tract level primary health practitioner shortage areas
- Zip code level non-emergency access to geriatric medical specialists
- Zip code level non-emergency access to emergency medical specialists
- Zip code level non-emergency access to obstetric medical specialists
- Zip code level non-emergency access to pediatric medical specialists
- Zip code level non-emergency access to primary medical specialists
- Tract level non-emergency access to federally qualified health centers
- Tract level non-emergency access to Hill Burton facilities
- Tract level non-emergency access to rural health centers
- Tract level access to emergency medical transport services
- Tract level non-emergency access to county health clinics
- Tract level non-emergency access to free health clinic

Health Care System Capability

The second major component of medical vulnerability that is a requisite part for understanding how a place or population may be differentially impacted by disasters is the functional capabilities present within the health care system. Here, we aim to identify and spatially display differences in county and community ability to assist populations residing within their respective jurisdictions. This portion of the assessment focuses on a host of medical vulnerability variables directly connected to fostering efficient and effective response to disasters and medical events. Included here are:

- County level community emergency response team (CERT) capacity
- Zip code level community emergency response team (CERT) capacity

- County level funding of 501c(3) health care organizations
- County level home health facility capacity
- County level homemaker and companion service facilities
- Tract level interventional cardiac capability
- Tract level stroke care capability
- Tract level pediatric trauma capability
- Tract level emergency maternity capability
- Tract level trauma level 1 or level 2 capability
- Tract level emergency mental health capability
- Tract level emergency hospital capability
- Tract level emergency burn service capability

Medical Need

The third tenet of medical vulnerability centers on population health and the identification of characteristics that often combine to create adverse situations for at risk populations. This portion of the assessment aims to identify and spatially quantify a host of characteristics related to poor health for the state. Understanding the spatial variations in underlying medical need will provide the baseline information needed to adequately plan for extreme hazard events. This section specifically identifies health indicators that are known to either put people at risk during a disaster or (in combination) create a more vulnerable population group. To this end, we analyzed the following medical need characteristics:

- County level percentage of uninsured populations
- County level percentage of Medicaid recipients
- County level percentage of developmentally disabled populations
- County level percentage of seriously emotionally disturbed children
- County level percentage of adults with serious mental illness
- County level percentage of oxygen dependent populations
- County level percentage of adults with probable Alzheimer’s Disease[22]
- County level percentage of elders (age 65+) living alone
- County level percentage of person’s reporting poor overall health
- County level percentage of diabetic populations
- Zip code level percentage of dialysis patients
- County level percentage of adults with chronic heart disease
- County level percentage of adults with hypertension
- County level percentage of adults with asthma
- County level percentage of adults with debilitating arthritis
- County level percentage of low birth weight babies
- County level per capita number of violent crimes
- County level per capita number of domestic crimes
- County level perception of access to medical care
- County level perception of medical care quality
- Zip code level of water borne communicable diseases
- Zip code level sum of (Old Age, Survivors And Disability Insurance Program) - OASDI beneficiaries

[22] http://www.floridacharts.com/Charts/documents/VP_Data_Sources.pdf

- Zip code level percentage of brain and spinal cord injuries
- Zip code level percentage of pregnant mothers enrolled in WIC program
- Zip code level percentage of children's medical service patients
- County level per capita number of nursing home beds
- County level per capita number of assisted living beds
- County level per capita number of hospice facilities

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4. Vulnerability to Hurricane Winds

Methods

Hurricanes pose a multi-faceted threat to coastal communities including storm surges, rainfall and flooding, tornadoes, and destructive winds. The last of these, tropical storm and hurricane force winds, can affect areas far afield from the storm's center. While coastal areas currently plan for hurricane impacts, interior counties may be less aware of the potential destruction of high winds. In these areas, it will be high winds, not storm surge, that cause a majority of damage during hurricane events.

Tropical storm and hurricane wind hazard zones were created for the state of Florida using historical wind speed information from the Extended Best Track (EBT) dataset for storms occurring between 1988 and 2012.[23] This dataset provides satellite-based estimates on the maximum radial extent of wind within each of four quadrants around the hurricane eye. These wind speeds and associated distances form the basis from which polygonal representations of each hurricane path are created. The extent of tropical storm strength winds (those greater than 34 kt) in the vicinity of Florida for 1998's Hurricane Georges is shown as an example (Figure 5A). A polygon is made using each set of four points (Figure 5B). Those individual polygons are dissolved into a single polygon (Figure 5C). Finally, the polygon is smoothed to more accurately approximate the storm's circular shape (Figure 5D).

EBT is not available for storms occurring between 1952 and 1987. Instead, an idealized buffer is created around each segment of the storm's track. The buffer has a greater distance for stronger wind speeds at the storm's center. All of the resulting wind zone representations are combined into a single hurricane wind hazard layer, and the number of hurricane zone overlaps were counted and associated with each unique overlapping polygon. This sum of hurricane or tropical storm events was then divided by the number of years in the record to determine the annual frequency of occurrence for each census tract in the state (Figure 6). Tropical storm wind risk is defined using an equal interval classification scheme applied to all historical storms where low risk is < 25% historical frequency of tropical storm winds, medium risk is between 25%-50% historical frequency, high risk is between 50%-75% historical frequency, and extreme risk is > 75% historical frequency. Because the frequency of hurricane winds is much lower than that of tropical storm force winds hurricane wind risk was classified using a manual

[23] The "extended" best track file was created by supplementing the North American Hurricane Database (HURDAT) with additional storm parameters determined by NHC. The additional parameters include the following:

1. Maximum radial extent of 34, 50 and 64 kt wind in four quadrants
2. Radius of maximum wind
3. Eye diameter if available
4. Pressure and radius of the outer closed isobar. More information at http://rammb.cira.colostate.edu/research/tropical_cyclones/tc_extended_best_track_dataset/index.asp

method where low risk is < 5% historical frequency of hurricane winds, medium risk is between 5%-10% historical frequency, high risk is between 10%-15% historical frequency, and extreme risk is > 15% historical frequency.

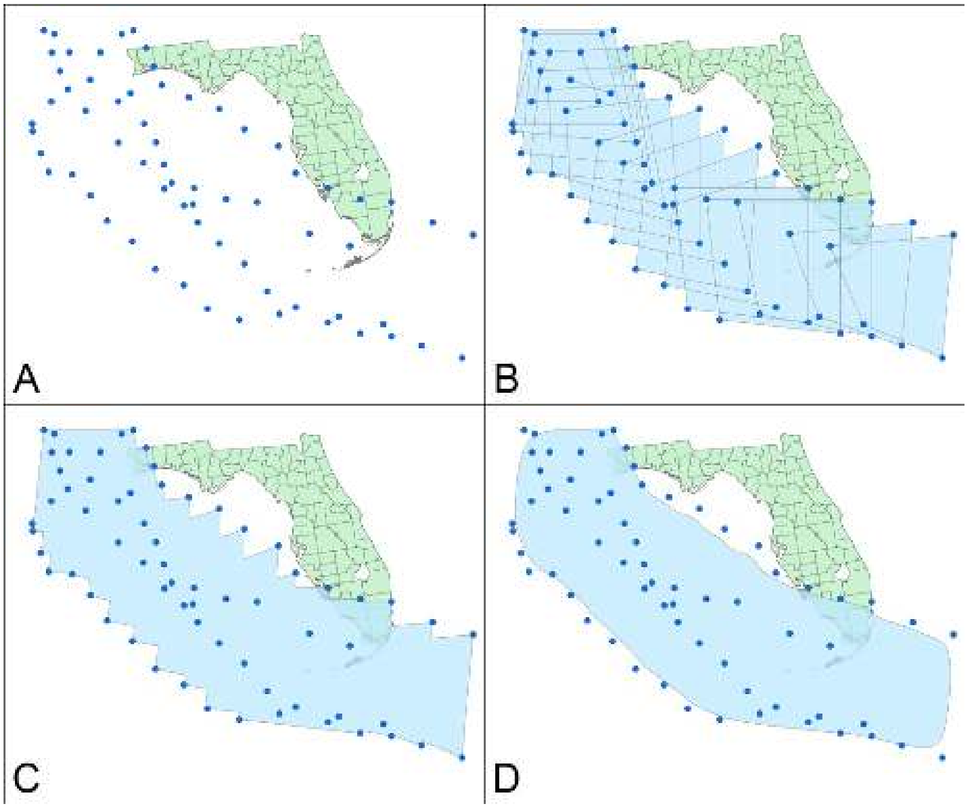

Figure 5: Process of creating historical hurricane wind zones.

State Summary

An analysis based on historical tropical storm and hurricane force winds shows a medium to high risk for tropical storm force winds for the majority of the state, with the highest risk to the east (Figure 6). Counties most affected include Miami-Dade, Palm Beach, and Orange Counties, each with more than 1 million residents in the high risk category (Table 14). While no counties in the state have tracts included in the extreme risk category (

Table 13), only a small portion of the state (5%) is at low risk to tropical storm force winds. Florida's hurricane force wind hazard risk tells a much different story, with the highest areas of risk along the southeastern coast and in the panhandle (Figure 7). Nearly 15% of the state is at high risk to hurricane force winds (Table 15), accounting for almost 3 million people (Table 16).

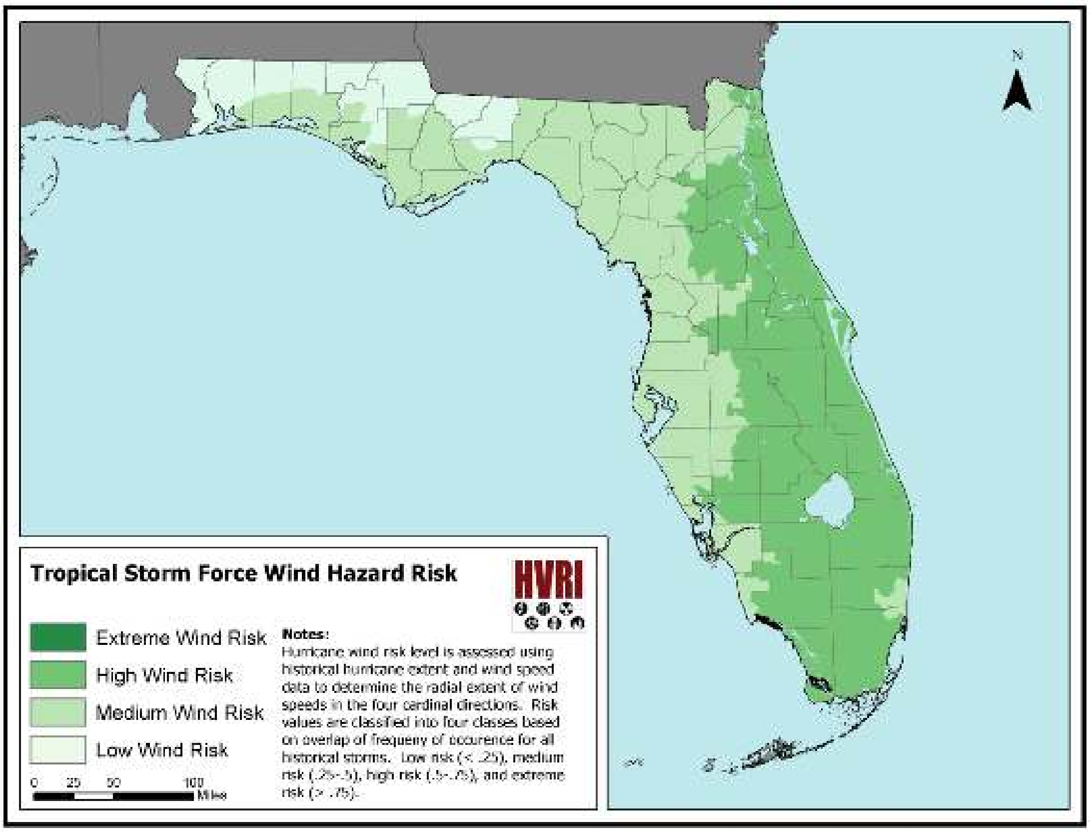

Figure 6: Tropical storm force wind hazard risk in Florida.

Table 13: Census tract summary for tropical storm force wind hazard risk.

County Name	Tropical Storm Wind Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	5.36%	94.64%	-	-
Baker	-	-	100.00%	-	-
Bay	-	-	54.55%	45.45%	-
Bradford	-	25.00%	75.00%	-	-
Brevard	-	100.00%	-	-	-
Broward	-	40.72%	59.28%	-	-
Calhoun	-	-	66.67%	33.33%	-
Charlotte	-	66.67%	33.33%	-	-
Citrus	-	-	100.00%	-	-
Clay	-	50.00%	50.00%	-	-
Collier	-	5.41%	94.59%	-	-
Columbia	-	-	100.00%	-	-
DeSoto	-	55.56%	44.44%	-	-
Dixie	-	-	100.00%	-	-
Duval	-	49.13%	50.87%	-	-
Escambia	-	-	1.41%	98.59%	-
Flagler	-	100.00%	-	-	-
Franklin	-	-	100.00%	-	-
Gadsden	-	-	-	100.00%	-
Gilchrist	-	-	100.00%	-	-
Glades	-	100.00%	-	-	-
Gulf	-	-	100.00%	-	-
Hamilton	-	-	100.00%	-	-
Hardee	-	33.33%	66.67%	-	-
Hendry	-	100.00%	-	-	-
Hernando	-	2.22%	97.78%	-	-
Highlands	-	96.30%	3.70%	-	-
Hillsborough	-	-	100.00%	-	-
Holmes	-	-	-	100.00%	-
Indian River	-	100.00%	-	-	-
Jackson	-	-	-	100.00%	-
Jefferson	-	-	100.00%	-	-
Lafayette	-	-	100.00%	-	-
Lake	-	41.07%	58.93%	-	-
Lee	-	-	100.00%	-	-
Leon	-	-	-	100.00%	-
Levy	-	-	100.00%	-	-
Liberty	-	-	100.00%	-	-
Madison	-	-	100.00%	-	-
Manatee	-	-	100.00%	-	-
Marion	-	69.84%	30.16%	-	-
Martin	-	100.00%	-	-	-
Miami-Dade	-	74.76%	25.24%	-	-
Monroe	-	77.42%	22.58%	-	-
Nassau	-	58.33%	41.67%	-	-
Okaloosa	-	-	80.49%	19.51%	-
Okeechobee	-	100.00%	-	-	-
Orange	-	95.17%	4.83%	-	-
Osceola	-	100.00%	-	-	-
Palm Beach	-	100.00%	-	-	-
Pasco	-	-	100.00%	-	-
Pinellas	-	-	100.00%	-	-
Polk	-	38.31%	61.69%	-	-
Putnam	-	100.00%	-	-	-
Santa Rosa	-	-	20.00%	80.00%	-
Sarasota	-	1.06%	98.94%	-	-
Seminole	-	100.00%	-	-	-
St. Johns	-	100.00%	-	-	-
St. Lucie	-	100.00%	-	-	-
Sumter	-	10.53%	89.47%	-	-
Suwannee	-	-	100.00%	-	-
Taylor	-	-	100.00%	-	-
Union	-	-	100.00%	-	-
Volusia	-	100.00%	-	-	-
Wakulla	-	-	75.00%	25.00%	-
Walton	-	-	63.64%	36.36%	-
Washington	-	-	14.29%	85.71%	-
State Total	-	46.38%	48.35%	5.27%	-

Table 14: Census tract population summary for tropical storm force wind hazard risk.

County Name	Tropical Storm Wind Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	10,116	237,220	-	-
Baker	-	-	27,115	-	-
Bay	-	-	72,458	96,394	-
Bradford	-	7,635	20,885	-	-
Brevard	-	543,369	-	-	-
Broward	-	726,001	1,022,065	-	-
Calhoun	-	-	12,192	2,433	-
Charlotte	-	104,699	55,279	-	-
Citrus	-	-	141,236	-	-
Clay	-	98,146	92,719	-	-
Collier	-	37,825	283,695	-	-
Columbia	-	-	67,531	-	-
DeSoto	-	17,692	17,170	-	-
Dixie	-	-	16,422	-	-
Duval	-	465,581	398,682	-	-
Escambia	-	-	2,136	295,483	-
Flagler	-	95,696	-	-	-
Franklin	-	-	11,549	-	-
Gadsden	-	-	-	46,389	-
Gilchrist	-	-	16,939	-	-
Glades	-	12,884	-	-	-
Gulf	-	-	15,863	-	-
Hamilton	-	-	14,799	-	-
Hardee	-	7,973	19,758	-	-
Hendry	-	39,140	-	-	-
Hernando	-	4,785	167,993	-	-
Highlands	-	95,985	2,801	-	-
Hillsborough	-	-	1,229,226	-	-
Holmes	-	-	-	19,927	-
Indian River	-	138,028	-	-	-
Jackson	-	-	-	49,746	-
Jefferson	-	-	14,761	-	-
Lafayette	-	-	8,870	-	-
Lake	-	161,026	136,026	-	-

County Name	Tropical Storm Wind Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Lee	-	-	618,754	-	-
Leon	-	-	-	275,487	-
Levy	-	-	40,801	-	-
Liberty	-	-	8,365	-	-
Madison	-	-	19,224	-	-
Manatee	-	-	322,833	-	-
Marion	-	210,256	121,042	-	-
Martin	-	146,318	-	-	-
Miami-Dade	-	1,855,502	637,625	-	-
Monroe	-	54,882	18,208	-	-
Nassau	-	40,204	33,110	-	-
Okaloosa	-	-	126,855	53,967	-
Okeechobee	-	39,996	-	-	-
Orange	-	1,096,602	49,354	-	-
Osceola	-	268,685	-	-	-
Palm Beach	-	1,319,462	-	-	-
Pasco	-	-	464,697	-	-
Pinellas	-	-	916,542	-	-
Polk	-	253,613	348,482	-	-
Putnam	-	74,364	-	-	-
Santa Rosa	-	-	41,114	110,258	-
Sarasota	-	33,041	346,407	-	-
Seminole	-	422,718	-	-	-
St. Johns	-	190,039	-	-	-
St. Lucie	-	277,789	-	-	-
Sumter	-	5,601	81,422	-	-
Suwannee	-	-	41,551	-	-
Taylor	-	-	22,570	-	-
Union	-	-	15,535	-	-
Volusia	-	494,593	-	-	-
Wakulla	-	-	21,909	8,867	-
Walton	-	-	34,262	20,781	-
Washington	-	-	6,615	18,281	-
State Total	-	9,350,246	8,442,667	998,013	-

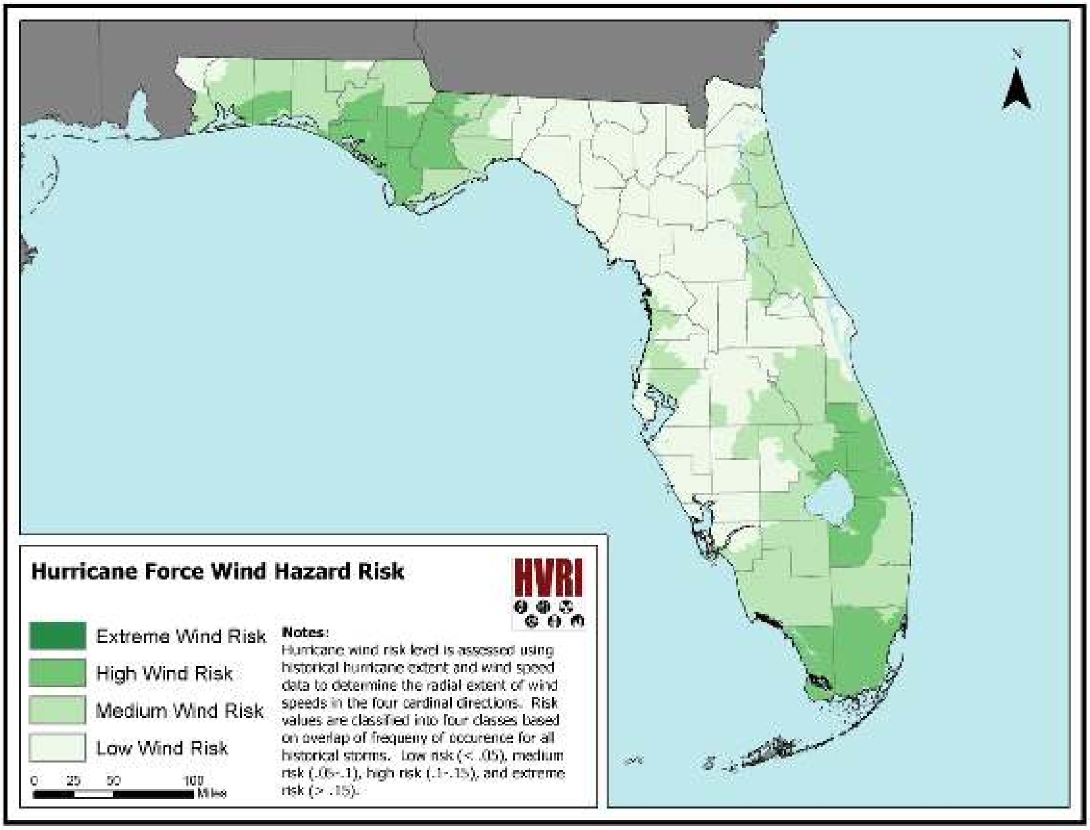

Figure 7: Hurricane force wind hazard risk in Florida.

Table 15: Census tract summary for hurricane force wind hazard risk.

County Name	Hurricane Wind Hazard Risk Extreme (>15%)	High (10%-15%)	Medium (5%-10%)	Low (<5%)	Out
Alachua	-	-	-	100.00%	-
Baker	-	-	-	100.00%	-
Bay	-	97.73%	2.27%	-	-
Bradford	-	-	-	100.00%	-
Brevard	-	-	14.16%	85.84%	-
Broward	-	-	100.00%	-	-
Calhoun	-	66.67%	33.33%	-	-
Charlotte	-	-	-	100.00%	-
Citrus	-	-	7.14%	92.86%	-
Clay	-	-	3.33%	96.67%	-
Collier	-	-	100.00%	-	-
Columbia	-	-	-	100.00%	-
DeSoto	-	-	-	100.00%	-
Dixie	-	-	-	100.00%	-
Duval	-	-	21.97%	78.03%	-
Escambia	-	4.23%	91.55%	4.23%	-
Flagler	-	-	100.00%	-	-
Franklin	-	25.00%	75.00%	-	-
Gadsden	-	33.33%	66.67%	-	-
Gilchrist	-	-	-	100.00%	-
Glades	-	25.00%	75.00%	-	-
Gulf	-	100.00%	-	-	-
Hamilton	-	-	-	100.00%	-
Hardee	-	-	33.33%	66.67%	-
Hendry	-	-	66.67%	33.33%	-
Hernando	-	-	20.00%	80.00%	-
Highlands	-	-	40.74%	59.26%	-
Hillsborough	-	-	66.67%	33.33%	-
Holmes	-	-	75.00%	25.00%	-
Indian River	-	66.67%	33.33%	-	-
Jackson	-	-	100.00%	-	-
Jefferson	-	-	-	100.00%	-
Lafayette	-	-	-	100.00%	-
Lake	-	-	8.93%	91.07%	-
Lee	-	-	38.32%	61.68%	-
Leon	-	-	36.76%	63.24%	-
Levy	-	-	-	100.00%	-
Liberty	-	100.00%	-	-	-
Madison	-	-	-	100.00%	-
Manatee	-	-	-	100.00%	-
Marion	-	-	-	100.00%	-
Martin	-	94.12%	5.88%	-	-
Miami-Dade	-	80.15%	19.85%	-	-
Monroe	3.23%	96.77%	-	-	-
Nassau	-	-	-	100.00%	-
Okaloosa	-	12.20%	87.80%	-	-
Okeechobee	-	90.91%	9.09%	-	-
Orange	-	-	0.48%	99.52%	-
Osceola	-	-	31.71%	68.29%	-
Palm Beach	-	1.49%	98.51%	-	-
Pasco	-	-	55.22%	44.78%	-
Pinellas	-	-	5.31%	94.69%	-
Polk	-	-	8.44%	91.56%	-
Putnam	-	-	47.06%	52.94%	-
Santa Rosa	-	28.00%	68.00%	4.00%	-
Sarasota	-	-	-	100.00%	-
Seminole	-	-	5.81%	94.19%	-
St. Johns	-	-	100.00%	-	-
St. Lucie	-	100.00%	-	-	-
Sumter	-	-	-	100.00%	-
Suwannee	-	-	-	100.00%	-
Taylor	-	-	-	100.00%	-
Union	-	-	-	100.00%	-
Volusia	-	-	87.72%	12.28%	-
Wakulla	-	-	100.00%	-	-
Walton	-	9.09%	90.91%	-	-
Washington	-	42.86%	57.14%	-	-
State Total	0.02%	14.97%	40.88%	44.13%	-

Table 16: Census tract population summary for hurricane force wind hazard risk.

County Name	Hurricane Wind Hazard Risk					County Name	Hurricane Wind Hazard Risk				
	Extreme (>15%)	High (10%-15%)	Medium (5%-10%)	Low (<5%)	Out		Extreme (>15%)	High (10%-15%)	Medium (5%-10%)	Low (<5%)	Out
Alachua	-	-	-	247,336	-	Lee	-	-	211,964	406,790	-
Baker	-	-	-	27,115	-	Leon	-	-	110,076	165,411	-
Bay	-	168,852	-	-	-	Levy	-	-	-	40,801	-
Bradford	-	-	-	28,520	-	Liberty	-	8,365	-	-	-
Brevard	-	-	106,372	436,997	-	Madison	-	-	-	19,224	-
Broward	-	-	1,748,066	-	-	Manatee	-	-	-	322,833	-
Calhoun	-	12,192	2,433	-	-	Marion	-	-	-	331,298	-
Charlotte	-	-	-	159,978	-	Martin	-	141,056	5,262	-	-
Citrus	-	-	9,747	131,489	-	Miami-Dade	-	1,947,436	545,691	-	-
Clay	-	-	3,251	187,614	-	Monroe	20	73,070	-	-	-
Collier	-	-	321,520	-	-	Nassau	-	-	-	73,314	-
Columbia	-	-	-	67,531	-	Okaloosa	-	21,449	159,373	-	-
DeSoto	-	-	-	34,862	-	Okeechobee	-	37,175	2,821	-	-
Dixie	-	-	-	16,422	-	Orange	-	-	2,916	1,143,040	-
Duval	-	-	222,006	642,257	-	Osceola	-	-	69,975	198,710	-
Escambia	-	10,743	272,651	14,225	-	Palm Beach	-	25,086	1,294,376	-	-
Flagler	-	-	95,696	-	-	Pasco	-	-	268,850	195,847	-
Franklin	-	1,690	9,859	-	-	Pinellas	-	-	59,286	857,256	-
Gadsden	-	15,973	30,416	-	-	Polk	-	-	38,483	563,612	-
Gilchrist	-	-	-	16,939	-	Putnam	-	-	35,528	38,836	-
Glades	-	2,266	10,618	-	-	Santa Rosa	-	40,818	106,273	4,281	-
Gulf	-	15,863	-	-	-	Sarasota	-	-	-	379,448	-
Hamilton	-	-	-	14,799	-	Seminole	-	-	41,396	381,322	-
Hardee	-	-	7,973	19,758	-	St. Johns	-	-	190,039	-	-
Hendry	-	-	27,698	11,442	-	St. Lucie	-	277,789	-	-	-
Hernando	-	-	32,131	140,647	-	Sumter	-	-	-	87,023	-
Highlands	-	-	42,346	56,440	-	Suwannee	-	-	-	41,551	-
Hillsborough	-	-	805,817	423,409	-	Taylor	-	-	-	22,570	-
Holmes	-	-	15,977	3,950	-	Union	-	-	-	15,535	-
Indian River	-	84,231	53,797	-	-	Volusia	-	-	440,158	54,435	-
Jackson	-	-	49,746	-	-	Wakulla	-	-	30,776	-	-
Jefferson	-	-	-	14,761	-	Walton	-	2,506	52,537	-	-
Lafayette	-	-	-	8,870	-	Washington	-	13,058	11,838	-	-
Lake	-	-	27,409	269,643	-	**State Total**	20	2,899,618	7,573,147	8,318,141	-

Analyzing Tropical Cyclone Wind Hazards in Combination with SoVI and MedVI

About Bivariate Classifications

Here, we keep the exposure constant by using the same hazard threat surface but use different vulnerability perspectives (social and medical) in bivariate representations to create an easily understood depiction of not only increased threat but also a limited ability to adequately prepare for and respond to these threats. In doing so, we are able to quickly identify three specific geographic areas of interest:

1. Areas where the hazard itself should be the focus of planning and mitigation,

2. Areas where understanding the underlying socioeconomics and demographics would prove to be the most advantageous input point to create positive change, and

3. Areas where a combination of classic hazard mitigation techniques and social mitigation practices should be utilized in order to maximize optimal outcomes.

The following maps utilize a three by three bivariate representation in which one can easily identify areas of limited to elevated SoVI in relation to areas with low to extreme hazard classifications. Places identified in item number one in the preceding list are shaded in the blue colors and can be understood as locations where hazard susceptibility is higher than SoVI or MedVI. Areas identified in item number two above, indicating where socioeconomics and demographics play an important role, are shaded in the pink/red colors and can be conceived as locations where SoVI or MedVI are greater than physical hazard threats. Places identified in item number three above are shaded either in gray-tones or in a dark burgundy color and can be understood as areas that have equal vulnerability and hazard classification scores.

Integrating Hurricane Wind Hazard Risk with SoVI and MedVI

With regards to tropical storm force wind risk, much of the panhandle has low social vulnerability and low hazard risk, while areas along the Kissimmee River and the southeastern coast exhibit the highest combination of social vulnerability and hazard vulnerability (Figure 8). Counties with more than 100,000 people displaying high tropical storm force wind hazard risk and high social vulnerability include Broward, Miami-Dade, Orange, Osceola, Palm Beach, and Polk Counties, comprising 489 of the 573 census tracts in that category (

Table 17). When comparing social vulnerability to the risk of hurricane force winds, the coast of Miami-Dade county stands out as having high social vulnerability as well as high hazard vulnerability (Figure 9). Conversely, the panhandle of Florida presents an area of high hazard risk and low social vulnerability. Most of the population at high risk for hurricane force winds are in 267 tracts in Miami-Dade County, totaling nearly 1.4 million people (Table 18). Additionally, Broward and Miami-Dade Counties each contained more than 500,000 people at medium risk.

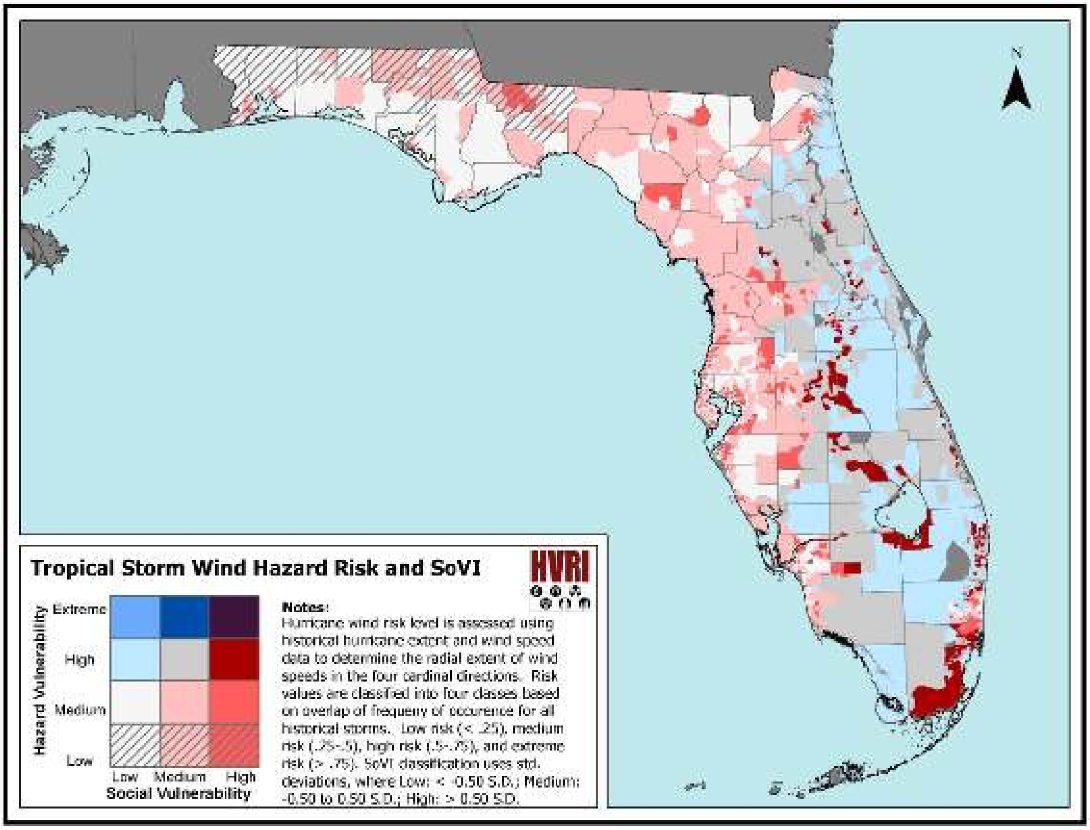

Figure 8: Bivariate representation of SoVI and tropical storm force wind hazard risk in Florida

Table 17: Tract and population summary for counties with high SoVI and medium or greater tropical storm force wind hazard risk.

County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts
High Tropical Storm Force Wind Hazard Risk										
Brevard	6	20,847		Broward	37	171,243		Charlotte	4	14,263
Clay	1	5,311		Collier	1	4,657		Duval	1	4,046
Flagler	3	15,884		Hendry	3	21,846		Highlands	8	35,116
Indian River	5	14,670		Marion	8	41,502		Martin	2	4,091
Miami-Dade	269	1,406,413		Okeechobee	3	10,116		Orange	42	209,995
Osceola	14	103,651		Palm Beach	104	378,320		Polk	23	112,273
Putnam	3	10,480		Seminole	7	25,901		St. Johns	1	4,155
St. Lucie	10	37,115		Volusia	18	83,236			-	-
State Total	**573**	**2,735,131**			-	-			-	-
Medium Tropical Storm Force Wind Hazard Risk										
Alachua	4	19,406		Bay	2	5,186		Broward	74	378,305
Charlotte	1	3,642		Citrus	5	23,598		Collier	14	72,025
Columbia	1	2,872		DeSoto	3	13,900		Dixie	1	7,331
Duval	36	146,380		Hamilton	1	1,760		Hardee	2	10,630
Hernando	15	62,301		Hillsborough	73	279,785		Lake	9	40,805
Lee	32	100,752		Manatee	19	84,453		Marion	7	60,714
Miami-Dade	90	494,208		Orange	8	42,353		Pasco	28	87,242
Pinellas	37	132,662		Polk	29	107,187		Sarasota	13	46,430
Sumter	6	52,106		Suwannee	1	7,016			-	-
State Total	**511**	**2,283,049**			-	-			-	-

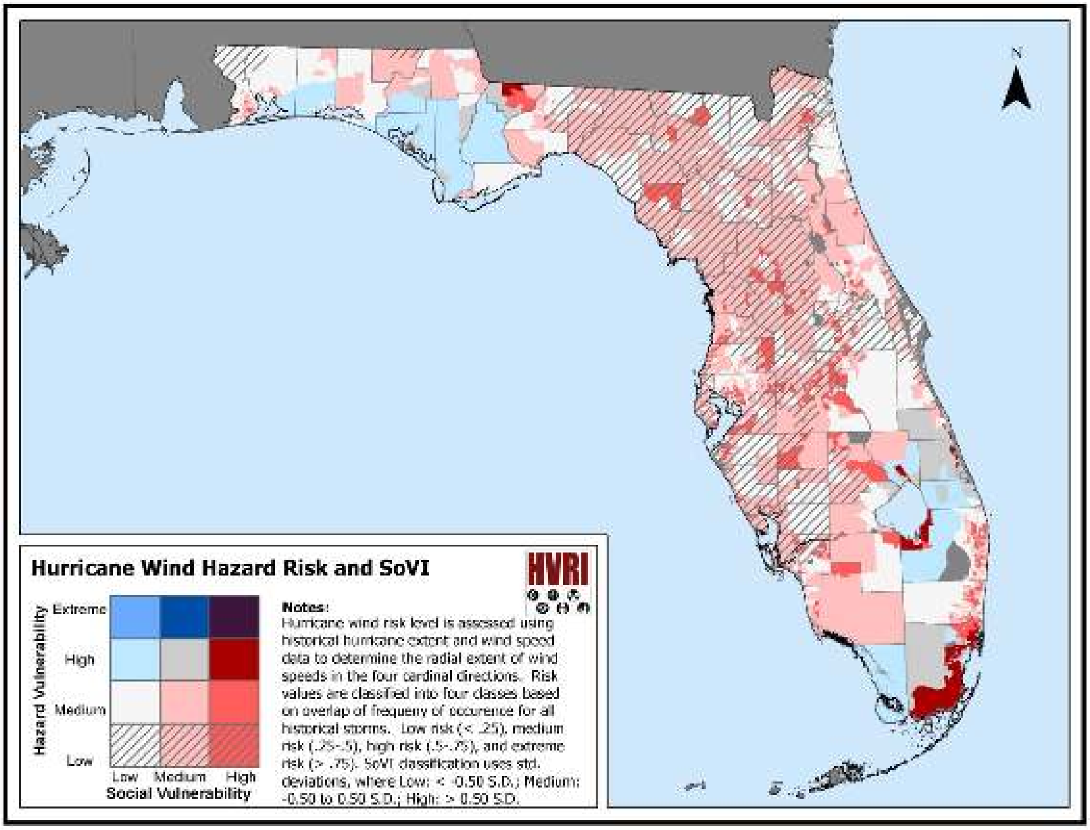

Figure 9: Bivariate representation of SoVI and hurricane force wind hazard risk in Florida.

Table 18: Tract and population summary for counties with high SoVI and medium or greater hurricane force wind hazard risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Hurricane Force Wind Hazard Risk								
Bay	3	8,846	Gadsden	1	5,540	Indian River	3	5,566
Martin	2	4,091	Miami-Dade	267	1,398,628	Okeechobee	3	10,116
Palm Beach	4	15,858	St. Lucie	10	37,115			
State Total	**293**	**1,485,760**		-	-		-	-
Medium Hurricane Force Wind Hazard Risk								
Brevard	1	5,430	Broward	111	549,548	Collier	15	76,682
Escambia	12	39,923	Flagler	3	15,884	Gadsden	4	19,493
Hendry	2	14,316	Hernando	1	4,029	Highlands	6	27,137
Hillsborough	52	203,144	Indian River	2	9,104	Lee	8	19,380
Miami-Dade	92	501,993	Osceola	1	4,355	Palm Beach	100	362,462
Pasco	11	38,187	Polk	2	5,069	Putnam	1	3,342
Santa Rosa	1	6,115	St. Johns	1	4,155	Volusia	17	79,273
State Total	**443**	**1,989,021**		-	-		-	-

As shown in Figure 10, medical vulnerability is highest in the northern and central portions of the state, with the highest combination of medical vulnerability and tropical storm force wind hazard risk from the center of the peninsula eastward toward the Atlantic Ocean. Counties with the highest populations in the high tropical storm force wind hazard risk coupled with high medical vulnerability include Marion, Osceola, Polk, St. Lucie, and Volusia Counties, each with more than 200,000 people at high hazard risk (Table 19). Low medical vulnerability coupled with high hazard risk is most present in south Florida, although there are some tracts where medical vulnerability is high. When comparing medical vulnerability to hurricane force wind hazard risk, areas most at risk still include north and central Florida, but with the higher risks present in the panhandle (Figure 11). St. Lucie and Bay Counties have the most people at high risk, totaling more than 400,000 people across 75 tracts. An additional 438 tracts across 30 counties represent 1.9 million people at medium risk and high medical vulnerability (Table 20).

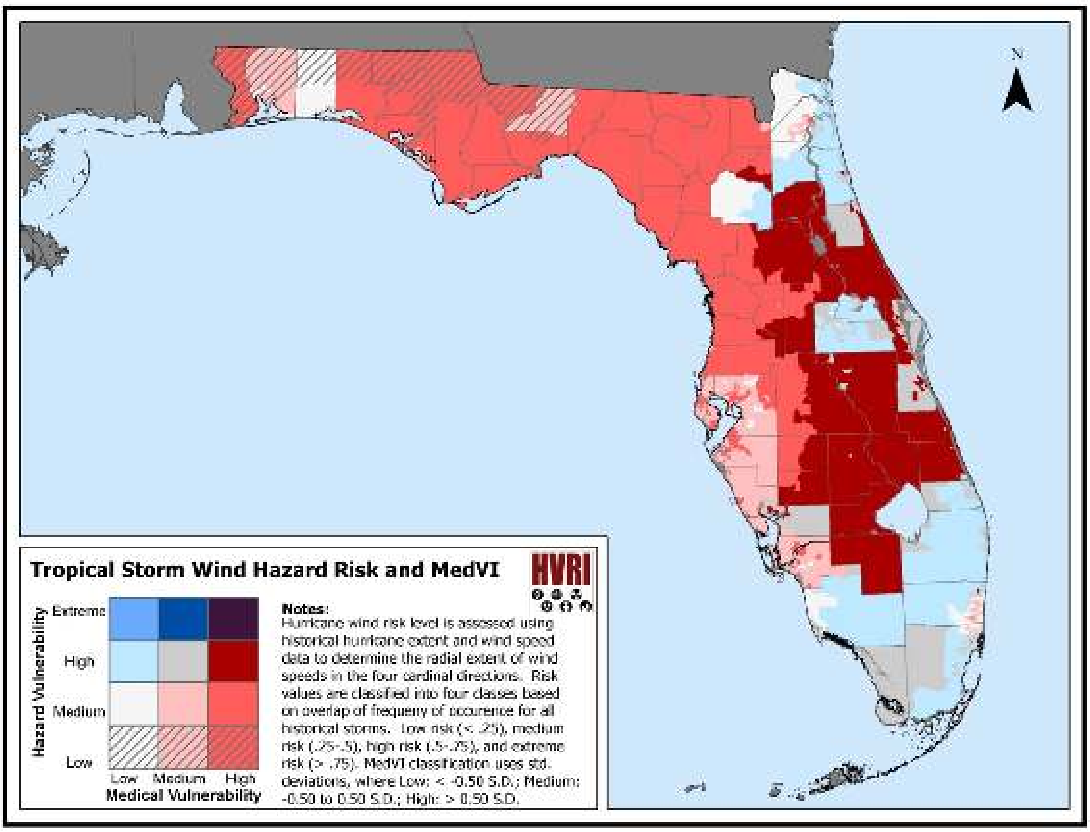

Figure 10: Bivariate representation of MedVI and tropical storm force wind hazard risk in Florida.

Table 19: Tract and population summary for counties with high MedVI and medium or greater tropical storm force wind hazard risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Tropical Storm Force Wind Hazard Risk								
Bradford	1	7,635	Brevard	27	158,238	Broward	1	8,694
Charlotte	7	32,234	DeSoto	5	17,692	Flagler	6	24,521
Glades	3	12,884	Hardee	2	7,973	Hendry	6	39,140
Hernando	1	4,785	Highlands	25	95,984	Indian River	29	138,028
Lake	23	161,026	Marion	43	210,256	Miami-Dade	4	12,514
Okeechobee	11	39,996	Osceola	39	264,577	Polk	58	253,610
Putnam	17	74,364	St. Johns	2	7,673	St. Lucie	43	277,789
Sumter	2	5,601	Volusia	113	494,593		-	-
State Total	**468**	**2,349,807**		-	-		-	-
Medium Tropical Storm Force Wind Hazard Risk								
Baker	3	20,431	Bay	20	65,546	Bradford	3	20,885
Broward	3	18,422	Calhoun	2	12,192	Citrus	27	141,236
Columbia	12	67,531	DeSoto	4	17,170	Dixie	3	16,422
Duval	10	34,821	Escambia	1	2,136	Franklin	4	11,549
Gilchrist	5	16,939	Gulf	3	15,863	Hamilton	3	14,799
Hardee	4	19,758	Hernando	43	167,993	Highlands	1	2,801
Hillsborough	85	307,926	Jefferson	3	14,761	Lafayette	2	8,870
Lake	33	136,026	Lee	32	136,588	Levy	9	40,801
Liberty	2	8,365	Madison	5	19,224	Manatee	17	73,525
Marion	19	121,042	Pasco	131	458,710	Pinellas	68	272,992
Polk	95	348,482	Sarasota	16	63,596	Sumter	16	81,422
Suwannee	7	41,551	Taylor	4	22,570	Union	3	15,535
Wakulla	3	21,909	Walton	7	34,262	Washington	1	6,615
State Total	**709**	**2,901,266**		-	-		-	-

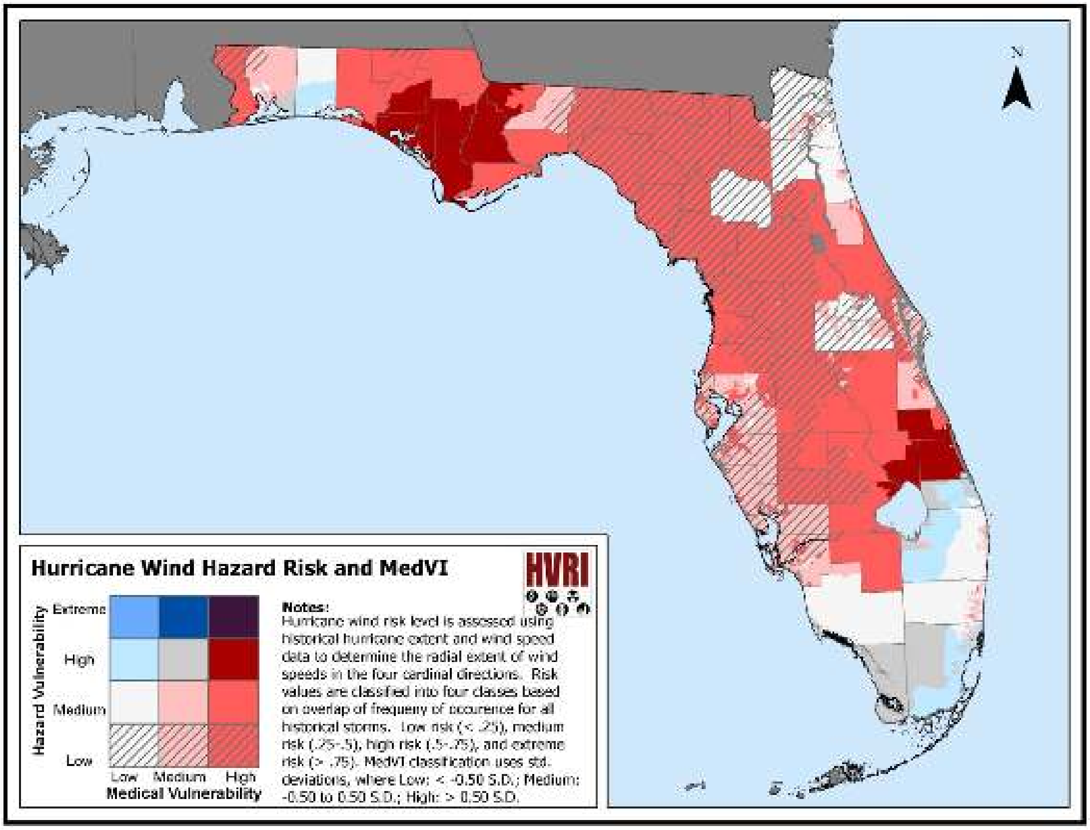

Figure 11: Bivariate representation of MedVI and hurricane force wind hazard risk in Florida.

Table 20: Tract and population summary for counties with high MedVI and medium or greater hurricane force wind hazard risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Hurricane Force Wind Hazard Risk								
Bay	32	127,796	Calhoun	2	12,192	Escambia	3	10,743
Franklin	1	1,690	Gadsden	3	15,973	Glades	1	2,266
Gulf	3	15,863	Indian River	19	84,231	Liberty	2	8,365
Miami-Dade	4	12,514	Okeechobee	10	37,175	St. Lucie	43	277,789
Walton	1	2,506	Washington	3	13,058			
State Total	**127**	**622,161**		-	-		-	-
Medium Hurricane Force Wind Hazard Risk								
Brevard	2	17,274	Broward	4	27,116	Calhoun	1	2,433
Citrus	2	9,747	Escambia	64	269,428	Flagler	6	24,521
Franklin	3	9,859	Gadsden	6	30,416	Glades	2	10,618
Hardee	2	7,973	Hendry	4	27,698	Hernando	8	32,131
Highlands	11	42,346	Hillsborough	65	231,817	Holmes	3	15,977
Indian River	10	53,797	Jackson	11	49,746	Lake	5	27,409
Lee	4	26,611	Okeechobee	1	2,821	Osceola	12	69,799
Pasco	71	262,863	Pinellas	1	4,322	Polk	13	38,483
Putnam	8	35,528	St. Johns	2	7,673	Volusia	99	440,158
Wakulla	4	30,776	Walton	10	52,537	Washington	4	11,838
State Total	**438**	**1,873,715**		-	-		-	-

5. Vulnerability to Storm Surge

Methods

Storm surge refers to elevated water level that is pushed towards the shore by the force of strong winds that result in the piling up of water. The advancing surge combines with the normal tides, which in extreme cases can increase the normal water height over 20 ft. The storm surge arrives ahead of the storm's actual landfall, and the more intense the hurricane is, the sooner the surge arrives. Water rise can be very rapid and can move far inland, posing a serious threat to those who have not yet evacuated flood-prone areas. Debris carried by the waves can also contribute to damage. As a storm approaches the shore, the greatest storm surge will be to the north of the hurricane eye, in the right-front quadrant of the direction in which the hurricane is moving. Such a surge of high water topped by waves driven by hurricane force winds can be devastating to coastal regions, causing severe beach erosion and property damage along the immediate coast. Storm surge heights, and associated waves, are dependent upon the shape of the continental shelf (narrow or wide) and the depth of the ocean bottom (bathymetry). A narrow shelf, or one that drops steeply from the shoreline and subsequently produces deep water close to the shoreline, tends to produce a lower surge but with higher and more powerful storm waves. While disassociated with the Saffir-Simpson Scale which measures hurricane wind intensity, storm surge remains the leading killer of residents along immediate coastal areas.

Recent research (Knutson et al., 2010; Jagger and Elsner, 2006) has indicated that although the overall number of hurricanes is unlikely to increase in the future, there is a much higher likelihood that the number of strong hurricanes (i.e., Categories 4 and 5) will increase, leading to higher levels of storm surge. To analyze the potential impact of future storm surge on Florida's coastline, NOAA's Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model was used to estimate storm surge heights from historical, hypothetical, and projected hurricanes. Florida SLOSH data were downloaded directly from the Florida Division of Emergency Management's GIS data clearinghouse (http://floridadisaster.org/gis/data/) and were imported into ArcMap for GIS analysis. SLOSH zones for hurricane Categories 1 through 5 were overlaid with Florida census tracts to estimate areas exposed to storm surge (Figure 12). For hurricane Categories 2 through 5, the total exposed area represents cumulative exposure (e.g., Category 5 includes the areas exposed to Categories 1 through 4 storm surge). Each tract was then categorized into one of five classes based on the probable land area impacted by each hurricane category using the following equal interval classification scheme so that future changes in risk at the tract- level can be easily seen in comparison to the current risk level:

- Out = No land area in the surge zone
- Low = Less than 25% of the tract area in the surge zone
- Medium = Between 25% - 50% of the tract area in the surge zone
- High = Between 50%-75% of the tract area in the surge zone
- Extreme = Greater than 75% of the tract area in the surge zone

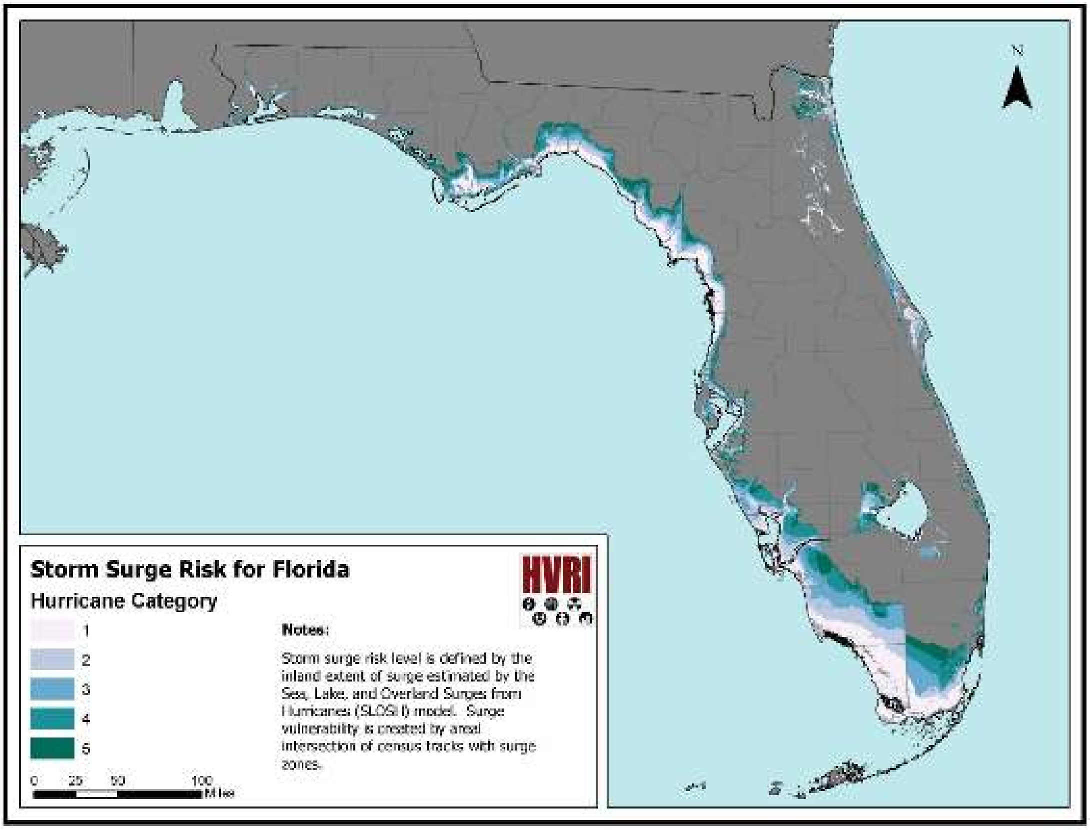

Figure 12: SLOSH zones in Florida.

State Summary

Every coastal county within the state is a potential target for hurricane storm surge but some have higher risk than others do (Figure 13). More than a quarter of total census tracts within Charlotte (25%), Collier (34%), Franklin (25%), Lee (28%), and Monroe (65%) Counties are at high or extreme risk to Category 1 storm surge (Table 21). Within these places where storm surge could have the greatest impact reside some large populations within Charlotte (> 30,000), Collier (> 65,000), Franklin (> 1,500), Lee (> 150,000), and Monroe (> 44,000) Counties (Table 22). However, these numbers do not tell the whole story. Places like Miami-Dade County, which has very few high or extreme risk Category 1 census tracts (1.93% of total land area according to Table 21), can have many people at risk (> 39,000) (Table 22).

Both the total number of tracts and the total number of people increase in a nearly linear fashion as the hurricane surge category increases. As the intensity of the hurricane threat increases, so does the possible impact of people and places along the coast. Four hundred eighty-one tracts have a large percentage of their land area located in high or extreme risk areas for Category 2 storm surge (Figure 14 and Table 23), in which 1.6 million people reside (Table 24). Category 3 surge zones represent nearly a doubling of the number of tracts (Table 25) at risk (n=805) and an increase of the population at high or extreme risk to 2.9 million across the state (Table 26). For Category 4 storms, 35 counties have census tracts (n=1,109) in the high and extreme risk zones (Table 27). Populations in these areas of high surge risk exceed 4.2 million people across the state with one-quarter of a million or more in Hillsborough (274,000), Lee (564,000), Miami-Dade (883,000), and Pinellas (454,000) Counties (Table 28). High and extreme risk areas for Category 5 storms include 1,438 census tracts across 36 counties representing 5.6 million people (Table 29 and Table 30).

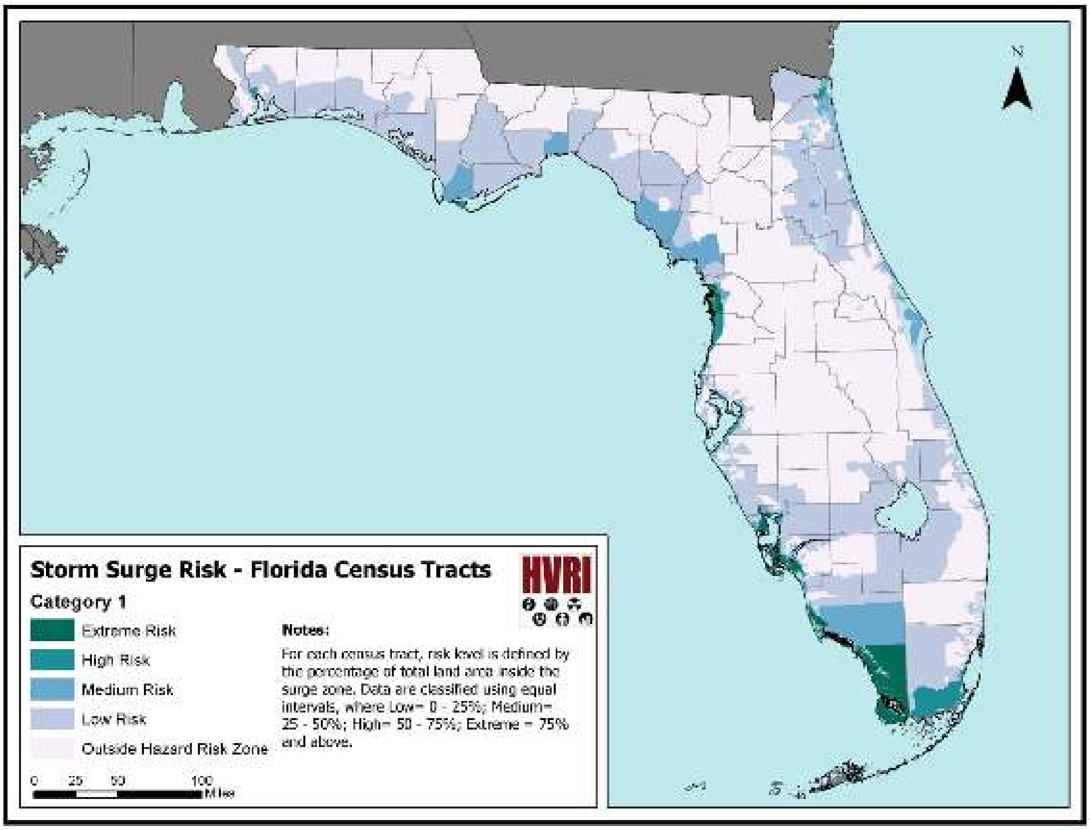

Figure 13: Category 1 storm surge risk in Florida.

Table 21: Census tract summary for Category 1 storm surge risk.

County Name	Category 1 Storm Surge Hazard Risk					County Name	Category 1 Storm Surge Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out		Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	-	100.00%	Lee	14.97%	13.17%	8.38%	25.15%	38.32%
Baker	-	-	-	-	100.00%	Leon	-	-	-	-	100.00%
Bay	-	-	-	84.09%	15.91%	Levy	-	-	10.00%	30.00%	60.00%
Bradford	-	-	-	-	100.00%	Liberty	-	-	-	100.00%	-
Brevard	-	-	5.31%	46.90%	47.79%	Madison	-	-	-	-	100.00%
Broward	-	0.28%	1.11%	27.70%	70.91%	Manatee	2.56%	6.41%	5.13%	38.46%	47.44%
Calhoun	-	-	-	-	100.00%	Marion	-	-	-	4.76%	95.24%
Charlotte	10.26%	15.38%	20.51%	43.59%	10.26%	Martin	-	-	5.88%	61.76%	32.35%
Citrus	7.14%	-	10.71%	10.71%	71.43%	Miami-Dade	-	1.93%	0.77%	36.99%	60.31%
Clay	-	-	3.33%	63.33%	33.33%	Monroe	22.58%	41.94%	19.35%	12.90%	3.23%
Collier	20.27%	13.51%	8.11%	36.49%	21.62%	Nassau	-	8.33%	8.33%	75.00%	8.33%
Columbia	-	-	-	-	100.00%	Okaloosa	-	-	-	68.29%	31.71%
DeSoto	-	-	11.11%	33.33%	55.56%	Okeechobee	-	-	9.09%	54.55%	36.36%
Dixie	-	-	33.33%	33.33%	33.33%	Orange	-	-	-	-	100.00%
Duval	-	0.58%	6.36%	47.98%	45.09%	Osceola	-	-	-	-	100.00%
Escambia	-	-	-	42.25%	57.75%	Palm Beach	-	-	0.60%	21.43%	77.98%
Flagler	-	5.00%	20.00%	30.00%	45.00%	Pasco	5.22%	2.24%	2.99%	9.70%	79.85%
Franklin	-	25.00%	25.00%	50.00%	-	Pinellas	4.08%	8.57%	6.53%	34.29%	46.53%
Gadsden	-	-	-	-	100.00%	Polk	-	-	-	-	100.00%
Gilchrist	-	-	-	40.00%	60.00%	Putnam	-	-	17.65%	64.71%	17.65%
Glades	-	-	-	75.00%	25.00%	Santa Rosa	-	4.00%	-	72.00%	24.00%
Gulf	-	-	33.33%	66.67%	-	Sarasota	3.19%	5.32%	6.38%	55.32%	29.79%
Hamilton	-	-	-	-	100.00%	Seminole	-	-	-	-	100.00%
Hardee	-	-	-	-	100.00%	St. Johns	-	5.13%	17.95%	66.67%	10.26%
Hendry	-	-	-	83.33%	16.67%	St. Lucie	-	6.82%	4.55%	43.18%	45.45%
Hernando	-	8.89%	-	-	91.11%	Sumter	-	-	-	-	100.00%
Highlands	-	-	-	3.70%	96.30%	Suwannee	-	-	-	-	100.00%
Hillsborough	1.25%	1.87%	4.36%	19.94%	72.59%	Taylor	-	-	-	50.00%	50.00%
Holmes	-	-	-	-	100.00%	Union	-	-	-	-	100.00%
Indian River	-	-	6.67%	60.00%	33.33%	Volusia	-	0.88%	7.02%	33.33%	58.77%
Jackson	-	-	-	-	100.00%	Wakulla	-	-	25.00%	75.00%	-
Jefferson	-	-	-	33.33%	66.67%	Walton	-	-	-	54.55%	45.45%
Lafayette	-	-	-	50.00%	50.00%	Washington	-	-	-	14.29%	85.71%
Lake	-	-	-	-	100.00%	**State Total**	**1.87%**	**2.78%**	**3.44%**	**27.59%**	**64.32%**

Table 22: Census tract population summary for Category 1 storm surge risk.

County Name	Category 1 Storm Surge Hazard Risk					County Name	Category 1 Storm Surge Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out		Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	-	247,336	Lee	72,741	77,897	53,920	175,569	238,627
Baker	-	-	-	-	27,115	Leon	-	-	-	-	275,487
Bay	-	-	-	144,783	24,069	Levy	-	-	3,289	10,867	26,645
Bradford	-	-	-	-	28,520	Liberty	-	-	-	8,365	-
Brevard	-	-	23,342	197,825	322,202	Madison	-	-	-	-	19,224
Broward	-	1,533	13,272	410,914	1,322,347	Manatee	6,681	14,878	12,130	136,913	152,231
Calhoun	-	-	-	-	14,625	Marion	-	-	-	3,446	327,852
Charlotte	13,787	16,816	29,976	83,466	15,933	Martin	-	-	6,398	75,808	64,112
Citrus	9,092	-	15,609	12,806	103,729	Miami-Dade	-	39,683	19,116	897,358	1,536,970
Clay	-	-	13,596	147,755	29,514	Monroe	13,465	31,503	20,421	7,681	20
Collier	40,113	25,665	22,949	137,476	95,317	Nassau	-	12,311	1,759	55,185	4,059
Columbia	-	-	-	-	67,531	Okaloosa	-	-	-	108,985	71,837
DeSoto	-	-	1,218	9,431	24,213	Okeechobee	-	-	4,221	18,987	16,788
Dixie	-	-	4,101	7,331	4,990	Orange	-	-	-	-	1,145,956
Duval	-	6,261	55,662	406,195	396,145	Osceola	-	-	-	-	268,685
Escambia	-	-	-	131,964	165,655	Palm Beach	-	-	3,481	252,424	1,063,557
Flagler	-	3,217	11,313	27,674	53,492	Pasco	15,322	7,585	11,793	43,250	386,747
Franklin	-	1,690	2,804	7,055	-	Pinellas	22,665	69,607	57,706	331,813	434,751
Gadsden	-	-	-	-	46,389	Polk	-	-	-	-	602,095
Gilchrist	-	-	-	8,398	8,541	Putnam	-	-	9,421	49,578	15,365
Glades	-	-	-	12,884	-	Santa Rosa	-	4,266	-	117,951	29,155
Gulf	-	-	4,450	11,413	-	Sarasota	6,363	9,748	19,467	197,053	146,817
Hamilton	-	-	-	-	14,799	Seminole	-	-	-	-	422,718
Hardee	-	-	-	-	27,731	St. Johns	-	6,822	22,136	147,532	13,549
Hendry	-	-	-	31,336	7,804	St. Lucie	-	9,527	4,520	119,023	144,719
Hernando	-	12,229	-	-	160,549	Sumter	-	-	-	-	87,023
Highlands	-	-	-	5,124	93,662	Suwannee	-	-	-	-	41,551
Hillsborough	6,350	18,773	46,526	226,178	931,399	Taylor	-	-	-	13,097	9,473
Holmes	-	-	-	-	19,927	Union	-	-	-	-	15,535
Indian River	-	-	6,797	70,920	60,311	Volusia	-	2,315	23,659	148,548	320,071
Jackson	-	-	-	-	49,746	Wakulla	-	-	8,332	22,444	-
Jefferson	-	-	-	4,380	10,381	Walton	-	-	-	31,317	23,726
Lafayette	-	-	-	5,706	3,164	Washington	-	-	-	6,615	18,281
Lake	-	-	-	-	297,052	**State Total**	**206,579**	**372,326**	**533,384**	**5,080,823**	**12,597,814**

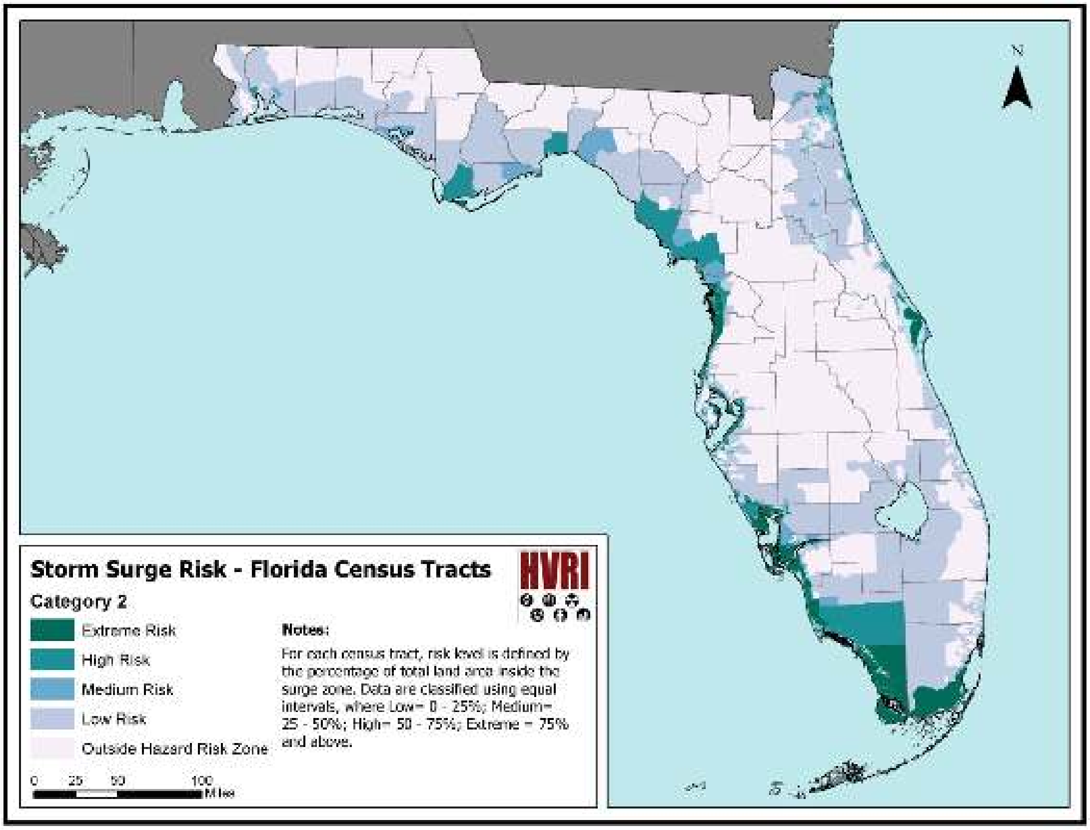

Figure 14: Category 2 storm surge risk in Florida.

Table 23: Census tract summary for Category 2 storm surge risk.

County Name	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out	County Name	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
	Category 2 Storm Surge Hazard Risk						Category 2 Storm Surge Hazard Risk				
Alachua	-	-	-	-	100.00%	Lee	50.90%	5.99%	6.59%	13.77%	22.75%
Baker	-	-	-	-	100.00%	Leon	-	-	-	-	100.00%
Bay	-	-	15.91%	72.73%	11.36%	Levy	-	10.00%	20.00%	10.00%	60.00%
Bradford	-	-	-	-	100.00%	Liberty	-	-	-	100.00%	-
Brevard	6.19%	7.96%	7.08%	32.74%	46.02%	Madison	-	-	-	-	100.00%
Broward	-	1.39%	2.22%	31.02%	65.37%	Manatee	8.97%	7.69%	7.69%	32.05%	43.59%
Calhoun	-	-	-	-	100.00%	Marion	-	-	-	4.76%	95.24%
Charlotte	64.10%	10.26%	7.69%	12.82%	5.13%	Martin	-	-	5.88%	61.76%	32.35%
Citrus	7.14%	14.29%	7.14%	10.71%	60.71%	Miami-Dade	3.85%	2.12%	6.74%	33.72%	53.56%
Clay	-	-	3.33%	63.33%	33.33%	Monroe	64.52%	22.58%	6.45%	3.23%	3.23%
Collier	72.97%	8.11%	5.41%	4.05%	9.46%	Nassau	-	16.67%	33.33%	41.67%	8.33%
Columbia	-	-	-	-	100.00%	Okaloosa	-	-	4.88%	63.41%	31.71%
DeSoto	-	-	11.11%	66.67%	22.22%	Okeechobee	-	-	18.18%	45.45%	36.36%
Dixie	-	33.33%	-	33.33%	33.33%	Orange	-	-	-	-	100.00%
Duval	-	2.31%	9.25%	45.66%	42.77%	Osceola	-	-	-	-	100.00%
Escambia	-	2.82%	1.41%	39.44%	56.34%	Palm Beach	0.60%	1.49%	4.17%	17.26%	76.49%
Flagler	5.00%	5.00%	20.00%	25.00%	45.00%	Pasco	8.96%	10.45%	7.46%	13.43%	59.70%
Franklin	25.00%	25.00%	25.00%	25.00%	-	Pinellas	18.78%	5.31%	12.65%	24.90%	38.37%
Gadsden	-	-	-	-	100.00%	Polk	-	-	-	-	100.00%
Gilchrist	-	-	-	40.00%	60.00%	Putnam	-	-	17.65%	64.71%	17.65%
Glades	-	-	-	75.00%	25.00%	Santa Rosa	-	4.00%	4.00%	80.00%	12.00%
Gulf	-	33.33%	-	66.67%	-	Sarasota	18.09%	9.57%	11.70%	39.36%	21.28%
Hamilton	-	-	-	-	100.00%	Seminole	-	-	-	-	100.00%
Hardee	-	-	-	-	100.00%	St. Johns	12.82%	7.69%	15.38%	56.41%	7.69%
Hendry	-	-	-	83.33%	16.67%	St. Lucie	6.82%	2.27%	2.27%	43.18%	45.45%
Hernando	6.67%	2.22%	-	2.22%	88.89%	Sumter	-	-	-	-	100.00%
Highlands	-	-	-	3.70%	96.30%	Suwannee	-	-	-	-	100.00%
Hillsborough	10.59%	2.18%	4.36%	16.82%	66.04%	Taylor	-	-	25.00%	50.00%	25.00%
Holmes	-	-	-	-	100.00%	Union	-	-	-	-	100.00%
Indian River	-	6.67%	13.33%	50.00%	30.00%	Volusia	0.88%	3.51%	7.89%	28.95%	58.77%
Jackson	-	-	-	-	100.00%	Wakulla	-	25.00%	-	75.00%	-
Jefferson	-	-	-	33.33%	66.67%	Walton	-	-	-	54.55%	45.45%
Lafayette	-	-	-	50.00%	50.00%	Washington	-	-	-	14.29%	85.71%
Lake	-	-	-	-	100.00%	**State Total**	**8.19%**	**3.23%**	**5.39%**	**23.58%**	**59.62%**

Table 24: Census tract population summary for Category 2 storm surge risk.

County Name	Category 2 Storm Surge Hazard Risk					County Name	Category 2 Storm Surge Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out		Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	-	247,336	Lee	326,862	38,451	39,784	91,074	122,583
Baker	-	-	-	-	27,115	Leon	-	-	-	-	275,487
Bay	-	-	26,398	124,208	18,246	Levy	-	3,289	4,656	6,211	26,645
Bradford	-	-	-	-	28,520	Liberty	-	-	-	8,365	-
Brevard	23,989	32,681	24,378	152,175	310,146	Madison	-	-	-	-	19,224
Broward	-	15,873	22,724	490,102	1,219,367	Manatee	16,517	25,983	22,072	122,551	135,710
Calhoun	-	-	-	-	14,625	Marion	-	-	-	3,446	327,852
Charlotte	93,807	14,823	19,947	29,491	1,910	Martin	-	-	6,398	75,808	64,112
Citrus	9,092	22,097	12,729	15,087	82,231	Miami-Dade	85,092	36,942	143,264	841,386	1,386,443
Clay	-	-	13,596	147,755	29,514	Monroe	50,873	15,354	5,744	1,099	20
Collier	187,749	24,311	29,482	35,089	44,889	Nassau	-	14,070	22,594	32,591	4,059
Columbia	-	-	-	-	67,531	Okaloosa	-	-	2,444	106,541	71,837
DeSoto	-	-	1,218	22,672	10,972	Okeechobee	-	-	6,316	16,892	16,788
Dixie	-	4,101	-	7,331	4,990	Orange	-	-	-	-	1,145,956
Duval	-	19,359	79,989	390,515	374,400	Osceola	-	-	-	-	268,685
Escambia	-	3,245	3,978	128,686	161,710	Palm Beach	2,673	10,779	35,697	223,207	1,047,106
Flagler	2,862	3,217	12,114	24,011	53,492	Pasco	29,636	39,078	31,695	66,663	297,625
Franklin	1,690	2,804	3,966	3,089	-	Pinellas	150,113	47,924	114,585	240,577	363,343
Gadsden	-	-	-	-	46,389	Polk	-	-	-	-	602,095
Gilchrist	-	-	-	8,398	8,541	Putnam	-	-	9,421	49,578	15,365
Glades	-	-	-	12,884	-	Santa Rosa	-	4,266	4,996	128,349	13,761
Gulf	-	4,450	-	11,413	-	Sarasota	41,160	32,194	44,256	177,791	84,047
Hamilton	-	-	-	-	14,799	Seminole	-	-	-	-	422,718
Hardee	-	-	-	-	27,731	St. Johns	16,699	11,457	23,055	128,266	10,562
Hendry	-	-	-	31,336	7,804	St. Lucie	9,527	2,777	1,743	119,023	144,719
Hernando	12,229	-	-	5,346	155,203	Sumter	-	-	-	-	87,023
Highlands	-	-	-	5,124	93,662	Suwannee	-	-	-	-	41,551
Hillsborough	117,296	17,186	49,424	199,578	845,742	Taylor	-	-	5,220	13,917	3,433
Holmes	-	-	-	-	19,927	Union	-	-	-	-	15,535
Indian River	-	6,797	12,047	64,227	54,957	Volusia	2,315	10,612	33,948	127,647	320,071
Jackson	-	-	-	-	49,746	Wakulla	-	8,332	-	22,444	-
Jefferson	-	-	-	4,380	10,381	Walton	-	-	-	31,317	23,726
Lafayette	-	-	-	5,706	3,164	Washington	-	-	-	6,615	18,281
Lake	-	-	-	-	297,052	**State Total**	**1,180,181**	**472,452**	**869,878**	**4,559,961**	**11,708,454**

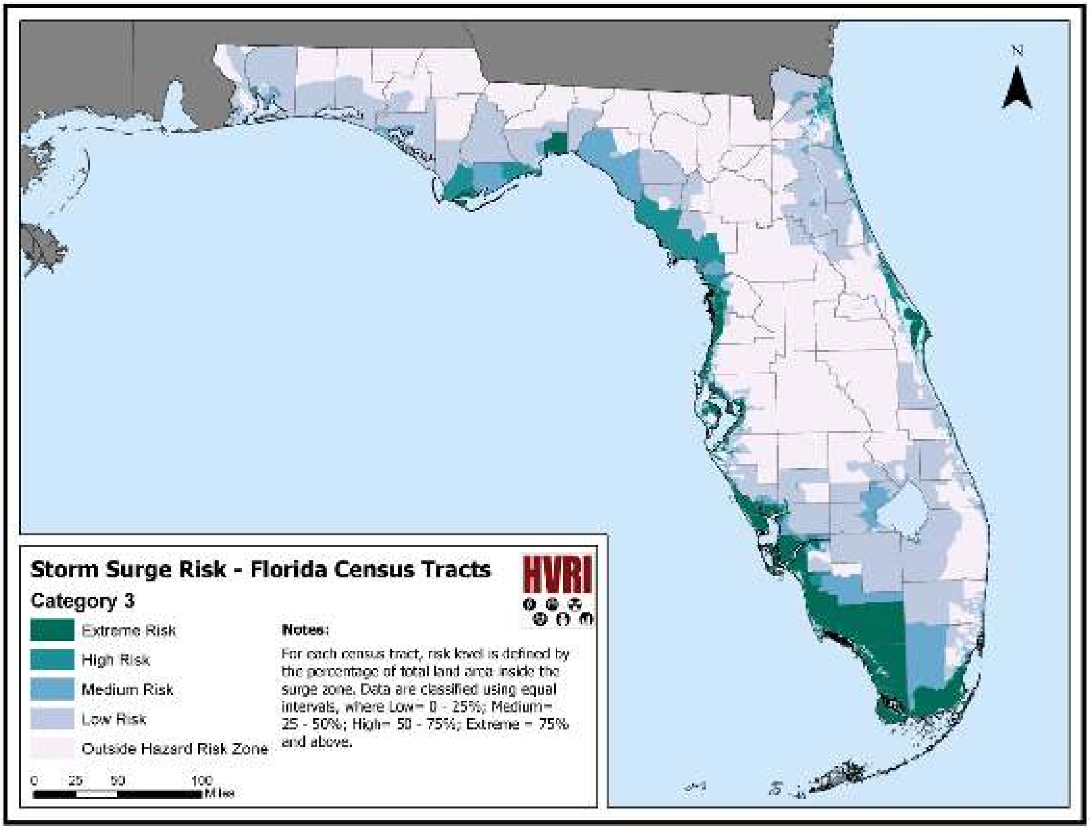

Figure 15: Category 3 storm surge risk in Florida.

Table 25: Census tract summary for Category 3 storm surge risk.

County Name	Category 3 Storm Surge Hazard Risk: Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out	County Name	Category 3 Storm Surge Hazard Risk: Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	-	100.00%	Lee	74.85%	4.19%	4.19%	4.19%	12.57%
Baker	-	-	-	-	100.00%	Leon	-	-	-	2.94%	97.06%
Bay	-	9.09%	18.18%	61.36%	11.36%	Levy	-	20.00%	10.00%	20.00%	50.00%
Bradford	-	-	-	-	100.00%	Liberty	-	-	-	100.00%	-
Brevard	27.43%	4.42%	2.65%	27.43%	38.05%	Madison	-	-	-	-	100.00%
Broward	1.39%	2.22%	6.37%	29.92%	60.11%	Manatee	17.95%	7.69%	10.26%	28.21%	35.90%
Calhoun	-	-	-	-	100.00%	Marion	-	-	-	4.76%	95.24%
Charlotte	79.49%	7.69%	5.13%	5.13%	2.56%	Martin	2.94%	-	17.65%	52.94%	26.47%
Citrus	10.71%	17.86%	-	10.71%	60.71%	Miami-Dade	9.25%	7.51%	8.86%	27.94%	46.44%
Clay	-	-	10.00%	56.67%	33.33%	Monroe	87.10%	6.45%	-	3.23%	3.23%
Collier	90.54%	1.35%	1.35%	-	6.76%	Nassau	8.33%	16.67%	33.33%	33.33%	8.33%
Columbia	-	-	-	-	100.00%	Okaloosa	2.44%	2.44%	9.76%	58.54%	26.83%
DeSoto	-	11.11%	11.11%	66.67%	11.11%	Okeechobee	-	-	18.18%	45.45%	36.36%
Dixie	-	33.33%	-	33.33%	33.33%	Orange	-	-	-	-	100.00%
Duval	7.51%	6.36%	6.94%	38.73%	40.46%	Osceola	-	-	-	-	100.00%
Escambia	2.82%	1.41%	5.63%	42.25%	47.89%	Palm Beach	0.89%	5.65%	4.17%	13.69%	75.60%
Flagler	15.00%	10.00%	15.00%	15.00%	45.00%	Pasco	25.37%	5.97%	6.72%	8.96%	52.99%
Franklin	50.00%	25.00%	25.00%	-	-	Pinellas	30.61%	8.57%	13.88%	17.55%	29.39%
Gadsden	-	-	-	-	100.00%	Polk	-	-	-	-	100.00%
Gilchrist	-	-	-	40.00%	60.00%	Putnam	-	-	17.65%	64.71%	17.65%
Glades	-	-	25.00%	50.00%	25.00%	Santa Rosa	-	4.00%	20.00%	68.00%	8.00%
Gulf	-	33.33%	-	66.67%	-	Sarasota	44.68%	7.45%	9.57%	20.21%	18.09%
Hamilton	-	-	-	-	100.00%	Seminole	-	-	-	-	100.00%
Hardee	-	-	-	-	100.00%	St. Johns	28.21%	15.38%	10.26%	38.46%	7.69%
Hendry	-	-	-	100.00%	-	St. Lucie	9.09%	-	2.27%	45.45%	43.18%
Hernando	6.67%	2.22%	-	13.33%	77.78%	Sumter	-	-	-	-	100.00%
Highlands	-	-	-	7.41%	92.59%	Suwannee	-	-	-	-	100.00%
Hillsborough	14.64%	4.67%	4.36%	14.95%	61.37%	Taylor	-	-	50.00%	25.00%	25.00%
Holmes	-	-	-	-	100.00%	Union	-	-	-	-	100.00%
Indian River	10.00%	16.67%	6.67%	36.67%	30.00%	Volusia	14.04%	5.26%	10.53%	18.42%	51.75%
Jackson	-	-	-	-	100.00%	Wakulla	25.00%	-	25.00%	50.00%	-
Jefferson	-	-	-	33.33%	66.67%	Walton	-	-	9.09%	45.45%	45.45%
Lafayette	-	-	-	50.00%	50.00%	Washington	-	-	-	14.29%	85.71%
Lake	-	-	-	-	100.00%	**State Total**	**14.54%**	**4.56%**	**5.95%**	**19.55%**	**55.40%**

Table 26: Census tract population summary for Category 3 storm surge risk.

County Name	Category 3 Storm Surge Hazard Risk					County Name	Category 3 Storm Surge Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out		Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	-	247,336	Lee	488,476	17,733	25,181	15,734	71,630
Baker	-	-	-	-	27,115	Leon	-	-	-	8,099	267,388
Bay	-	6,474	32,383	111,749	18,246	Levy	-	4,691	3,254	10,234	22,622
Bradford	-	-	-	-	28,520	Liberty	-	-	-	8,365	-
Brevard	106,206	16,922	11,132	160,492	248,617	Madison	-	-	-	-	19,224
Broward	15,759	27,890	87,256	495,734	1,121,427	Manatee	46,072	28,188	35,295	103,240	110,038
Calhoun	-	-	-	-	14,625	Marion	-	-	-	3,446	327,852
Charlotte	128,013	14,386	11,832	5,747	-	Martin	2,691	-	19,083	73,560	50,984
Citrus	13,747	30,171	-	15,087	82,231	Miami-Dade	223,803	153,340	185,334	738,875	1,191,775
Clay	-	-	32,358	128,993	29,514	Monroe	68,846	3,125	-	1,099	20
Collier	276,280	2,018	18,805	-	24,417	Nassau	1,759	15,076	23,165	29,255	4,059
Columbia	-	-	-	-	67,531	Okaloosa	1,354	1,090	12,728	101,000	64,650
DeSoto	-	1,218	2,308	26,648	4,688	Okeechobee	-	-	6,316	16,892	16,788
Dixie	-	4,101	-	7,331	4,990	Orange	-	-	-	-	1,145,956
Duval	52,436	58,739	45,056	352,107	355,925	Osceola	-	-	-	-	268,685
Escambia	3,245	3,978	12,012	140,514	137,870	Palm Beach	3,771	49,612	45,467	188,434	1,032,178
Flagler	8,933	5,337	10,929	17,005	53,492	Pasco	94,129	28,918	32,074	44,675	264,901
Franklin	4,494	3,966	3,089	-	-	Pinellas	258,191	79,406	133,678	174,981	270,286
Gadsden	-	-	-	-	46,389	Polk	-	-	-	-	602,095
Gilchrist	-	-	-	8,398	8,541	Putnam	-	-	9,421	49,578	15,365
Glades	-	-	3,748	9,136	-	Santa Rosa	-	4,266	27,178	110,071	9,857
Gulf	-	4,450	-	11,413	-	Sarasota	143,026	18,624	68,466	76,240	73,092
Hamilton	-	-	-	-	14,799	Seminole	-	-	-	-	422,718
Hardee	-	-	-	-	27,731	St. Johns	40,280	18,732	24,574	95,891	10,562
Hendry	-	-	-	39,140	-	St. Lucie	12,304	-	1,743	123,373	140,369
Hernando	12,229	-	-	19,922	140,627	Sumter	-	-	-	-	87,023
Highlands	-	-	-	6,442	92,344	Suwannee	-	-	-	-	41,551
Hillsborough	170,545	45,391	41,816	188,619	782,855	Taylor	-	-	13,097	6,040	3,433
Holmes	-	-	-	-	19,927	Union	-	-	-	-	15,535
Indian River	8,503	14,065	7,309	53,194	54,957	Volusia	55,018	24,839	50,721	80,179	283,836
Jackson	-	-	-	-	49,746	Wakulla	8,332	-	8,301	14,143	-
Jefferson	-	-	-	4,380	10,381	Walton	-	-	7,367	23,950	23,726
Lafayette	-	-	-	5,706	3,164	Washington	-	-	-	6,615	18,281
Lake	-	-	-	-	297,052	**State Total**	**2,248,442**	**686,746**	**1,052,476**	**3,911,726**	**10,891,536**

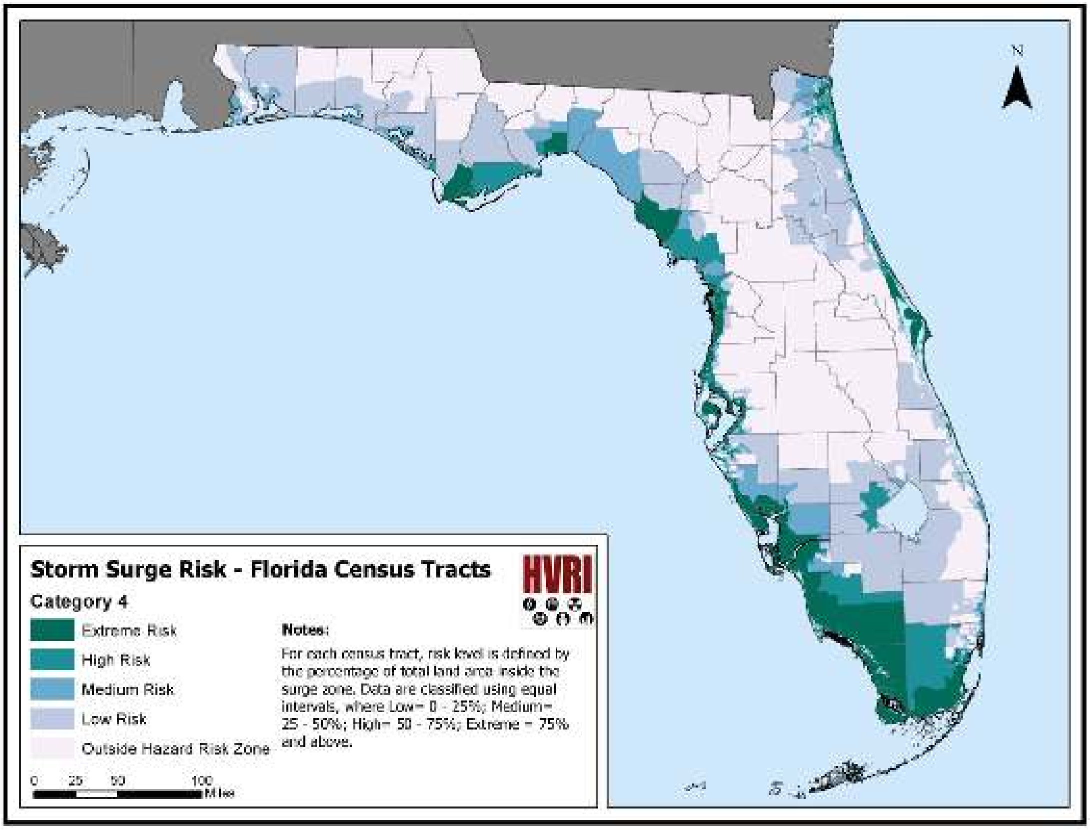

Figure 16: Category 4 storm surge risk in Florida.

Table 27: Census tract summary for Category 4 storm surge risk.

County Name	Category 4 Storm Surge Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	-	100.00%
Baker	-	-	-	-	100.00%
Bay	4.55%	22.73%	11.36%	50.00%	11.36%
Bradford	-	-	-	-	100.00%
Brevard	31.86%	3.54%	4.42%	29.20%	30.97%
Broward	4.43%	6.93%	8.03%	26.87%	53.74%
Calhoun	-	-	-	-	100.00%
Charlotte	92.31%	2.56%	2.56%	-	2.56%
Citrus	10.71%	17.86%	-	10.71%	60.71%
Clay	-	-	13.33%	53.33%	33.33%
Collier	90.54%	2.70%	1.35%	2.70%	2.70%
Columbia	-	-	-	-	100.00%
DeSoto	11.11%	-	22.22%	66.67%	-
Dixie	33.33%	-	-	66.67%	-
Duval	10.98%	6.94%	12.72%	30.64%	38.73%
Escambia	4.23%	4.23%	8.45%	39.44%	43.66%
Flagler	20.00%	5.00%	15.00%	15.00%	45.00%
Franklin	50.00%	50.00%	-	-	-
Gadsden	-	-	-	-	100.00%
Gilchrist	-	-	-	40.00%	60.00%
Glades	-	25.00%	-	50.00%	25.00%
Gulf	33.33%	-	-	66.67%	-
Hamilton	-	-	-	-	100.00%
Hardee	-	-	-	-	100.00%
Hendry	-	-	-	100.00%	-
Hernando	6.67%	2.22%	2.22%	17.78%	71.11%
Highlands	-	-	-	11.11%	88.89%
Hillsborough	21.18%	3.74%	4.98%	11.21%	58.88%
Holmes	-	-	-	-	100.00%
Indian River	30.00%	3.33%	3.33%	40.00%	23.33%
Jackson	-	-	-	-	100.00%
Jefferson	-	-	33.33%	-	66.67%
Lafayette	-	-	-	50.00%	50.00%
Lake	-	-	-	-	100.00%

County Name	Category 4 Storm Surge Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Lee	86.23%	2.40%	2.99%	4.19%	4.19%
Leon	-	-	1.47%	2.94%	95.59%
Levy	-	20.00%	20.00%	10.00%	50.00%
Liberty	-	-	-	100.00%	-
Madison	-	-	-	-	100.00%
Manatee	29.49%	7.69%	17.95%	25.64%	19.23%
Marion	-	-	-	4.76%	95.24%
Martin	2.94%	14.71%	17.65%	44.12%	20.59%
Miami-Dade	23.51%	13.49%	10.02%	21.58%	31.41%
Monroe	87.10%	6.45%	-	3.23%	3.23%
Nassau	41.67%	-	25.00%	25.00%	8.33%
Okaloosa	4.88%	4.88%	21.95%	41.46%	26.83%
Okeechobee	-	-	27.27%	36.36%	36.36%
Orange	-	-	-	-	100.00%
Osceola	-	-	-	-	100.00%
Palm Beach	2.98%	5.95%	6.55%	9.52%	75.00%
Pasco	34.33%	6.72%	3.73%	4.48%	50.75%
Pinellas	42.04%	8.57%	10.61%	13.47%	25.31%
Polk	-	-	-	-	100.00%
Putnam	-	-	17.65%	64.71%	17.65%
Santa Rosa	-	8.00%	28.00%	60.00%	4.00%
Sarasota	57.45%	5.32%	10.64%	11.70%	14.89%
Seminole	-	-	-	-	100.00%
St. Johns	38.46%	7.69%	7.69%	38.46%	7.69%
St. Lucie	9.09%	-	6.82%	40.91%	43.18%
Sumter	-	-	-	-	100.00%
Suwannee	-	-	-	-	100.00%
Taylor	-	-	75.00%	-	25.00%
Union	-	-	-	-	100.00%
Volusia	37.72%	4.39%	7.89%	8.77%	41.23%
Wakulla	25.00%	25.00%	25.00%	25.00%	-
Walton	-	9.09%	18.18%	27.27%	45.45%
Washington	-	-	-	14.29%	85.71%
State Total	**20.66%**	**5.65%**	**6.79%**	**16.13%**	**50.77%**

Table 28: Census tract population summary for Category 4 storm surge risk.

	Category 4 Storm Surge Hazard Risk						Category 4 Storm Surge Hazard Risk				
County Name	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out	County Name	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	-	247,336	Lee	551,533	12,534	23,240	18,560	12,887
Baker	-	-	-	-	27,115	Leon	-	-	3,108	9,969	262,410
Bay	3,101	31,502	26,708	89,295	18,246	Levy	-	4,691	9,465	4,023	22,622
Bradford	-	-	-	-	28,520	Liberty	-	-	-	8,365	-
Brevard	122,197	15,073	19,700	187,540	198,859	Madison	-	-	-	-	19,224
Broward	66,699	84,489	105,714	489,948	1,001,216	Manatee	84,514	29,491	58,348	89,551	60,929
Calhoun	-	-	-	-	14,625	Marion	-	-	-	3,446	327,852
Charlotte	154,008	2,133	3,837	-	-	Martin	2,691	17,607	21,780	64,226	40,014
Citrus	13,747	30,171	-	15,087	82,231	Miami-Dade	582,755	300,734	241,604	581,961	786,073
Clay	-	-	41,538	119,813	29,514	Monroe	68,846	3,125	-	1,099	20
Collier	276,280	20,823	5,920	11,176	7,321	Nassau	26,392	-	21,049	21,814	4,059
Columbia	-	-	-	-	67,531	Okaloosa	3,695	4,854	36,617	71,006	64,650
DeSoto	1,218	-	5,276	28,368	-	Okeechobee	-	-	8,119	15,089	16,788
Dixie	4,101	-	-	12,321	-	Orange	-	-	-	-	1,145,956
Duval	77,713	56,333	106,713	274,844	348,660	Osceola	-	-	-	-	268,685
Escambia	7,223	9,087	28,482	126,923	125,904	Palm Beach	28,894	47,890	85,410	134,305	1,022,963
Flagler	11,053	3,217	10,929	17,005	53,492	Pasco	137,222	33,682	19,852	24,822	249,119
Franklin	4,494	7,055	-	-	-	Pinellas	373,788	81,185	100,973	128,101	232,495
Gadsden	-	-	-	-	46,389	Polk	-	-	-	-	602,095
Gilchrist	-	-	-	8,398	8,541	Putnam	-	-	9,421	49,578	15,365
Glades	-	3,748	-	9,136	-	Santa Rosa	-	8,935	45,269	92,609	4,559
Gulf	4,450	-	-	11,413	-	Sarasota	215,998	19,959	38,171	44,947	60,373
Hamilton	-	-	-	-	14,799	Seminole	-	-	-	-	422,718
Hardee	-	-	-	-	27,731	St. Johns	54,327	7,585	21,674	95,891	10,562
Hendry	-	-	-	39,140	-	St. Lucie	12,304	-	9,114	116,002	140,369
Hernando	12,229	-	5,779	25,876	128,894	Sumter	-	-	-	-	87,023
Highlands	-	-	-	12,521	86,265	Suwannee	-	-	-	-	41,551
Hillsborough	245,534	28,919	64,289	131,293	759,191	Taylor	-	-	19,137	-	3,433
Holmes	-	-	-	-	19,927	Union	-	-	-	-	15,535
Indian River	26,701	3,176	3,750	64,900	39,501	Volusia	141,763	22,092	42,548	53,767	234,423
Jackson	-	-	-	-	49,746	Wakulla	8,332	8,301	8,867	5,276	-
Jefferson	-	-	4,380	-	10,381	Walton	-	7,367	12,304	11,646	23,726
Lafayette	-	-	-	5,706	3,164	Washington	-	-	-	6,615	18,281
Lake	-	-	-	-	297,052	**State Total**	**3,323,802**	**905,758**	**1,269,085**	**3,333,371**	**9,958,910**

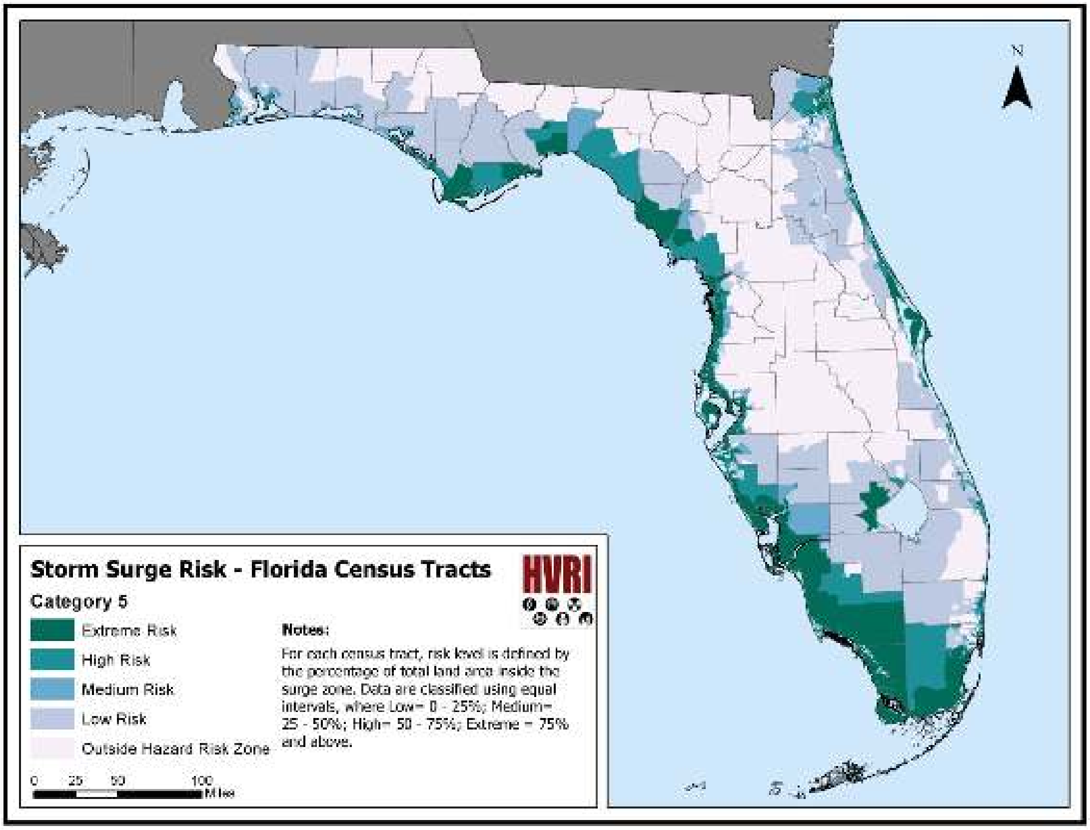

Figure 17: Category 5 storm surge risk in Florida.

Table 29: Census tract summary for Category 5 storm surge risk.

County Name	Category 5 Storm Surge Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	-	100.00%
Baker	-	-	-	-	100.00%
Bay	22.73%	15.91%	9.09%	45.45%	6.82%
Bradford	-	-	-	-	100.00%
Brevard	38.94%	6.19%	5.31%	26.55%	23.01%
Broward	13.30%	9.42%	4.71%	23.55%	49.03%
Calhoun	-	-	-	66.67%	33.33%
Charlotte	92.31%	2.56%	2.56%	-	2.56%
Citrus	14.29%	14.29%	-	14.29%	57.14%
Clay	-	-	16.67%	53.33%	30.00%
Collier	90.54%	5.41%	1.35%	-	2.70%
Columbia	-	-	-	-	100.00%
DeSoto	11.11%	11.11%	11.11%	66.67%	-
Dixie	33.33%	-	-	66.67%	-
Duval	17.92%	8.09%	9.83%	32.37%	31.79%
Escambia	5.63%	7.04%	7.04%	39.44%	40.85%
Flagler	30.00%	15.00%	-	20.00%	35.00%
Franklin	75.00%	25.00%	-	-	-
Gadsden	-	-	-	-	100.00%
Gilchrist	-	-	20.00%	20.00%	60.00%
Glades	25.00%	-	-	50.00%	25.00%
Gulf	33.33%	33.33%	-	33.33%	-
Hamilton	-	-	-	-	100.00%
Hardee	-	-	-	33.33%	66.67%
Hendry	-	-	-	100.00%	-
Hernando	8.89%	8.89%	15.56%	8.89%	57.78%
Highlands	-	-	-	11.11%	88.89%
Hillsborough	25.23%	4.98%	6.54%	8.10%	55.14%
Holmes	-	-	-	-	100.00%
Indian River	33.33%	-	6.67%	40.00%	20.00%
Jackson	-	-	-	-	100.00%
Jefferson	-	-	33.33%	-	66.67%
Lafayette	-	-	-	50.00%	50.00%
Lake	-	-	-	-	100.00%

County Name	Category 5 Storm Surge Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Lee	94.01%	1.80%	0.60%	2.99%	0.60%
Leon	1.47%	1.47%	-	2.94%	94.12%
Levy	10.00%	20.00%	10.00%	10.00%	50.00%
Liberty	-	-	-	100.00%	-
Madison	-	-	-	-	100.00%
Manatee	48.72%	21.79%	5.13%	17.95%	6.41%
Marion	-	-	-	6.35%	93.65%
Martin	14.71%	26.47%	17.65%	29.41%	11.76%
Miami-Dade	42.77%	12.14%	8.86%	15.03%	21.19%
Monroe	90.32%	3.23%	-	3.23%	3.23%
Nassau	41.67%	16.67%	16.67%	25.00%	-
Okaloosa	12.20%	9.76%	29.27%	26.83%	21.95%
Okeechobee	-	9.09%	18.18%	45.45%	27.27%
Orange	-	-	-	-	100.00%
Osceola	-	-	-	-	100.00%
Palm Beach	7.44%	6.55%	5.65%	7.74%	72.62%
Pasco	40.30%	5.22%	2.99%	4.48%	47.01%
Pinellas	48.98%	10.61%	5.71%	11.43%	23.27%
Polk	-	-	-	-	100.00%
Putnam	-	-	17.65%	64.71%	17.65%
Santa Rosa	4.00%	16.00%	28.00%	48.00%	4.00%
Sarasota	72.34%	7.45%	5.32%	8.51%	6.38%
Seminole	-	-	-	-	100.00%
St. Johns	43.59%	5.13%	7.69%	35.90%	7.69%
St. Lucie	9.09%	6.82%	2.27%	40.91%	40.91%
Sumter	-	-	-	-	100.00%
Suwannee	-	-	-	-	100.00%
Taylor	-	50.00%	25.00%	-	25.00%
Union	-	-	-	-	100.00%
Volusia	40.35%	6.14%	6.14%	7.89%	39.47%
Wakulla	50.00%	25.00%	-	25.00%	-
Walton	-	9.09%	18.18%	27.27%	45.45%
Washington	-	-	-	28.57%	71.43%
State Total	**27.31%**	**6.81%**	**5.43%**	**13.88%**	**46.57%**

Table 30: Census tract population summary for Category 5 storm surge risk.

County Name	Category 5 Storm Surge Hazard Risk					County Name	Category 5 Storm Surge Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out		Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	-	247,336	Lee	591,863	12,534	2,800	11,557	-
Baker	-	-	-	-	27,115	Leon	4,991	3,108	-	9,883	257,505
Bay	24,753	33,155	15,353	86,526	9,065	Levy	1,402	6,543	6,211	4,023	22,622
Bradford	-	-	-	-	28,520	Liberty	-	-	-	8,365	-
Brevard	152,406	30,006	29,119	179,447	152,391	Madison	-	-	-	-	19,224
Broward	175,493	124,565	82,085	439,193	926,730	Manatee	147,238	75,856	15,357	61,569	22,813
Calhoun	-	-	-	12,192	2,433	Marion	-	-	-	9,822	321,476
Charlotte	154,008	2,133	3,837	-	-	Martin	16,120	35,030	23,043	57,272	14,853
Citrus	20,065	23,853	-	19,673	77,645	Miami-Dade	1,065,743	287,344	228,214	383,815	528,011
Clay	-	-	51,691	112,579	26,595	Monroe	71,971	-	-	1,099	20
Collier	276,280	33,112	4,807	-	7,321	Nassau	26,392	13,608	14,272	19,042	-
Columbia	-	-	-	-	67,531	Okaloosa	13,639	10,593	54,442	49,114	53,034
DeSoto	1,218	2,308	2,968	28,368	-	Okeechobee	-	1,803	6,316	19,890	11,987
Dixie	4,101	-	-	12,321	-	Orange	-	-	-	-	1,145,956
Duval	130,682	88,084	72,233	284,053	289,211	Osceola	-	-	-	-	268,685
Escambia	12,011	12,569	25,903	130,787	116,349	Palm Beach	79,166	62,776	75,570	113,458	988,492
Flagler	18,868	10,648	-	25,208	40,972	Pasco	168,610	26,412	17,687	20,805	231,183
Franklin	8,460	3,089	-	-	-	Pinellas	444,404	94,518	53,109	109,472	215,039
Gadsden	-	-	-	-	46,389	Polk	-	-	-	-	602,095
Gilchrist	-	-	3,040	5,358	8,541	Putnam	-	-	9,421	49,578	15,365
Glades	3,748	-	-	9,136	-	Santa Rosa	5,763	20,333	43,230	77,487	4,559
Gulf	4,450	3,076	-	8,337	-	Sarasota	264,135	29,899	14,958	40,377	30,079
Hamilton	-	-	-	-	14,799	Seminole	-	-	-	-	422,718
Hardee	-	-	-	10,347	17,384	St. Johns	59,012	8,234	17,177	95,054	10,562
Hendry	-	-	-	39,140	-	St. Lucie	12,304	9,114	4,468	115,019	136,884
Hernando	16,258	12,328	23,756	17,881	102,555	Sumter	-	-	-	-	87,023
Highlands	-	-	-	12,521	86,265	Suwannee	-	-	-	-	41,551
Hillsborough	278,825	73,528	69,702	99,775	707,396	Taylor	-	13,097	6,040	-	3,433
Holmes	-	-	-	-	19,927	Union	-	-	-	-	15,535
Indian River	29,877	-	7,638	67,126	33,387	Volusia	151,544	34,019	39,785	46,696	222,549
Jackson	-	-	-	-	49,746	Wakulla	16,633	8,867	-	5,276	-
Jefferson	-	-	4,380	-	10,381	Walton	-	7,367	12,304	11,646	23,726
Lafayette	-	-	-	5,706	3,164	Washington	-	-	-	10,239	14,657
Lake	-	-	-	-	297,052	**State Total**	**4,452,433**	**1,213,509**	**1,040,916**	**2,936,232**	**9,147,836**

Analyzing Hurricane Storm Surge in Combination with SoVI and MedVI

About Bivariate Classifications

Here we keep the exposure constant by using the same hazard threat surface but use different vulnerability perspectives (Social and Medical) in bivariate representations to create an easily understood depiction of not only increased threat but also a limited ability to adequately prepare for and respond to these threats. In doing so, we are able to quickly identify three specific geographic areas of interest:

1. Areas where the hazard itself should be the focus of planning and mitigation,
2. Areas where understanding the underlying socioeconomics and demographics would prove to be the most advantageous input point to create positive change, and
3. Areas where a combination of classic hazard mitigation techniques and social mitigation practices should be utilized in order to maximize optimal outcomes.

The following maps utilize a three by three bivariate representation in which one can easily identify areas of limited to elevated SoVI in relation to areas with low to extreme hazard classifications. Places identified in item number one in the preceding list are shaded in the blue colors and can be understood as locations where hazard susceptibility is higher than SoVI or MedVI. Areas identified in item number two above, indicating where socioeconomics and demographics play an important role, are shaded in the pink/red colors and can be conceived as locations where SoVI or MedVI are greater than physical hazard threats. Places identified in item number three above are shaded either in gray-tones or in a dark burgundy color and can be understood as areas that have equal vulnerability and hazard classification scores.

Integrating Category 1 Storm Surge Risk with SoVI and MedVI

The threat of hurricane storm surge is greatest in low-lying areas. Figure 18 represents the combination of social vulnerability and threat from Category 1 storm surge across the state. Even a "small" Category 1 hurricane making landfall could have dire consequences for many places. Collier, Lee, Pasco, and Pinellas Counties all have census tracts characterized with high SoVI and at extreme risk during a Category 1 hurricane, representing almost 17,000 people (Table 31). Census tracts with high SoVI and at high risk are in Collier, Hillsborough, Lee, Miami-Dade, and Pinellas Counties, totaling 9 tracts and over 40,000 people (Table 31).

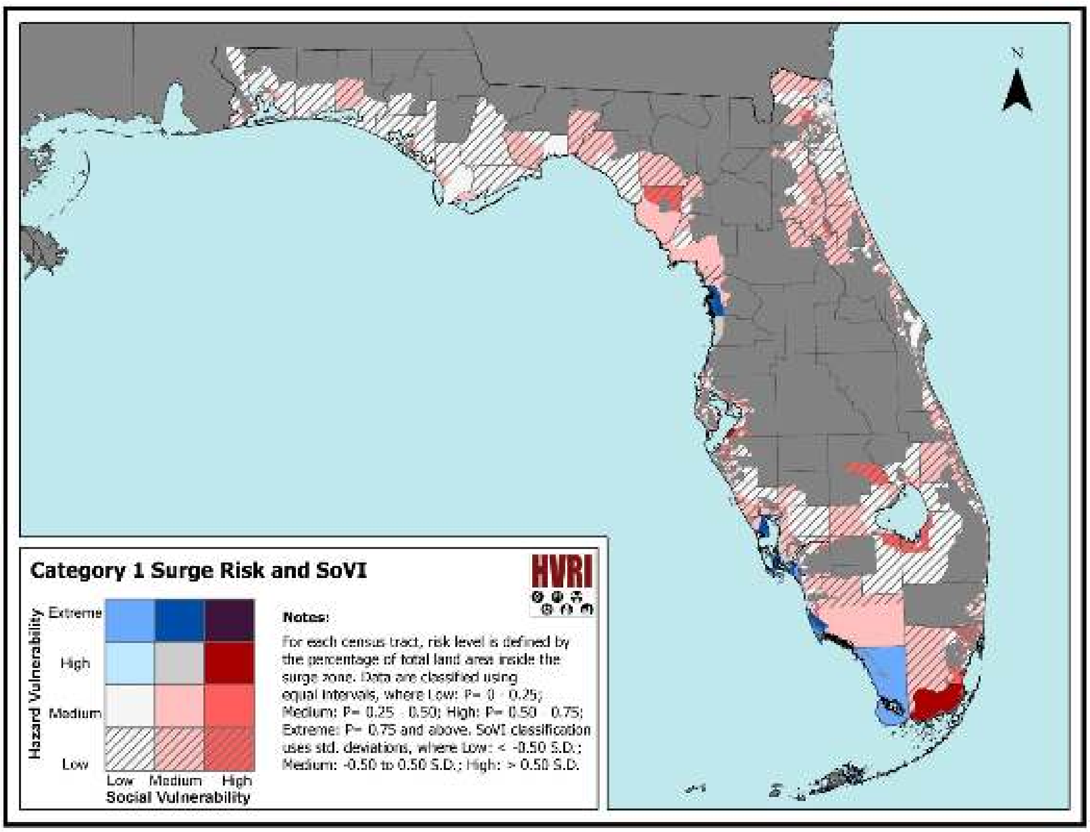

Figure 18: Bivariate representation of SoVI and Category 1 storm surge risk in Florida.

Table 31: Tract and population summary for counties with high SoVI and medium or greater Category 1 storm surge risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Category 1 Storm Surge								
Collier	1	2,225	Lee	4	11,647	Pasco	1	1,487
Pinellas	1	1,463		-	-		-	-
State Total	**7**	**16,822**		-	-		-	-
High Risk from Category 1 Storm Surge								
Collier	1	1,184	Hillsborough	1	1,304	Lee	1	2,768
Miami-Dade	5	31,942	Pinellas	1	3,252		-	-
State Total	**9**	**40,450**		-	-		-	-
Medium Risk from Category 1 Storm Surge								
Hillsborough	2	8,439	Indian River	1	1,506	Lee	1	1,714
Manatee	1	4,914	Miami-Dade	1	9,319	Pasco	2	5,145
Pinellas	1	2,440	Putnam	1	3,107	Sarasota	1	2,562
St. Lucie	1	1,743		-	-		-	-
State Total	**12**	**40,889**		-	-		-	-

The combination of Category 1 storm surge and MedVI provides a similar picture where portions of the Big Bend area of Florida exhibit high MedVI but only low to medium Category 1 surge threat. However, low lying portions of Citrus and Hernando Counties on the Gulf Coast have both high to extreme MedVI and high to extreme hazard risk (Figure 19). In total, more than 200,000 people live across 19 counties characterized by both high medical vulnerability and medium or greater Category 1 storm surge risk (Table 32).

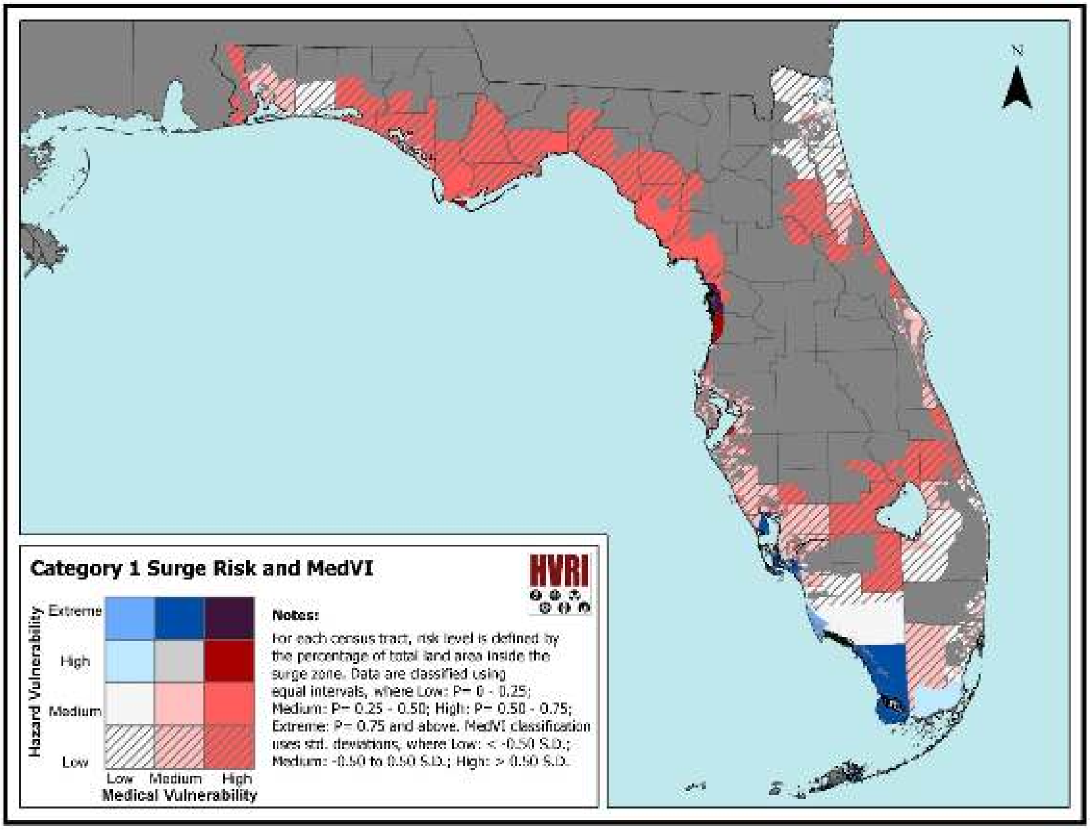

Figure 19: Bivariate representation of MedVI and Category1 storm surge risk in Florida.

Table 32: Tract and population summary for counties with high MedVI and medium or greater Category 1 storm surge risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Category 1 Storm Surge								
Citrus	2	9,092	Lee	1	9,415	Pasco	7	15,322
State Total	**10**	**33,829**		-	-		-	-
High Risk from Category 1 Storm Surge								
Flagler	1	3,217	Franklin	1	1,690	Hernando	3	12,229
Hillsborough	2	5,057	Lee	3	12,341	Pasco	2	5,198
St. Lucie	3	9,527	Volusia	1	2,315		-	-
State Total	**16**	**51,574**		-	-		-	-
Medium Risk from Category 1 Storm Surge								
Charlotte	1	4,425	Citrus	3	15,609	DeSoto	1	1,218
Dixie	1	4,101	Flagler	2	4,465	Franklin	1	2,804
Gulf	1	4,450	Hillsborough	1	2,721	Indian River	2	6,797
Lee	3	8,816	Levy	1	3,289	Okeechobee	1	4,221
Pasco	4	11,793	Pinellas	1	4,797	Putnam	2	9,421
St. Lucie	2	4,520	Volusia	8	23,659	Wakulla	1	8,332
State Total	**36**	**125,438**		-	-		-	-

Integrating Category 2 Storm Surge Risk with SoVI and MedVI

Category 2 storm surge is likely to heavily impact counties in southwest, west central, and south Florida along with Duval and Brevard Counties (Figure 20) where social vulnerability is also often elevated. Sixteen counties across the state have tracts that are both high in social vulnerability and have at least a medium level of risk from hurricane storm surge. Nearly 350,000 people live within the 85 census tracts meeting these criteria (Table 33).

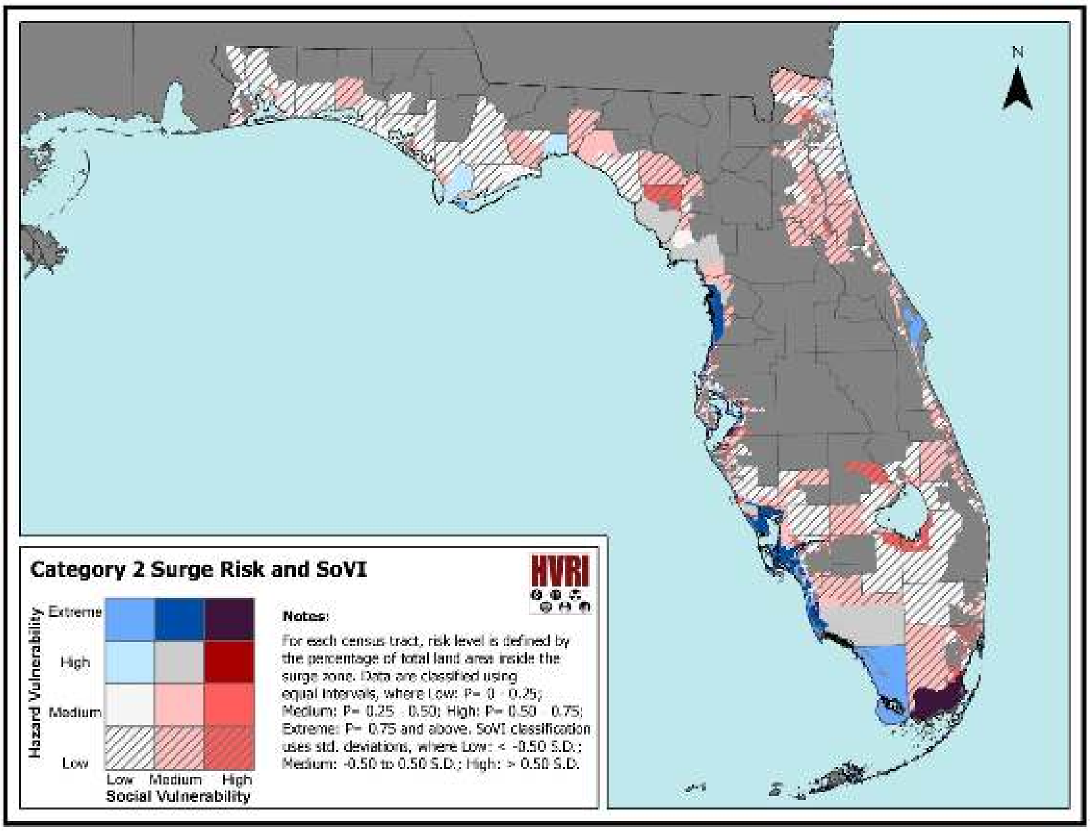

Figure 20: Bivariate representation of SoVI and Category 2 storm surge risk in Florida.

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Table 33: Tract and population summary for counties with high SoVI and medium or greater Category 2 storm surge risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Category 2 Storm Surge								
Charlotte	2	7,730	Collier	10	52,265	Hillsborough	3	11,504
Lee	7	18,770	Miami-Dade	9	54,607	Pasco	1	1,487
Pinellas	3	7,523	Sarasota	2	5,317		-	-
State Total	**37**	**159,203**		-	-		-	-
High Risk from Category 2 Storm Surge								
Broward	1	3,098	Charlotte	2	8,265	Hillsborough	2	6,931
Indian River	1	1,506	Lee	2	6,381	Manatee	2	9,322
Miami-Dade	1	4,106	Pasco	5	12,636	Pinellas	2	6,817
Sarasota	3	7,077		-	-		-	-
State Total	**21**	**66,139**		-	-		-	-
Medium Risk from Category 2 Storm Surge								
Citrus	1	6,411	Duval	2	7,238	Hillsborough	2	6,479
Indian River	2	4,060	Lee	3	11,051	Manatee	2	10,045
Miami-Dade	8	55,051	Okeechobee	1	2,095	Pasco	1	2,517
Pinellas	3	12,090	Putnam	1	3,107	St. Lucie	1	1,743
State Total	**27**	**121,887**		-	-		-	-

Coupling medical vulnerability with Category 2 storm surge generates a different view of risks and vulnerabilities across the state (Figure 21). More than 25 counties have populated census tracts characterized by high medical vulnerability corresponding with medium to extreme Category 2 storm surge. Table 34 provides details on the locations of the most medically vulnerable places at risk to Category 2 storm surge and includes nearly 160 census tracts and more than 550,000 people.

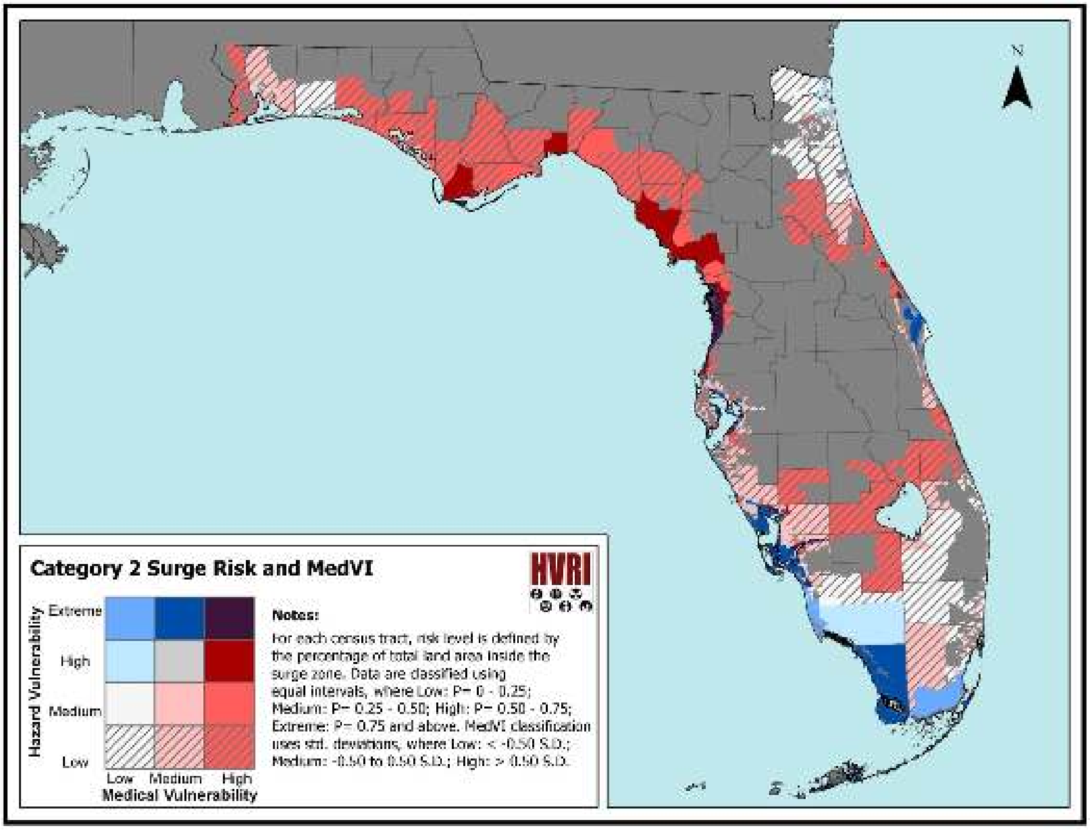

Figure 21: Bivariate representation of MedVI and Category 2 storm surge risk in Florida.

Table 34: Tract and population summary for counties with high MedVI and medium or greater Category 2 storm surge risk.

County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Category 2 Storm Surge										
Charlotte	5	22,311		Citrus	2	9,092		Franklin	1	1,690
Hernando	1	12,229		Hillsborough	4	10,820		Lee	15	73,462
Pasco	11	27,249		Pinellas	2	8,401		Sarasota	2	4,834
St. Lucie	3	9,527		Volusia	1	2,315			-	-
State Total	**47**	**181,930**			-	-			-	-
High Risk from Category 2 Storm Surge										
Charlotte	2	9,923		Citrus	4	22,097		Dixie	1	4,101
Escambia	2	3,245		Flagler	1	3,217		Franklin	1	2,804
Gulf	1	4,450		Hillsborough	1	3,736		Indian River	2	6,797
Lee	4	13,531		Levy	1	3,289		Manatee	1	3,476
Pasco	14	39,078		Pinellas	3	9,405		Sarasota	1	2,679
St. Lucie	1	2,777		Volusia	4	10,612		Wakulla	1	8,332
State Total	**45**	**153,549**			-	-			-	-
Medium Risk from Category 2 Storm Surge										
Bay	3	13,447		Citrus	2	12,729		DeSoto	1	1,218
Escambia	1	3,978		Flagler	2	4,465		Franklin	1	3,966
Hillsborough	6	15,864		Indian River	4	12,047		Lee	3	11,301
Levy	2	4,656		Okeechobee	2	6,316		Pasco	10	31,695
Pinellas	10	40,765		Putnam	2	9,421		Sarasota	4	21,814
St. Johns	1	3,518		St. Lucie	1	1,743		Taylor	1	5,220
Volusia	9	33,948			-	-			-	-
State Total	**65**	**238,111**			-	-			-	-

Integrating Category 3 Storm Surge Risk with SoVI and MedVI

Looking at the combination of social vulnerability and Category 3 storm surge we see that the west coast of Florida is extremely vulnerable from both the social and hazard perspectives (Figure 22). Table 35 indicates that 21 counties containing 155 census tracts and more than 650,000 people are characterized by high levels of social vulnerability and at least a medium level of Category 3 storm surge risk. In particular, Miami-Dade County has 23 census tracts and more than 140,000 people in the intersection of extreme hazard risk and high social vulnerability.

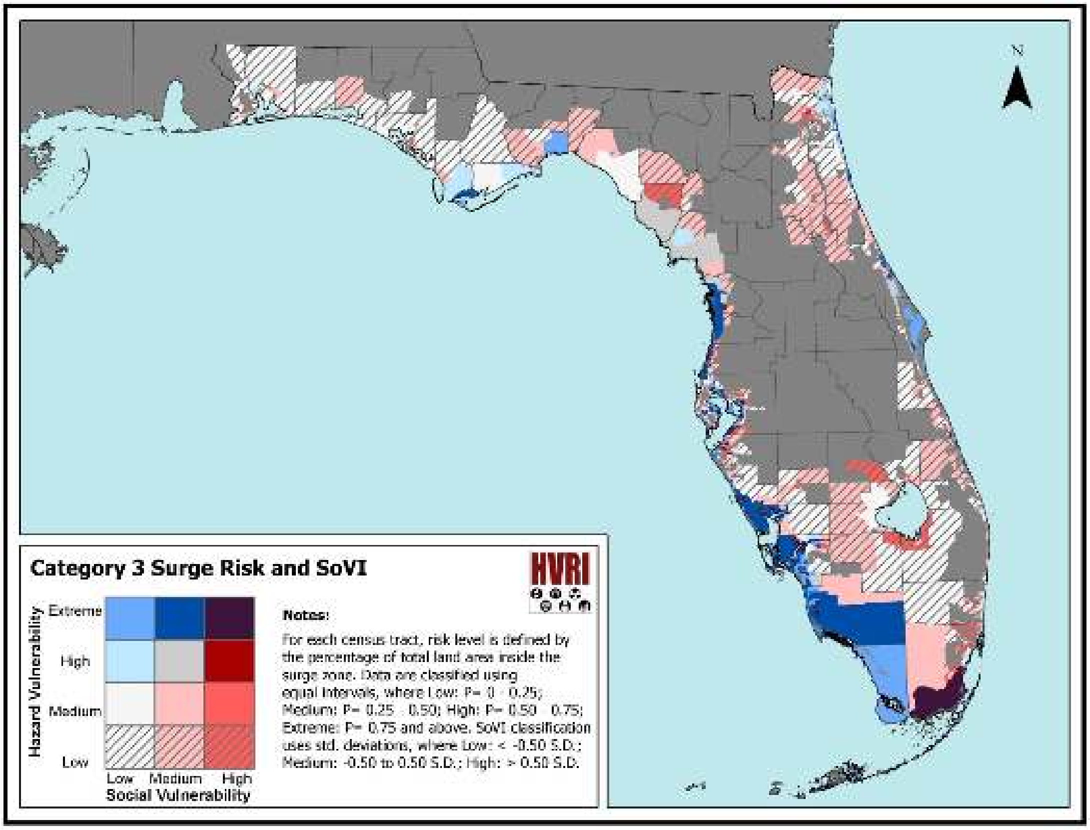

Figure 22: Bivariate representation of SoVI and Category 3 storm surge risk in Florida.

Table 35: Tract and population summary for counties with high SoVI and medium or greater Category 3 storm surge risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Category 3 Storm Surge								
Broward	1	3,098	Charlotte	4	15,995	Collier	10	52,265
Hillsborough	5	18,435	Indian River	2	3,212	Lee	17	53,007
Manatee	1	4,408	Miami-Dade	23	140,460	Pasco	5	11,272
Pinellas	5	13,891	Sarasota	7	22,157		-	-
State Total	**80**	**338,200**		-	-		-	-
High Risk from Category 3 Storm Surge								
Citrus	1	6,411	Duval	3	10,830	Hillsborough	4	15,402
Indian River	1	2,354	Lee	2	6,395	Manatee	3	15,416
Miami-Dade	10	57,571	Pasco	4	13,321	Pinellas	5	20,525
Sarasota	1	3,370		-	-		-	-
State Total	**34**	**151,595**		-	-		-	-
Medium Risk from Category 3 Storm Surge								
Brevard	1	3,232	DeSoto	1	2,308	Duval	5	14,145
Hillsborough	2	10,175	Manatee	1	5,502	Miami-Dade	15	79,529
Okeechobee	1	2,095	Palm Beach	2	6,999	Pasco	4	17,288
Pinellas	3	10,785	Putnam	1	3,107	Santa Rosa	1	6,115
Sarasota	1	5,257	St. Lucie	1	1,743	Volusia	2	6,722
State Total	**41**	**175,002**		-	-		-	-

The pattern of medical vulnerability for Category 3 storm surge paints much the same picture with large portions of the entire coast exhibiting medium or greater storm surge risk (Figure 23). Included in the 29 counties exhibiting both high medical vulnerability and medium or greater surge risk are 250 census tracts and nearly 1 million people (Table 36). Counties with the highest population at extreme risk are Lee and Pasco Counties with more than 122,000 and 91,000 people, respectively, living at extreme risk and exhibiting high medical vulnerability.

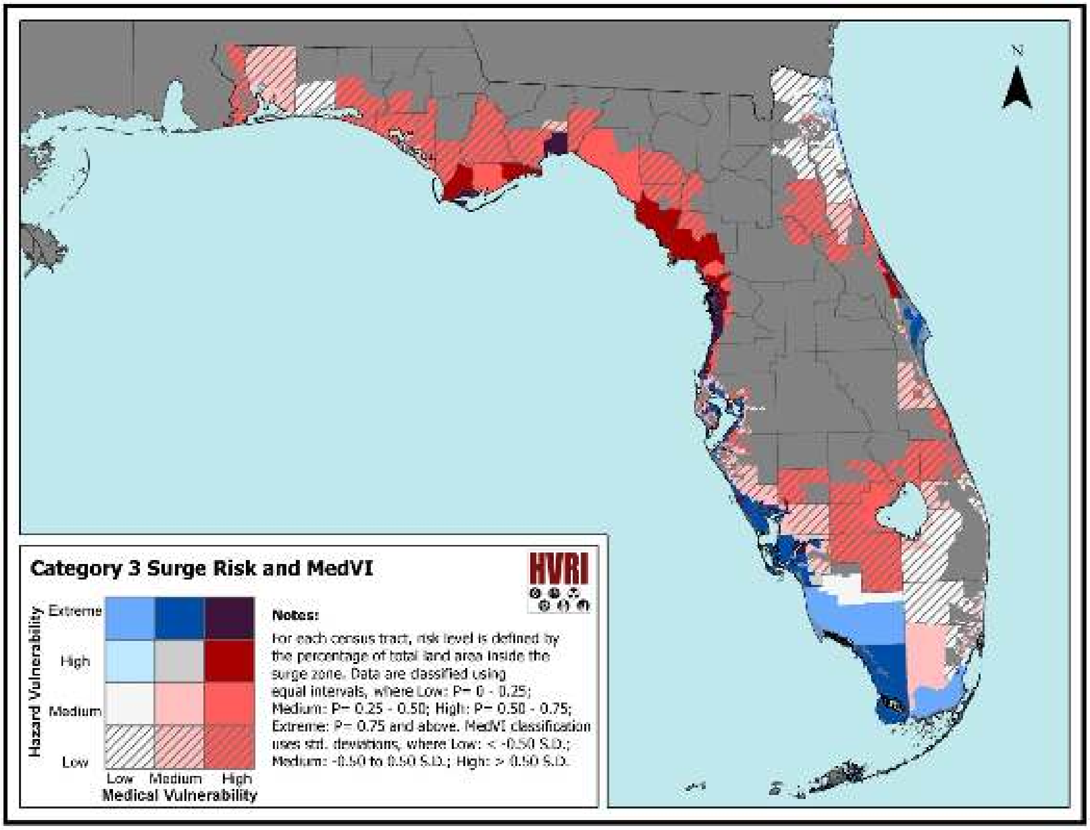

Figure 23: Bivariate representation of MedVI and Category 3 storm surge risk in Florida.

Table 36: Tract and population summary for counties with high MedVI and medium or greater Category 3 storm surge risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Category 3 Storm Surge								
Charlotte	7	32,234	Citrus	3	13,747	Escambia	2	3,245
Franklin	2	4,494	Hernando	3	12,229	Hillsborough	7	24,398
Indian River	3	8,503	Lee	28	122,331	Manatee	1	3,476
Pasco	33	91,742	Pinellas	8	30,874	Sarasota	11	44,950
St. Lucie	4	12,304	Volusia	16	55,018	Wakulla	1	8,332
State Total	**129**	**467,877**		-	-		-	-
High Risk from Category 3 Storm Surge								
Bay	2	3,373	Citrus	5	30,171	DeSoto	1	1,218
Dixie	1	4,101	Escambia	1	3,978	Flagler	2	5,337
Franklin	1	3,966	Gulf	1	4,450	Hillsborough	6	16,908
Indian River	5	14,065	Lee	1	2,489	Levy	2	4,691
Manatee	1	5,959	Pasco	8	28,918	Pinellas	8	32,963
Sarasota	2	6,101	St. Johns	1	3,518	Volusia	6	24,839
State Total	**54**	**197,045**		-	-		-	-
Medium Risk from Category 3 Storm Surge								
Bay	5	19,794	Brevard	1	3,232	DeSoto	1	2,308
Duval	2	4,901	Escambia	4	12,012	Flagler	2	6,943
Franklin	1	3,089	Glades	1	3,748	Hillsborough	3	8,850
Indian River	2	7,309	Levy	1	3,254	Okeechobee	2	6,316
Pasco	9	32,074	Pinellas	13	48,795	Putnam	2	9,421
Sarasota	1	5,257	St. Lucie	1	1,743	Taylor	2	13,097
Volusia	12	50,721	Wakulla	1	8,301	Walton	1	7,367
State Total	**67**	**258,532**		-	-		-	-

Integrating Category 4 Storm Surge Risk with SoVI and MedVI

The pattern of risk and vulnerability for Category 4 storm surge indicates a high level of hazard vulnerability along nearly the entire western Gulf Coast in addition to most of Miami-Dade and Palm Beach Counties (Figure 24). Fourteen counties including 158 census tracts and 700,000 people exhibit high social vulnerability coupled with extreme storm surge risk from Category 4 storms (Table 37). An additional 122 tracts and more than 550,000 people are classified as living within areas of medium or high risk.

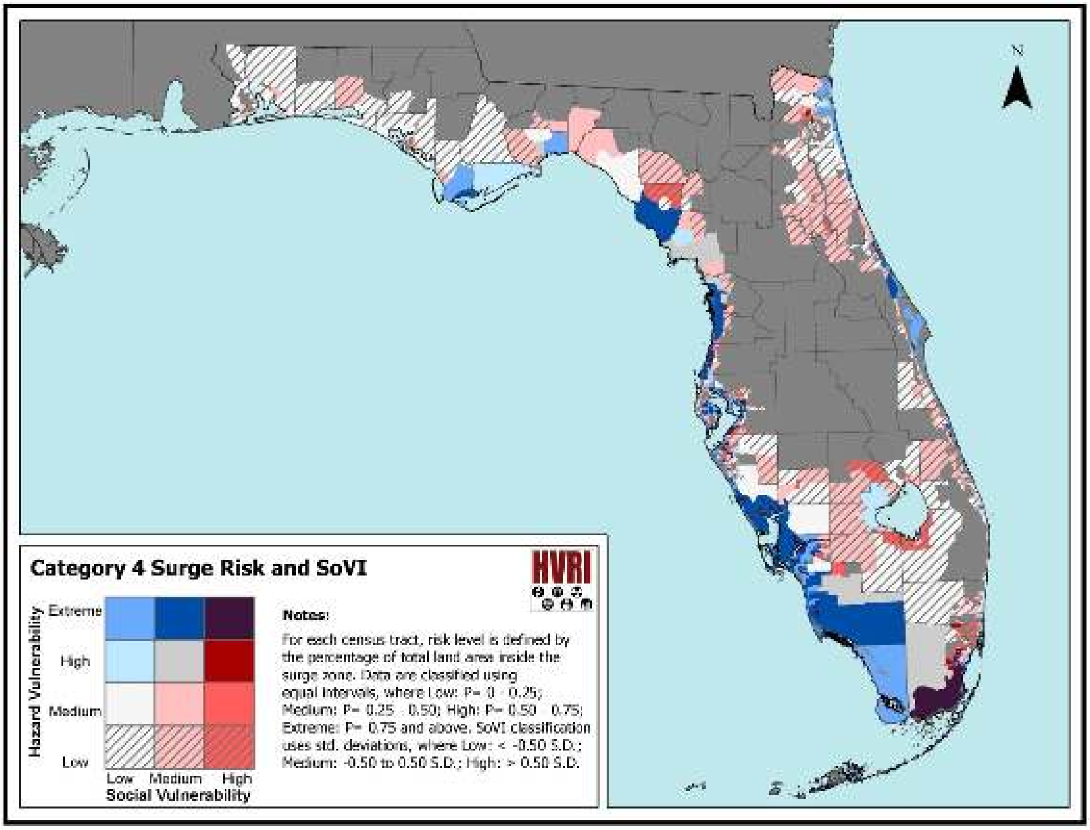

Figure 24: Bivariate representation of SoVI and Category 4 storm surge risk in Florida.

Table 37: Tract and population summary for counties with high SoVI and medium or greater Category 4 storm surge risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Category 4 Storm Surge								
Brevard	1	3,232	Broward	1	3,098	Charlotte	5	17,905
Collier	10	52,265	Duval	3	10,464	Hillsborough	9	33,837
Indian River	3	5,566	Lee	24	76,593	Manatee	5	25,326
Miami-Dade	63	368,005	Pasco	10	30,269	Pinellas	11	39,618
Sarasota	8	25,527	Volusia	5	16,050		-	-
State Total	**158**	**707,755**		-	-		-	-
High Risk from Category 4 Storm Surge								
Broward	2	8,813	Citrus	1	6,411	Duval	6	17,392
Hillsborough	2	8,538	Manatee	1	5,071	Miami-Dade	28	150,051
Pasco	3	11,612	Pinellas	4	13,968	Sarasota	1	5,257
State Total	**48**	**227,113**		-	-		-	-
Medium Risk from Category 4 Storm Surge								
Broward	4	20,101	Collier	1	5,920	DeSoto	1	2,308
Duval	5	21,683	Hernando	1	5,779	Hillsborough	6	23,000
Indian River	1	3,750	Lee	2	9,924	Manatee	7	28,299
Martin	1	2,217	Miami-Dade	28	149,135	Okeechobee	1	2,095
Palm Beach	2	6,999	Pasco	2	6,442	Pinellas	4	13,843
Putnam	1	3,107	Santa Rosa	1	6,115	Sarasota	1	3,851
St. Lucie	2	2,668	Volusia	3	13,550		-	-
State Total	**74**	**330,786**		-	-		-	-

Nearly the entire big bend area of the state is faced with high or extreme levels of surge threat along with high MedVI (Figure 25). Here, 39% of counties exhibiting medium to extreme risk have more than 30,000 people each in tracts characterized by high medical vulnerability (Table 38). Of these, Volusia County has the most at risk and medically vulnerable population (more than 200,000 people), followed by Pasco County with more than 188,000 people in 59 tracts.

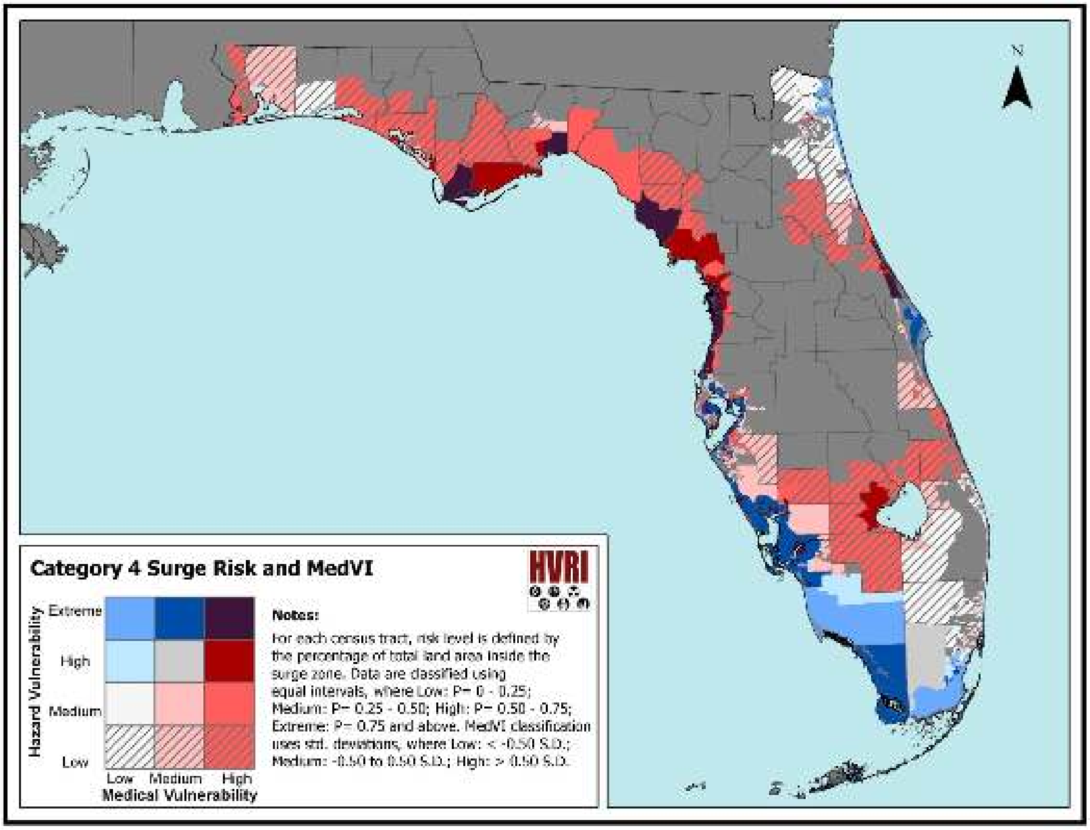

Figure 25: Bivariate representation of MedVI and Category 4 storm surge risk in Florida.

Table 38: Tract and population summary for counties with high MedVI and medium or greater Category 4 storm surge risk.

County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Category 4 Storm Surge										
Brevard	1	3,232		Charlotte	7	32,234		Citrus	3	13,747
DeSoto	1	1,218		Dixie	1	4,101		Escambia	3	7,223
Flagler	1	2,120		Franklin	2	4,494		Gulf	1	4,450
Hernando	3	12,229		Hillsborough	14	46,778		Indian River	9	26,701
Lee	29	124,820		Manatee	2	9,435		Pasco	45	134,835
Pinellas	20	87,154		Sarasota	13	51,051		St. Lucie	4	12,304
Volusia	43	141,763		Wakulla	1	8,332			-	-
State Total	**203**	**728,221**			-	-			-	-
High Risk from Category 4 Storm Surge										
Bay	7	18,913		Citrus	5	30,171		Duval	2	4,901
Escambia	3	9,087		Flagler	1	3,217		Franklin	2	7,055
Glades	1	3,748		Hillsborough	5	10,131		Indian River	1	3,176
Levy	2	4,691		Manatee	2	7,765		Pasco	9	33,682
Pinellas	3	13,295		Sarasota	1	5,257		St. Johns	1	3,518
Volusia	5	22,092		Wakulla	1	8,301		Walton	1	7,367
State Total	**52**	**196,367**			-	-			-	-
Medium Risk from Category 4 Storm Surge										
Bay	2	12,437		Brevard	1	3,300		DeSoto	2	5,276
Duval	2	11,567		Escambia	6	28,482		Flagler	2	6,943
Hernando	1	5,779		Hillsborough	6	20,453		Indian River	1	3,750
Jefferson	1	4,380		Lee	1	3,924		Levy	2	9,465
Manatee	5	17,853		Miami-Dade	1	2,453		Okeechobee	3	8,119
Pasco	5	19,852		Pinellas	13	45,963		Putnam	2	9,421
Sarasota	1	3,408		St. Lucie	3	9,114		Taylor	3	19,137
Volusia	9	42,548		Wakulla	1	8,867		Walton	2	12,304
State Total	**75**	**314,795**			-	-			-	-

Integrating Category 5 Storm Surge Risk with SoVI and MedVI

Category 5 storm surge risk reaches far inland to many tracts with medium to high social vulnerability. Nearly all of Lee County is situated in a high or extreme Category 5 risk zone and many of these tracts exhibit high levels of social vulnerability (Figure 26). Fifteen counties containing 225 census tracts and 1.2 million people are both at extreme risk of Category 5 storm surge and characterized by high social vulnerability (Table 39). An additional 71 tracts across 18 counties containing more than 330,000 people have high surge risk coupled with high vulnerability.

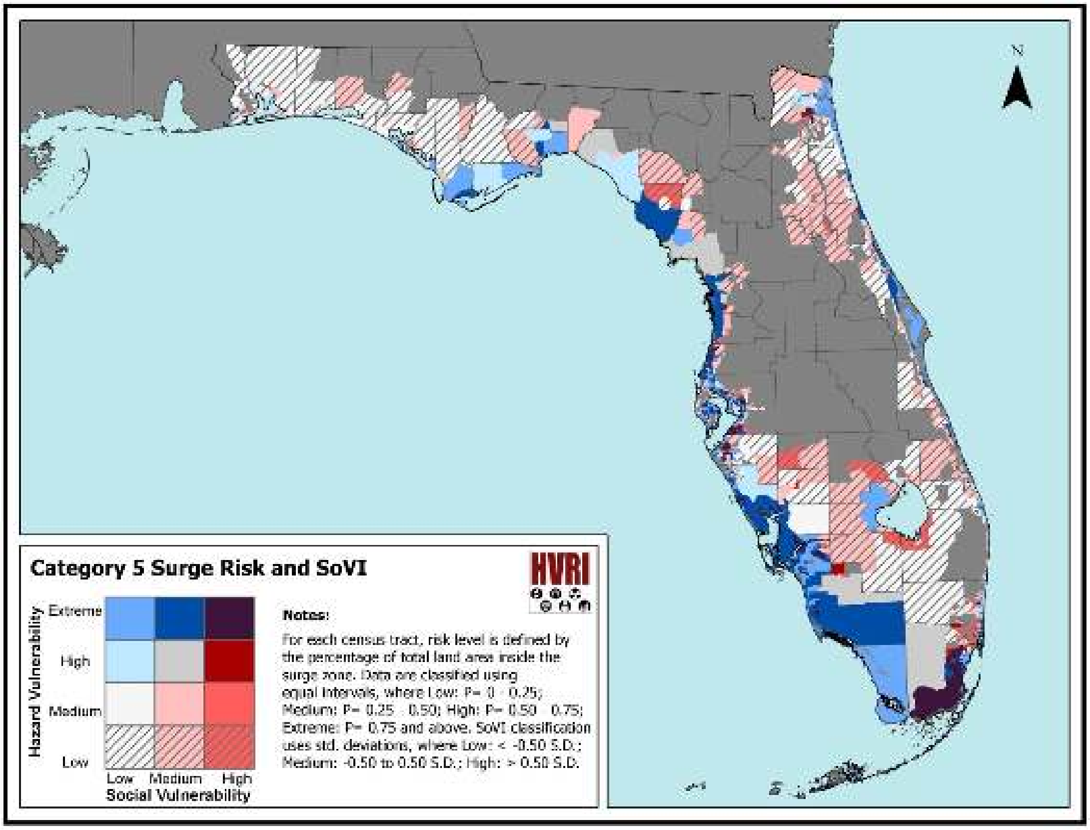

Figure 26: Bivariate representation of SoVI and Category 5 storm surge risk in Florida.

Table 39: Tract and population summary for counties with high SoVI and medium or greater Category 5 storm surge risk.

County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Category 5 Storm Surge										
Brevard	1	3,232		Broward	5	19,173		Charlotte	5	17,905
Collier	10	52,265		Duval	10	32,654		Hernando	1	4,029
Hillsborough	13	51,770		Indian River	3	5,566		Lee	29	95,433
Manatee	11	46,876		Miami-Dade	127	710,725		Pasco	12	37,488
Pinellas	14	51,146		Sarasota	9	30,784		Volusia	5	16,050
State Total	**255**	**1,175,096**			-	-			-	-
High Risk from Category 5 Storm Surge										
Brevard	1	2,486		Broward	2	9,456		Citrus	1	6,411
Collier	2	12,289		DeSoto	1	2,308		Duval	6	30,599
Flagler	1	4,317		Hernando	1	5,779		Hillsborough	4	15,445
Manatee	4	20,659		Martin	1	2,217		Miami-Dade	36	192,194
Palm Beach	1	2,472		Pasco	3	10,835		Pinellas	3	7,682
Sarasota	1	3,851		St. Lucie	2	2,668		Volusia	1	3,963
State Total	**71**	**335,631**			-	-			-	-
Medium Risk from Category 5 Storm Surge										
Broward	6	34,035		Collier	1	4,807		Duval	2	9,247
Hernando	4	10,363		Hillsborough	6	25,918		Indian River	1	3,750
Miami-Dade	32	182,801		Okeechobee	1	2,095		Palm Beach	4	17,875
Pinellas	3	15,334		Putnam	1	3,107		Santa Rosa	1	6,115
Sarasota	1	3,043		Volusia	2	9,587			-	-
State Total	**65**	**328,077**			-	-			-	-

All of south central Florida is at risk to Category 5 storm surge – depending on the direction of the storm – and a good portion of the Lake Okeechobee area has medium to high MedVI (Figure 27) indicating that these populations will require additional medical attention before, during, and following a disaster event. In fact, more than 915,000 residents within 255 census tracts across 25 counties exhibit both high medical vulnerability and extreme Category 5 storm surge risk (Table 40). Additionally, more than 250,000 people reside in high risk surge zones and more than 260,000 live in medium risk hazard zones while exhibiting high levels of medical vulnerability.

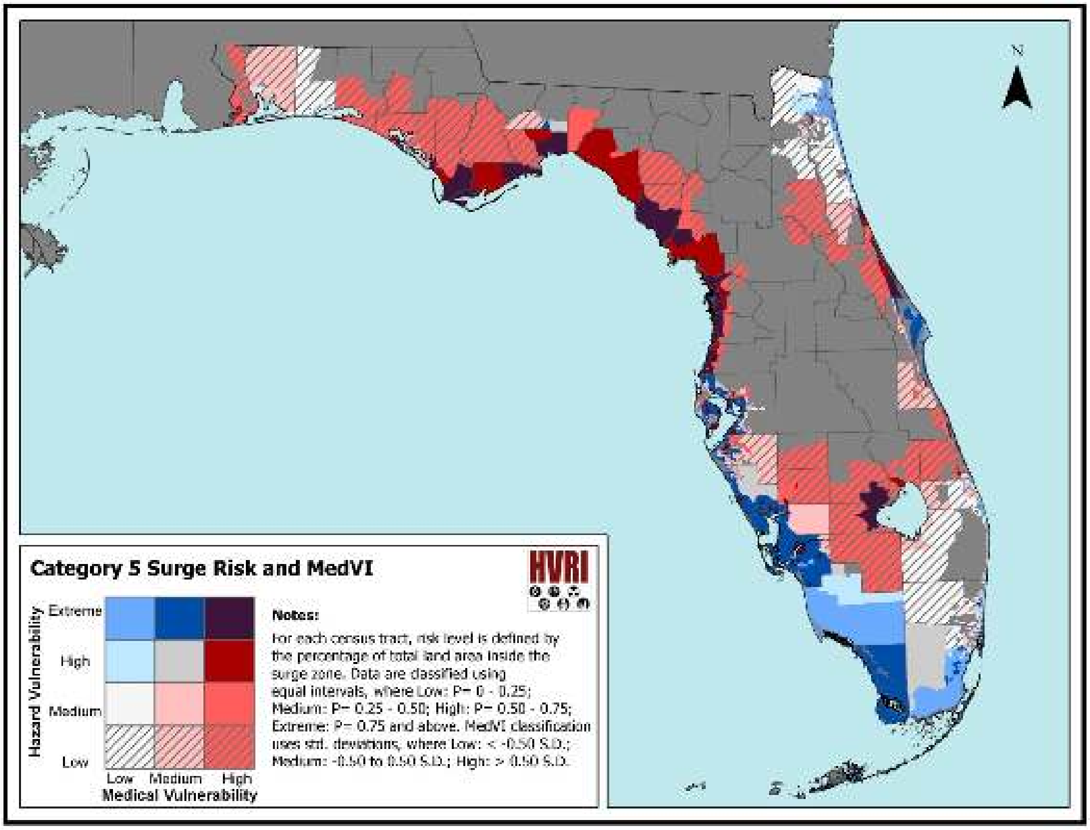

Figure 27: Bivariate representation of MedVI and Category 5 storm surge risk in Florida.

Table 40: Tract and population summary for counties with high MedVI and medium or greater Category 5 storm surge risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Category 5 Storm Surge								
Bay	7	18,913	Brevard	3	10,176	Charlotte	7	32,234
Citrus	4	20,065	DeSoto	1	1,218	Dixie	1	4,101
Duval	3	10,384	Escambia	4	12,011	Flagler	3	9,935
Franklin	3	8,460	Glades	1	3,748	Gulf	1	4,450
Hernando	4	16,258	Hillsborough	21	67,661	Indian River	10	29,877
Lee	32	136,588	Levy	1	1,402	Manatee	7	26,456
Pasco	53	166,223	Pinellas	22	96,127	Sarasota	14	56,308
St. Johns	1	3,518	St. Lucie	4	12,304	Volusia	46	151,544
Wakulla	2	16,633		-	-		-	-
State Total	**255**	**916,594**		-	-		-	-
High Risk from Category 5 Storm Surge								
Bay	2	9,034	Citrus	4	23,853	DeSoto	1	2,308
Duval	1	6,084	Escambia	5	12,569	Flagler	2	6,662
Franklin	1	3,089	Gulf	1	3,076	Hernando	3	12,328
Hillsborough	6	21,780	Levy	2	6,543	Manatee	2	10,271
Okeechobee	1	1,803	Pasco	7	26,412	Pinellas	10	35,419
Sarasota	1	3,408	St. Lucie	3	9,114	Taylor	2	13,097
Volusia	7	34,019	Wakulla	1	8,867	Walton	1	7,367
State Total	**63**	**257,103**		-	-		-	-
Medium Risk from Category 5 Storm Surge								
Bay	3	11,088	Brevard	4	19,162	DeSoto	1	2,968
Duval	3	9,123	Escambia	5	25,903	Gilchrist	1	3,040
Hernando	7	23,756	Hillsborough	7	24,517	Indian River	2	7,638
Jefferson	1	4,380	Levy	1	6,211	Manatee	1	2,848
Miami-Dade	1	2,453	Okeechobee	2	6,316	Pasco	4	17,687
Pinellas	6	24,932	Putnam	2	9,421	St. Lucie	1	4,468
Taylor	1	6,040	Volusia	7	39,785	Walton	2	12,304
State Total	**62**	**264,040**		-	-		-	-

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6. Vulnerability to Flash Flooding caused by Extreme Precipitation

Methods

Flash flood events represent an area of overlap between meteorology, geology, topography, and hydrology that is not well understood. The one necessary and underlying component of flash flooding is precipitation; without rain, the probability of flash flooding is zero. Beyond that, the characteristics of an area that cause flash flooding are variable across the landscape. In some places like Big Thompson Canyon in Colorado, a deadly flood in 1976 was as much a function of slope and impermeable surfaces as it was the rainfall preceding the event. Florida, however, presents a distinctly different landscape where slopes are generally not very large, yet the possibility of flash flooding and ponding is still an ever-present threat. Climate science points to a future where the overall rainfall is about the same as today, meaning that Florida should expect to see the same annual average volume of water to fall in one year. However, these same predictions also indicate that rainfall events will be less frequent and more severe. The location of severe rainfall events cannot currently be modeled with certainty. In lieu of identified geographic areas where more rainfall will be found in Florida, a modeled surface of flash flood potential index is used to identify areas of interest for planning and adaptation.

The Flash Flood Potential Index (FFPI)

The goal of the FFPI is to empirically define a place's risk of flash flooding based on its pre-event characteristics: slope, land cover, soil drainability, and land use. The FFPI is an index allowing users to see which places are more pre-disposed to flash flooding than others are. The FFPI has been applied to numerous areas across the United States using different weighting combinations depending on the focus area.

First, Smith (2003) developed the FFPI for the Colorado River basin as a supplement to the Flash Flood Monitoring and Prediction System. The FFPI was originally created by Smith because limitations in conventional flash flood guidance lead to inaccurate flash flood forecasts. Limitations addressed by Smith included base data scale, the coarse resolution of soil data, and the need to use a long time series of hydrological data to calibrate the model. The original FFPI developed GIS raster surfaces for each of the four inputs (slope, land use/land cover, soil type/texture, and vegetation cover or density). Each of these was scaled from 1 – 10, added in a weighted linear model where values for M are more than 1, and divided by 4 to derive a final FFPI between 1 – 10 (equation below).

$$FFPI = \frac{M + L + S + V}{N}$$

Where

M = Slope

L = Land Cover/Use

S= Soil Type/ Texture

V = Vegetation Cover/Forest Density

N = Number of input variables. (L, S, and V are given weights of 1. Max N is greater than 4 since M was given a weight slightly higher than 1 because of the significant influence slope has in flash flood development [Smith, 2003]).

In 2009, Brewster modified the original Smith version of the FFPI for implementation in Binghamton, NY. This version of the model gave greater weight to the slope and vegetation cover than the land use and soil type, effectively prescribing great flash flood potential to areas with greater slope (equation below).

$$FFPI = \frac{1.5(M) + L + S + 0.5(V)}{4}$$

Kruzdlo (2010) implemented the FFPI for State College, Pennsylvania where the FFPI equation diverges from the original Smith FFPI by utilizing an equal weighting scheme originated by Smith (2003). Ceru (2012) modified the initial State College equation to give higher weighting to slope and land use/land cover based on “precedence from previous runs of FFPI at other offices, and consulting hydrologists at the Mid Atlantic River Forecast Center” (Ceru, 2012, slide 21) (equation below).

$$FFPI = \frac{M + L + S + V}{4}$$

Where

N = Number of input variables. (L, S, and V are given weights of 1. Max N is greater than 4 since slope and land use/cover were given a weight slightly higher than 1[Smith, 2003]).

Most recently, Zogg and Deitsch (2013) implemented each of the proposed equations for FFPI for Des Moines, Iowa. The authors took care to provide many details about the sources and preparation of the data for use in the FFPI. For each input, they describe source data, manipulation of data to standardize and normalize, and the process used to combine the data.

This report utilized findings from Zogg and Deitsch (2013) to create an ArcGIS model to define FFPI for Florida. The average value for each tract was chosen to represent flash flood risk in lieu of maximum value because nearly every tract has a maximum flash flood potential near 100%. However, while the maximum for each tract is very high, the number of grid cells (land area) characterized by this value is generally low in each tract. Using average FFPI value highlights areas where higher values dominate across the area. The average FFPI value for each census tract represents cumulative exposure. Each tract was then categorized into one of four classes based on the level of flash flood potential using the following equal interval classification scheme so that future changes in risk at the tract-level can be easily seen in comparison to the current risk level:

- Low = Less than 2.5 FFPI
- Medium = Between 2.5 – 5 FFPI
- High = Between 5 – 7.5 FFPI
- Extreme = Greater than 7.5 FFPI

A straight additive model was implemented for Florida because of a lack of *a priori* understanding of input variable importance. The FFPI for Florida (Figure 28) fits well with known geographic variations across the state related to slope and land cover.

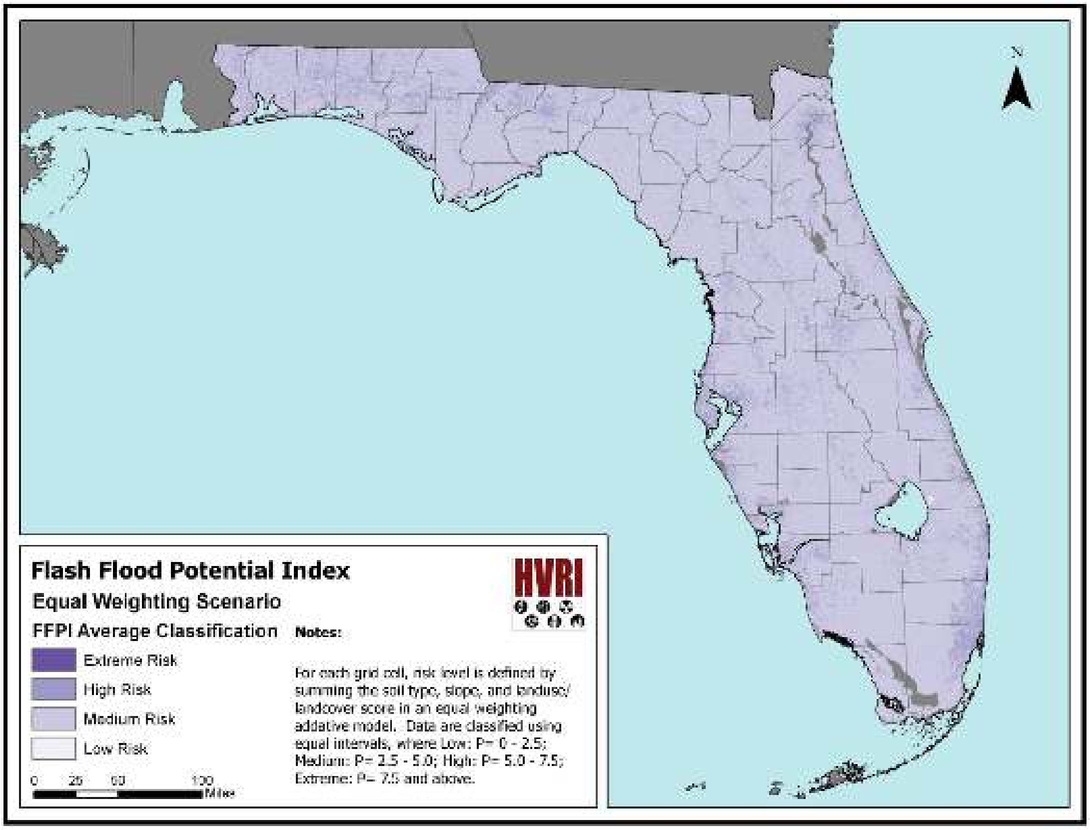

Figure 28: Flash flood potential index surface for Florida.

State Summary

The pattern of average FFPI for each county in Florida displays a pattern of high flash flood risk in urban areas surrounding Cape Coral, Jacksonville, Miami, Tampa, and Tallahassee (Figure 29). Very few places in and around Orlando have high flash flood potential, indicating that the model does not merely mimic urban areas. However, the Clermont area in central Florida has a high flash flood probability stemming from the many lakes and drastic (albeit small) slope changes in the area (Figure 30). Nine counties, including Broward, Collier, Duval, Hillsborough, Lee, Leon, Miami-Dade, Palm Beach, and Pinellas, each have more than 50,000 people living in areas with high average FFPI census tracts including nearly 80% of tracts and nearly 2,000,000 people in Miami-Dade County alone (Table 41 and Table 42). Nearly 50% of Monroe County tracts and 30% of Broward County tracts add 500,000 more people to the list of those at high risk from flash flooding should extreme precipitation occur.

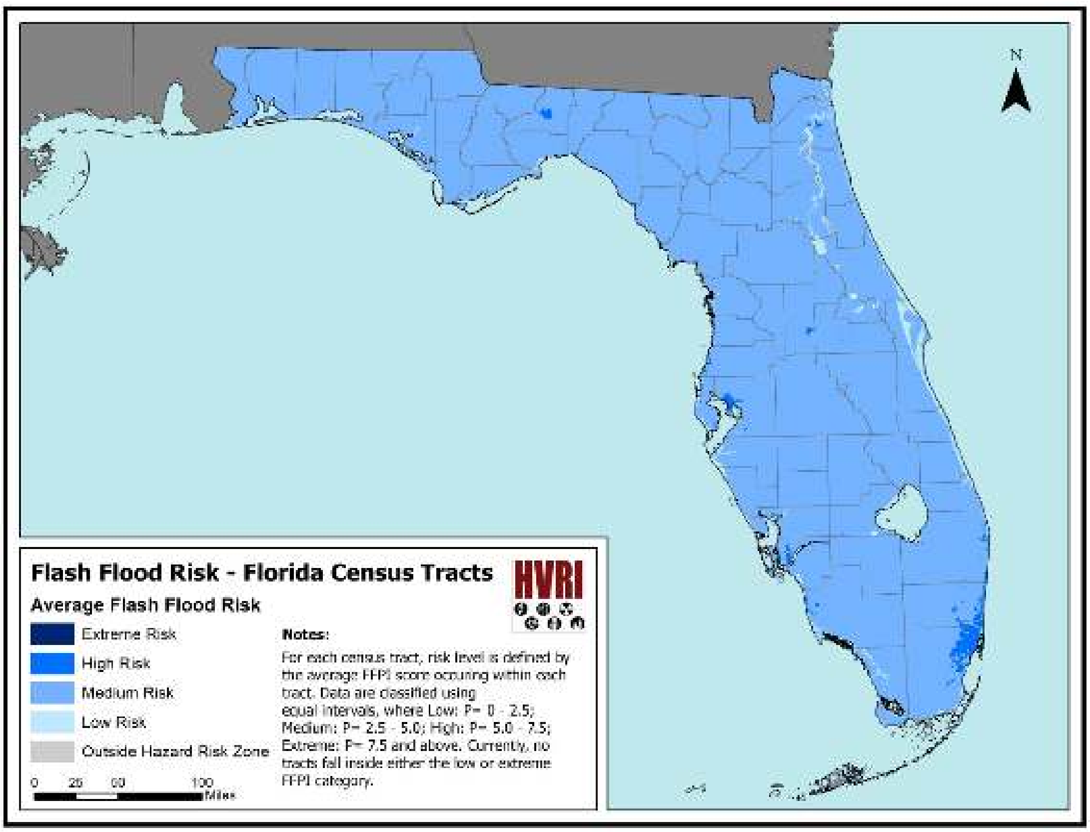

Figure 29: Average flash flood risk for Florida census tracts.

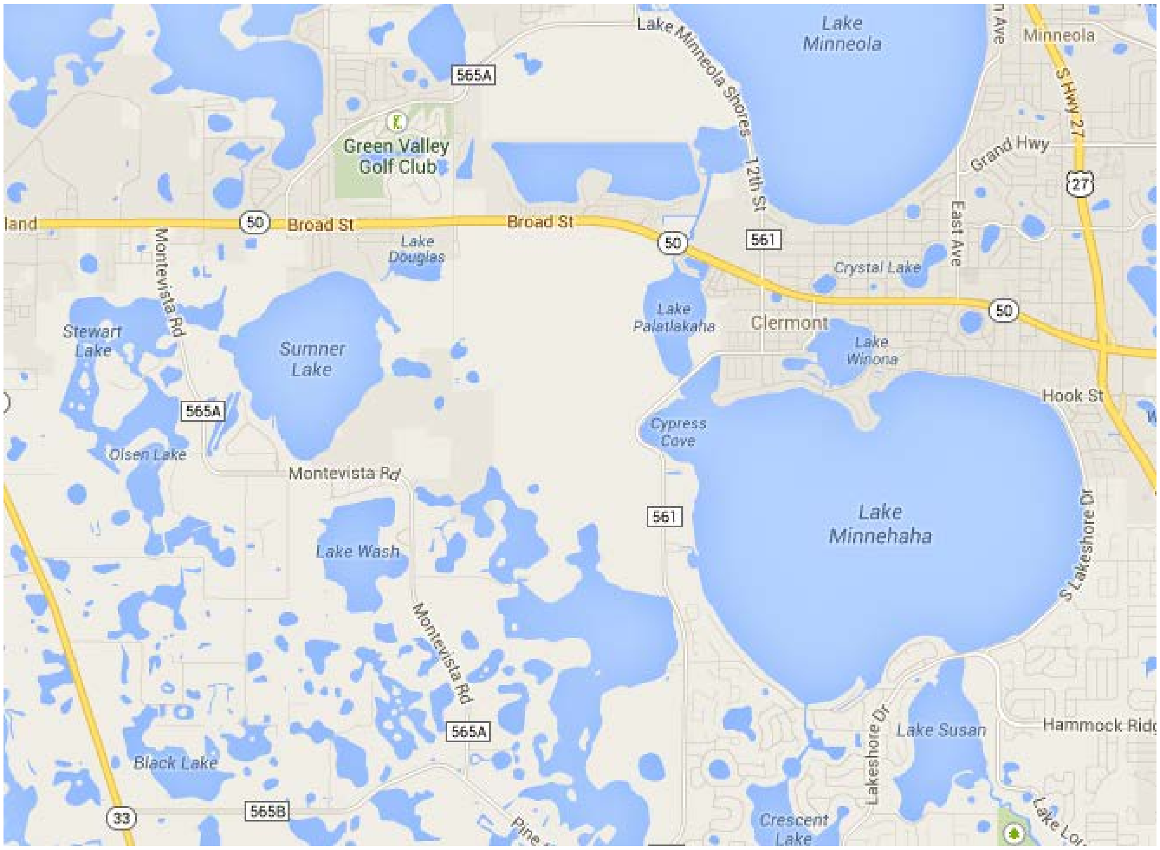

Figure 30: Clermont area surface hydrology.

Table 41: Census tract summary for flash flood hazard risk.

County Name	Flash Flood Hazard Risk				
	Extreme (> 7.5)	High (5 - 7.5)	Medium (2.5-5)	Low (<2.5)	Out
Alachua	-	-	100.00%	-	-
Baker	-	-	100.00%	-	-
Bay	-	6.82%	93.18%	-	-
Bradford	-	-	100.00%	-	-
Brevard	-	4.42%	95.58%	-	-
Broward	-	29.64%	70.36%	-	-
Calhoun	-	-	100.00%	-	-
Charlotte	-	12.82%	87.18%	-	-
Citrus	-	-	100.00%	-	-
Clay	-	-	100.00%	-	-
Collier	-	29.73%	70.27%	-	-
Columbia	-	-	100.00%	-	-
DeSoto	-	-	100.00%	-	-
Dixie	-	-	100.00%	-	-
Duval	-	9.25%	90.75%	-	-
Escambia	-	7.04%	92.96%	-	-
Flagler	-	-	100.00%	-	-
Franklin	-	-	100.00%	-	-
Gadsden	-	-	100.00%	-	-
Gilchrist	-	-	100.00%	-	-
Glades	-	-	100.00%	-	-
Gulf	-	-	100.00%	-	-
Hamilton	-	-	100.00%	-	-
Hardee	-	-	100.00%	-	-
Hendry	-	-	100.00%	-	-
Hernando	-	-	100.00%	-	-
Highlands	-	-	100.00%	-	-
Hillsborough	-	17.13%	82.87%	-	-
Holmes	-	-	100.00%	-	-
Indian River	-	-	100.00%	-	-
Jackson	-	-	100.00%	-	-
Jefferson	-	-	100.00%	-	-
Lafayette	-	-	100.00%	-	-
Lake	-	1.79%	98.21%	-	-
Lee	-	10.18%	89.82%	-	-
Leon	-	44.12%	55.88%	-	-
Levy	-	-	100.00%	-	-
Liberty	-	-	100.00%	-	-
Madison	-	-	100.00%	-	-
Manatee	-	1.28%	98.72%	-	-
Marion	-	-	100.00%	-	-
Martin	-	2.94%	97.06%	-	-
Miami-Dade	-	79.58%	20.42%	-	-
Monroe	-	45.16%	54.84%	-	-
Nassau	-	-	100.00%	-	-
Okaloosa	-	7.32%	92.68%	-	-
Okeechobee	-	-	100.00%	-	-
Orange	-	2.42%	97.58%	-	-
Osceola	-	-	100.00%	-	-
Palm Beach	-	13.39%	86.61%	-	-
Pasco	-	8.96%	91.04%	-	-
Pinellas	-	8.98%	91.02%	-	-
Polk	-	-	100.00%	-	-
Putnam	-	-	100.00%	-	-
Santa Rosa	-	-	100.00%	-	-
Sarasota	-	4.26%	95.74%	-	-
Seminole	-	-	100.00%	-	-
St. Johns	-	2.56%	97.44%	-	-
St. Lucie	-	2.27%	97.73%	-	-
Sumter	-	-	100.00%	-	-
Suwannee	-	-	100.00%	-	-
Taylor	-	-	100.00%	-	-
Union	-	-	100.00%	-	-
Volusia	-	5.26%	94.74%	-	-
Wakulla	-	-	100.00%	-	-
Walton	-	-	100.00%	-	-
Washington	-	-	100.00%	-	-
State Total	-	18.84%	81.16%	-	-

Table 42: Census tract population summary for flash flood hazard risk.

County Name	Flash Flood Hazard Risk Extreme (> 7.5)	High (5 - 7.5)	Medium (2.5-5)	Low (<2.5)	Out	County Name	Flash Flood Hazard Risk Extreme (> 7.5)	High (5 - 7.5)	Medium (2.5-5)	Low (<2.5)	Out
Alachua	-	-	247,336	-	-	Lee	-	69,383	549,371	-	-
Baker	-	-	27,115	-	-	Leon	-	115,286	160,201	-	-
Bay	-	3,947	164,905	-	-	Levy	-	-	40,801	-	-
Bradford	-	-	28,520	-	-	Liberty	-	-	8,365	-	-
Brevard	-	12,807	530,562	-	-	Madison	-	-	19,224	-	-
Broward	-	456,143	1,291,923	-	-	Manatee	-	1,682	321,151	-	-
Calhoun	-	-	14,625	-	-	Marion	-	-	331,298	-	-
Charlotte	-	12,207	147,771	-	-	Martin	-	1,998	144,320	-	-
Citrus	-	-	141,236	-	-	Miami-Dade	-	1,959,826	533,301	-	-
Clay	-	-	190,865	-	-	Monroe	-	41,783	31,307	-	-
Collier	-	66,314	255,206	-	-	Nassau	-	-	73,314	-	-
Columbia	-	-	67,531	-	-	Okaloosa	-	4,618	176,204	-	-
DeSoto	-	-	34,862	-	-	Okeechobee	-	-	39,996	-	-
Dixie	-	-	16,422	-	-	Orange	-	15,778	1,130,178	-	-
Duval	-	64,687	799,576	-	-	Osceola	-	-	268,685	-	-
Escambia	-	11,830	285,789	-	-	Palm Beach	-	143,821	1,175,641	-	-
Flagler	-	-	95,696	-	-	Pasco	-	39,180	425,517	-	-
Franklin	-	-	11,549	-	-	Pinellas	-	56,668	859,874	-	-
Gadsden	-	-	46,389	-	-	Polk	-	-	602,095	-	-
Gilchrist	-	-	16,939	-	-	Putnam	-	-	74,364	-	-
Glades	-	-	12,884	-	-	Santa Rosa	-	-	151,372	-	-
Gulf	-	-	15,863	-	-	Sarasota	-	10,438	369,010	-	-
Hamilton	-	-	14,799	-	-	Seminole	-	-	422,718	-	-
Hardee	-	-	27,731	-	-	St. Johns	-	1,931	188,108	-	-
Hendry	-	-	39,140	-	-	St. Lucie	-	925	276,864	-	-
Hernando	-	-	172,778	-	-	Sumter	-	-	87,023	-	-
Highlands	-	-	98,786	-	-	Suwannee	-	-	41,551	-	-
Hillsborough	-	182,965	1,046,261	-	-	Taylor	-	-	22,570	-	-
Holmes	-	-	19,927	-	-	Union	-	-	15,535	-	-
Indian River	-	-	138,028	-	-	Volusia	-	16,480	478,113	-	-
Jackson	-	-	49,746	-	-	Wakulla	-	-	30,776	-	-
Jefferson	-	-	14,761	-	-	Walton	-	-	55,043	-	-
Lafayette	-	-	8,870	-	-	Washington	-	-	24,896	-	-
Lake	-	17,784	279,268	-	-	**State Total**	**-**	**3,308,481**	**15,482,445**	**-**	**-**

Analyzing Flash Flooding Hazard in Combination with SoVI and MedVI

About Bivariate Classifications

Here, we keep the exposure constant by using the same hazard threat surface but use different vulnerability perspectives (social and medical) in bivariate representations to create an easily understood depiction of not only increased threat but also a limited ability to adequately prepare for and respond to these threats. In doing so, we are able to quickly identify three specific geographic areas of interest:

1. Areas where the hazard itself should be the focus of planning and mitigation,
2. Areas where understanding the underlying socioeconomics and demographics would prove to be the most advantageous input point to create positive change, and
3. Areas where a combination of classic hazard mitigation techniques and social mitigation practices should be utilized in order to maximize optimal outcomes.

The following maps utilize a three by three bivariate representation in which one can easily identify areas of limited to elevated SoVI in relation to areas with low to extreme hazard classifications. Places identified in item number one in the preceding list are shaded in the blue colors and can be understood as locations where hazard susceptibility is higher than SoVI or MedVI. Areas identified in item number two above, indicating where socioeconomics and demographics play an important role, are shaded in the pink/red colors and can be conceived as locations where SoVI or MedVI are greater than physical hazard threats. Places identified in item number three above are shaded either in gray-tones or in a dark burgundy color and can be understood as areas that have equal vulnerability and hazard classification scores.

Integrating Flash Flood Hazard Risk with SoVI and MedVI

Areas where high flash flood risk and high SoVI coincide include the southeastern coast of Florida and the Tampa Bay area (Figure 31). In particular, large portions of Miami-Dade County where more than 1.5 million people reside in nearly 300 census tracts are included in this characterization (Table 43). Broward, Palm Beach, and Hillsborough Counties also have multiple tracts characterized by both high SoVI and high flash flood hazard risk. Here, 93,000, 54,000, and 46,000 residents, respectively, live in hazard-prone areas and may be less able to prepare for, respond to, and rebound from a disaster event. An additional 3.3 million people across 45 counties live in areas with a medium flash flood potential coupled with high SoVI (Table 43).

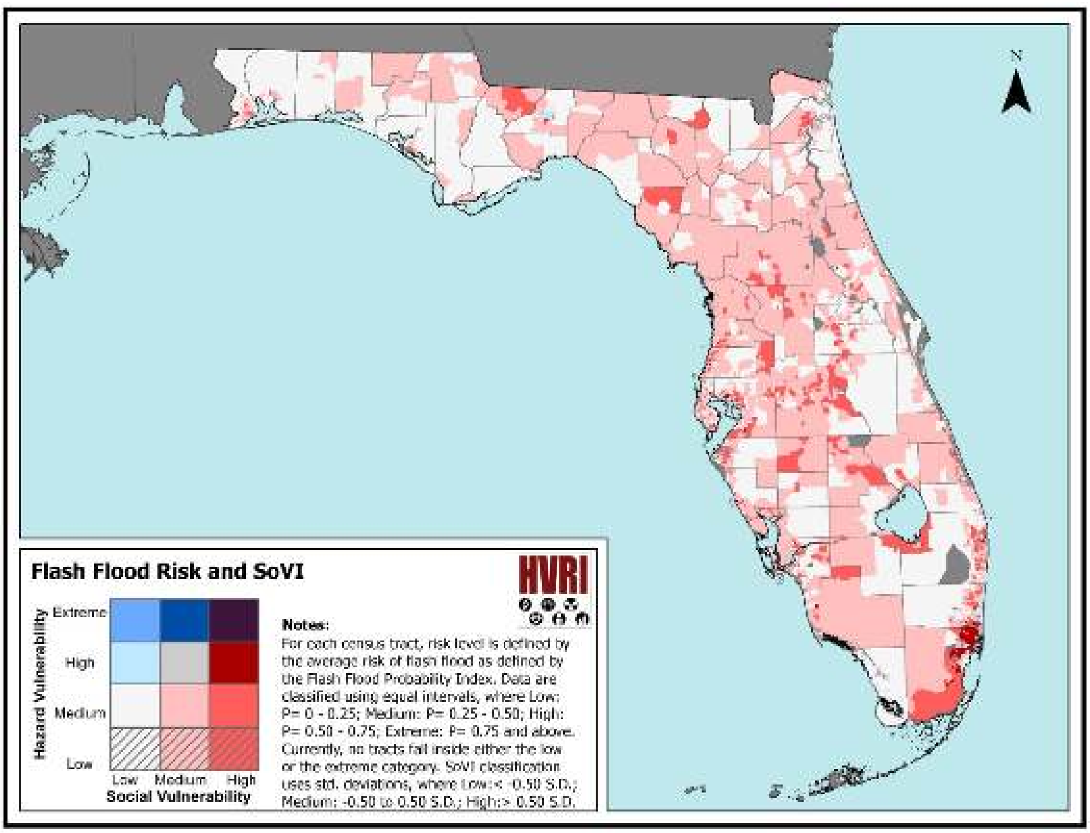

Figure 31: Bivariate representation of SoVI and flash flood hazard risk in Florida.

Table 43: Tract and population summary for counties with high SoVI and medium or greater flash flood hazard risk.

County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts
High Flash Flood Hazard Risk										
Broward	18	93,395		Collier	5	25,145		Duval	2	5,472
Escambia	1	1,864		Hillsborough	12	46,159		Leon	2	5,588
Miami-Dade	292	1,512,381		Orange	4	11,900		Palm Beach	18	54,556
Pasco	3	11,218		Pinellas	3	6,397		Sarasota	1	2,562
St. Lucie	1	925			-	-			-	-
State Total	**362**	**1,777,562**			-	-			-	-
Medium Flash Flood Hazard Risk										
Alachua	4	19,406		Bay	3	8,846		Brevard	6	20,847
Broward	93	456,153		Charlotte	5	17,905		Citrus	5	23,598
Clay	1	5,311		Collier	10	51,237		Columbia	1	2,872
DeSoto	3	13,900		Dixie	1	7,331		Duval	35	144,954
Escambia	11	38,059		Flagler	3	15,884		Gadsden	5	25,033
Hamilton	1	1,760		Hardee	2	10,630		Hendry	3	21,846
Hernando	15	62,301		Highlands	8	35,116		Hillsborough	61	233,626
Indian River	5	14,670		Lake	9	40,805		Lee	32	100,752
Leon	4	12,310		Manatee	19	84,453		Marion	15	102,216
Martin	2	4,091		Miami-Dade	67	388,240		Okeechobee	3	10,116
Orange	46	240,448		Osceola	14	103,651		Palm Beach	86	323,764
Pasco	25	76,024		Pinellas	34	126,265		Polk	52	219,460
Putnam	3	10,480		Santa Rosa	1	6,115		Sarasota	12	43,868
Seminole	7	25,901		St. Johns	1	4,155		St. Lucie	9	36,190
Sumter	6	52,106		Suwannee	1	7,016		Volusia	18	83,236
State Total	**747**	**3,332,947**			-	-			-	-

Coupling medical vulnerability with flash flood risk shows that a majority of the central peninsula and central panhandle have both high medical vulnerability and medium flash flood potential. Portions of Hillsborough and Lake Counties have high MedVI and high FFPI, while other places like Alachua, Orange, and Seminole Counties appear to be less vulnerable (Figure 32). Although these have the same hazard level as a majority of the state, their relatively low MedVI decreases overall risk to adverse outcomes. Table 44 indicates that the map does not tell the entire story. Here, we can see that there are eleven counties containing 65 tracts and more than 220,000 people characterized by high flash flood risk and high medical vulnerability. An additional 1,229 high MedVI tracts across 54 counties have 5.5 million residents located in medium flash flood potential areas.

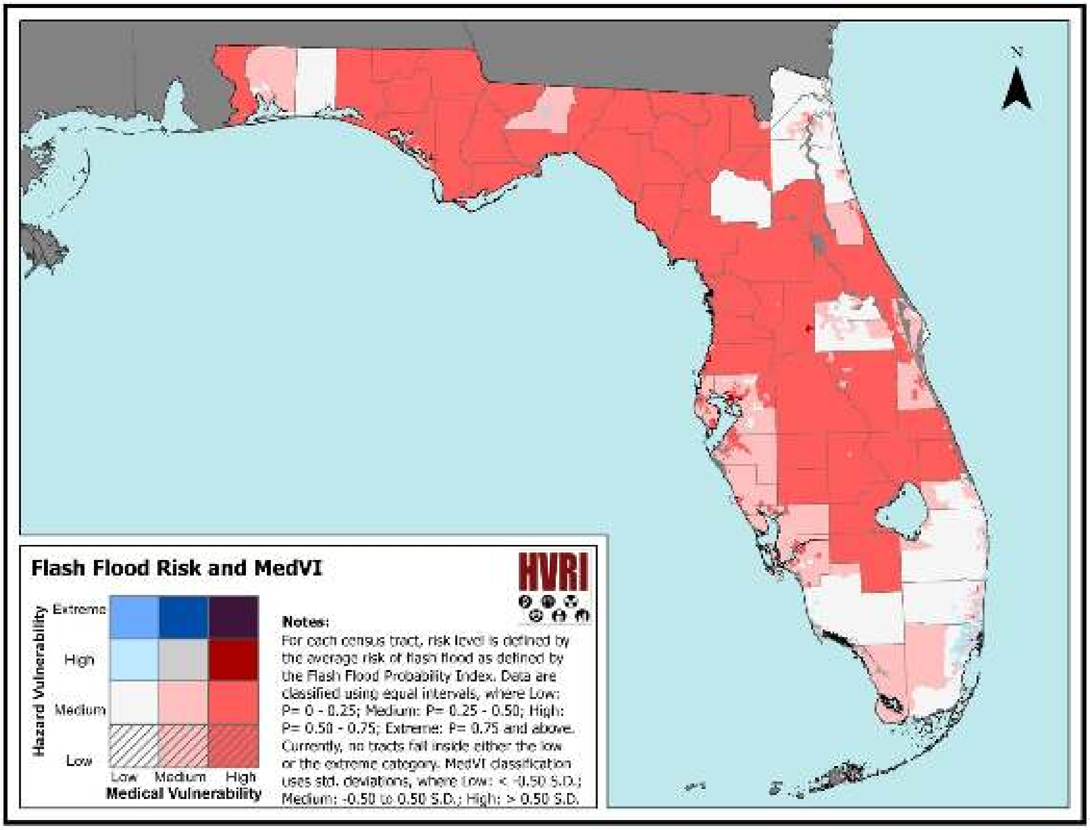

Figure 32: Bivariate representation of MedVI and flash flood hazard risk in Florida.

Table 44: Tract and population summary for counties with high MedVI and medium or greater flash flood hazard risk.

County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts
High Flash Flood Hazard Risk										
Bay	2	2,769		Broward	1	6,647		Duval	2	7,510
Escambia	5	11,830		Hillsborough	27	93,020		Lake	1	17,784
Miami-Dade	4	12,514		Pasco	12	39,180		Pinellas	4	15,947
St. Lucie	1	925		Volusia	6	16,480			-	-
State Total	**65**	**224,606**			-	-			-	-
Medium Flash Flood Hazard Risk										
Baker	3	20431		Bay	30	125027		Bradford	4	28520
Brevard	27	158,238		Broward	3	20,469		Calhoun	3	14,625
Charlotte	7	32,234		Citrus	27	141,236		Columbia	12	67,531
DeSoto	9	34,862		Dixie	3	16,422		Duval	8	27,311
Escambia	65	282,566		Flagler	6	24,521		Franklin	4	11,549
Gadsden	9	46,389		Gilchrist	5	16,939		Glades	3	12,884
Gulf	3	15,863		Hamilton	3	14,799		Hardee	6	27,731
Hendry	6	39,140		Hernando	44	172,778		Highlands	26	98,785
Hillsborough	58	214,906		Holmes	4	19,927		Indian River	29	138,028
Jackson	11	49,746		Jefferson	3	14,761		Lafayette	2	8,870
Lake	55	279,268		Lee	32	136,588		Levy	9	40,801
Liberty	2	8,365		Madison	5	19,224		Manatee	17	73,525
Marion	62	331,298		Okeechobee	11	39,996		Osceola	39	264,577
Pasco	119	419,530		Pinellas	64	257,045		Polk	153	602,092
Putnam	17	74,364		Sarasota	16	63,596		St. Johns	2	7,673
St. Lucie	42	276,864		Sumter	18	87,023		Suwannee	7	41,551
Taylor	4	22,570		Union	3	15,535		Volusia	107	478,113
Wakulla	4	30,776		Walton	11	55,043		Washington	7	24,896
State Total	**1,229**	**5,547,401**			-	-			-	-

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7. Vulnerability to Sea Level Rise

Methods

Modeling potential sea level rise (SLR) is not a new scientific endeavor, but one steeped in a modest history based on scientific evidence (Hoffman et al., 1983; Camber, 1992; Rahmstorf, 2007; Allison et al., 2009), theory, and hypotheses as to the specific impacts that estimated SLR will have on international (Awosika et al., 1992; Stocher et al., 2010), national (Dunbar et al., 1992; FEMA, 1991; Titus et al., 1991; Smith and Tirpak, 1989; Yohe, 1990; Yohe et al., 1996), and local (Kana et al., 1984; Kana et al., 1986; Kana et al., 1988) environments and human use systems (Diaz and Murnane, 2008). However, the science behind understanding the spatial dynamics between water height and inundation area is rooted in sound geospatial processes (Engelen et al., 1981) and utilized in many discrete analyses (Dasgupta, 2009; Li et al., 2009; Neumann et al., 2010). As early as 1995, probabilities of Atlantic Ocean SLR based on non-anthropogenic climate change ranged from 55 cm to 120 cm by 2010 (Titus and Narayanan, 1995). More recent projections estimate an anthropogenic warming induced rise of between 0.5 and 1.4 m from 1990 levels by 2100 (Rahmstorf, 2007).

To represent Florida's risk to sea level rise hazards, LIDAR[24]-derived digital elevation model (DEM) data were collected from the Florida Geographic Data Library (FGDL). The final DEM[25] mosaic represents best-available elevation data, combined to provide statewide coverage. The FGDL lists four sources of the component elevation data, in order of priority:

1. Northwest Florida Water Management District (NWFWMD) DEM. Reported vertical accuracy ranges from 13 to 30 cm.
2. National Oceanic and Atmospheric Association (NOAA) LIDAR Coastal DEM. Produced using FEMA accuracy standards from the Guidelines and Specifications for Flood Hazard Mapping Partners (FEMA 2013).
3. Florida Fish and Wildlife Conservation Commission (FWC) Florida Statewide 5-Meter DEM. Produced using U.S. National Map accuracy standards (U.S. National Map 2013).
4. Contour Derived DEM - based on 2-ft contours from the coastal LIDAR project. The biggest portion of this source data is around Lake Okeechobee, where LIDAR data was provided by Merrick & Company.

Spatial identification of the potential inundation zones was accomplished with a typical "bathtub" flood modeling approach similar to those used in other studies (Mazria and Kershner, 2007; Poulter and Halpin, 2007; Rowley et al., 2007). Here, the 5-m resolution LIDAR-derived raster DEM was classified as flooded by first identifying the DEM grid cells that have an elevation at or below a given sea level rise scenario. For this work, we identified three scenarios from the IPCC Special Report on Emission Scenarios (SRES 2000), illustrating a low, middle, and high sea level rise prediction:

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[24] Light Detection and Ranging (LIDAR) is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light.
[25] Digital Elevation Model (DEM) is a digital model or 3D representation of a terrain's surface created from terrain elevation data.

1. Low scenario is based on University Corporation for Atmospheric Research's MAGICC processing of an IPCC B1 scenario implying 28.5 cm (0.9 ft) of SLR by 2100 compared to 1990 levels (see UCAR 2013).
2. Mid scenario, also based on MAGICC processing, but of the IPCC A1B scenario, implying 66.9 cm (2.2 ft) of SLR by 2100 compared to 1990 levels (see UCAR 2013).
3. High scenario is based on Rahmstorf (2007) maximum, implying 126.3 cm (4.1 ft) of SLR by 2100 compared to 1990 levels.

The resulting selection of grid cells includes all areas within the state with elevations at or below each scenario threshold, regardless of situation to the coast. We chose to include this as a potential SLR risk scenario in Florida to document possible inland water table influences. Secondarily, the selection was further dissected to remove grid cells that met the elevation criteria but are not geospatially connected or contiguous to the shore. A standard spatial cost distance algorithm (McCoy and Johnson, 2001) further culled cells based on connectivity where the "cost" to travel across a non-flooded grid cell would preclude non-adjacent cells from being counted as flooded. Each census tract was then categorized into one of five classes based on the probable land area impacted by each SLR scenario using the following equal interval classification scheme so that future changes in risk at the tract-level can be easily seen in comparison to the current risk level:

- Out = No land area in the SLR zone
- Low = Less than 25% of the tract area in the SLR zone
- Medium = Between 25%-50% of the tract area in the SLR zone
- High = Between 50%-75% of the tract area in the SLR zone
- Extreme = Greater than 75% of the tract area in the SLR zone

Caveats

Postulating about the impacts of possible sea level rise throughout Florida is an inexact science. Not only are the projections of sea level rise in 10, 20, or 100 years a moving target, but also the methods, tools, and techniques for measuring incremental changes on the surface of the earth are continuously evolving. Couple these facts with the current level of detail available from LIDAR-derived elevation datasets which are collected in piecemeal fashion with little or no regard for standardizing elevation above sea level based on tidal fluctuations, and the picture becomes less clear. However, we can, with some regional certainty, identify those areas (census tracts) where increases in sea level will interfere with the current human use system. Additionally, we can combine the current understanding of coastal elevation and projections of SLR to discover and analyze discrete entities on the ground (e.g., emergency facilities, human settlements). These feed the creation of informatics about potential impacts that are useful for planning sustainable and adaptable development strategies along coastal Florida. Caution should be taken, however, in using these types of analyses for highly resolved (local) geographic areas. In such places, the spatial differences between elevation and potential SLR could produce spatial inaccuracies and should not be employed beyond simple visual display.

State Summary

Twelve of Florida's counties have residents at extreme risk to even the lowest prediction of sea level rise investigated here, with DeSoto, Levy, and Monroe exhibiting the highest levels of risk to 28.5 cm of SLR (Figure 33). In the above counties, at least 50% of the land area (representing both high and extreme risk) in some census tracts is below this elevation (Table 45). These census tracts correspond to an estimated 67,000 people living in areas at high or extreme risk of inundation by as little as 1 ft of sea level rise (Table 46). It is important to note that some of these counties (such as Lee and Marion) contain small numbers of census tracts at risk, but in which no people reside. The picture changes drastically when a middle estimate of 66.9 cm is modeled (Figure 34). Here, 17 counties (Table 47) contain tracts with greater than 50% of land area and more than 168,000 people (Table 48) in a high or extreme risk zone. Modeling a high estimate of SLR within the next 100 years of 126.3 cm points to catastrophic impacts to coastal and inland Florida (Figure 35) without adaptation and mitigation, including 28 counties with census tracts categorized as having high or extreme risk (Table 49), corresponding to nearly 600,000 residents (Table 50).

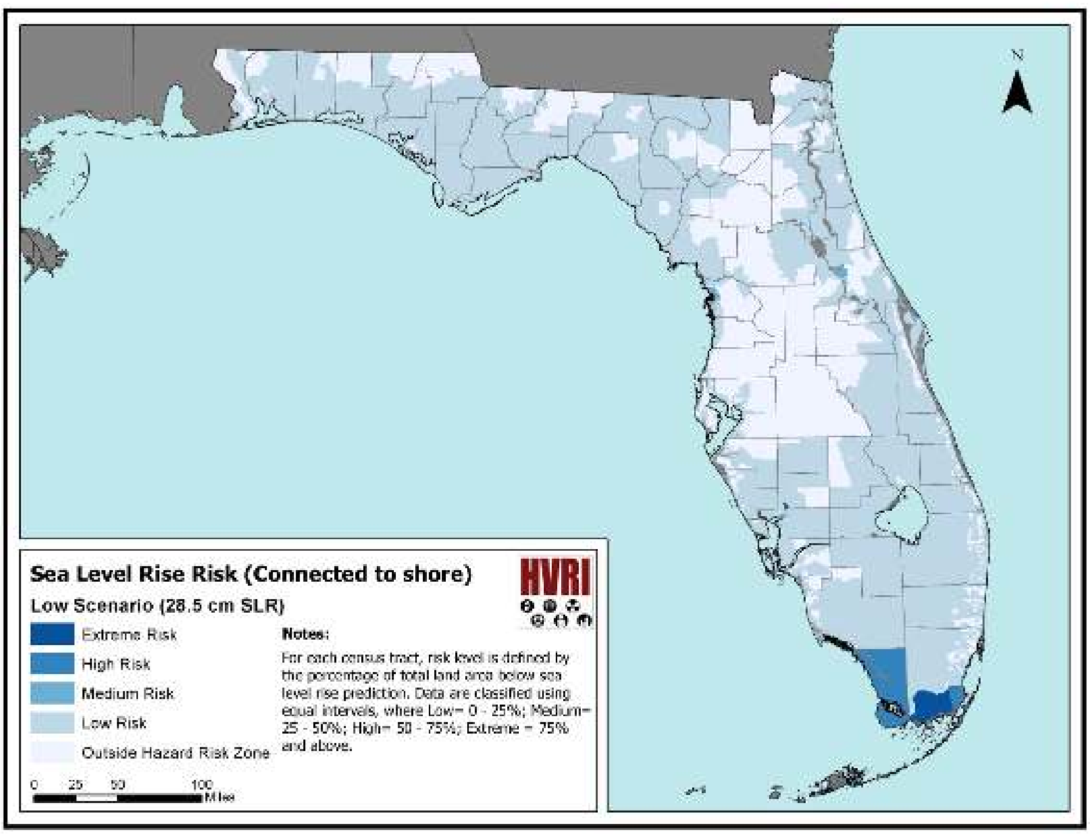

Figure 33: Sea level rise risk in Florida – low scenario (28.5 cm by 2100). Areas included are connected to the shore.

Table 45: Census tract summary for low connected SLR estimate risk.

County Name	SLR - Low Estimate (Connected Area Under 28.5 cm) Hazard Risk					County Name	SLR - Low Estimate (Connected Area Under 28.5 cm) Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out		Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	3.57%	96.43%	Lee	0.60%	-	1.20%	61.68%	36.53%
Baker	-	-	-	-	100.00%	Leon	-	-	-	7.35%	92.65%
Bay	-	-	-	84.09%	15.91%	Levy	10.00%	-	-	40.00%	50.00%
Bradford	-	-	-	-	100.00%	Liberty	-	-	-	100.00%	-
Brevard	-	-	3.54%	62.83%	33.63%	Madison	-	-	-	60.00%	40.00%
Broward	-	0.28%	0.28%	58.73%	40.72%	Manatee	-	-	-	57.69%	42.31%
Calhoun	-	-	-	100.00%	-	Marion	1.59%	-	-	19.05%	79.37%
Charlotte	2.56%	-	10.26%	82.05%	5.13%	Martin	-	-	2.94%	73.53%	23.53%
Citrus	3.57%	-	3.57%	14.29%	78.57%	Miami-Dade	0.39%	0.77%	1.16%	53.56%	44.12%
Clay	-	-	-	60.00%	40.00%	Monroe	12.90%	35.48%	19.35%	25.81%	6.45%
Collier	1.35%	-	1.35%	56.76%	40.54%	Nassau	-	-	-	83.33%	16.67%
Columbia	-	-	-	33.33%	66.67%	Okaloosa	-	-	-	78.05%	21.95%
DeSoto	11.11%	-	-	66.67%	22.22%	Okeechobee	-	-	-	81.82%	18.18%
Dixie	-	-	-	66.67%	33.33%	Orange	-	-	-	0.97%	99.03%
Duval	-	-	-	52.60%	47.40%	Osceola	-	-	-	2.44%	97.56%
Escambia	-	-	-	43.66%	56.34%	Palm Beach	-	-	-	73.21%	26.79%
Flagler	-	-	5.00%	50.00%	45.00%	Pasco	0.75%	-	-	15.67%	83.58%
Franklin	-	-	-	100.00%	-	Pinellas	-	0.41%	0.41%	53.47%	45.71%
Gadsden	-	-	-	55.56%	44.44%	Polk	-	-	-	-	100.00%
Gilchrist	-	-	-	60.00%	40.00%	Putnam	-	-	5.88%	70.59%	23.53%
Glades	-	-	-	100.00%	-	Santa Rosa	-	-	-	88.00%	12.00%
Gulf	-	-	-	100.00%	-	Sarasota	-	-	-	67.02%	32.98%
Hamilton	-	-	-	100.00%	-	Seminole	-	-	1.16%	13.95%	84.88%
Hardee	-	-	-	83.33%	16.67%	St. Johns	-	-	2.56%	69.23%	28.21%
Hendry	-	-	-	100.00%	-	St. Lucie	-	4.55%	2.27%	63.64%	29.55%
Hernando	2.22%	-	-	6.67%	91.11%	Sumter	-	-	-	-	100.00%
Highlands	-	-	-	29.63%	70.37%	Suwannee	-	-	-	71.43%	28.57%
Hillsborough	-	-	-	33.02%	66.98%	Taylor	-	-	-	50.00%	50.00%
Holmes	-	-	-	25.00%	75.00%	Union	-	-	-	-	100.00%
Indian River	-	-	-	80.00%	20.00%	Volusia	0.88%	-	1.75%	46.49%	50.88%
Jackson	-	-	-	45.45%	54.55%	Wakulla	-	-	-	100.00%	-
Jefferson	-	-	-	33.33%	66.67%	Walton	-	-	-	63.64%	36.36%
Lafayette	-	-	-	100.00%	-	Washington	-	-	-	57.14%	42.86%
Lake	-	-	-	5.36%	94.64%	**State Total**	**0.38%**	**0.45%**	**0.81%**	**45.72%**	**52.65%**

Table 46: Census tract population summary for low connected SLR estimate risk.

	SLR - Low Estimate (Connected Area Under 28.5 cm) Hazard Risk						SLR - Low Estimate (Connected Area Under 28.5 cm) Hazard Risk				
County Name	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out	County Name	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	16,164	231,172	Lee	-	-	6,011	404,477	208,266
Baker	-	-	-	-	27,115	Leon	-	-	-	18,183	257,304
Bay	-	-	-	140,824	28,028	Levy	-	-	-	14,156	26,645
Bradford	-	-	-	-	28,520	Liberty	-	-	-	8,365	-
Brevard	-	-	10,698	332,245	200,426	Madison	-	-	-	10,553	8,671
Broward	-	1,533	1,896	1,014,254	730,383	Manatee	-	-	-	183,405	139,428
Calhoun	-	-	-	14,625	-	Marion	-	-	-	45,980	285,318
Charlotte	-	-	11,094	139,481	9,403	Martin	-	-	2,691	103,156	40,471
Citrus	-	-	4,498	19,717	117,021	Miami-Dade	6,218	26,123	18,327	1,338,834	1,103,625
Clay	-	-	-	137,327	53,538	Monroe	3,067	21,512	16,756	26,233	5,522
Collier	-	-	2,939	180,544	138,037	Nassau	-	-	-	60,227	13,087
Columbia	-	-	-	24,177	43,354	Okaloosa	-	-	-	141,294	39,528
DeSoto	1,218	-	-	22,672	10,972	Okeechobee	-	-	-	30,627	9,369
Dixie	-	-	-	11,432	4,990	Orange	-	-	-	24,945	1,121,011
Duval	-	-	-	444,475	419,788	Osceola	-	-	-	7,194	261,491
Escambia	-	-	-	133,084	164,535	Palm Beach	-	-	-	967,952	351,510
Flagler	-	-	3,217	38,987	53,492	Pasco	-	-	-	59,863	404,834
Franklin	-	-	-	11,549	-	Pinellas	-	1,572	4,149	472,298	438,523
Gadsden	-	-	-	26,582	19,807	Polk	-	-	-	-	602,095
Gilchrist	-	-	-	10,510	6,429	Putnam	-	-	-	55,400	18,964
Glades	-	-	-	12,884	-	Santa Rosa	-	-	-	137,234	14,138
Gulf	-	-	-	15,863	-	Sarasota	-	-	-	251,950	127,498
Hamilton	-	-	-	14,799	-	Seminole	-	-	3,053	82,304	337,361
Hardee	-	-	-	26,772	959	St. Johns	-	-	2,455	136,694	50,890
Hendry	-	-	-	39,140	-	St. Lucie	-	5,841	3,686	203,154	65,108
Hernando	-	-	-	12,229	160,549	Sumter	-	-	-	-	87,023
Highlands	-	-	-	26,792	71,994	Suwannee	-	-	-	25,419	16,132
Hillsborough	-	-	-	376,514	852,712	Taylor	-	-	-	13,097	9,473
Holmes	-	-	-	5,544	14,383	Union	-	-	-	-	15,535
Indian River	-	-	-	97,664	40,364	Volusia	-	-	8,994	214,208	271,391
Jackson	-	-	-	25,398	24,348	Wakulla	-	-	-	30,776	-
Jefferson	-	-	-	4,380	10,381	Walton	-	-	-	34,262	20,781
Lafayette	-	-	-	8,870	-	Washington	-	-	-	16,682	8,214
Lake	-	-	-	17,380	279,672	**State Total**	**10,503**	**56,581**	**100,464**	**8,521,800**	**10,101,578**

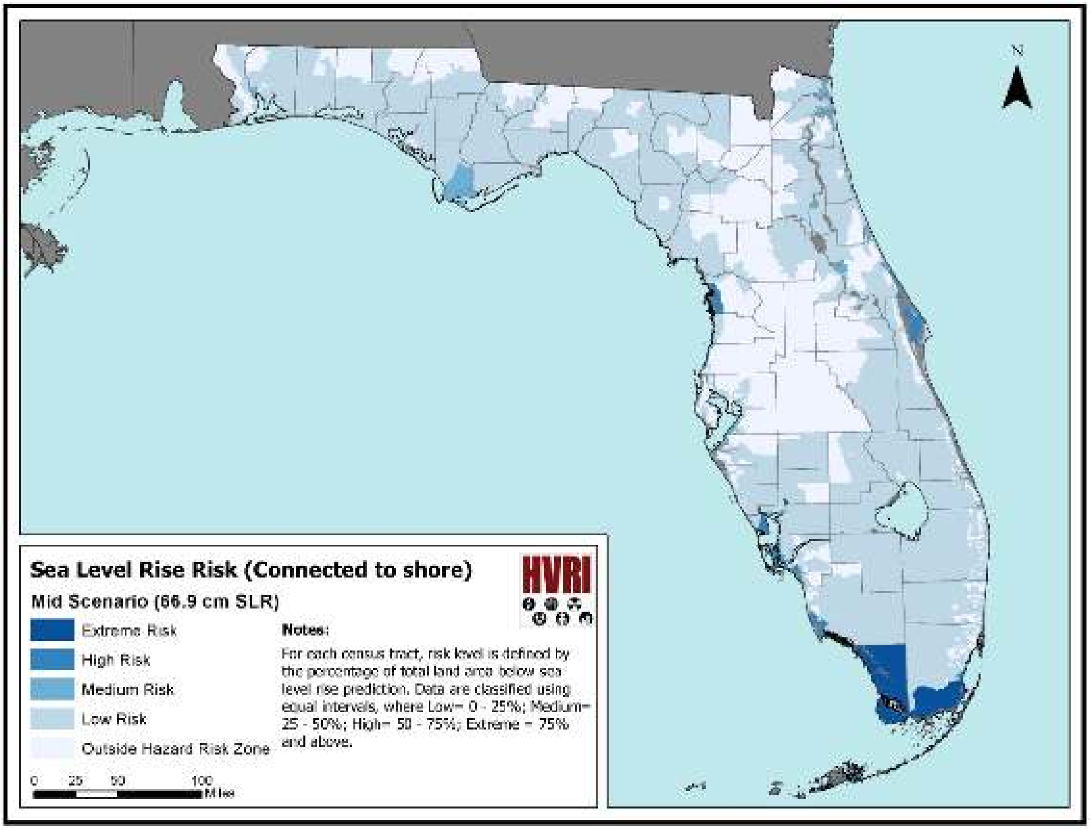

Figure 34: Sea level rise risk in Florida – mid scenario (66.9 cm by 2100). Areas included are connected to the shore.

Table 47: Census tract summary for mid connected SLR estimate risk.

County Name	SLR - Middle Estimate (Connected Area Under 66.9 cm) Hazard Risk					County Name	SLR - Middle Estimate (Connected Area Under 66.9 cm) Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out		Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	3.57%	96.43%	Lee	0.60%	5.39%	6.59%	52.10%	35.33%
Baker	-	-	-	-	100.00%	Leon	-	-	-	7.35%	92.65%
Bay	-	-	2.27%	84.09%	13.64%	Levy	10.00%	-	-	40.00%	50.00%
Bradford	-	-	-	-	100.00%	Liberty	-	-	-	100.00%	-
Brevard	-	1.77%	4.42%	61.06%	32.74%	Madison	-	-	-	60.00%	40.00%
Broward	-	0.28%	0.83%	59.56%	39.34%	Manatee	-	-	10.26%	48.72%	41.03%
Calhoun	-	-	-	100.00%	-	Marion	1.59%	-	-	19.05%	79.37%
Charlotte	2.56%	5.13%	12.82%	76.92%	2.56%	Martin	-	-	5.88%	73.53%	20.59%
Citrus	3.57%	7.14%	-	10.71%	78.57%	Miami-Dade	0.58%	1.16%	1.93%	53.37%	42.97%
Clay	-	-	3.33%	66.67%	30.00%	Monroe	29.03%	35.48%	16.13%	19.35%	-
Collier	1.35%	5.41%	4.05%	51.35%	37.84%	Nassau	-	-	16.67%	66.67%	16.67%
Columbia	-	-	-	33.33%	66.67%	Okaloosa	-	-	-	78.05%	21.95%
DeSoto	11.11%	-	-	66.67%	22.22%	Okeechobee	-	-	-	81.82%	18.18%
Dixie	-	-	-	66.67%	33.33%	Orange	-	-	-	0.97%	99.03%
Duval	-	-	4.62%	50.29%	45.09%	Osceola	-	-	-	2.44%	97.56%
Escambia	-	-	-	45.07%	54.93%	Palm Beach	-	-	-	73.51%	26.49%
Flagler	-	-	5.00%	50.00%	45.00%	Pasco	0.75%	-	3.73%	12.69%	82.84%
Franklin	-	-	50.00%	50.00%	-	Pinellas	-	0.41%	3.27%	51.02%	45.31%
Gadsden	-	-	-	55.56%	44.44%	Polk	-	-	-	-	100.00%
Gilchrist	-	-	-	60.00%	40.00%	Putnam	-	-	17.65%	64.71%	17.65%
Glades	-	-	-	100.00%	-	Santa Rosa	-	-	4.00%	84.00%	12.00%
Gulf	-	-	33.33%	66.67%	-	Sarasota	-	-	-	68.09%	31.91%
Hamilton	-	-	-	100.00%	-	Seminole	-	-	1.16%	13.95%	84.88%
Hardee	-	-	-	83.33%	16.67%	St. Johns	-	-	10.26%	66.67%	23.08%
Hendry	-	-	-	100.00%	-	St. Lucie	-	4.55%	4.55%	61.36%	29.55%
Hernando	2.22%	-	2.22%	4.44%	91.11%	Sumter	-	-	-	-	100.00%
Highlands	-	-	-	29.63%	70.37%	Suwannee	-	-	-	71.43%	28.57%
Hillsborough	-	0.31%	1.25%	31.78%	66.67%	Taylor	-	-	-	50.00%	50.00%
Holmes	-	-	-	25.00%	75.00%	Union	-	-	-	-	100.00%
Indian River	-	-	13.33%	70.00%	16.67%	Volusia	0.88%	1.75%	6.14%	42.11%	49.12%
Jackson	-	-	-	45.45%	54.55%	Wakulla	-	-	-	100.00%	-
Jefferson	-	-	-	33.33%	66.67%	Walton	-	-	-	63.64%	36.36%
Lafayette	-	-	-	100.00%	-	Washington	-	-	-	57.14%	42.86%
Lake	-	-	-	5.36%	94.64%	**State Total**	**0.52%**	**1.02%**	**2.56%**	**44.22%**	**51.67%**

Table 48: Census tract population summary for mid connected SLR estimate risk.

County Name	SLR - Middle Estimate (Connected Area Under 66.9 cm) Hazard Risk					County Name	SLR - Middle Estimate (Connected Area Under 66.9 cm) Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out		Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	16,164	231,172	Lee	-	25,592	45,451	347,809	199,902
Baker	-	-	-	-	27,115	Leon	-	-	-	18,183	257,304
Bay	-	-	-	140,824	28,028	Levy	-	-	-	14,156	26,645
Bradford	-	-	-	-	28,520	Liberty	-	-	-	8,365	-
Brevard	-	12,494	13,831	318,618	198,426	Madison	-	-	-	10,553	8,671
Broward	-	1,533	9,746	1,028,013	708,774	Manatee	-	-	23,096	165,541	134,196
Calhoun	-	-	-	14,625	-	Marion	-	-	-	45,980	285,318
Charlotte	-	7,710	13,764	136,594	1,910	Martin	-	-	6,398	106,908	33,012
Citrus	-	9,092	-	15,123	117,021	Miami-Dade	21,605	22,462	36,107	1,330,273	1,082,680
Clay	-	-	13,596	147,739	29,530	Monroe	11,580	28,234	13,711	19,565	-
Collier	-	15,145	8,317	166,584	131,474	Nassau	-	-	14,070	46,157	13,087
Columbia	-	-	-	24,177	43,354	Okaloosa	-	-	-	141,294	39,528
DeSoto	1,218	-	-	22,672	10,972	Okeechobee	-	-	-	30,627	9,369
Dixie	-	-	-	11,432	4,990	Orange	-	-	-	24,945	1,121,011
Duval	-	-	39,923	424,616	399,724	Osceola	-	-	-	7,194	261,491
Escambia	-	-	-	140,259	157,360	Palm Beach	-	-	-	972,228	347,234
Flagler	-	-	3,217	38,987	53,492	Pasco	-	-	10,571	53,587	400,539
Franklin	-	-	4,494	7,055	-	Pinellas	-	1,572	28,149	451,809	435,012
Gadsden	-	-	-	26,582	19,807	Polk	-	-	-	-	602,095
Gilchrist	-	-	-	10,510	6,429	Putnam	-	-	9,421	49,578	15,365
Glades	-	-	-	12,884	-	Santa Rosa	-	-	4,266	132,968	14,138
Gulf	-	-	4,450	11,413	-	Sarasota	-	-	-	254,581	124,867
Hamilton	-	-	-	14,799	-	Seminole	-	-	3,053	82,304	337,361
Hardee	-	-	-	26,772	959	St. Johns	-	-	11,077	144,894	34,068
Hendry	-	-	-	39,140	-	St. Lucie	-	5,841	5,429	201,411	65,108
Hernando	-	-	3,027	9,202	160,549	Sumter	-	-	-	-	87,023
Highlands	-	-	-	26,792	71,994	Suwannee	-	-	-	25,419	16,132
Hillsborough	-	-	4,562	376,649	848,015	Taylor	-	-	-	13,097	9,473
Holmes	-	-	-	5,544	14,383	Union	-	-	-	-	15,535
Indian River	-	-	10,857	95,387	31,784	Volusia	-	4,381	31,230	195,280	263,702
Jackson	-	-	-	25,398	24,348	Wakulla	-	-	-	30,776	-
Jefferson	-	-	-	4,380	10,381	Walton	-	-	-	34,262	20,781
Lafayette	-	-	-	8,870	-	Washington	-	-	-	16,682	8,214
Lake	-	-	-	17,380	279,672	**State Total**	**34,403**	**134,056**	**371,813**	**8,341,610**	**9,909,044**

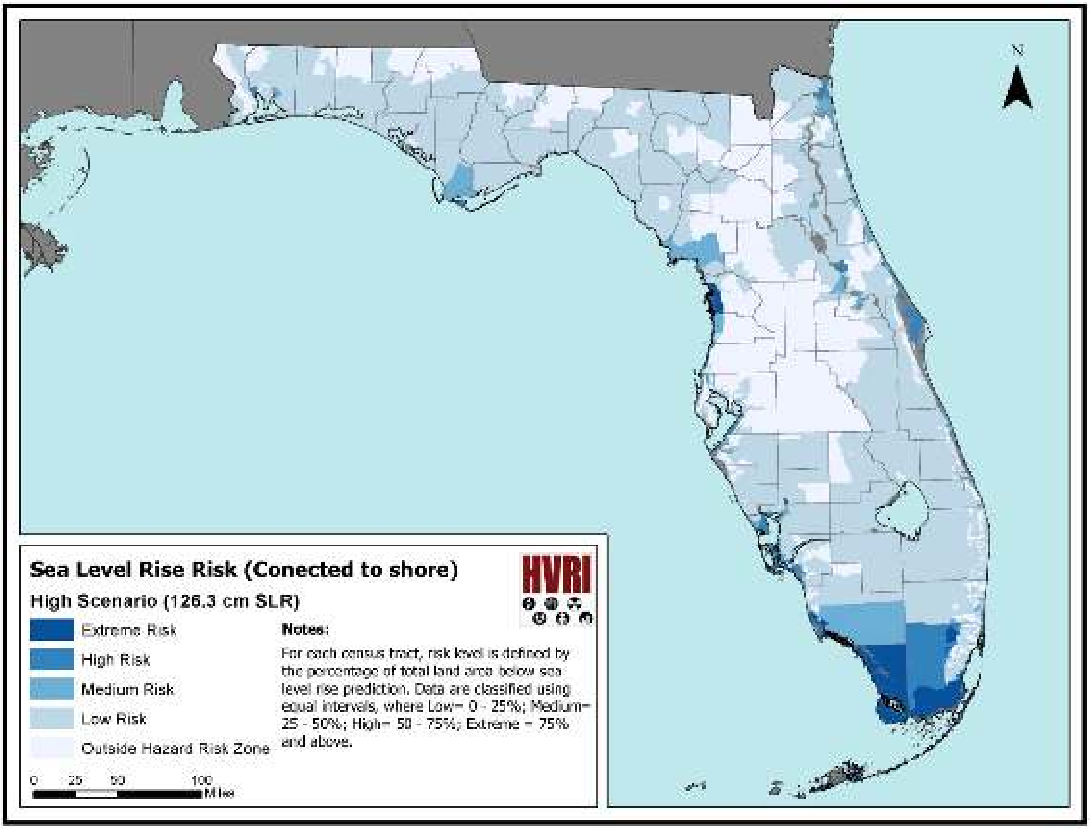

Figure 35: Sea level rise risk in Florida – high scenario (126.3 cm by 2100). Areas included are connected to the shore.

Table 49: Census tract summary for high connected SLR estimate risk.

County Name	SLR - High Estimate (Connected Area Under 126.3 cm) Hazard Risk					County Name	SLR - High Estimate (Connected Area Under 126.3 cm) Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out		Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	3.57%	96.43%	Lee	3.59%	8.98%	9.58%	46.11%	31.74%
Baker	-	-	-	-	100.00%	Leon	-	-	-	7.35%	92.65%
Bay	2.27%	-	6.82%	77.27%	13.64%	Levy	10.00%	-	10.00%	30.00%	50.00%
Bradford	-	-	-	-	100.00%	Liberty	-	-	-	100.00%	-
Brevard	0.88%	5.31%	7.08%	54.87%	31.86%	Madison	-	-	-	60.00%	40.00%
Broward	0.83%	1.94%	8.86%	53.46%	34.90%	Manatee	1.28%	6.41%	7.69%	50.00%	34.62%
Calhoun	-	-	-	100.00%	-	Marion	1.59%	-	-	19.05%	79.37%
Charlotte	2.56%	12.82%	20.51%	61.54%	2.56%	Martin	-	-	17.65%	61.76%	20.59%
Citrus	10.71%	-	-	14.29%	75.00%	Miami-Dade	4.24%	6.55%	8.09%	44.12%	36.99%
Clay	-	-	3.33%	70.00%	26.67%	Monroe	70.97%	16.13%	6.45%	6.45%	-
Collier	5.41%	5.41%	10.81%	45.95%	32.43%	Nassau	-	8.33%	16.67%	66.67%	8.33%
Columbia	-	-	-	33.33%	66.67%	Okaloosa	-	-	-	78.05%	21.95%
DeSoto	11.11%	-	-	66.67%	22.22%	Okeechobee	-	-	-	81.82%	18.18%
Dixie	-	-	-	66.67%	33.33%	Orange	-	-	-	0.97%	99.03%
Duval	-	0.58%	6.94%	50.29%	42.20%	Osceola	-	-	-	2.44%	97.56%
Escambia	-	-	1.41%	43.66%	54.93%	Palm Beach	-	0.30%	2.68%	70.54%	26.49%
Flagler	-	5.00%	5.00%	45.00%	45.00%	Pasco	1.49%	2.99%	4.48%	11.19%	79.85%
Franklin	-	25.00%	25.00%	50.00%	-	Pinellas	0.41%	3.27%	11.84%	41.22%	43.27%
Gadsden	-	-	-	55.56%	44.44%	Polk	-	-	-	-	100.00%
Gilchrist	-	-	-	60.00%	40.00%	Putnam	-	-	17.65%	64.71%	17.65%
Glades	-	-	-	100.00%	-	Santa Rosa	-	4.00%	4.00%	80.00%	12.00%
Gulf	-	-	33.33%	66.67%	-	Sarasota	-	3.19%	4.26%	63.83%	28.72%
Hamilton	-	-	-	100.00%	-	Seminole	-	-	2.33%	12.79%	84.88%
Hardee	-	-	-	83.33%	16.67%	St. Johns	-	5.13%	15.38%	61.54%	17.95%
Hendry	-	-	-	100.00%	-	St. Lucie	4.55%	2.27%	4.55%	59.09%	29.55%
Hernando	2.22%	2.22%	2.22%	2.22%	91.11%	Sumter	-	-	-	-	100.00%
Highlands	-	-	-	29.63%	70.37%	Suwannee	-	-	-	71.43%	28.57%
Hillsborough	0.93%	0.62%	1.87%	32.09%	64.49%	Taylor	-	-	-	50.00%	50.00%
Holmes	-	-	-	25.00%	75.00%	Union	-	-	-	-	100.00%
Indian River	-	6.67%	16.67%	63.33%	13.33%	Volusia	0.88%	3.51%	12.28%	37.72%	45.61%
Jackson	-	-	-	45.45%	54.55%	Wakulla	-	-	-	100.00%	-
Jefferson	-	-	-	33.33%	66.67%	Walton	-	-	-	63.64%	36.36%
Lafayette	-	-	-	100.00%	-	Washington	-	-	-	57.14%	42.86%
Lake	-	-	1.79%	5.36%	92.86%	**State Total**	**1.83%**	**2.70%**	**5.69%**	**40.43%**	**49.35%**

Table 50: Census tract population summary for high connected SLR estimate risk.

	SLR - High Estimate (Connected Area Under 126.3 cm) Hazard Risk						SLR - High Estimate (Connected Area Under 126.3 cm) Hazard Risk				
County Name	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out	County Name	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	16,164	231,172	Lee	8,607	39,046	72,318	320,537	178,246
Baker	-	-	-	-	27,115	Leon	-	-	-	18,183	257,304
Bay	-	-	6,946	133,878	28,028	Levy	-	-	3,289	10,867	26,645
Bradford	-	-	-	-	28,520	Liberty	-	-	-	8,365	-
Brevard	3,300	23,025	25,929	296,824	194,291	Madison	-	-	-	10,553	8,671
Broward	8,638	26,566	147,664	940,949	624,249	Manatee	4,849	14,032	20,278	171,894	111,780
Calhoun	-	-	-	14,625	-	Marion	-	-	-	45,980	285,318
Charlotte	-	18,010	24,122	115,936	1,910	Martin	-	-	17,752	95,554	33,012
Citrus	9,092	-	-	21,077	111,067	Miami-Dade	89,865	137,904	168,936	1,167,648	928,774
Clay	-	-	13,596	154,992	22,277	Monroe	49,345	14,453	3,548	5,744	-
Collier	11,601	11,861	23,527	159,380	115,151	Nassau	-	12,311	7,980	48,964	4,059
Columbia	-	-	-	24,177	43,354	Okaloosa	-	-	-	141,294	39,528
DeSoto	1,218	-	-	22,672	10,972	Okeechobee	-	-	-	30,627	9,369
Dixie	-	-	-	11,432	4,990	Orange	-	-	-	24,945	1,121,011
Duval	-	6,261	70,385	413,209	374,408	Osceola	-	-	-	7,194	261,491
Escambia	-	-	3,978	136,281	157,360	Palm Beach	-	1,683	14,521	956,024	347,234
Flagler	-	3,217	3,986	35,001	53,492	Pasco	1,487	8,141	16,134	50,114	388,821
Franklin	-	1,690	2,804	7,055	-	Pinellas	-	27,854	95,871	377,269	415,548
Gadsden	-	-	-	26,582	19,807	Polk	-	-	-	-	602,095
Gilchrist	-	-	-	10,510	6,429	Putnam	-	-	9,421	49,578	15,365
Glades	-	-	-	12,884	-	Santa Rosa	-	4,266	4,996	127,972	14,138
Gulf	-	-	4,450	11,413	-	Sarasota	-	6,331	8,425	253,376	111,316
Hamilton	-	-	-	14,799	-	Seminole	-	-	7,396	77,961	337,361
Hardee	-	-	-	26,772	959	St. Johns	-	6,822	17,256	142,915	23,046
Hendry	-	-	-	39,140	-	St. Lucie	5,841	3,686	4,520	198,634	65,108
Hernando	-	3,027	5,516	3,686	160,549	Sumter	-	-	-	-	87,023
Highlands	-	-	-	26,792	71,994	Suwannee	-	-	-	25,419	16,132
Hillsborough	15	4,547	16,947	377,145	830,572	Taylor	-	-	-	13,097	9,473
Holmes	-	-	-	5,544	14,383	Union	-	-	-	-	15,535
Indian River	-	3,212	19,765	88,621	26,430	Volusia	-	15,470	53,573	180,162	245,388
Jackson	-	-	-	25,398	24,348	Wakulla	-	-	-	30,776	-
Jefferson	-	-	-	4,380	10,381	Walton	-	-	-	34,262	20,781
Lafayette	-	-	-	8,870	-	Washington	-	-	-	16,682	8,214
Lake	-	-	1,634	21,594	273,824	**State Total**	**193,858**	**393,415**	**897,463**	**7,850,372**	**9,455,818**

Analyzing Sea Level Rise in Combination with SoVI and MedVI

Overlaying hazard threats and vulnerable populations provides a unique perspective into the diverse set of mitigation and adaptation possibilities that might otherwise be too complicated to tease out of tabular data. Figure 36 through Figure 41 display bivariate representations of the three different SLR scenarios coupled with social and medical vulnerability.

About Bivariate Classifications

Here, we keep the exposure constant by using the same hazard threat surface but use different vulnerability perspectives (social and medical) in bivariate representations to create an easily understood depiction of not only increased threat but also a limited ability to adequately prepare for and respond to these threats. In doing so, we are able to quickly identify three specific geographic areas of interest:

1. Areas where the hazard itself should be the focus of planning and mitigation,

2. Areas where understanding the underlying socioeconomics and demographics would prove to be the most advantageous input point to create positive change, and

3. Areas where a combination of classic hazard mitigation techniques and social mitigation practices should be utilized in order to maximize optimal outcomes.

The following maps utilize a three by three bivariate representation in which one can easily identify areas of limited to elevated SoVI in relation to areas with low to extreme hazard classifications. Places identified in item number one in the preceding list are shaded in the blue colors and can be understood as locations where hazard susceptibility is higher than SoVI or MedVI. Areas identified in item number two above, indicating where socioeconomics and demographics play an important role, are shaded in the pink/red colors and can be conceived as locations where SoVI or MedVI are greater than physical hazard threats. Places identified in item number three above are shaded either in gray-tones or in a dark burgundy color and can be understood as areas that have equal vulnerability and hazard classification scores.

Integrating Low Projected Sea Level Rise with SoVI and MedVI

Figure 36 depicts the intersection of social vulnerability and low projected SLR risk for the entire state of Florida. The hatched lines indicate areas where limited (< 25%) land area would be inundated by 28.5 cm of SLR in association with the underlying social vulnerability of the census tract. Here, southern Miami-Dade County can be clearly identified with extreme SLR risk and high social vulnerability. This is the only tract in the state with both high social vulnerability and extreme hazard vulnerability, representing a population of 6,000 (Table 51). In this purple-shaded census tract, both mitigation of the threat source (physical protection) and adaptation strategies should be utilized to combat the possible impacts of SLR. Places symbolized in red shades indicate places where social vulnerability is generally higher than hazard vulnerability (high and medium SLR risk in Table 51). In these places, with 6 census tracts and 34,000 residents, social mitigation programs aimed at assisting people can greatly influence hazard impacts. An additional 419 tracts across 32 counties containing 1.9 million people are characterized by high SoVI coincident with low risk from low estimated SLR.

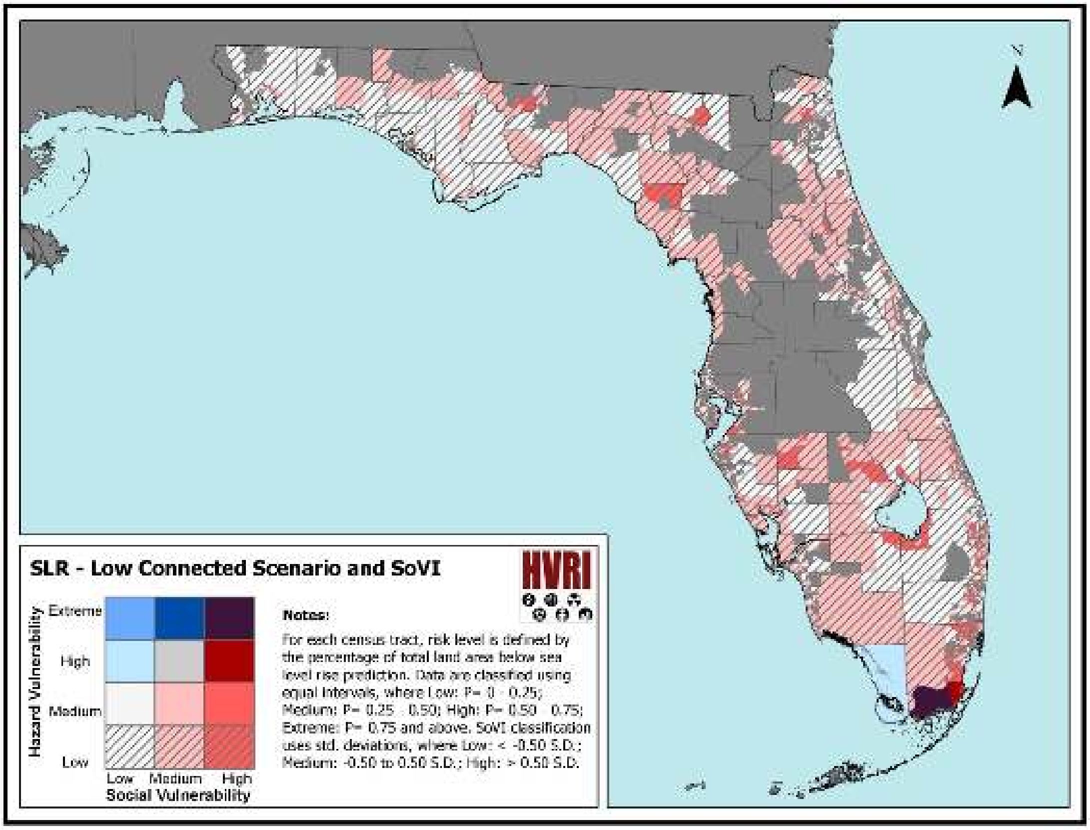

Figure 36: Bivariate representation of SoVI and low connected SLR risk in Florida.

Table 51: Tract and population summary for counties with high SoVI and medium or greater low SLR estimate risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Low SLR Estimate								
Miami-Dade	1	6,218		-	-		-	-
State Total	**1**	**6,218**		-	-		-	-
High Risk from Low SLR Estimate								
Miami-Dade	2	20,771		-	-		-	-
State Total	**2**	**20,771**		-	-		-	-
Medium Risk from Low SLR Estimate								
Lee	1	3,057	Miami-Dade	3	10,658		-	-
State Total	**4**	**13,715**		-	-		-	-

Figure 37 displays the combination of low SLR prediction inundation risk and MedVI. Here, a different story begins to emerge as the focus is on human health rather than underlying socioeconomics and demographics. The same census tract in southern Miami-Dade County that has high SoVI is actually one of the only tracts with low MedVI and extreme threat from low SLR inundation (Figure 37). Table 52 lists counties, tracts, and population totals for those places that have both high MedVI and extreme to medium risk from low estimate SLR. Note that only eight census tracts containing fewer than 30,000 people have high medical vulnerability coupled with a medium or higher threat from low estimate SLR. These places, although rare, face adverse impacts from hazard events and have communities and populations with less ability to medically prepare for and cope with these threats. Fifty counties contain census tracts characterized by high MedVI and low risk from a low estimate of SLR. Nearly 2 million people reside within these 448 census tracts.

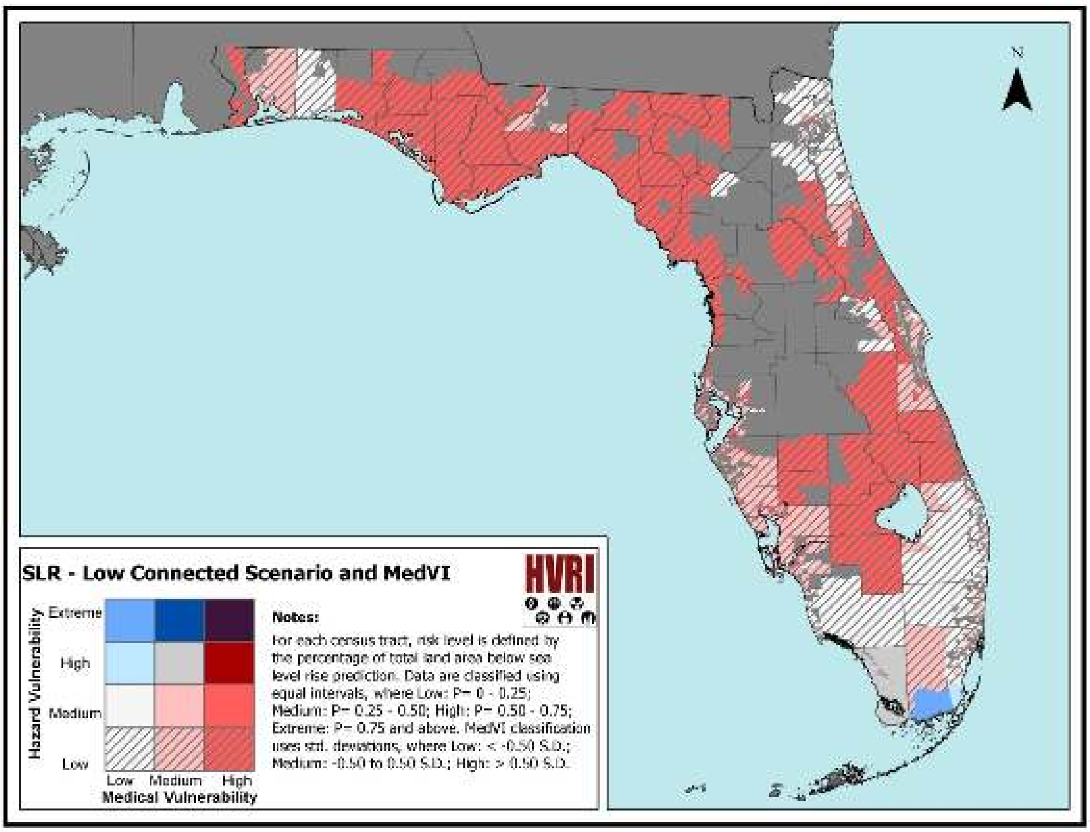

Figure 37: Bivariate representation of MedVI and low connected SLR risk in Florida.

Table 52: Tract and population summary for counties with high MedVI and medium or greater low SLR estimate risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Low SLR Estimate								
DeSoto	1	1,218		-	-		-	-
State Total	**1**	**1,218**		-	-		-	-
High Risk from Low SLR Estimate								
St. Lucie	2	5,841		-	-		-	-
State Total	**2**	**5,841**		-	-		-	-
Medium Risk from Low SLR Estimate								
Citrus	1	4,498	Flagler	1	3,217	St. Lucie	1	3,686
Volusia	2	8,994		-	-		-	-
State Total	**5**	**20,395**		-	-		-	-

Integrating Moderate Projected Sea Level Rise with SoVI and MedVI

Figure 38 provides a glimpse into moderate SLR threat (66.9 cm) in combination with social vulnerability. Here, much the same as the lower SLR prediction, south Florida has a higher risk and a higher social vulnerability while portions of north Florida begin to move into medium SLR risk categories coupled with lower to moderate levels of social vulnerability. Eight counties contain 18 tracts with high SoVI populations and medium to extreme risk levels related to moderate estimates of SLR (Table 53). More than 75,000 people reside in these areas that may see impacts from a moderate sea level rise in the future.

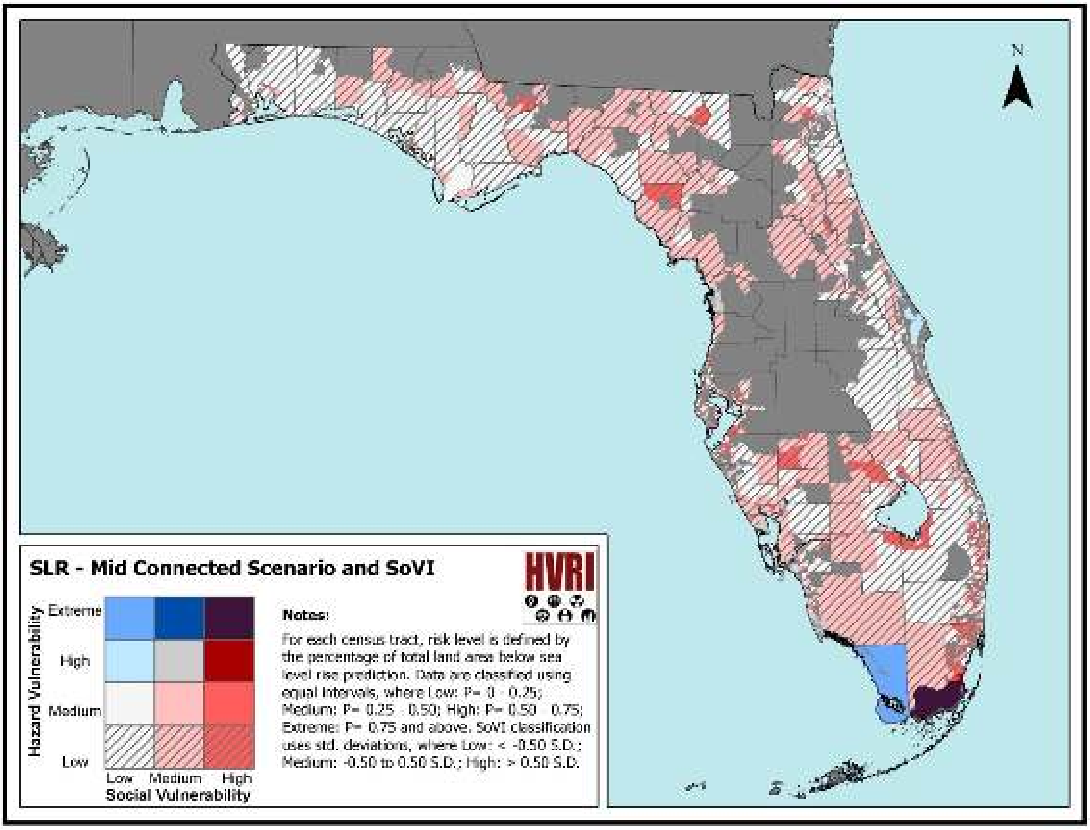

Figure 38: Bivariate representation of SoVI and mid connected SLR risk in Florida.

Table 53: Tract and population summary for counties with high SoVI and medium or greater moderate SLR estimate risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Moderate SLR Estimate								
Miami-Dade	2	21,605		-	-		-	-
State Total	**2**	**21,605**		-	-		-	-
High Risk from Moderate SLR Estimate								
Lee	1	3,057	Miami-Dade	3	14,721		-	-
State Total	**4**	**17,778**		-	-		-	-
Medium Risk from Moderate SLR Estimate								
Hillsborough	1	1,304	Indian River	3	5,566	Lee	1	2,768
Manatee	1	4,914	Miami-Dade	3	15,575	Pasco	1	1,487
Putnam	1	3,107	St. Lucie	1	1,743		-	-
State Total	**12**	**36,464**		-	-		-	-

When MedVI is coupled with moderate risk, a few areas appear as priorities. Much of the northwest coast of Florida has a low to moderate high SLR threat and high MedVI (Figure 39). Included here are 12 counties in which over 100,000 people reside in 32 medium to extreme SLR risk tracts (Table 54). An additional 50 counties containing 432 census tracts and 1.9 million people have coincident low risk from moderate SLR and high medical vulnerability. While these places are less threatened by the possibility of sea level rise, they have a higher pre-disposition to adverse impacts based on their medical characteristics.

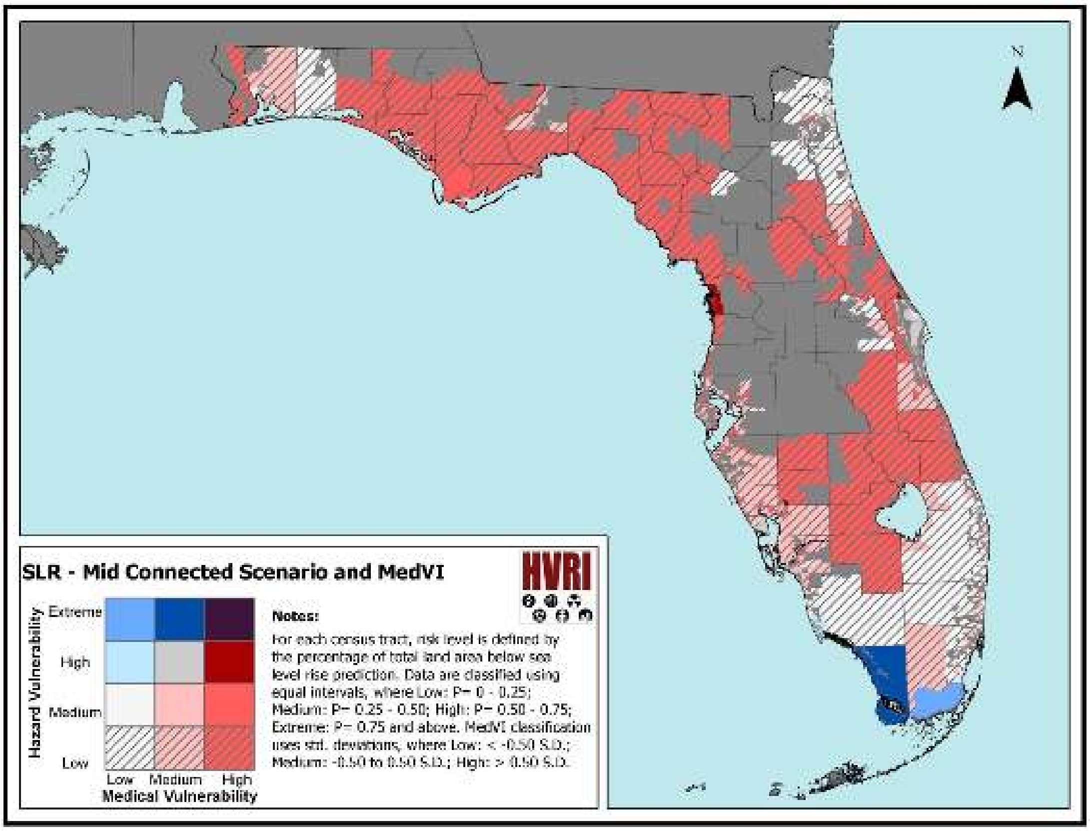

Figure 39: Bivariate representation of MedVI and mid connected SLR risk in Florida.

Table 54: Tract and population summary for counties with high MedVI and medium or greater moderate SLR estimate risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from Moderate SLR Estimate								
DeSoto	1	1,218		-	-		-	-
State Total	**1**	**1,218**		-	-		-	-
High Risk from Moderate SLR Estimate								
Citrus	2	9,092	St. Lucie	2	5,841	Volusia	2	4,381
State Total	**6**	**19,314**		-	-		-	-
Medium Risk from Moderate SLR Estimate								
Flagler	1	3,217	Franklin	2	4,494	Gulf	1	4,450
Hernando	1	3,027	Hillsborough	1	1,304	Indian River	4	10,857
Pasco	4	8,184	Putnam	2	9,421	St. Lucie	2	5,429
Volusia	7	31,230		-	-		-	-
State Total	**25**	**81,613**		-	-		-	-

Integrating High Projected Sea Level Rise with SoVI and MedVI

High predicated SLR (126.3 cm) stands to heavily impact much of coastal Florida. Broward, Citrus, Miami-Date, and Okeechobee Counties are highlighted in the depiction of social vulnerability and high SLR risk presented in Figure 40. Ten counties contain 48 tracts and nearly 330,000 residents characterized by high social vulnerability and a medium to high level of SLR risk in this scenario (Table 55). Furthermore, many inland portions of Miami-Dade exhibit extreme levels of SLR risk coupled with various levels of social vulnerability. An additional 32 counties including 417 tracts and nearly 2 million people have at least a low level of SLR risk and high social vulnerability.

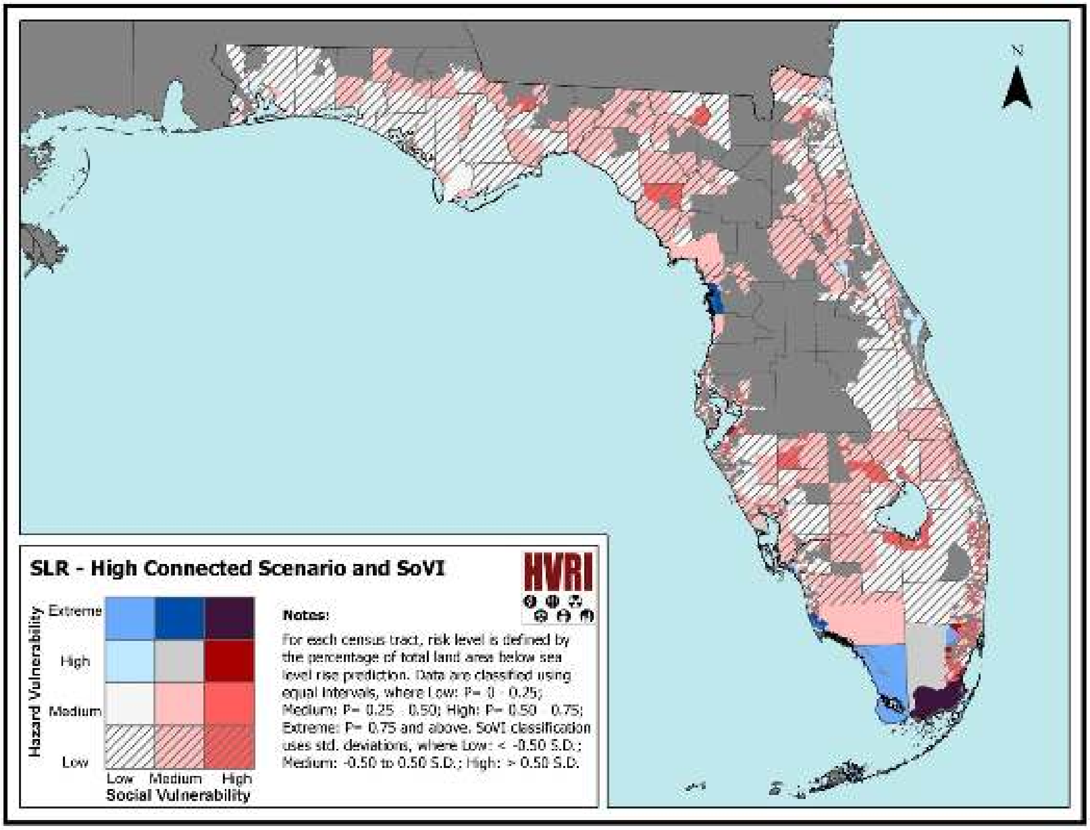

Figure 40: Bivariate representation of SoVI and high connected SLR risk in Florida.

Table 55: Tract and population summary for counties with high SoVI and medium or greater high SLR estimate risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from High SLR Estimate								
Broward	1	3,098	Lee	1	3,057	Miami-Dade	7	51,608
Pasco	1	1,487		-	-		-	-
State Total	**10**	**59,250**		-	-		-	-
High Risk from High SLR Estimate								
Hillsborough	1	1,304	Indian River	2	3,212	Lee	1	2,768
Miami-Dade	10	59,006		-	-		-	-
State Total	**14**	**66,290**		-	-		-	-
Medium Risk from High SLR Estimate								
Collier	2	3,409	Indian River	1	2,354	Manatee	2	9,457
Miami-Dade	17	83,610	Putnam	1	3,107	St. Lucie	1	1,743
State Total	**24**	**103,680**		-	-		-	-

Areas mentioned above as having higher levels of SoVI tend to have lower levels of MedVI (Figure 41). However, portions of inland and coastal Volusia County as well as coastal Citrus County begin to stand out with higher MedVI and high to extreme SLR risk. Sixty-two tracts within 19 counties exhibit both high medical vulnerability and medium to high SLR risk in this scenario (Table 56). Unlike with SoVI, the greatest risk of SLR coupled with MedVI does not occur in southeast or southwest Florida but rather in Citrus County where 9,000 people live in extreme threat and high MedVI areas and in St. Lucie County where nearly 6,000 people meet these criteria.

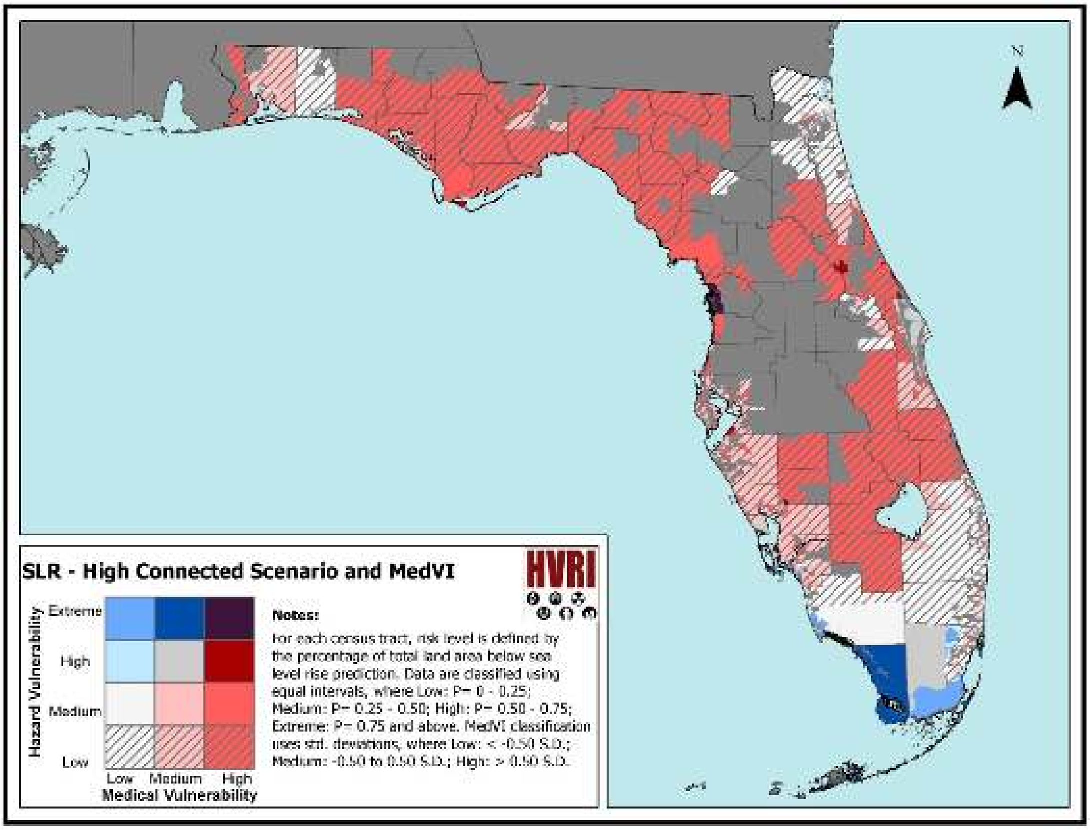

Figure 41: Bivariate representation of MedVI and high connected SLR risk in Florida.

Table 56: Tract and population summary for counties with high MedVI and medium or greater high SLR estimate risk.

County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts
Extreme Risk from High SLR Estimate										
Citrus	2	9,092		DeSoto	1	1,218		Pasco	1	1,487
St. Lucie	2	5,841			-	-			-	-
State Total	**6**	**17,638**			-	-			-	-
High Risk from High SLR Estimate										
Flagler	1	3,217		Franklin	1	1,690		Hernando	1	3,027
Hillsborough	1	1,304		Indian River	2	3,212		Pasco	3	5,754
St. Lucie	1	3,686		Volusia	4	15,470			-	-
State Total	**14**	**37,360**			-	-			-	-
Medium Risk from High SLR Estimate										
Bay	1	2,190		Charlotte	1	4,425		Escambia	1	3,978
Franklin	1	2,804		Gulf	1	4,450		Hernando	1	5,516
Hillsborough	2	6,474		Indian River	5	19,765		Lake	1	1,634
Lee	3	16,593		Levy	1	3,289		Pasco	6	16,134
Putnam	2	9,421		St. Lucie	2	4,520		Volusia	14	53,573
State Total	**42**	**154,766**			-	-			-	-

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8. Vulnerability to Extreme Heat

Methods

Future heat hazard risks for Florida were derived using an ArcGIS plugin named SimCLIM.[26] The SimCLIM tool for ArcGIS provides spatial representations of climate data for both the current climate baseline (1960-1991) and projected future climate out to the year 2100. State-specific data for Florida represents downscaled global climate data derived for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). SimCLIM data related to temperature includes projections of minimum, maximum, and departure from current baseline temperature. This project utilizes the maximum and temperature change from baseline to identify different risk levels and areas across the state of Florida. A detailed discussion of the approach used to downscale the Florida-specific data is provided below followed by an explanation of the methods used to create the tract-level future heat risk.

Downscaling Global Climate Data

Monthly projections of monthly-mean daily maximum temperature calculated by the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset are used in the downscaling represented in this report (Maurer et al., 2007). CMIP3 compares different climate models and downscaling techniques and was used for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). While climate projections that will be used in the Fifth Assessment Report (AR5) are currently available for analysis, they are not utilized here because the IPCC Synthesis Report has not yet been released.

CMIP3 includes 21 different global climate models (GCMs). These models are combined to make ensembles. Models and ensembles are run with many different settings. The settings used to create the projections presented here were selected to represent the low end, high end, and middle of the range of projections (Figure 42). The 50th percentile ensembles are used for this assessment.

[26] SimCLIM is an integrated modeling system for assessing climate change impacts and adaptation. Amongst a range of applications, it can be used to assist in climate proofing across various sectors including: water, agriculture, health, ecosystems, coastal zone issues (sea level rise and coastal erosion). More information from www.climsystems.com/simclim/.

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a]		Sea Level Rise) (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Figure 42: The six illustrative cases of carbon dioxide, methane, nitrous oxide, and sulfur dioxide emissions used in AR4.

Most climate models cover the entire globe, but this requires the use of a relatively coarse spatial resolution. In order to provide more detail, climate scientists use a process called downscaling. There are two ways to downscale data: statistical downscaling and dynamical downscaling. Dynamical downscaling involves increasing the modeled detail of physical processes. However, statistical downscaling requires less computing power than dynamical downscaling or running a regional climate model, and these other approaches are not necessarily more accurate (Brekke et al., 2013). The downscaling method used by CMIP3 that is shown here is a type of statistical downscaling known as bias corrected spatial disaggregation (BCSD) (Wood et al., 2004). BCSD is one of the most robust statistical downscaling methods (Brekke et al., 2013), and it yields results that are sufficiently comparable to other techniques (Maurer et al., 2010; Abatzoglou and Brown, 2011; Wood et al., 2004).

The fact that Florida is a peninsula creates some unique challenges. Global climate models do not have an ideal spatial resolution for representing the effects of the coast on Florida's climate (Misra et al., 2011). This also makes the use of statistical downscaling more challenging (Barsugli and Anderson, 2009). In addition, some models have difficulty representing certain climate cycles, such as the El Niño Southern Oscillation (ENSO), that affect Florida's climate (Misra et al., 2011; Joseph and Nigam, 2006).

Downscaled data for Florida representing one-km by one-km grids was utilized to create a spatial representation of annual heat hazard areas in 2100 (Figure 43) and temperature change from the 1960-1991 baseline (Figure 44) for the A1B scenario. These were compared to 2100 heat hazard areas during the warmest months of the year (June-August) (Figure 46) and temperature change during these months as compared to the 1960-1991 baseline (Figure 46) to identify areas where both temperature extremes and more rapid temperature changes will likely occur. While the monthly-mean maximum temperature (annualized high temperatures) will be highest across central Florida and into south and southwest Florida (Figure 43), the temperatures during the warmest months of the year will be highest throughout the entire state with the exception of the eastern seaboard (Figure 45). This analysis will focus on the months of June to August given the enhanced hazard risk present during that time frame. However, note that in neither instance will the modeled monthly-mean daily maximum temperatures exceed 100°F. What is perhaps more important to consider is the fact that the panhandle will experience a disproportionate increase in maximum temperatures compared to the current baseline temperature (Figure 46). It is in these places, from Panama City through Apalachicola to Jacksonville, that temperature change will likely require more adaptation, mitigation, and protective action.

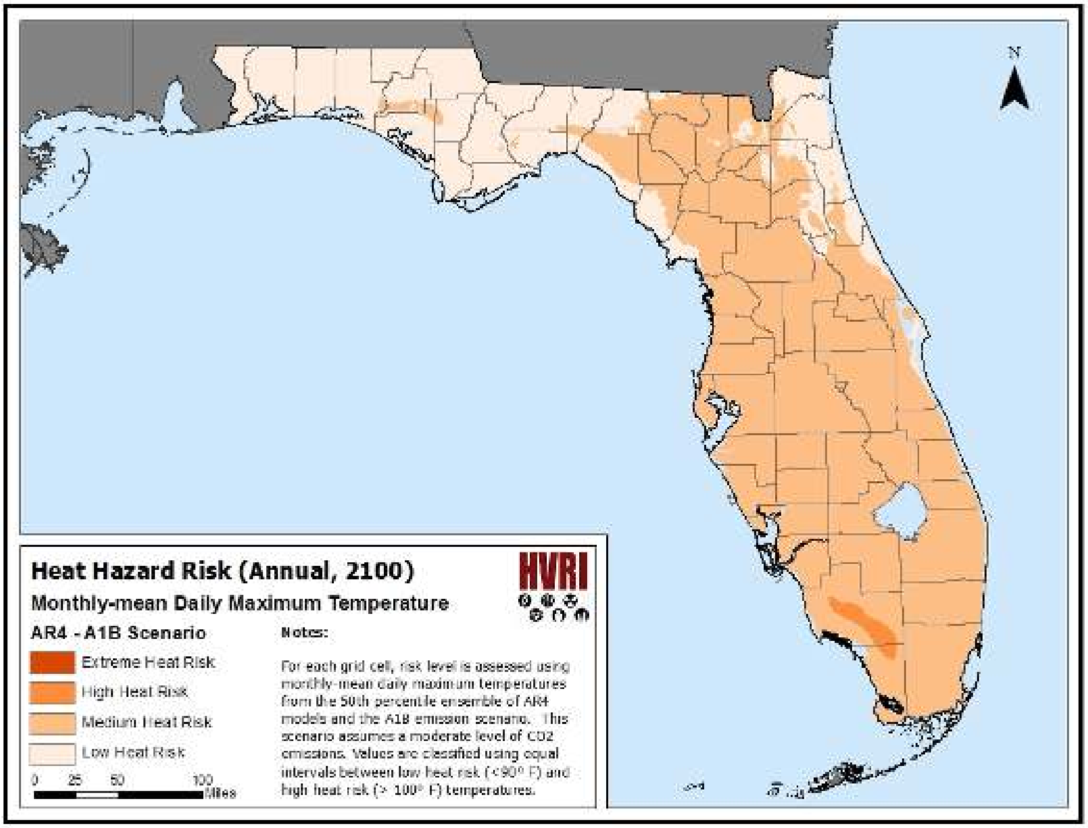

Figure 43: Monthly-mean daily maximum temperature for the A1B scenario in Florida, 2100.

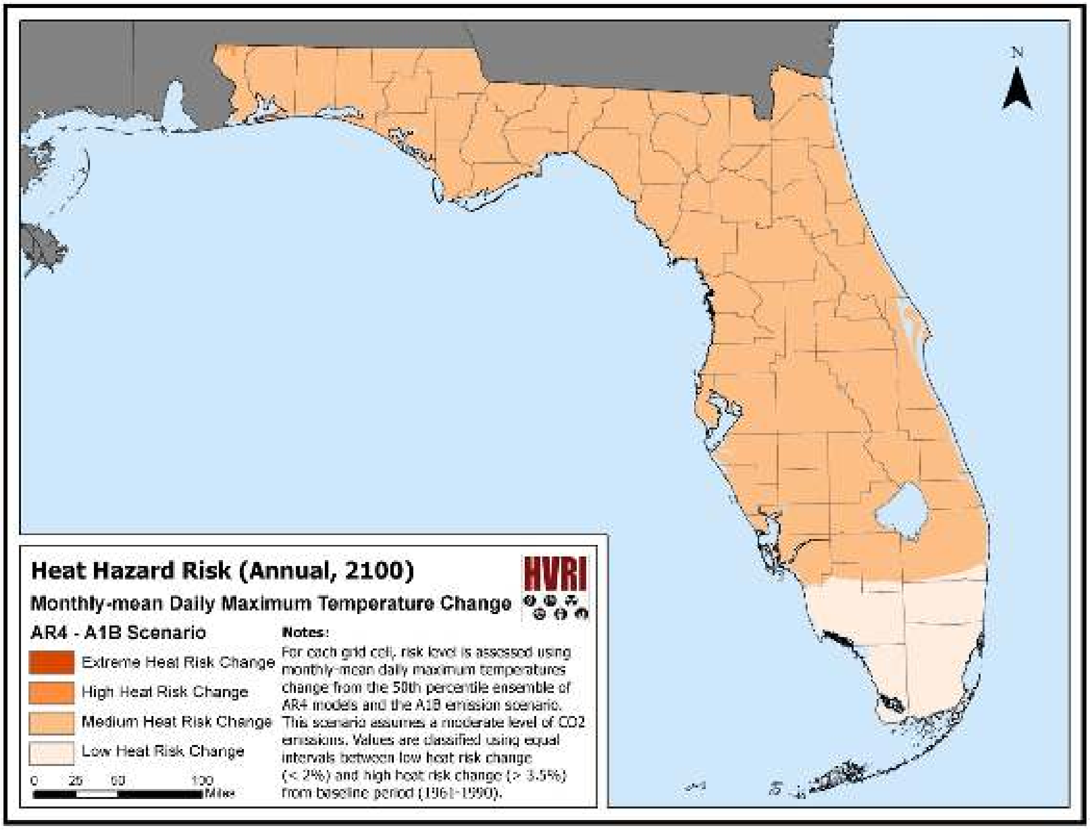

Figure 44: Annual change in monthly-mean daily maximum temperature for the A1B scenario in Florida from 1990 baseline to 2100.

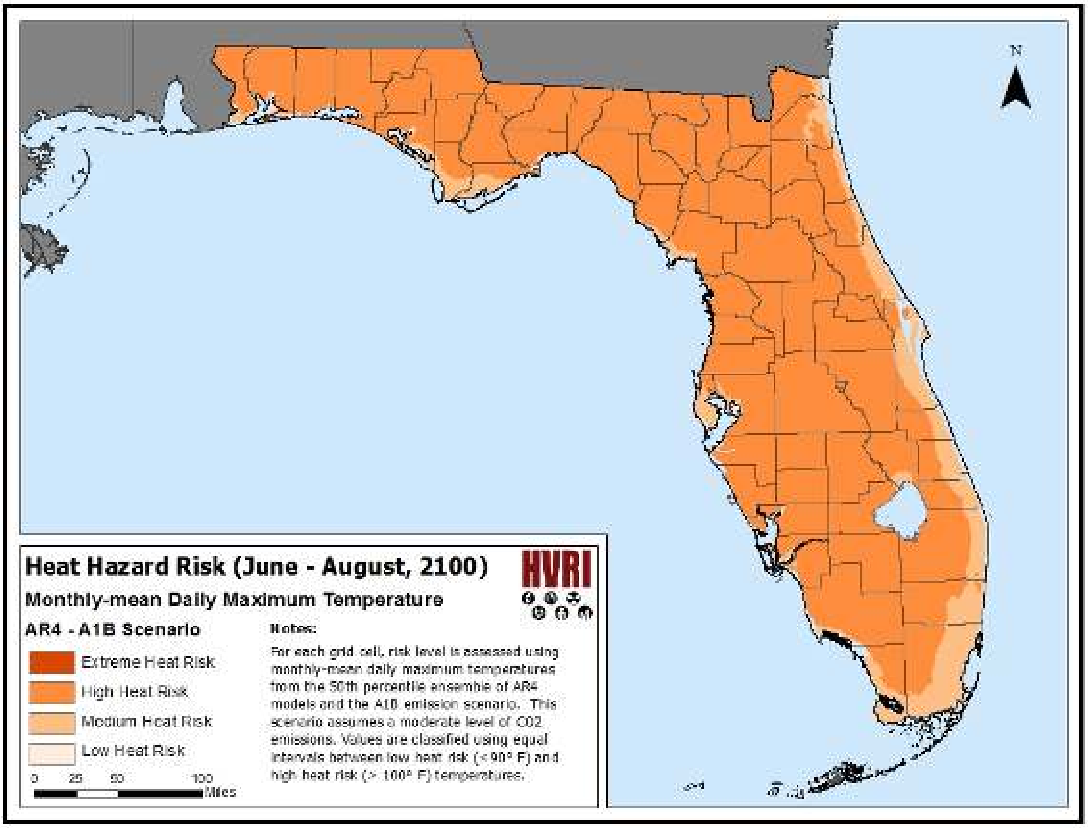

Figure 45: Monthly-mean daily maximum temperature for the A1B scenario in Florida - June-August, 2100.

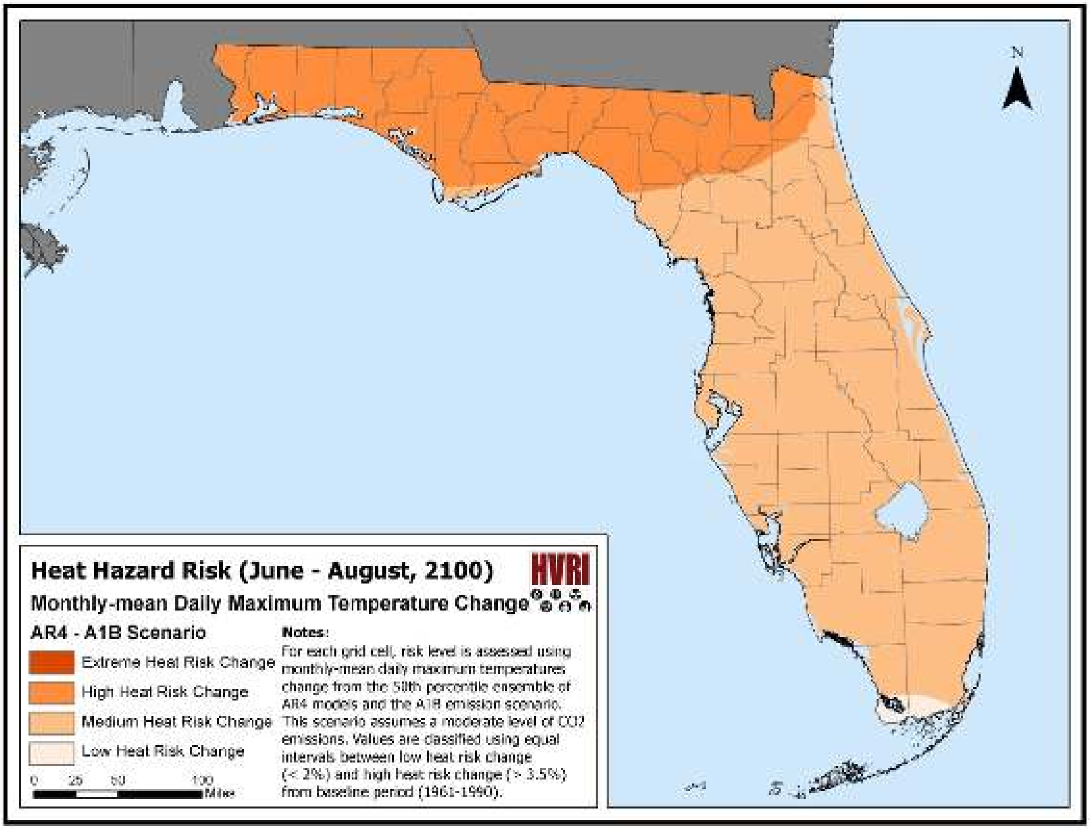

Figure 46: June-August change in monthly-mean daily maximum temperature for the A1B scenario in Florida from 1990 baseline to 2100.

Zonal statistics (min, max, average, standard deviation) utilizing known geographies – in this case census tracts - enable a transition from downscaled climate data on heat hazards to enumeration units more readily understood and analyzed. In this case, each census tract was categorized into one of five classes based on the average monthly-mean daily maximum temperature from June – August, coinciding (spatially) with it. Using the following equal interval classification scheme, future changes in risk at the tract- level can be easily seen in comparison to the current risk level:

- Low = Less than 90°F average monthly-mean daily maximum temperature from June – August
- Medium = Between 90°F - 95°F average monthly-mean daily maximum temperature from June – August
- High = Between 95°F - 100°F average monthly-mean daily maximum temperature from June – August
- Extreme = Greater than 100°F average monthly-mean daily maximum temperature from June – August

State Summary

The AR4-B1 scenario shows the vast majority of the state (97% as shown in Table 57) in the medium heat risk category (90°F - 95°F daily maximum temperatures) during the warmest months of the year (Figure 47), with over 18 million people at a medium level of risk (Table 58). In this scenario, there are no areas of the state within the low or extreme risk categories.

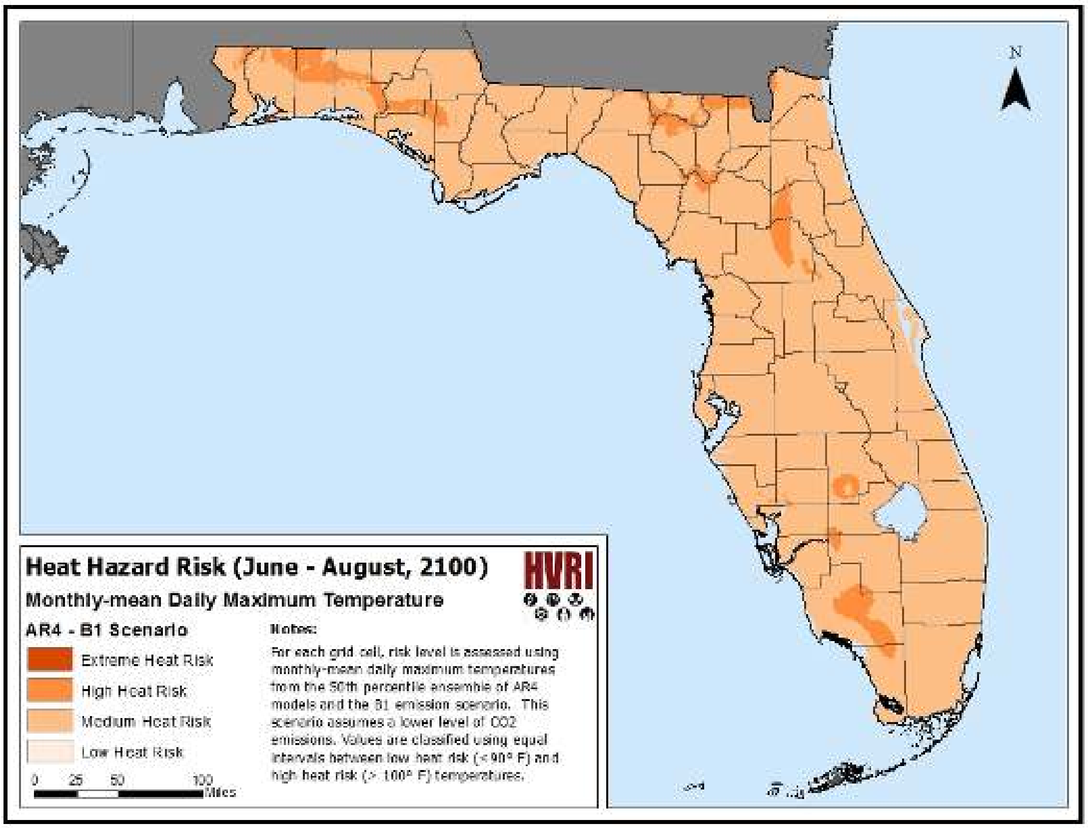

Figure 47: Heat hazard risk for B1 scenario in Florida - June-August, 2100.

Table 57: Census tract summary for heat hazard risk using the B1 scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario					County Name	Heat Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario				
	Extreme (>100°)	High (95°-100°)	Medium (90°- 95°)	Low (<90°)	Out		Extreme (>100°)	High (95°-100°)	Medium (90°- 95°)	Low (<90°)	Out
Alachua	-	5.36%	94.64%	-	-	Lee	-	0.60%	99.40%	-	-
Baker	-	25.00%	75.00%	-	-	Leon	-	-	100.00%	-	-
Bay	-	2.27%	97.73%	-	-	Levy	-	-	100.00%	-	-
Bradford	-	-	100.00%	-	-	Liberty	-	-	100.00%	-	-
Brevard	-	-	100.00%	-	-	Madison	-	60.00%	40.00%	-	-
Broward	-	-	100.00%	-	-	Manatee	-	-	100.00%	-	-
Calhoun	-	66.67%	33.33%	-	-	Marion	-	17.46%	82.54%	-	-
Charlotte	-	2.56%	97.44%	-	-	Martin	-	-	100.00%	-	-
Citrus	-	-	100.00%	-	-	Miami-Dade	-	-	100.00%	-	-
Clay	-	10.00%	90.00%	-	-	Monroe	-	74.19%	25.81%	-	-
Collier	-	5.41%	94.59%	-	-	Nassau	-	16.67%	83.33%	-	-
Columbia	-	50.00%	50.00%	-	-	Okaloosa	-	24.39%	75.61%	-	-
DeSoto	-	33.33%	66.67%	-	-	Okeechobee	-	-	100.00%	-	-
Dixie	-	-	100.00%	-	-	Orange	-	-	100.00%	-	-
Duval	-	-	100.00%	-	-	Osceola	-	-	100.00%	-	-
Escambia	-	2.82%	97.18%	-	-	Palm Beach	-	-	100.00%	-	-
Flagler	-	-	100.00%	-	-	Pasco	-	-	100.00%	-	-
Franklin	-	-	100.00%	-	-	Pinellas	-	-	100.00%	-	-
Gadsden	-	-	100.00%	-	-	Polk	-	-	100.00%	-	-
Gilchrist	-	40.00%	60.00%	-	-	Putnam	-	29.41%	70.59%	-	-
Glades	-	75.00%	25.00%	-	-	Santa Rosa	-	8.00%	92.00%	-	-
Gulf	-	-	100.00%	-	-	Sarasota	-	2.13%	97.87%	-	-
Hamilton	-	100.00%	-	-	-	Seminole	-	-	100.00%	-	-
Hardee	-	-	100.00%	-	-	St. Johns	-	-	100.00%	-	-
Hendry	-	66.67%	33.33%	-	-	St. Lucie	-	-	100.00%	-	-
Hernando	-	-	100.00%	-	-	Sumter	-	-	100.00%	-	-
Highlands	-	14.81%	85.19%	-	-	Suwannee	-	85.71%	14.29%	-	-
Hillsborough	-	-	100.00%	-	-	Taylor	-	-	100.00%	-	-
Holmes	-	25.00%	75.00%	-	-	Union	-	-	100.00%	-	-
Indian River	-	-	100.00%	-	-	Volusia	-	-	100.00%	-	-
Jackson	-	18.18%	81.82%	-	-	Wakulla	-	25.00%	75.00%	-	-
Jefferson	-	33.33%	66.67%	-	-	Walton	-	63.64%	36.36%	-	-
Lafayette	-	50.00%	50.00%	-	-	Washington	-	57.14%	42.86%	-	-
Lake	-	3.57%	96.43%	-	-	**State Total**	-	2.99%	97.01%	-	-

Table 58: Census tract population summary for heat hazard risk using the B1 scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario					County Name	Heat Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario				
	Extreme (>100°)	High (95°-100°)	Medium (90° - 95°)	Low (<90°)	Out		Extreme (>100°)	High (95°-100°)	Medium (90° - 95°)	Low (<90°)	Out
Alachua	-	21,821	225,515	-	-	Lee	-	2,800	615,954	-	-
Baker	-	7,519	19,596	-	-	Leon	-	-	275,487	-	-
Bay	-	8,552	160,300	-	-	Levy	-	-	40,801	-	-
Bradford	-	-	28,520	-	-	Liberty	-	-	8,365	-	-
Brevard	-	-	543,369	-	-	Madison	-	10,553	8,671	-	-
Broward	-	-	1,748,066	-	-	Manatee	-	-	322,833	-	-
Calhoun	-	12,192	2,433	-	-	Marion	-	38,293	293,005	-	-
Charlotte	-	3,837	156,141	-	-	Martin	-	-	146,318	-	-
Citrus	-	-	141,236	-	-	Miami-Dade	-	-	2,493,127	-	-
Clay	-	12,461	178,404	-	-	Monroe	-	54,862	18,228	-	-
Collier	-	32,680	288,840	-	-	Nassau	-	14,983	58,331	-	-
Columbia	-	33,918	33,613	-	-	Okaloosa	-	66,486	114,336	-	-
DeSoto	-	8,341	26,521	-	-	Okeechobee	-	-	39,996	-	-
Dixie	-	-	16,422	-	-	Orange	-	-	1,145,956	-	-
Duval	-	-	864,263	-	-	Osceola	-	-	268,685	-	-
Escambia	-	9,859	287,760	-	-	Palm Beach	-	-	1,319,462	-	-
Flagler	-	-	95,696	-	-	Pasco	-	-	464,697	-	-
Franklin	-	-	11,549	-	-	Pinellas	-	-	916,542	-	-
Gadsden	-	-	46,389	-	-	Polk	-	-	602,095	-	-
Gilchrist	-	7,470	9,469	-	-	Putnam	-	25,540	48,824	-	-
Glades	-	10,618	2,266	-	-	Santa Rosa	-	8,185	143,187	-	-
Gulf	-	-	15,863	-	-	Sarasota	-	41,193	338,255	-	-
Hamilton	-	14,799	-	-	-	Seminole	-	-	422,718	-	-
Hardee	-	-	27,731	-	-	St. Johns	-	-	190,039	-	-
Hendry	-	24,824	14,316	-	-	St. Lucie	-	-	277,789	-	-
Hernando	-	-	172,778	-	-	Sumter	-	-	87,023	-	-
Highlands	-	14,709	84,077	-	-	Suwannee	-	39,748	1,803	-	-
Hillsborough	-	-	1,229,226	-	-	Taylor	-	-	22,570	-	-
Holmes	-	5,544	14,383	-	-	Union	-	-	15,535	-	-
Indian River	-	-	138,028	-	-	Volusia	-	-	494,593	-	-
Jackson	-	9,293	40,453	-	-	Wakulla	-	5,276	25,500	-	-
Jefferson	-	4,496	10,265	-	-	Walton	-	32,866	22,177	-	-
Lafayette	-	5,706	3,164	-	-	Washington	-	16,682	8,214	-	-
Lake	-	5,077	291,975	-	-	**State Total**	-	611,183	18,179,743	-	-

Looking at the A1B scenario tells a different story, with most census tracts within the state falling into a high heat risk category (95°F - 100°F daily maximum temperatures). The exception can be seen (Figure 48) along the entire eastern seaboard where daily maximum temperatures will be slightly cooler. As with the B1 scenario, no populations in Florida will fall into the extreme risk category in the A1B scenario (Table 60). However, the converse is also true in that no place in Florida will be in the low heat risk category (<85°F) using this scenario. Additionally, the A1B scenario places a much higher percentage of census tracts in the high risk zone (Table 59) than did the B1 scenario.

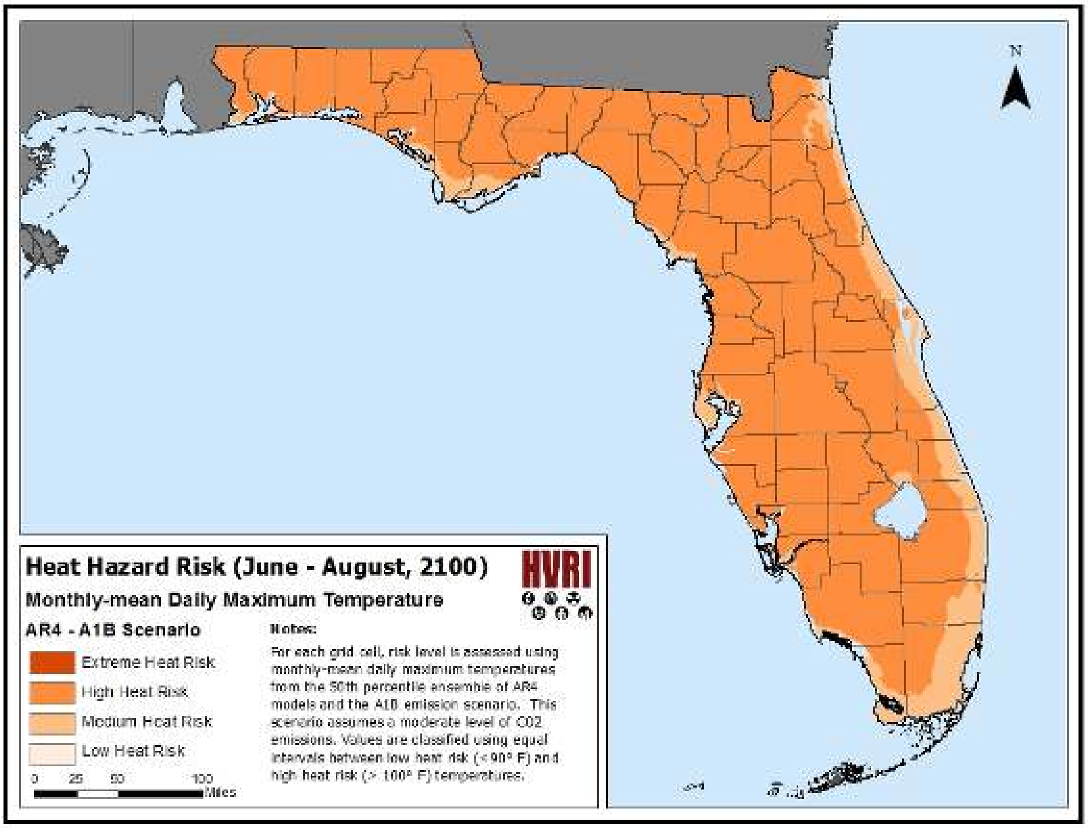

Figure 48: Heat hazard risk for A1B scenario in Florida - June-August, 2100.

Table 59: Census tract summary for heat hazard risk using the A1B scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-A1B (Mid-emission) scenario					County Name	Heat Hazard Risk in June - August 2100 using AR4-A1B (Mid-emission) scenario				
	Extreme (>100°)	High (95° - 100°)	Medium (90° - 95°)	Low (<90°)	Out		Extreme (>100°)	High (95° - 100°)	Medium (90° - 95°)	Low (<90°)	Out
Alachua	-	100.00%	-	-	-	Lee	-	89.22%	10.78%	-	-
Baker	-	100.00%	-	-	-	Leon	-	100.00%	-	-	-
Bay	-	77.27%	22.73%	-	-	Levy	-	100.00%	-	-	-
Bradford	-	100.00%	-	-	-	Liberty	-	100.00%	-	-	-
Brevard	-	18.58%	81.42%	-	-	Madison	-	100.00%	-	-	-
Broward	-	8.59%	91.41%	-	-	Manatee	-	100.00%	-	-	-
Calhoun	-	100.00%	-	-	-	Marion	-	100.00%	-	-	-
Charlotte	-	100.00%	-	-	-	Martin	-	8.82%	91.18%	-	-
Citrus	-	100.00%	-	-	-	Miami-Dade	-	0.58%	99.42%	-	-
Clay	-	100.00%	-	-	-	Monroe	-	74.19%	25.81%	-	-
Collier	-	91.89%	8.11%	-	-	Nassau	-	50.00%	50.00%	-	-
Columbia	-	100.00%	-	-	-	Okaloosa	-	85.37%	14.63%	-	-
DeSoto	-	100.00%	-	-	-	Okeechobee	-	63.64%	36.36%	-	-
Dixie	-	100.00%	-	-	-	Orange	-	100.00%	-	-	-
Duval	-	78.61%	21.39%	-	-	Osceola	-	100.00%	-	-	-
Escambia	-	80.28%	19.72%	-	-	Palm Beach	-	16.37%	83.63%	-	-
Flagler	-	50.00%	50.00%	-	-	Pasco	-	100.00%	-	-	-
Franklin	-	50.00%	50.00%	-	-	Pinellas	-	13.88%	86.12%	-	-
Gadsden	-	100.00%	-	-	-	Polk	-	100.00%	-	-	-
Gilchrist	-	100.00%	-	-	-	Putnam	-	100.00%	-	-	-
Glades	-	100.00%	-	-	-	Santa Rosa	-	80.00%	20.00%	-	-
Gulf	-	66.67%	33.33%	-	-	Sarasota	-	100.00%	-	-	-
Hamilton	-	100.00%	-	-	-	Seminole	-	100.00%	-	-	-
Hardee	-	100.00%	-	-	-	St. Johns	-	43.59%	56.41%	-	-
Hendry	-	100.00%	-	-	-	St. Lucie	-	4.55%	95.45%	-	-
Hernando	-	100.00%	-	-	-	Sumter	-	100.00%	-	-	-
Highlands	-	100.00%	-	-	-	Suwannee	-	100.00%	-	-	-
Hillsborough	-	86.92%	13.08%	-	-	Taylor	-	100.00%	-	-	-
Holmes	-	100.00%	-	-	-	Union	-	100.00%	-	-	-
Indian River	-	6.67%	93.33%	-	-	Volusia	-	38.60%	61.40%	-	-
Jackson	-	100.00%	-	-	-	Wakulla	-	100.00%	-	-	-
Jefferson	-	100.00%	-	-	-	Walton	-	100.00%	-	-	-
Lafayette	-	100.00%	-	-	-	Washington	-	100.00%	-	-	-
Lake	-	100.00%	-	-	-	**State Total**	-	57.49%	42.51%	-	-

Table 60: Census tract population summary for heat hazard risk using the A1B scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-A1B (Mid-emission) scenario				
	Extreme (>100°)	High (95° - 100°)	Medium (90° - 95°)	Low (<90°)	Out
Alachua	-	247,336	-	-	-
Baker	-	27,115	-	-	-
Bay	-	138,206	30,646	-	-
Bradford	-	28,520	-	-	-
Brevard	-	119,319	424,050	-	-
Broward	-	176,747	1,571,319	-	-
Calhoun	-	14,625	-	-	-
Charlotte	-	159,978	-	-	-
Citrus	-	141,236	-	-	-
Clay	-	190,865	-	-	-
Collier	-	304,840	16,680	-	-
Columbia	-	67,531	-	-	-
DeSoto	-	34,862	-	-	-
Dixie	-	16,422	-	-	-
Duval	-	669,106	195,157	-	-
Escambia	-	241,653	55,966	-	-
Flagler	-	59,397	36,299	-	-
Franklin	-	7,055	4,494	-	-
Gadsden	-	46,389	-	-	-
Gilchrist	-	16,939	-	-	-
Glades	-	12,884	-	-	-
Gulf	-	12,787	3,076	-	-
Hamilton	-	14,799	-	-	-
Hardee	-	27,731	-	-	-
Hendry	-	39,140	-	-	-
Hernando	-	172,778	-	-	-
Highlands	-	98,786	-	-	-
Hillsborough	-	1,082,424	146,802	-	-
Holmes	-	19,927	-	-	-
Indian River	-	14,368	123,660	-	-
Jackson	-	49,746	-	-	-
Jefferson	-	14,761	-	-	-
Lafayette	-	8,870	-	-	-
Lake	-	297,052	-	-	-
Lee	-	553,882	64,872	-	-
Leon	-	275,487	-	-	-
Levy	-	40,801	-	-	-
Liberty	-	8,365	-	-	-
Madison	-	19,224	-	-	-
Manatee	-	322,833	-	-	-
Marion	-	331,298	-	-	-
Martin	-	20,302	126,016	-	-
Miami-Dade	-	12,923	2,480,204	-	-
Monroe	-	54,862	18,228	-	-
Nassau	-	40,551	32,763	-	-
Okaloosa	-	165,257	15,565	-	-
Okeechobee	-	25,456	14,540	-	-
Orange	-	1,145,956	-	-	-
Osceola	-	268,685	-	-	-
Palm Beach	-	252,699	1,066,763	-	-
Pasco	-	464,697	-	-	-
Pinellas	-	143,008	773,534	-	-
Polk	-	602,095	-	-	-
Putnam	-	74,364	-	-	-
Santa Rosa	-	123,191	28,181	-	-
Sarasota	-	379,448	-	-	-
Seminole	-	422,718	-	-	-
St. Johns	-	106,445	83,594	-	-
St. Lucie	-	14,523	263,266	-	-
Sumter	-	87,023	-	-	-
Suwannee	-	41,551	-	-	-
Taylor	-	22,570	-	-	-
Union	-	15,535	-	-	-
Volusia	-	228,217	266,376	-	-
Wakulla	-	30,776	-	-	-
Walton	-	55,043	-	-	-
Washington	-	24,896	-	-	-
State Total	-	10,948,875	7,842,051	-	-

The A1FI scenario plays out the most extreme projection for the state of Florida, with almost 96% of the census tracts in the state in the high risk category (Table 61) corresponding to over 18 million people (Table 62). This scenario also includes some extreme risk areas in northern Florida and in the panhandle (Figure 49), with a small portion of Miami-Dade County being the only part of the state in the medium risk category.

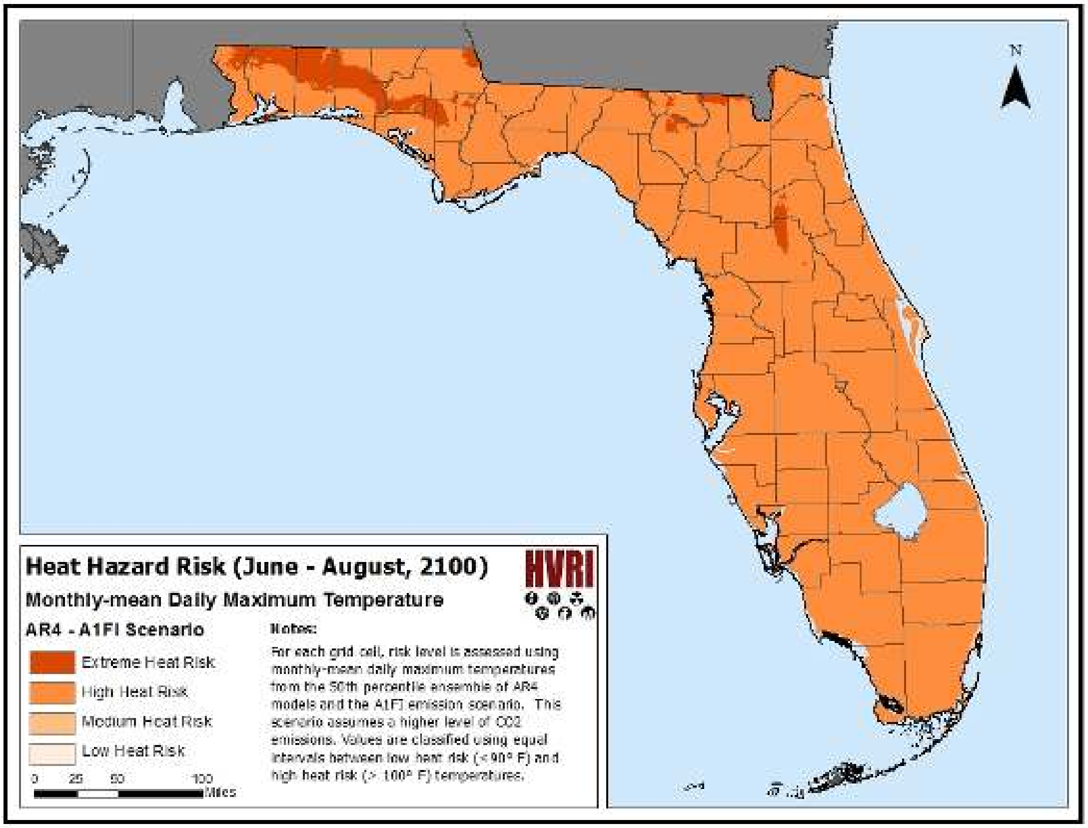

Figure 49: Heat hazard risk for A1FI scenario in Florida - June-August, 2100.

Table 61: Census tract summary for heat hazard risk using the A1FI scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario					County Name	Heat Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario				
	Extreme (>100°)	High (95°-100°)	Medium (90°-95°)	Low (<90°)	Out		Extreme (>100°)	High (95°-100°)	Medium (90°-95°)	Low (<90°)	Out
Alachua	-	100.00%	-	-	-	Lee	-	100.00%	-	-	-
Baker	25.00%	75.00%	-	-	-	Leon	-	100.00%	-	-	-
Bay	2.27%	97.73%	-	-	-	Levy	-	100.00%	-	-	-
Bradford	-	100.00%	-	-	-	Liberty	100.00%	-	-	-	-
Brevard	-	100.00%	-	-	-	Madison	40.00%	60.00%	-	-	-
Broward	-	100.00%	-	-	-	Manatee	-	100.00%	-	-	-
Calhoun	100.00%	-	-	-	-	Marion	11.11%	88.89%	-	-	-
Charlotte	-	100.00%	-	-	-	Martin	-	100.00%	-	-	-
Citrus	-	100.00%	-	-	-	Miami-Dade	-	79.77%	20.23%	-	-
Clay	-	100.00%	-	-	-	Monroe	-	100.00%	-	-	-
Collier	-	100.00%	-	-	-	Nassau	16.67%	83.33%	-	-	-
Columbia	16.67%	83.33%	-	-	-	Okaloosa	24.39%	75.61%	-	-	-
DeSoto	-	100.00%	-	-	-	Okeechobee	-	100.00%	-	-	-
Dixie	-	100.00%	-	-	-	Orange	-	100.00%	-	-	-
Duval	-	100.00%	-	-	-	Osceola	-	100.00%	-	-	-
Escambia	4.23%	95.77%	-	-	-	Palm Beach	-	100.00%	-	-	-
Flagler	-	100.00%	-	-	-	Pasco	-	100.00%	-	-	-
Franklin	-	100.00%	-	-	-	Pinellas	-	100.00%	-	-	-
Gadsden	11.11%	88.89%	-	-	-	Polk	-	100.00%	-	-	-
Gilchrist	-	100.00%	-	-	-	Putnam	23.53%	76.47%	-	-	-
Glades	-	100.00%	-	-	-	Santa Rosa	12.00%	88.00%	-	-	-
Gulf	-	100.00%	-	-	-	Sarasota	-	100.00%	-	-	-
Hamilton	100.00%	-	-	-	-	Seminole	-	100.00%	-	-	-
Hardee	-	100.00%	-	-	-	St. Johns	-	100.00%	-	-	-
Hendry	-	100.00%	-	-	-	St. Lucie	-	100.00%	-	-	-
Hernando	-	100.00%	-	-	-	Sumter	-	100.00%	-	-	-
Highlands	-	100.00%	-	-	-	Suwannee	71.43%	28.57%	-	-	-
Hillsborough	-	100.00%	-	-	-	Taylor	-	100.00%	-	-	-
Holmes	25.00%	75.00%	-	-	-	Union	-	100.00%	-	-	-
Indian River	-	100.00%	-	-	-	Volusia	-	100.00%	-	-	-
Jackson	27.27%	72.73%	-	-	-	Wakulla	-	100.00%	-	-	-
Jefferson	33.33%	66.67%	-	-	-	Walton	63.64%	36.36%	-	-	-
Lafayette	-	100.00%	-	-	-	Washington	57.14%	42.86%	-	-	-
Lake	-	100.00%	-	-	-	**State Total**	1.54%	95.97%	2.49%	-	-

Table 62: Census tract population summary for heat hazard risk using the A1FI scenario.

County Name	Heat Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario					County Name	Heat Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario				
	Extreme (>100°)	High (95°-100°)	Medium (90°-95°)	Low (<90°)	Out		Extreme (>100°)	High (95°-100°)	Medium (90°-95°)	Low (<90°)	Out
Alachua	-	247,336	-	-	-	Lee	-	618,754	-	-	-
Baker	7,519	19,596	-	-	-	Leon	-	275,487	-	-	-
Bay	8,552	160,300	-	-	-	Levy	-	40,801	-	-	-
Bradford	-	28,520	-	-	-	Liberty	8,365	-	-	-	-
Brevard	-	543,369	-	-	-	Madison	6,834	12,390	-	-	-
Broward	-	1,748,066	-	-	-	Manatee	-	322,833	-	-	-
Calhoun	14,625	-	-	-	-	Marion	20,909	310,389	-	-	-
Charlotte	-	159,978	-	-	-	Martin	-	146,318	-	-	-
Citrus	-	141,236	-	-	-	Miami-Dade	-	2,115,040	378,087	-	-
Clay	-	190,865	-	-	-	Monroe	-	73,090	-	-	-
Collier	-	321,520	-	-	-	Nassau	14,983	58,331	-	-	-
Columbia	14,284	53,247	-	-	-	Okaloosa	66,486	114,336	-	-	-
DeSoto	-	34,862	-	-	-	Okeechobee	-	39,996	-	-	-
Dixie	-	16,422	-	-	-	Orange	-	1,145,956	-	-	-
Duval	-	864,263	-	-	-	Osceola	-	268,685	-	-	-
Escambia	14,225	283,394	-	-	-	Palm Beach	-	1,319,462	-	-	-
Flagler	-	95,696	-	-	-	Pasco	-	464,697	-	-	-
Franklin	-	11,549	-	-	-	Pinellas	-	916,542	-	-	-
Gadsden	4,769	41,620	-	-	-	Polk	-	602,095	-	-	-
Gilchrist	-	16,939	-	-	-	Putnam	21,941	52,423	-	-	-
Glades	-	12,884	-	-	-	Santa Rosa	10,819	140,553	-	-	-
Gulf	-	15,863	-	-	-	Sarasota	-	379,448	-	-	-
Hamilton	14,799	-	-	-	-	Seminole	-	422,718	-	-	-
Hardee	-	27,731	-	-	-	St. Johns	-	190,039	-	-	-
Hendry	-	39,140	-	-	-	St. Lucie	-	277,789	-	-	-
Hernando	-	172,778	-	-	-	Sumter	-	87,023	-	-	-
Highlands	-	98,786	-	-	-	Suwannee	32,889	8,662	-	-	-
Hillsborough	-	1,229,226	-	-	-	Taylor	-	22,570	-	-	-
Holmes	5,544	14,383	-	-	-	Union	-	15,535	-	-	-
Indian River	-	138,028	-	-	-	Volusia	-	494,593	-	-	-
Jackson	13,618	36,128	-	-	-	Wakulla	-	30,776	-	-	-
Jefferson	4,496	10,265	-	-	-	Walton	32,866	22,177	-	-	-
Lafayette	-	8,870	-	-	-	Washington	16,682	8,214	-	-	-
Lake	-	297,052	-	-	-	**State Total**	335,205	18,077,634	378,087	-	-

Analyzing Heat Hazard in Combination with SoVI and MedVI

About Bivariate Classifications

Here, we keep the exposure constant by using the same hazard threat surface but use different vulnerability perspectives (Social and Medical) in bivariate representations to create an easily understood depiction of not only increased threat but also a limited ability to adequately prepare for and respond to these threats. In doing so, we are able to quickly identify three specific geographic areas of interest:

1. Areas where the hazard itself should be the focus of planning and mitigation,
2. Areas where understanding the underlying socioeconomics and demographics would prove to be the most advantageous input point to create positive change, and
3. Areas where a combination of classic hazard mitigation techniques and social mitigation practices should be utilized in order to maximize optimal outcomes.

The following maps utilize a three by three bivariate representation in which one can easily identify areas of limited to elevated SoVI in relation to areas with low to extreme hazard classifications. Places identified in item number one in the preceding list are shaded in the blue colors and can be understood as locations where hazard susceptibility is higher than SoVI or MedVI. Areas identified in item number two above, indicating where socioeconomics and demographics play an important role, are shaded in the pink/red colors and can be conceived as locations where SoVI or MedVI are greater than physical hazard threats. Places identified in item number three above are shaded either in gray-tones or in a dark burgundy color and can be understood as areas that have equal vulnerability and hazard classification scores.

Integrating B1 Scenario Extreme Heat with SoVI and MedVI

The pattern of social vulnerability comes through clearly when coupled with heat hazard because of the general lack of variation across Florida. Only three census tracts corresponding to just over 16,000 people are susceptible to high heat risk and high social vulnerability in the AR4-B1 scenario (Table 63), but census tracts throughout central and southern Florida display medium heat risk and high social vulnerability (Figure 50).

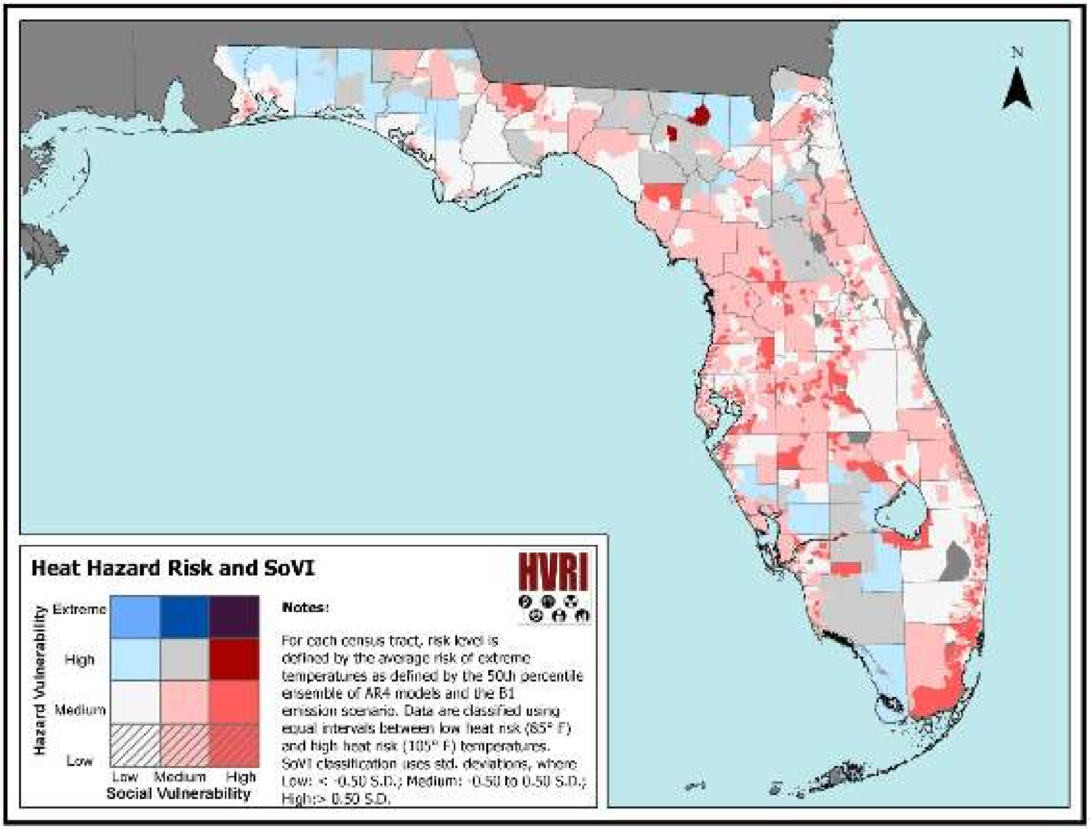

Figure 50: Bivariate representation of SoVI and heat hazard risk for B1 scenario in Florida.

Table 63: Tract and population summary for counties with high SoVI and medium or greater heat hazard risk using the B1 scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Heat Hazard Risk								
Hamilton	1	1,760	Hendry	1	7,530	Suwannee	1	7,016
State Total	**3**	**16,306**		-	-		-	-
Medium Heat Hazard Risk								
Alachua	4	19,406	Bay	3	8,846	Brevard	6	20,847
Broward	111	549,548	Charlotte	5	17,905	Citrus	5	23,598
Clay	1	5,311	Collier	15	76,682	Columbia	1	2,872
DeSoto	3	13,900	Dixie	1	7,331	Duval	37	150,426
Escambia	12	39,923	Flagler	3	15,884	Gadsden	5	25,033
Hardee	2	10,630	Hendry	2	14,316	Hernando	15	62,301
Highlands	8	35,116	Hillsborough	73	279,785	Indian River	5	14,670
Lake	9	40,805	Lee	32	100,752	Leon	6	17,898
Manatee	19	84,453	Marion	15	102,216	Martin	2	4,091
Miami-Dade	359	1,900,621	Okeechobee	3	10,116	Orange	50	252,348
Osceola	14	103,651	Palm Beach	104	378,320	Pasco	28	87,242
Pinellas	37	132,662	Polk	52	219,460	Putnam	3	10,480
Santa Rosa	1	6,115	Sarasota	13	46,430	Seminole	7	25,901
St. Johns	1	4,155	St. Lucie	10	37,115	Sumter	6	52,106
Volusia	18	83,236		-	-		-	-
State Total	**1,106**	**5,094,503**		-	-		-	-

Integrating heat hazard risk in the B1 scenario with MedVI shows a much different picture for the state of Florida. Here, a much higher percentage of the state falls into the high medical vulnerability category coupled with medium or high hazard vulnerability (Figure 51). Twenty-three counties across the state have tracts with high heat hazard risk and high medical vulnerability (Table 64). Columbia, Marion, Suwannee, and Walton Counties each have more than 30,000 people at high hazard risk coupled with high medical vulnerability. Another 5 million people with high MedVI are at medium risk.

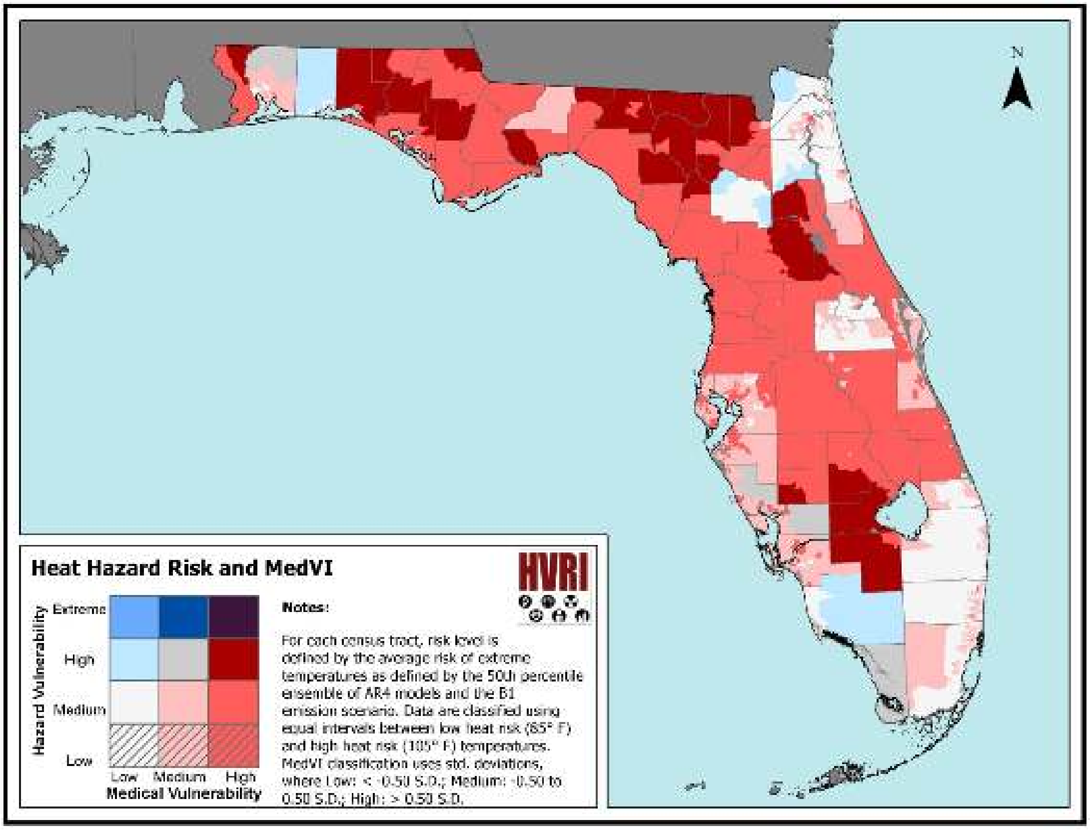

Figure 51: Bivariate representation of MedVI and heat hazard risk for B1 scenario in Florida.

Table 64: Tract and population summary for counties with high MedVI and medium or greater heat hazard risk using the B1 scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Heat Hazard Risk								
Baker	1	7,519	Bay	1	8,552	Calhoun	2	12,192
Columbia	6	33,918	DeSoto	3	8,341	Escambia	2	9,859
Gilchrist	2	7,470	Glades	2	10,618	Hamilton	3	14,799
Hendry	4	24,824	Highlands	4	14,709	Holmes	1	5,544
Jackson	2	9,293	Jefferson	1	4,496	Lafayette	1	5,706
Lake	2	5,077	Madison	3	10,553	Marion	11	38,293
Putnam	5	25,540	Suwannee	6	39,748	Wakulla	1	5,276
Walton	7	32,866	Washington	4	16,682		-	-
State Total	**74**	**351,875**		-	-		-	-
Medium Heat Hazard Risk								
Baker	2	12,912	Bay	31	119,244	Bradford	4	28,520
Brevard	27	158,238	Broward	4	27,116	Calhoun	1	2,433
Charlotte	7	32,234	Citrus	27	141,236	Columbia	6	33,613
DeSoto	6	26,521	Dixie	3	16,422	Duval	10	34,821
Escambia	68	284,537	Flagler	6	24,521	Franklin	4	11,549
Gadsden	9	46,389	Gilchrist	3	9,469	Glades	1	2,266
Gulf	3	15,863	Hardee	6	27,731	Hendry	2	14,316
Hernando	44	172,778	Highlands	22	84,076	Hillsborough	85	307,926
Holmes	3	14,383	Indian River	29	138,028	Jackson	9	40,453
Jefferson	2	10,265	Lafayette	1	3,164	Lake	54	291,975
Lee	32	136,588	Levy	9	40,801	Liberty	2	8,365
Madison	2	8,671	Manatee	17	73,525	Marion	51	293,005
Miami-Dade	4	12,514	Okeechobee	11	39,996	Osceola	39	264,577
Pasco	131	458,710	Pinellas	68	272,992	Polk	153	602,092
Putnam	12	48,824	Sarasota	16	63,596	St. Johns	2	7,673
St. Lucie	43	277,789	Sumter	18	87,023	Suwannee	1	1,803
Taylor	4	22,570	Union	3	15,535	Volusia	113	494,593
Wakulla	3	25,500	Walton	4	22,177	Washington	3	8,214
State Total	**1,220**	**5,420,132**		-	-		-	-

Integrating A1B Scenario Extreme Heat with SoVI and MedVI

When looking at the A1B scenario, census tracts characterized by high SoVI and high heat hazard risk span central and southern Florida, as well as the Gulf Coast (Figure 52). In particular, Collier, Duval, Hernando, Hillsborough, Lee, Manatee, Marion, Orange, Osceola, Pasco, Polk, Sumter, and Volusia Counties each have more than 50,000 people living in high SoVI and high heat hazard zones (Table 65). In total, almost 2 million people in the state of Florida are at high risk coupled with high SoVI, with 3 million people at medium risk.

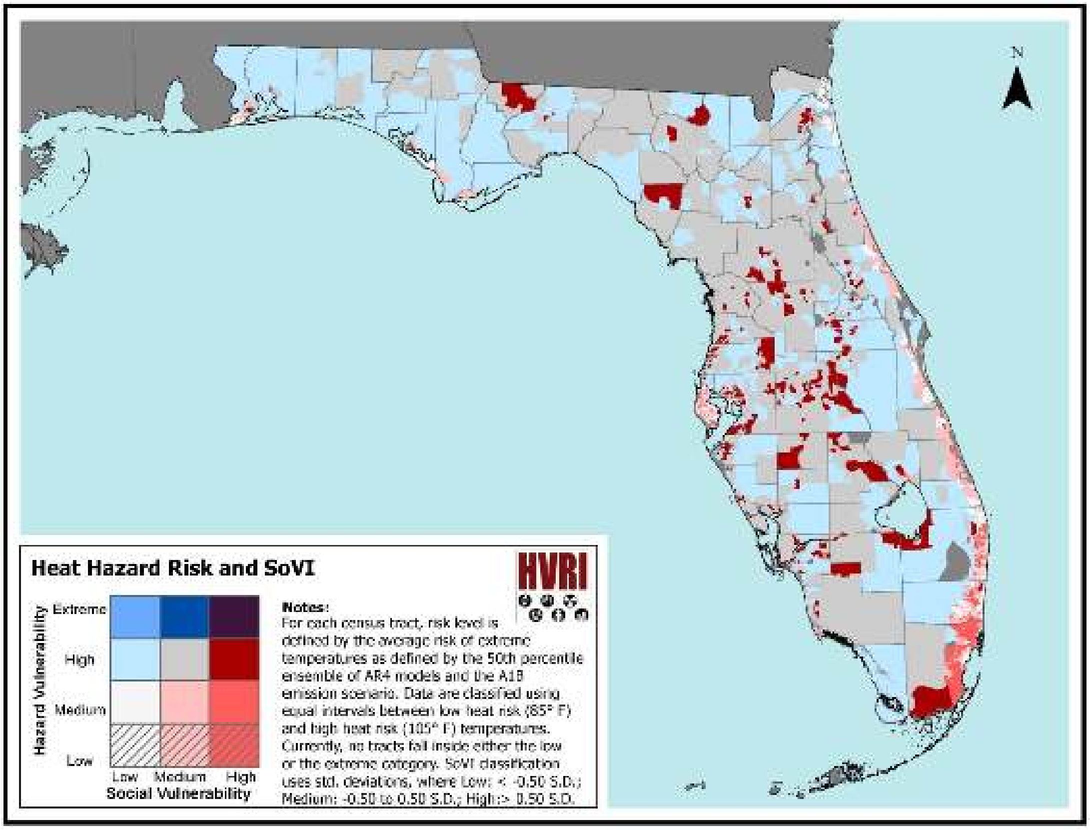

Figure 52: Bivariate representation of SoVI and heat hazard risk for A1B scenario in Florida.

Table 65: Tract and population summary for counties with high SoVI and medium or greater heat hazard risk using the A1B scenario.

County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts
High Heat Hazard Risk										
Alachua	4	19,406		Bay	2	6,725		Brevard	1	3,232
Broward	6	31,584		Charlotte	5	17,905		Citrus	5	23,598
Clay	1	5,311		Collier	15	76,682		Columbia	1	2,872
DeSoto	3	13,900		Dixie	1	7,331		Duval	35	142,066
Escambia	11	36,771		Flagler	1	6,321		Gadsden	5	25,033
Hamilton	1	1,760		Hardee	2	10,630		Hendry	3	21,846
Hernando	15	62,301		Highlands	8	35,116		Hillsborough	69	264,982
Lake	9	40,805		Lee	31	95,946		Leon	6	17,898
Manatee	19	84,453		Marion	15	102,216		Miami-Dade	1	6,218
Okeechobee	1	4,598		Orange	50	252,348		Osceola	14	103,651
Palm Beach	10	37,463		Pasco	28	87,242		Pinellas	2	10,973
Polk	52	87,242		Putnam	3	10,480		Santa Rosa	1	6,115
Sarasota	13	46,430		Seminole	7	25,901		Sumter	6	52,106
Suwannee	1	7,016		Volusia	10	53,636			-	-
State Total	**473**	**1,948,109**			-	-			-	-
Medium Heat Hazard Risk										
Bay	1	2,121		Brevard	5	17,615		Broward	105	517,964
Duval	2	8,360		Escambia	1	3,152		Flagler	2	9,563
Hillsborough	4	14,803		Indian River	5	14,670		Lee	1	4,806
Martin	2	4,091		Miami-Dade	358	1,894,403		Okeechobee	2	5,518
Palm Beach	94	340,857		Pinellas	35	121,689		St. Johns	1	4,155
St. Lucie	10	37,115		Volusia	8	29,600			-	-
State Total	**636**	**3,030,482**			-	-			-	-

The picture looks quite a bit different when medical vulnerability is considered in relation to heat hazard. A good portion of counties are nearly entirely comprised of tracts containing residents both highly at risk and highly vulnerable to heat hazards (Figure 53). These mainly rural tracts across south central to north Florida number more than 1,000 and contain 4.5 million people (Table 66). An additional 1.2 million people across nearly 300 tracts in 16 counties are characterized by a medium heat hazard risk and high medical vulnerability.

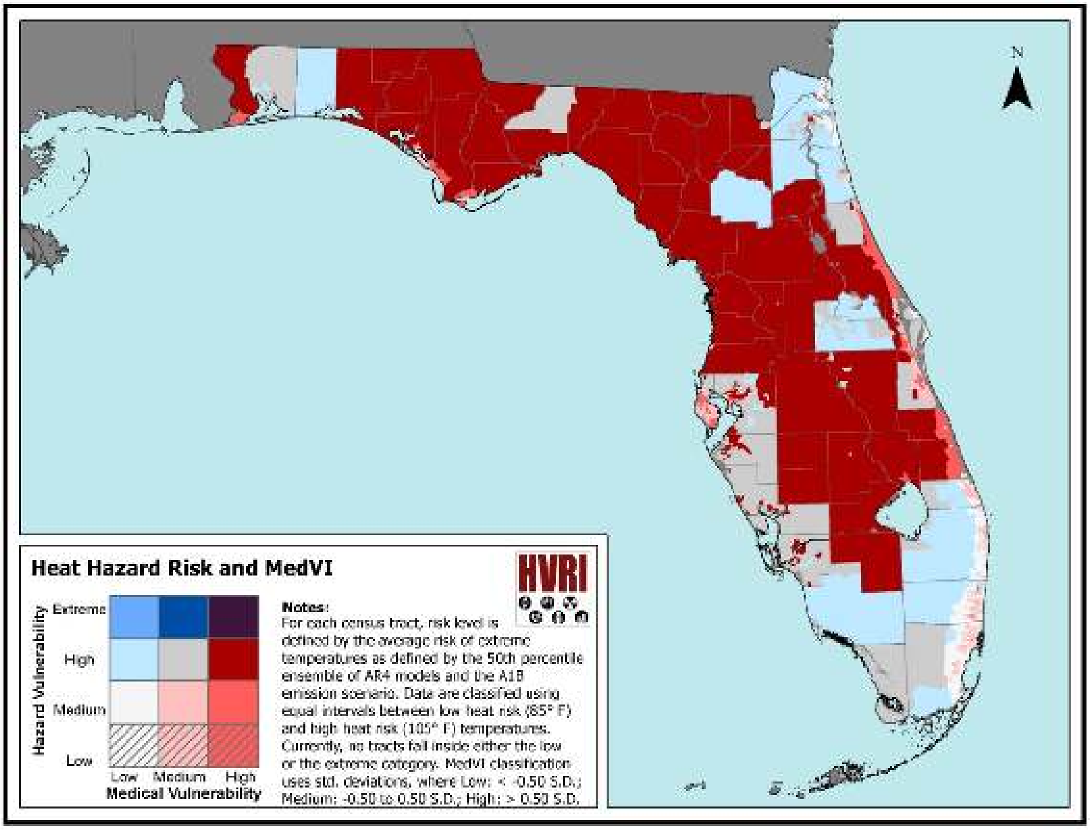

Figure 53: Bivariate representation of MedVI and heat hazard risk for A1B scenario in Florida.

Table 66: Tract and population summary for counties with high MedVI and medium or greater heat hazard risk using the A1B scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Heat Hazard Risk								
Baker	3	20,431	Bay	28	114,818	Bradford	4	28,520
Brevard	7	47,468	Calhoun	3	14,625	Charlotte	7	32,234
Citrus	27	141,236	Columbia	12	67,531	DeSoto	9	34,862
Dixie	3	16,422	Duval	8	23,254	Escambia	57	241,653
Flagler	1	7,924	Franklin	2	7,055	Gadsden	9	46,389
Gilchrist	5	16,939	Glades	3	12,884	Gulf	2	12,787
Hamilton	3	14,799	Hardee	6	27,731	Hendry	6	39,140
Hernando	44	172,778	Highlands	26	98,785	Hillsborough	72	261,611
Holmes	4	19,927	Indian River	2	14,368	Jackson	11	49,746
Jefferson	3	14,761	Lafayette	2	8,870	Lake	56	297,052
Lee	32	136,588	Levy	9	40,801	Liberty	2	8,365
Madison	5	19,224	Manatee	17	73,525	Marion	62	331,298
Okeechobee	7	25,456	Osceola	39	264,577	Pasco	131	458,710
Pinellas	2	8,501	Polk	153	602,092	Putnam	17	74,364
Sarasota	16	63,596	St. Lucie	2	14,523	Sumter	18	87,023
Suwannee	7	41,551	Taylor	4	22,570	Union	3	15,535
Volusia	44	228,217	Wakulla	4	30,776	Walton	11	55,043
Washington	7	24,896		-	-		-	-
State Total	**1,017**	**4,533,831**		-	-		-	-
Medium Heat Hazard Risk								
Bay	4	12,978	Brevard	20	110,770	Broward	4	27,116
Duval	2	11,567	Escambia	13	52,743	Flagler	5	16,597
Franklin	2	4,494	Gulf	1	3,076	Hillsborough	13	46,315
Indian River	27	123,660	Miami-Dade	4	12,514	Okeechobee	4	14,540
Pinellas	66	264,491	St. Johns	2	7,673	St. Lucie	41	263,266
Volusia	69	266,376		-	-		-	-
State Total	**277**	**1,238,176**		-	-		-	-

Integrating A1FI Scenario Extreme Heat with SoVI and MedVI

The A1FI scenario shows areas with high heat hazard risk coupled with high social vulnerability in similar areas to what was depicted with the A1B scenario. The biggest difference between the two scenarios occurs in the panhandle, with the heat hazard risk reaching the extreme category (Figure 54). Here, Hamilton and Suwannee Counties each have one census tract displaying extreme heat hazard risk and high social vulnerability, totaling 8,700 people (Table 67). Another 43 counties with over 1,000 tracts cover almost 5 million people in the high heat hazard risk and high social vulnerability categories.

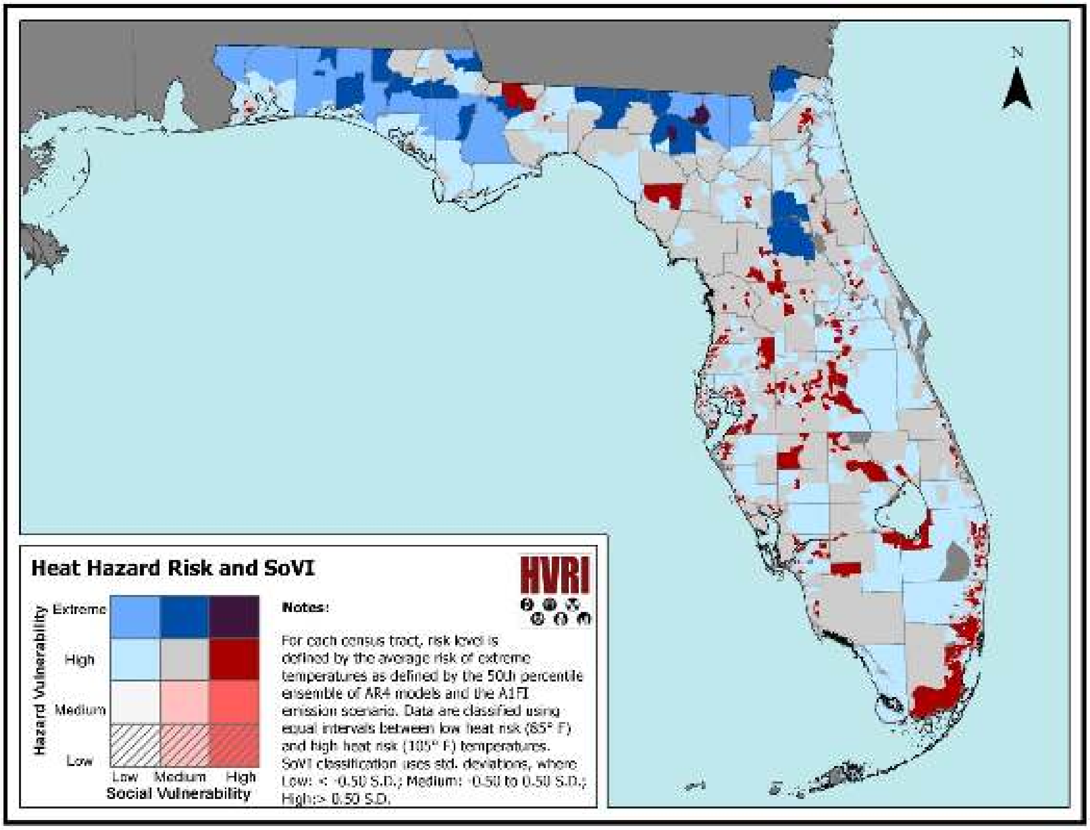

Figure 54: Bivariate representation of SoVI and heat hazard risk for A1FI scenario in Florida.

Table 67: Tract and population summary for counties with high SoVI and medium or greater heat hazard risk using the A1FI scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Heat Hazard Risk								
Hamilton	1	1,760	Suwannee	1	7,016		-	-
State Total	**2**	**8,776**		-	-		-	-
High Heat Hazard Risk								
Alachua	4	19,406	Bay	3	8,846	Brevard	6	20,847
Broward	111	549,548	Charlotte	5	17,905	Citrus	5	23,598
Clay	1	5,311	Collier	15	76,682	Columbia	1	2,872
DeSoto	3	13,900	Dixie	1	7,331	Duval	37	150,426
Escambia	12	39,923	Flagler	3	15,884	Gadsden	5	25,033
Hardee	2	10,630	Hendry	3	21,846	Hernando	15	62,301
Highlands	8	35,116	Hillsborough	73	279,785	Indian River	5	14,670
Lake	9	40,805	Lee	32	100,752	Leon	6	17,898
Manatee	19	84,453	Marion	15	102,216	Martin	2	4,091
Miami-Dade	319	1,727,866	Okeechobee	3	10,116	Orange	50	252,348
Osceola	14	103,651	Palm Beach	104	378,320	Pasco	28	87,242
Pinellas	37	132,662	Polk	52	219,460	Putnam	3	10,480
Santa Rosa	1	6,115	Sarasota	13	46,430	Seminole	7	25,901
St. Johns	1	4,155	St. Lucie	10	37,115	Sumter	6	52,106
Volusia	18	83,236		-	-		-	-
State Total	**1,067**	**4,929,278**		-	-		-	-
Medium Heat Hazard Risk								
Miami-Dade	40	172,755		-	-		-	-
State Total	**40**	**172,755**		-	-		-	-

When comparing the A1FI scenario of heat hazard risk to medical vulnerability, a large portion of the northern and central parts of the state display a high heat hazard risk and high MedVI (Figure 55). Conversely, much of south Florida, although in the high heat hazard risk category, falls into the low or medium category of medical vulnerability. There are 49 census tracts with both extreme heat hazard risk and high medical vulnerability (Table 68), mostly located in the panhandle and accounting for over 240,000 people. Additionally, 5.5 million people in 1,200 tracts across 52 counties are located in high heat hazard risk and high medical vulnerability tracts.

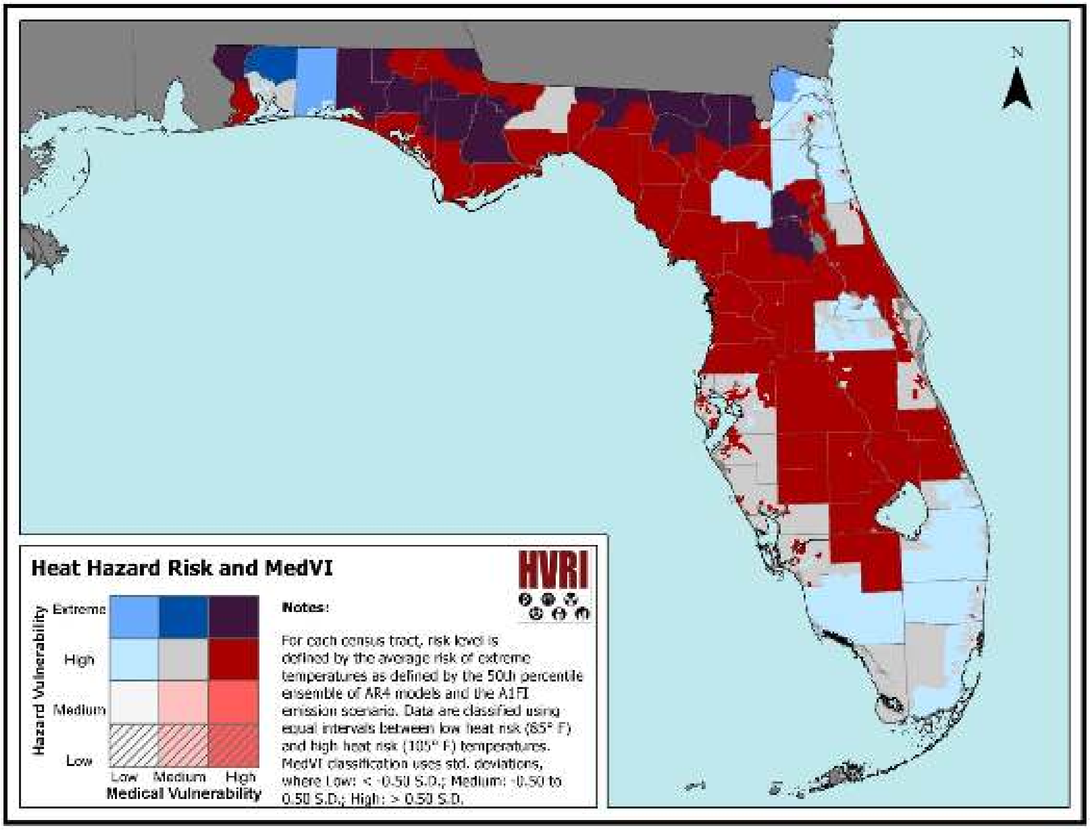

Figure 55: Bivariate representation of MedVI and heat hazard risk for A1FI scenario in Florida.

Table 68: Tract and population summary for counties with high MedVI and heat hazard risk using the A1FI scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Heat Hazard Risk								
Baker	1	7,519	Bay	1	8,552	Calhoun	3	14,625
Columbia	2	14,284	Escambia	2	14,225	Gadsden	1	4,769
Hamilton	3	14,799	Holmes	1	5,544	Jackson	3	13,618
Jefferson	1	4,496	Liberty	2	8,365	Madison	2	6,834
Marion	7	20,909	Putnam	4	21,941	Suwannee	5	32,889
Walton	7	32,866	Washington	4	16,682		-	-
State Total	**49**	**242,917**		-	-		-	-
High Heat Hazard Risk								
Baker	2	12,912	Bay	31	119,244	Bradford	4	28,520
Brevard	27	158,238	Broward	4	27,116	Charlotte	7	32,234
Citrus	27	141,236	Columbia	10	53,247	DeSoto	9	34,862
Dixie	3	16,422	Duval	10	34,821	Escambia	67	280,171
Flagler	6	24,521	Franklin	4	11,549	Gadsden	8	41,620
Gilchrist	5	16,939	Glades	3	12,884	Gulf	3	15,863
Hardee	6	27,731	Hendry	6	39,140	Hernando	44	172,778
Highlands	26	98,785	Hillsborough	85	307,926	Holmes	3	14,383
Indian River	29	138,028	Jackson	8	36,128	Jefferson	2	10,265
Lafayette	2	8,870	Lake	56	297,052	Lee	32	136,588
Levy	9	40,801	Madison	3	12,390	Manatee	17	73,525
Marion	55	310,389	Miami-Dade	3	10,061	Okeechobee	11	39,996
Osceola	39	264,577	Pasco	131	458,710	Pinellas	68	272,992
Polk	153	602,092	Putnam	13	52,423	Sarasota	16	63,596
St. Johns	2	7,673	St. Lucie	43	277,789	Sumter	18	87,023
Suwannee	2	8,662	Taylor	4	22,570	Union	3	15,535
Volusia	113	494,593	Wakulla	4	30,776	Walton	4	22,177
Washington	3	8,214		-	-		-	-
State Total	**1,243**	**5,526,637**		-	-		-	-
Medium Heat Hazard Risk								
Miami-Dade	1	2,453		-	-		-	-
State Total	**1**	**2,453**		-	-		-	-

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9. Vulnerability to Drought

Methods

The concept of drought is generally subdivided into three categories: meteorological drought, hydrological drought, and agricultural drought. Accompanying the three types of drought are many different indices that use varying inputs to measure drought. Of these indices, the Standardized Precipitation Index (SPI), a meteorological drought index, is widely accepted as one of the best, in part because it can display drought for many different time scales (Keyantash and Dracup, 2002) and is better able to quickly determine emerging drought (English et al., 2009). The SPI is a measure of the departure of precipitation from the average. Mathematically, it is defined as: $\mathrm{SPI} = \frac{(x_i - \bar{x})}{\sigma}$, where x_i is the observed or projected amount of precipitation, $\bar{x}$ is the precipitation mean, and σ is the standard deviation of the mean precipitation (McKee et al., 1993). In 2009, the SPI was recommended as the consensus index for drought monitoring at the Interregional Workshop on Indices and Early Warning Systems for Drought (Svoboda et al., 2012). Additionally, the SPI is the accepted standard used by the National Drought Mitigation Center.

SPI is calculated on a scale of -3 to 3, where negative values indicate drier conditions and positive values indicate wetter conditions. The value of the original classification scheme developed by McKee et al. in 1993 has been debated, because this scheme places an area in drought conditions 50% of the time (any time the SPI is less than zero). As this is not necessarily an accurate depiction of a particular area's climate, the World Meteorological Organization (WMO) has developed their own classification scheme to rectify this problem (Svoboda et al., 2012):

> 2	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-.99 to .99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
< -2	Extremely dry

The average 3-month SPI was calculated for summer (June, July, and August) and year-round for the year 2100. The 3-month SPI was calculated for each month by comparing the past three months of precipitation with the baseline average of precipitation of those three months. The 3-month SPI values were then averaged to give a mean value for the time period. The 3-month time scale was chosen as it is a good measure for looking at short-term and medium-term drought conditions.

SPI values were plotted using precipitation data from the Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC/AR4). While climate projections that will be used in the Fifth Assessment Report (AR5) are available, they are not included here because the IPCC Synthesis Report has not yet been released. The data used for AR4 came from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3; Maurer et al., 2007). CMIP3 includes 21 different global climate models (GCMs) that can be combined to make ensembles. Models and ensembles are run with many different settings. The settings used to create the projections presented here have been selected to represent the middle of the range of projections. The 50th percentile ensemble is shown here.

Climate model runs include different emissions scenarios for future climate. Average 3-month SPI values are shown for three emissions scenarios given in AR4. In the B1 (low) scenario (generally viewed as the best outcome scenario), the world has a more global, environmentally friendly focus. The second scenario, A1B (mid), represents the middle of the road scenario. The A1FI (high) scenario shows a world highly dependent on fossil fuels.

Most climate models cover the entire globe, but this requires the use of a relatively coarse spatial resolution. In order to provide more detail, climate scientists use a process called downscaling. There are two ways to downscale data: statistical downscaling and dynamical downscaling. Dynamical downscaling does not involve increasing the modeled detail of physical processes. However, statistical downscaling requires less computing power than dynamical downscaling or running a regional climate model, and these other approaches are not necessarily more accurate (Brekke et al., 2013). The downscaling method used by CMIP3 that is shown here is a type of statistical downscaling known as bias corrected spatial disaggregation (BCSD; Wood et al., 2004). BCSD is one of the most robust statistical downscaling methods (Brekke et al., 2013), and it yields results that are sufficiently comparable to other techniques (Maurer et al., 2010; Abatzoglou and Brown, 2011; Wood et al., 2004).

Temperature is another important aspect of measuring drought, as studies have shown that an increase in temperature increases the severity of droughts (Vicente-Serrano et al., 2010). In particular, warmer temperatures will lead to increasingly dry soil conditions (Hosansky et al., 2010). Because temperature is not included in the calculation of SPI, maps showing SPI should be used in conjunction with temperature maps to get a better picture of the overall severity of drought.

Downscaled data for Florida representing one-km by one-km grids was utilized to create a spatial representation of annual drought hazard areas in 2100 (Figure 56) for the A1B scenario. This was compared to 2100 drought hazard areas during the warmest months of the year (June-August) (Figure 58) to identify areas where extreme drought will likely occur. While the annual drought risk for Florida is low across the state, a much different picture is depicted when considering drought during the summer months (June to August). For this reason, potential drought hazard is analyzed using the June-August timeframe.

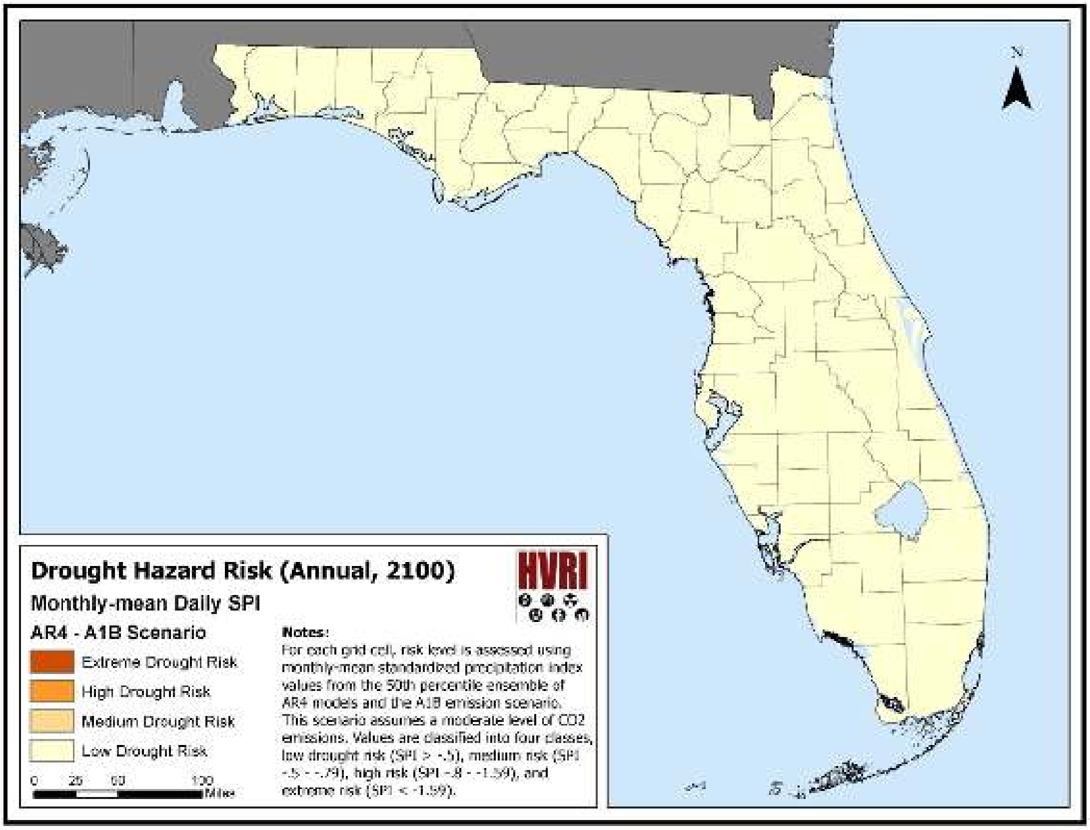

Figure 56: Monthly-mean daily SPI for A1B scenario in Florida, 2100.

State Summary

The low emissions scenario, B1, shows south Florida most at risk of drought in 2100, with areas in both the medium and high risk categories (Figure 57). All census tracts in Broward, Collier, Hendry, Miami-Dade, Monroe, and Palm Beach Counties are in the high risk category (Table 69), accounting for almost 6 million of the 7 million people at high risk of drought in this scenario (Table 70).

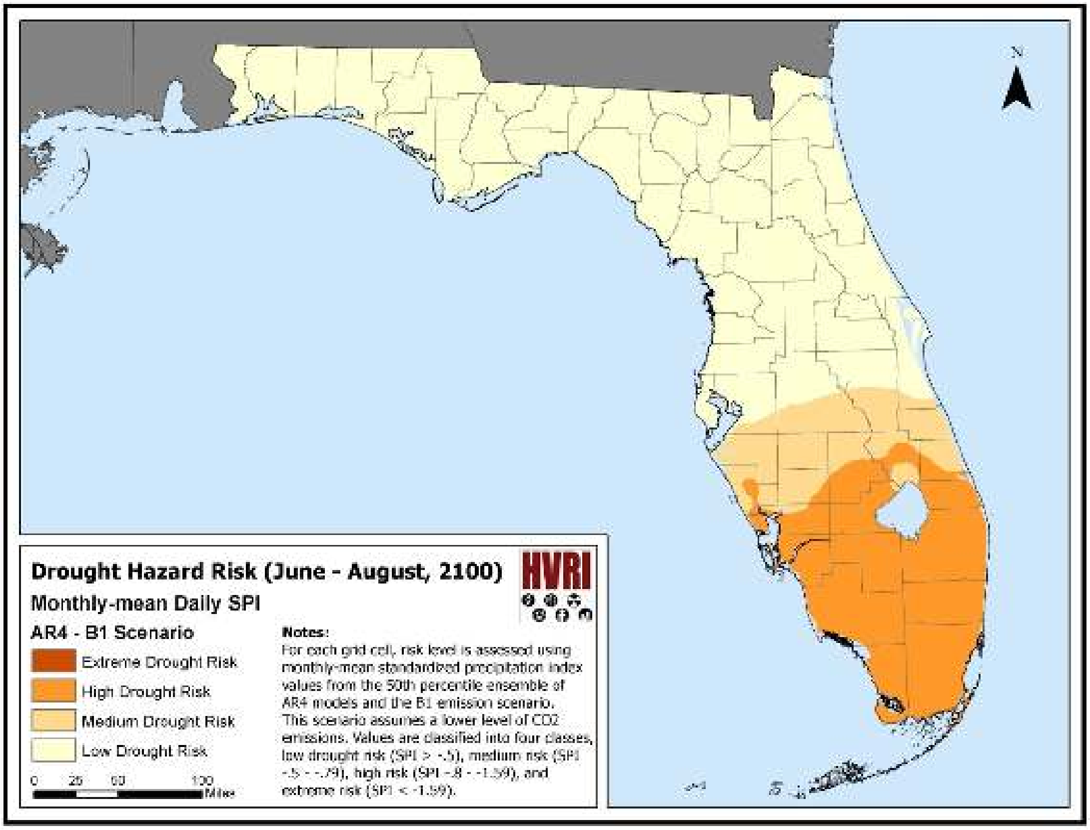

Figure 57: Monthly-mean daily SPI for B1 scenario in Florida – June-August, 2100.

Table 69: Census tract summary for drought hazard risk using the B1 scenario.

County Name	Drought Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario based on SPI					County Name	Drought Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario based on SPI				
	Extreme (< -1.59)	High (-.8 - -1.59)	Medium (-.5 - -.79)	Low (> -.5)	Out		Extreme (< -1.59)	High (-.8 - -1.59)	Medium (-.5 - -.79)	Low (> -.5)	Out
Alachua	-	-	-	100.00%	-	Lee	-	99.40%	0.60%	-	-
Baker	-	-	-	100.00%	-	Leon	-	-	-	100.00%	-
Bay	-	-	-	100.00%	-	Levy	-	-	-	100.00%	-
Bradford	-	-	-	100.00%	-	Liberty	-	-	-	100.00%	-
Brevard	-	-	1.77%	98.23%	-	Madison	-	-	-	100.00%	-
Broward	-	100.00%	-	-	-	Manatee	-	-	97.44%	2.56%	-
Calhoun	-	-	-	100.00%	-	Marion	-	-	-	100.00%	-
Charlotte	-	28.21%	71.79%	-	-	Martin	-	94.12%	5.88%	-	-
Citrus	-	-	-	100.00%	-	Miami-Dade	-	100.00%	-	-	-
Clay	-	-	-	100.00%	-	Monroe	-	100.00%	-	-	-
Collier	-	100.00%	-	-	-	Nassau	-	-	-	100.00%	-
Columbia	-	-	-	100.00%	-	Okaloosa	-	-	-	100.00%	-
DeSoto	-	-	100.00%	-	-	Okeechobee	-	-	100.00%	-	-
Dixie	-	-	-	100.00%	-	Orange	-	-	-	100.00%	-
Duval	-	-	-	100.00%	-	Osceola	-	-	-	100.00%	-
Escambia	-	-	-	100.00%	-	Palm Beach	-	100.00%	-	-	-
Flagler	-	-	-	100.00%	-	Pasco	-	-	-	100.00%	-
Franklin	-	-	-	100.00%	-	Pinellas	-	-	-	100.00%	-
Gadsden	-	-	-	100.00%	-	Polk	-	-	13.64%	86.36%	-
Gilchrist	-	-	-	100.00%	-	Putnam	-	-	-	100.00%	-
Glades	-	75.00%	25.00%	-	-	Santa Rosa	-	-	-	100.00%	-
Gulf	-	-	-	100.00%	-	Sarasota	-	-	100.00%	-	-
Hamilton	-	-	-	100.00%	-	Seminole	-	-	-	100.00%	-
Hardee	-	-	100.00%	-	-	St. Johns	-	-	-	100.00%	-
Hendry	-	100.00%	-	-	-	St. Lucie	-	2.27%	97.73%	-	-
Hernando	-	-	-	100.00%	-	Sumter	-	-	-	100.00%	-
Highlands	-	11.11%	88.89%	-	-	Suwannee	-	-	-	100.00%	-
Hillsborough	-	-	4.05%	95.95%	-	Taylor	-	-	-	100.00%	-
Holmes	-	-	-	100.00%	-	Union	-	-	-	100.00%	-
Indian River	-	-	100.00%	-	-	Volusia	-	-	-	100.00%	-
Jackson	-	-	-	100.00%	-	Wakulla	-	-	-	100.00%	-
Jefferson	-	-	-	100.00%	-	Walton	-	-	-	100.00%	-
Lafayette	-	-	-	100.00%	-	Washington	-	-	-	100.00%	-
Lake	-	-	-	100.00%	-	**State Total**	-	36.61%	8.56%	54.83%	-

Table 70: Census tract population summary for drought hazard risk using the B1 scenario.

County Name	Drought Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario based on SPI					County Name	Drought Hazard Risk in June - August 2100 using AR4-B1 (Low-emission) scenario based on SPI				
	Extreme (< -1.59)	High (-.8 - -1.59)	Medium (-.5 - -.79)	Low (> -.5)	Out		Extreme (< -1.59)	High (-.8 - -1.59)	Medium (-.5 - -.79)	Low (> -.5)	Out
Alachua	-	-	-	247,336	-	Lee	-	617,430	1,324	-	-
Baker	-	-	-	27,115	-	Leon	-	-	-	275,487	-
Bay	-	-	-	168,852	-	Levy	-	-	-	40,801	-
Bradford	-	-	-	28,520	-	Liberty	-	-	-	8,365	-
Brevard	-	-	9,076	534,293	-	Madison	-	-	-	19,224	-
Broward	-	1,748,066	-	-	-	Manatee	-	-	314,944	7,889	-
Calhoun	-	-	-	14,625	-	Marion	-	-	-	331,298	-
Charlotte	-	49,315	110,663	-	-	Martin	-	139,790	6,528	-	-
Citrus	-	-	-	141,236	-	Miami-Dade	-	2,493,127	-	-	-
Clay	-	-	-	190,865	-	Monroe	-	73,090	-	-	-
Collier	-	321,520	-	-	-	Nassau	-	-	-	73,314	-
Columbia	-	-	-	67,531	-	Okaloosa	-	-	-	180,822	-
DeSoto	-	-	34,862	-	-	Okeechobee	-	-	39,996	-	-
Dixie	-	-	-	16,422	-	Orange	-	-	-	1,145,956	-
Duval	-	-	-	864,263	-	Osceola	-	-	-	268,685	-
Escambia	-	-	-	297,619	-	Palm Beach	-	1,319,462	-	-	-
Flagler	-	-	-	95,696	-	Pasco	-	-	-	464,697	-
Franklin	-	-	-	11,549	-	Pinellas	-	-	-	916,542	-
Gadsden	-	-	-	46,389	-	Polk	-	-	61,108	540,987	-
Gilchrist	-	-	-	16,939	-	Putnam	-	-	-	74,364	-
Glades	-	10,618	2,266	-	-	Santa Rosa	-	-	-	151,372	-
Gulf	-	-	-	15,863	-	Sarasota	-	-	379,448	-	-
Hamilton	-	-	-	14,799	-	Seminole	-	-	-	422,718	-
Hardee	-	-	27,731	-	-	St. Johns	-	-	-	190,039	-
Hendry	-	39,140	-	-	-	St. Lucie	-	7,147	270,642	-	-
Hernando	-	-	-	172,778	-	Sumter	-	-	-	87,023	-
Highlands	-	13,673	85,113	-	-	Suwannee	-	-	-	41,551	-
Hillsborough	-	-	33,301	1,195,925	-	Taylor	-	-	-	22,570	-
Holmes	-	-	-	19,927	-	Union	-	-	-	15,535	-
Indian River	-	-	138,028	-	-	Volusia	-	-	-	494,593	-
Jackson	-	-	-	49,746	-	Wakulla	-	-	-	30,776	-
Jefferson	-	-	-	14,761	-	Walton	-	-	-	55,043	-
Lafayette	-	-	-	8,870	-	Washington	-	-	-	24,896	-
Lake	-	-	-	297,052	-	**State Total**	-	6,832,378	1,515,030	10,443,518	-

Like the B1 scenario, the A1B scenario places most of the northern part of the state in the low drought risk category (SPI > -.5) for the summer months, with higher risks occurring in the central and southern parts of Florida (Figure 58). The counties most at-risk are Miami-Dade County with 94% of its tracts falling within the extreme risk category (SPI < -1.59), and Broward County, which includes 83% of its tracts in the extreme risk category (Table 71). In total, there are more than 4 million people at extreme risk to drought hazard using the A1B scenario, with another 4 million people falling into the high risk category (Table 72).

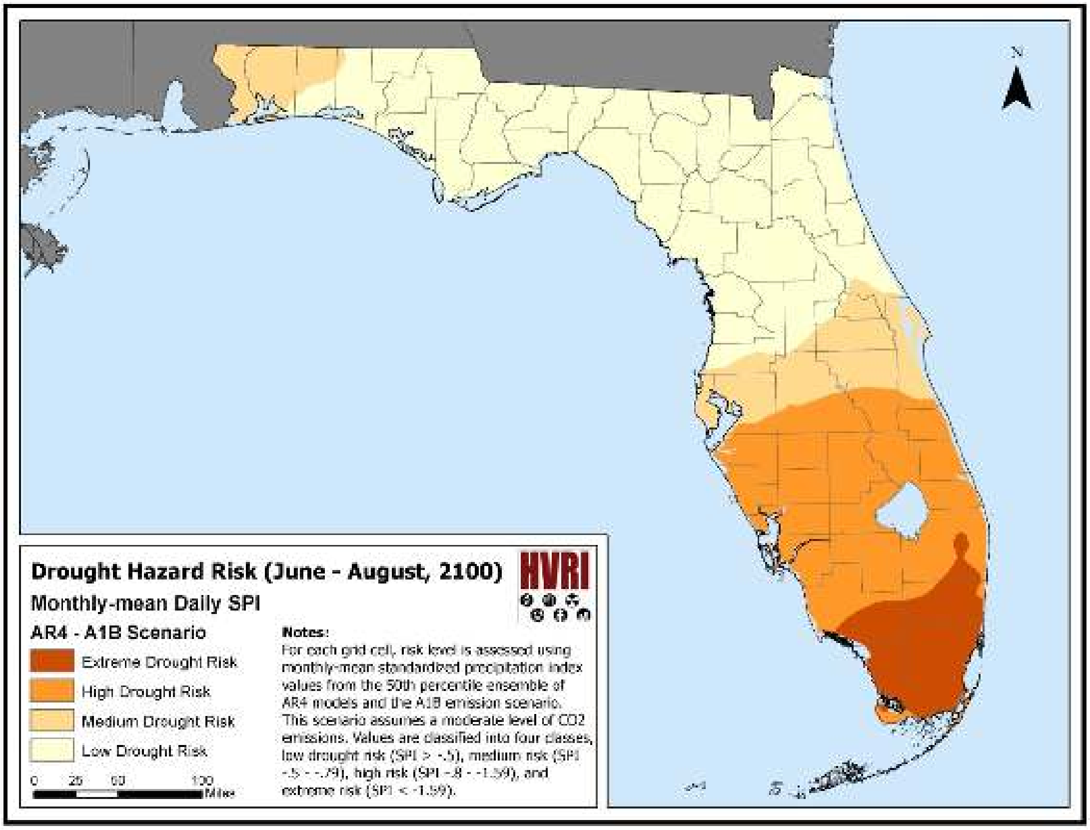

Figure 58: Monthly-mean daily SPI for A1B scenario in Florida – June-August, 2100.

Table 71: Census tract summary for drought hazard risk using the A1B scenario.

County Name	Drought Hazard Risk in June - August 2100 using AR4-A1B (Mid-emission) scenario based on SPI					County Name	Drought Hazard Risk in June - August 2100 using AR4-A1B (Mid-emission) scenario based on SPI				
	Extreme (< -1.59)	High (-.8 - -1.59)	Medium (-.5 - -.79)	Low (> -.5)	Out		Extreme (< -1.59)	High (-.8 - -1.59)	Medium (-.5 - -.79)	Low (> -.5)	Out
Alachua	-	-	-	100.00%	-	Lee	-	100.00%	-	-	-
Baker	-	-	-	100.00%	-	Leon	-	-	-	100.00%	-
Bay	-	-	-	100.00%	-	Levy	-	-	-	100.00%	-
Bradford	-	-	-	100.00%	-	Liberty	-	-	-	100.00%	-
Brevard	-	1.77%	98.23%	-	-	Madison	-	-	-	100.00%	-
Broward	83.93%	16.07%	-	-	-	Manatee	-	97.44%	2.56%	-	-
Calhoun	-	-	-	100.00%	-	Marion	-	-	-	100.00%	-
Charlotte	-	100.00%	-	-	-	Martin	-	100.00%	-	-	-
Citrus	-	-	-	100.00%	-	Miami-Dade	94.61%	5.39%	-	-	-
Clay	-	-	-	100.00%	-	Monroe	-	100.00%	-	-	-
Collier	-	100.00%	-	-	-	Nassau	-	-	-	100.00%	-
Columbia	-	-	-	100.00%	-	Okaloosa	-	-	17.07%	82.93%	-
DeSoto	-	100.00%	-	-	-	Okeechobee	-	100.00%	-	-	-
Dixie	-	-	-	100.00%	-	Orange	-	-	90.82%	9.18%	-
Duval	-	-	-	100.00%	-	Osceola	-	-	100.00%	-	-
Escambia	-	-	100.00%	-	-	Palm Beach	10.42%	89.58%	-	-	-
Flagler	-	-	-	100.00%	-	Pasco	-	-	47.01%	52.99%	-
Franklin	-	-	-	100.00%	-	Pinellas	-	-	100.00%	-	-
Gadsden	-	-	-	100.00%	-	Polk	-	11.04%	88.31%	0.65%	-
Gilchrist	-	-	-	100.00%	-	Putnam	-	-	-	100.00%	-
Glades	-	100.00%	-	-	-	Santa Rosa	-	-	80.00%	20.00%	-
Gulf	-	-	-	100.00%	-	Sarasota	-	100.00%	-	-	-
Hamilton	-	-	-	100.00%	-	Seminole	-	-	89.53%	10.47%	-
Hardee	-	100.00%	-	-	-	St. Johns	-	-	-	100.00%	-
Hendry	-	100.00%	-	-	-	St. Lucie	-	100.00%	-	-	-
Hernando	-	-	-	100.00%	-	Sumter	-	-	-	100.00%	-
Highlands	-	100.00%	-	-	-	Suwannee	-	-	-	100.00%	-
Hillsborough	-	3.74%	96.26%	-	-	Taylor	-	-	-	100.00%	-
Holmes	-	-	-	100.00%	-	Union	-	-	-	100.00%	-
Indian River	-	100.00%	-	-	-	Volusia	-	-	14.04%	85.96%	-
Jackson	-	-	-	100.00%	-	Wakulla	-	-	-	100.00%	-
Jefferson	-	-	-	100.00%	-	Walton	-	-	-	100.00%	-
Lafayette	-	-	-	100.00%	-	Washington	-	-	-	100.00%	-
Lake	-	-	-	100.00%	-	**State Total**	19.67%	25.39%	30.51%	24.44%	-

Table 72: Census tract population summary for drought hazard risk using the A1B scenario.

County Name	Drought Hazard Risk in June - August 2100 using AR4-A1B (Mid-emission) scenario based on SPI				
	Extreme (< -1.59)	High (-.8 - -1.59)	Medium (-.5 - -.79)	Low (> -.5)	Out
Alachua	-	-	-	247,336	-
Baker	-	-	-	27,115	-
Bay	-	-	-	168,852	-
Bradford	-	-	-	28,520	-
Brevard	-	9,076	534,293	-	-
Broward	1,528,246	219,820	-	-	-
Calhoun	-	-	-	14,625	-
Charlotte	-	159,978	-	-	-
Citrus	-	-	-	141,236	-
Clay	-	-	-	190,865	-
Collier	-	321,520	-	-	-
Columbia	-	-	-	67,531	-
DeSoto	-	34,862	-	-	-
Dixie	-	-	-	16,422	-
Duval	-	-	-	864,263	-
Escambia	-	-	297,619	-	-
Flagler	-	-	-	95,696	-
Franklin	-	-	-	11,549	-
Gadsden	-	-	-	46,389	-
Gilchrist	-	-	-	16,939	-
Glades	-	12,884	-	-	-
Gulf	-	-	-	15,863	-
Hamilton	-	-	-	14,799	-
Hardee	-	27,731	-	-	-
Hendry	-	39,140	-	-	-
Hernando	-	-	-	172,778	-
Highlands	-	98,786	-	-	-
Hillsborough	-	29,874	1,199,352	-	-
Holmes	-	-	-	19,927	-
Indian River	-	138,028	-	-	-
Jackson	-	-	-	49,746	-
Jefferson	-	-	-	14,761	-
Lafayette	-	-	-	8,870	-
Lake	-	-	-	297,052	-
Lee	-	618,754	-	-	-
Leon	-	-	-	275,487	-
Levy	-	-	-	40,801	-
Liberty	-	-	-	8,365	-
Madison	-	-	-	19,224	-
Manatee	-	314,944	7,889	-	-
Marion	-	-	-	331,298	-
Martin	-	146,318	-	-	-
Miami-Dade	2,407,836	85,291	-	-	-
Monroe	-	73,090	-	-	-
Nassau	-	-	-	73,314	-
Okaloosa	-	-	48,091	132,731	-
Okeechobee	-	39,996	-	-	-
Orange	-	-	1,022,004	123,952	-
Osceola	-	-	268,685	-	-
Palm Beach	140,316	1,179,146	-	-	-
Pasco	-	-	223,993	240,704	-
Pinellas	-	-	916,542	-	-
Polk	-	47,749	551,831	2,515	-
Putnam	-	-	-	74,364	-
Santa Rosa	-	-	110,258	41,114	-
Sarasota	-	379,448	-	-	-
Seminole	-	-	368,050	54,668	-
St. Johns	-	-	-	190,039	-
St. Lucie	-	277,789	-	-	-
Sumter	-	-	-	87,023	-
Suwannee	-	-	-	41,551	-
Taylor	-	-	-	22,570	-
Union	-	-	-	15,535	-
Volusia	-	-	89,896	404,697	-
Wakulla	-	-	-	30,776	-
Walton	-	-	-	55,043	-
Washington	-	-	-	24,896	-
State Total	4,076,398	4,254,224	5,638,503	4,821,801	-

The A1FI scenario shows the most intense drought projections, with all of south Florida falling into the extreme drought risk category (Figure 59), and parts of the western panhandle reaching the high risk category. The A1FI projection includes 11 counties where 100% of their census tracts are at extreme risk (Table 73). For the entire state, 15 counties totaling 7.7 million people are at extreme risk to drought in 2100, with another 7 million people classified in the medium and high risk categories (Table 74).

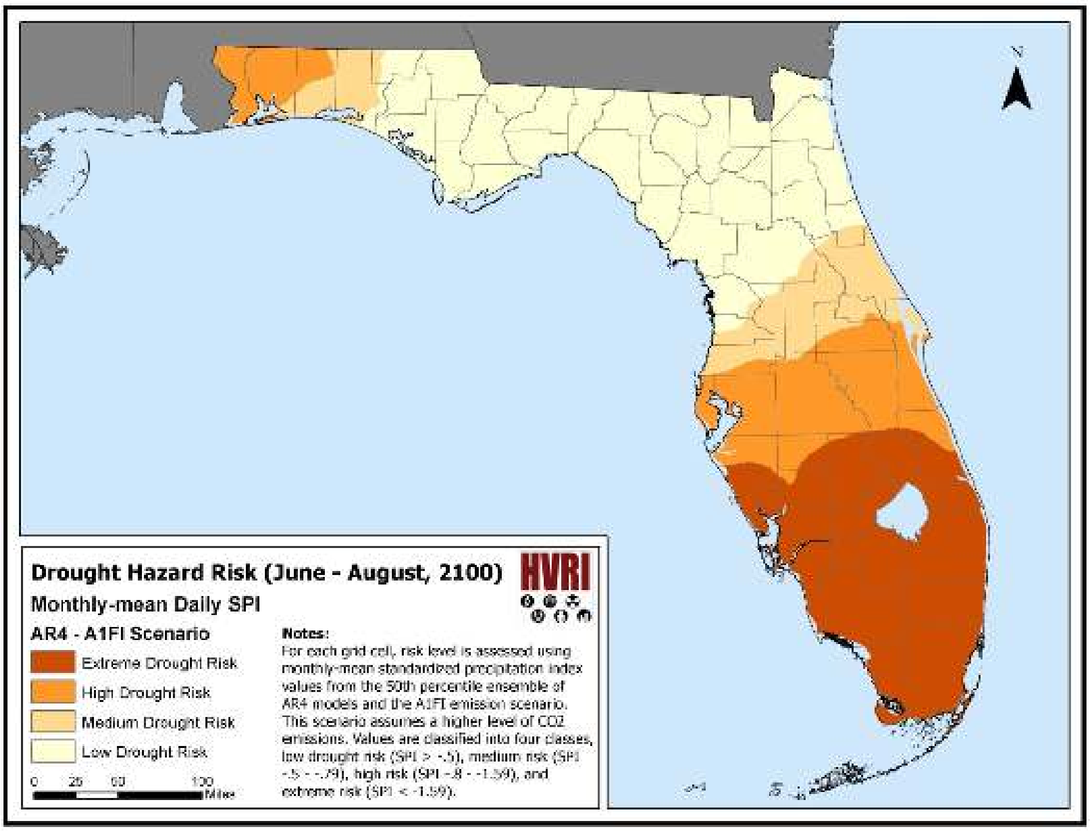

Figure 59: Monthly-mean daily SPI for A1FI scenario in Florida – June-August, 2100.

Table 73: Census tract summary for drought hazard risk using the A1FI scenario.

County Name	Drought Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario based on SPI					County Name	Drought Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario based on SPI				
	Extreme (< -1.59)	High (-.8 - -1.59)	Medium (-.5 - -.79)	Low (> -.5)	Out		Extreme (< -1.59)	High (-.8 - -1.59)	Medium (-.5 - -.79)	Low (> -.5)	Out
Alachua	-	-	-	100.00%	-	Lee	100.00%	-	-	-	-
Baker	-	-	-	100.00%	-	Leon	-	-	-	100.00%	-
Bay	-	-	-	100.00%	-	Levy	-	-	-	100.00%	-
Bradford	-	-	-	100.00%	-	Liberty	-	-	-	100.00%	-
Brevard	-	84.96%	15.04%	-	-	Madison	-	-	-	100.00%	-
Broward	100.00%	-	-	-	-	Manatee	-	100.00%	-	-	-
Calhoun	-	-	-	100.00%	-	Marion	-	-	1.59%	98.41%	-
Charlotte	100.00%	-	-	-	-	Martin	100.00%	-	-	-	-
Citrus	-	-	-	100.00%	-	Miami-Dade	100.00%	-	-	-	-
Clay	-	-	-	100.00%	-	Monroe	100.00%	-	-	-	-
Collier	100.00%	-	-	-	-	Nassau	-	-	-	100.00%	-
Columbia	-	-	-	100.00%	-	Okaloosa	-	7.32%	92.68%	-	-
DeSoto	88.89%	11.11%	-	-	-	Okeechobee	100.00%	-	-	-	-
Dixie	-	-	-	100.00%	-	Orange	-	47.34%	52.66%	-	-
Duval	-	-	-	100.00%	-	Osceola	-	100.00%	-	-	-
Escambia	-	100.00%	-	-	-	Palm Beach	100.00%	-	-	-	-
Flagler	-	-	-	100.00%	-	Pasco	-	28.36%	71.64%	-	-
Franklin	-	-	-	100.00%	-	Pinellas	-	100.00%	-	-	-
Gadsden	-	-	-	100.00%	-	Polk	-	98.70%	1.30%	-	-
Gilchrist	-	-	-	100.00%	-	Putnam	-	-	-	100.00%	-
Glades	100.00%	-	-	-	-	Santa Rosa	-	80.00%	20.00%	-	-
Gulf	-	-	-	100.00%	-	Sarasota	96.81%	3.19%	-	-	-
Hamilton	-	-	-	100.00%	-	Seminole	-	-	100.00%	-	-
Hardee	-	100.00%	-	-	-	St. Johns	-	-	-	100.00%	-
Hendry	100.00%	-	-	-	-	St. Lucie	79.55%	20.45%	-	-	-
Hernando	-	-	80.00%	20.00%	-	Sumter	-	-	63.16%	36.84%	-
Highlands	77.78%	22.22%	-	-	-	Suwannee	-	-	-	100.00%	-
Hillsborough	-	100.00%	-	-	-	Taylor	-	-	-	100.00%	-
Holmes	-	-	-	100.00%	-	Union	-	-	-	100.00%	-
Indian River	-	100.00%	-	-	-	Volusia	-	-	98.25%	1.75%	-
Jackson	-	-	-	100.00%	-	Wakulla	-	-	-	100.00%	-
Jefferson	-	-	-	100.00%	-	Walton	-	-	63.64%	36.36%	-
Lafayette	-	-	-	100.00%	-	Washington	-	-	-	100.00%	-
Lake	-	-	98.21%	1.79%	-	**State Total**	41.21%	28.90%	13.67%	16.23%	-

Table 74: Census tract population summary for drought hazard risk using the A1FI scenario.

	Drought Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario based on SPI						Drought Hazard Risk in June - August 2100 using AR4-A1FI (High-emission) scenario based on SPI				
County Name	Extreme (< -1.59)	High (-.8 - -1.59)	Medium (-.5 - -.79)	Low (> -.5)	Out	County Name	Extreme (< -1.59)	High (-.8 - -1.59)	Medium (-.5 - -.79)	Low (> -.5)	Out
Alachua	-	-	-	247,336	-	Lee	618,754	-	-	-	-
Baker	-	-	-	27,115	-	Leon	-	-	-	275,487	-
Bay	-	-	-	168,852	-	Levy	-	-	-	40,801	-
Bradford	-	-	-	28,520	-	Liberty	-	-	-	8,365	-
Brevard	-	483,800	59,569	-	-	Madison	-	-	-	19,224	-
Broward	1,748,066	-	-	-	-	Manatee	-	322,833	-	-	-
Calhoun	-	-	-	14,625	-	Marion	-	-	-	331,298	-
Charlotte	159,978	-	-	-	-	Martin	146,318	-	-	-	-
Citrus	-	-	-	141,236	-	Miami-Dade	2,493,127	-	-	-	-
Clay	-	-	-	190,865	-	Monroe	73,090	-	-	-	-
Collier	321,520	-	-	-	-	Nassau	-	-	-	73,314	-
Columbia	-	-	-	67,531	-	Okaloosa	-	19,737	161,085	-	-
DeSoto	31,592	3,270	-	-	-	Okeechobee	39,996	-	-	-	-
Dixie	-	-	-	16,422	-	Orange	-	575,274	570,682	-	-
Duval	-	-	-	864,263	-	Osceola	-	268,685	-	-	-
Escambia	-	297,619	-	-	-	Palm Beach	1,319,462	-	-	-	-
Flagler	-	-	-	95,696	-	Pasco	-	131,878	332,819	-	-
Franklin	-	-	-	11,549	-	Pinellas	-	916,542	-	-	-
Gadsden	-	-	-	46,389	-	Polk	-	589,659	12,436	-	-
Gilchrist	-	-	-	16,939	-	Putnam	-	-	-	74,364	-
Glades	12,884	-	-	-	-	Santa Rosa	-	110,258	41,114	-	-
Gulf	-	-	-	15,863	-	Sarasota	372,614	6,834	-	-	-
Hamilton	-	-	-	14,799	-	Seminole	-	-	422,718	-	-
Hardee	-	27,731	-	-	-	St. Johns	-	-	-	190,039	-
Hendry	39,140	-	-	-	-	St. Lucie	244,517	33,272	-	-	-
Hernando	-	-	140,102	32,676	-	Sumter	-	-	34,586	52,437	-
Highlands	79,280	19,506	-	-	-	Suwannee	-	-	-	41,551	-
Hillsborough	-	1,229,226	-	-	-	Taylor	-	-	-	22,570	-
Holmes	-	-	-	19,927	-	Union	-	-	-	15,535	-
Indian River	-	138,028	-	-	-	Volusia	-	-	486,362	8,231	-
Jackson	-	-	-	49,746	-	Wakulla	-	-	-	30,776	-
Jefferson	-	-	-	14,761	-	Walton	-	-	37,295	17,748	-
Lafayette	-	-	-	8,870	-	Washington	-	-	-	24,896	-
Lake	-	-	293,540	3,512	-	**State Total**	7,700,338	5,174,152	2,592,308	3,324,128	-

Analyzing Drought Hazard in Combination with SoVI and MedVI

About Bivariate Classifications

Here, we keep the exposure constant by using the same hazard threat surface but use different vulnerability perspectives (social and medical) in bivariate representations to create an easily understood depiction of not only increased threat but also a limited ability to adequately prepare for and respond to these threats. In doing so, we are able to quickly identify three specific geographic areas of interest:

1. Areas where the hazard itself should be the focus of planning and mitigation,
2. Areas where understanding the underlying socioeconomics and demographics would prove to be the most advantageous input point to create positive change, and
3. Areas where a combination of classic hazard mitigation techniques and social mitigation practices should be utilized in order to maximize optimal outcomes.

The following maps utilize a three by three bivariate representation in which one can easily identify areas of limited to elevated SoVI in relation to areas with low to extreme hazard classifications. Places identified in item number one in the preceding list are shaded in the blue colors and can be understood as locations where hazard susceptibility is higher than SoVI or MedVI. Areas identified in item number two above, indicating where socioeconomics and demographics play an important role, are shaded in the pink/red colors and can be conceived as locations where SoVI or MedVI are greater than physical hazard threats. Places identified in item number three above are shaded either in gray-tones or in a dark burgundy color and can be understood as areas that have equal vulnerability and hazard classification scores.

Integrating B1 (Low) Scenario Drought with SoVI and MedVI

Figure 60 shows a bivariate representation of the B1 drought hazard vulnerability and SoVI. Areas of high social vulnerability and high drought hazard risk include tracts along the Atlantic Coast in far southeastern Florida. This includes the cities of Miami and Fort Lauderdale. Broward, Miami-Dade, and Palm Beach Counties each contain more than 100 census tracts at high risk to drought that are characterized by high SoVI (Table 75), totaling 2.8 million people across the three counties.

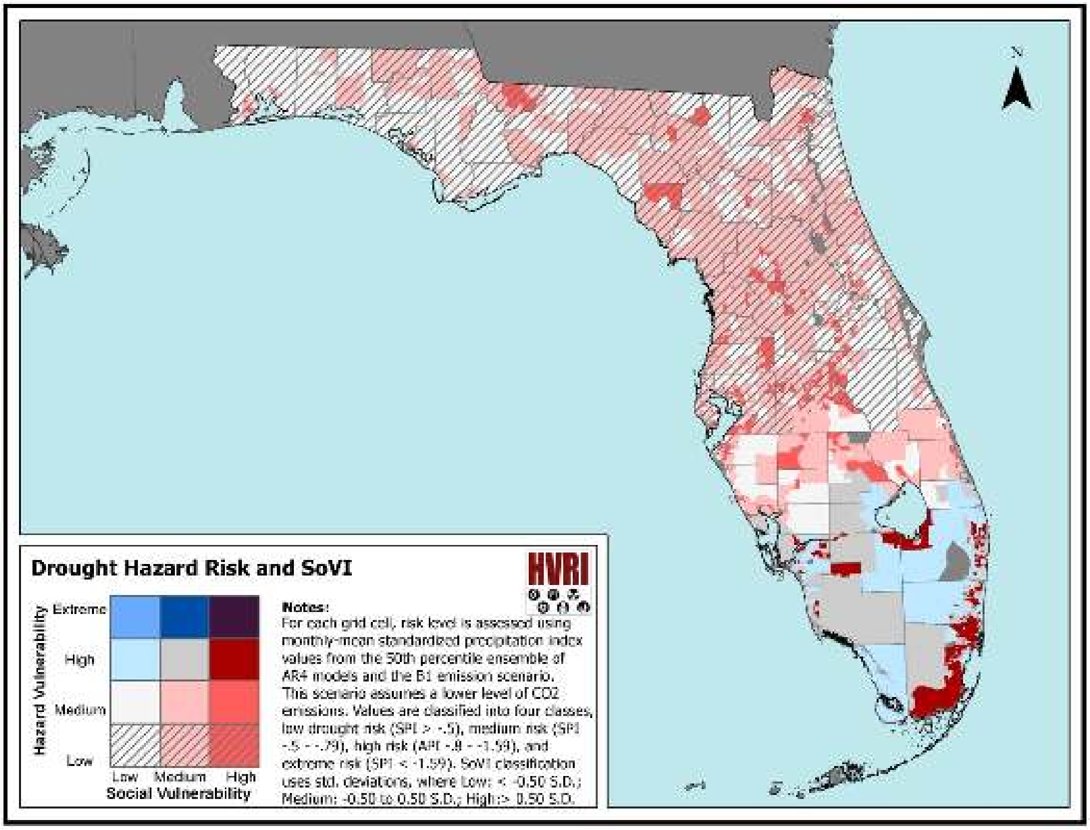

Figure 60: Bivariate representation of SoVI and drought hazard risk for B1 scenario in Florida.

Table 75: Tract and population summary for counties with high SoVI and medium or greater drought hazard risk using the B1 scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Drought Hazard Risk								
Broward	111	549,548	Collier	15	76,682	Hendry	3	21,846
Lee	32	100,752	Martin	2	4,091	Miami-Dade	359	1,900,621
Palm Beach	104	378,320		-	-		-	-
State Total	**626**	**3,031,860**		-	-		-	-
Medium Drought Hazard Risk								
Brevard	1	5,430	Charlotte	5	17,905	DeSoto	3	13,900
Hardee	2	10,630	Highlands	8	35,116	Hillsborough	9	27,904
Indian River	5	14,670	Manatee	19	84,453	Okeechobee	3	10,116
Polk	6	17,138	Sarasota	13	46,430	St. Lucie	10	37,115
State Total	**84**	**320,807**		-	-		-	-

When comparing drought hazard risk with medical vulnerability in the B1 scenario, we can see that much of the northern part of the state is in an area of high medical vulnerability but low hazard vulnerability (Figure 61). Conversely, the far southern part of the state has census tracts in the high hazard risk category coupled with low medical vulnerability. Seven counties comprise 52 census tracts with high drought hazard risk and high medical vulnerability, with another 181 tracts across 11 counties coupling medium drought hazard risk and high medical vulnerability (Table 76). Overall, more than 1 million people are characterized by high MedVI and medium to high drought hazard risk.

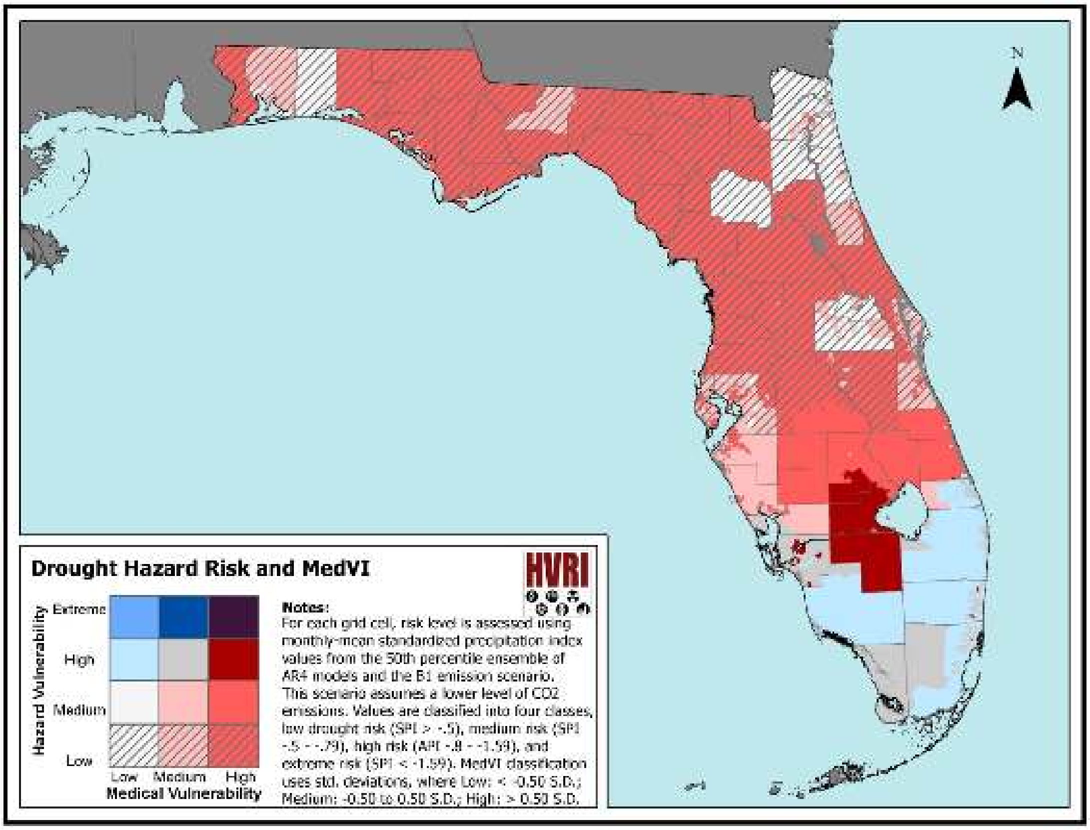

Figure 61: Bivariate representation of MedVI and drought hazard risk for B1 scenario in Florida.

Table 76: Tract and population summary for counties with high MedVI and medium or greater drought hazard risk using the B1 scenario.

County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts		County Name	Number of Tracts	Total Population of Tracts
High Drought Hazard Risk										
Broward	4	27,116		Glades	2	10,618		Hendry	6	39,140
Highlands	3	13,673		Lee	32	136,588		Miami-Dade	4	12,514
St. Lucie	1	7,147			-	-			-	-
State Total	**52**	**246,796**			-	-			-	-
Medium Drought Hazard Risk										
Charlotte	7	32,234		DeSoto	9	34,862		Glades	1	2,266
Hardee	6	27,731		Highlands	23	85,112		Indian River	29	138,028
Manatee	16	69,028		Okeechobee	11	39,996		Polk	21	61,108
Sarasota	16	63,596		St. Lucie	42	270,642			-	-
State Total	**181**	**824,603**			-	-			-	-

Integrating A1B (Mid) Scenario Drought with SoVI and MedVI

While all of south Florida and parts of central Florida identify with high or extreme hazard vulnerability in the A1B scenario, additional areas are highlighted when looked at in conjunction with social vulnerability. Areas of high social vulnerability and high or extreme hazard vulnerability include the southernmost part of the peninsula and extending northward through the cities of Miami and Fort Lauderdale (Figure 62). Broward, Miami-Dade, and Palm Beach Counties each contain census tracts with extreme drought hazard risk and high social vulnerability, with 2.4 million people living in 464 tracts (Table 77). An additional 2 million people have high social vulnerability coupled with either high or medium hazard vulnerability.

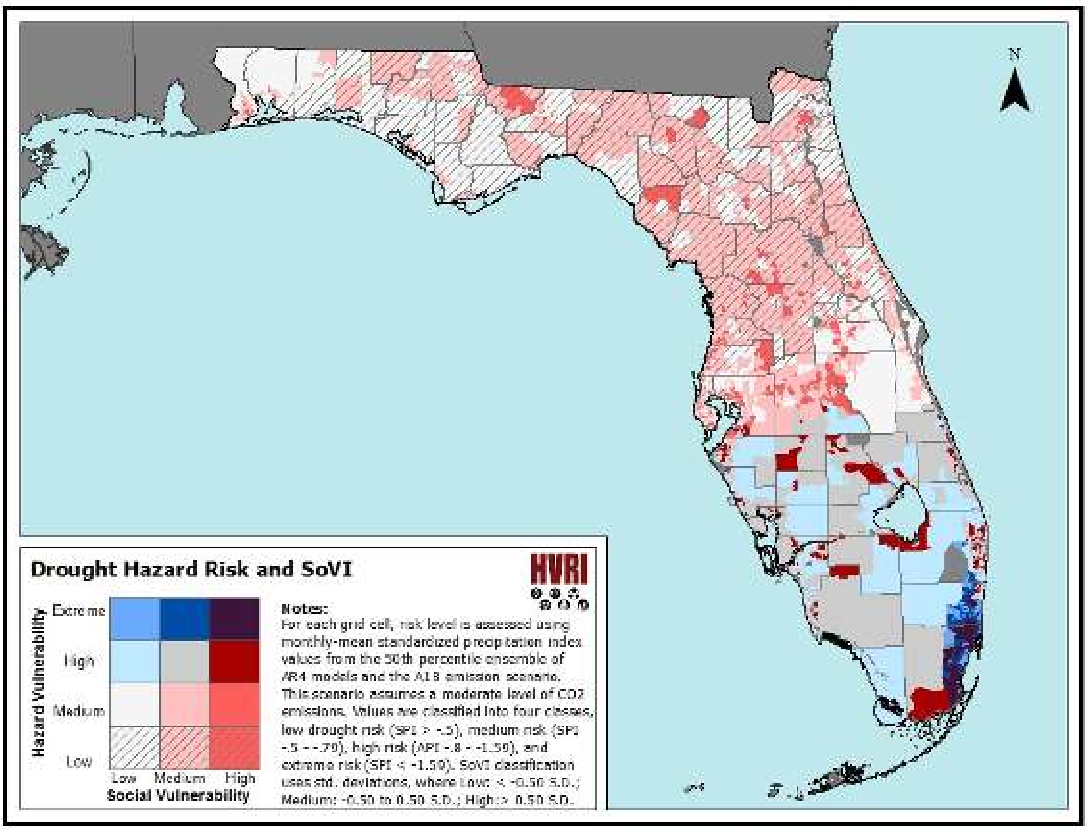

Figure 62: Bivariate representation of SoVI and drought hazard risk for A1B scenario in Florida.

Table 77: Tract and population summary for counties with high SoVI and medium or greater drought hazard risk using the A1B scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Drought Hazard Risk								
Broward	101	502,296	Miami-Dade	356	1,885,641	Palm Beach	7	19,722
State Total	**464**	**2,407,659**		-	-		-	-
High Drought Hazard Risk								
Brevard	1	5,430	Broward	10	47,252	Charlotte	5	17,905
Collier	15	76,682	DeSoto	3	13,900	Hardee	2	10,630
Hendry	3	21,846	Highlands	8	35,116	Hillsborough	8	24,477
Indian River	5	14,670	Lee	32	100,752	Manatee	19	84,453
Martin	2	4,091	Miami-Dade	3	14,980	Okeechobee	3	10,116
Palm Beach	97	358,598	Polk	5	12,400	Sarasota	13	46,430
St. Lucie	10	37,115		-	-		-	-
State Total	**244**	**936,843**		-	-		-	-
Medium Drought Hazard Risk								
Brevard	5	15,417	Escambia	12	39,923	Hillsborough	65	255,308
Orange	48	243,829	Osceola	14	103,651	Pasco	9	23,699
Pinellas	37	132,662	Polk	47	207,060	Santa Rosa	1	6,115
Seminole	7	25,901	Volusia	4	21,784		-	-
State Total	**249**	**1,075,349**		-	-		-	-

Comparing drought hazard risk with medical vulnerability tells a different story. Here, much of the panhandle and northern Florida are characterized by high medical vulnerability, while the hazard vulnerability in those areas is low (Figure 63). Unlike with social vulnerability, the counties of Miami-Dade and Broward do not stand out as much, with most of those areas displaying low to medium medical vulnerability. However, it is also within those two counties that seven census tracts and almost 31,000 people are characterized by extreme drought hazard risk and high medical vulnerability (Table 78). An additional 3.2 million people live in areas of medium to high hazard risk and high MedVI.

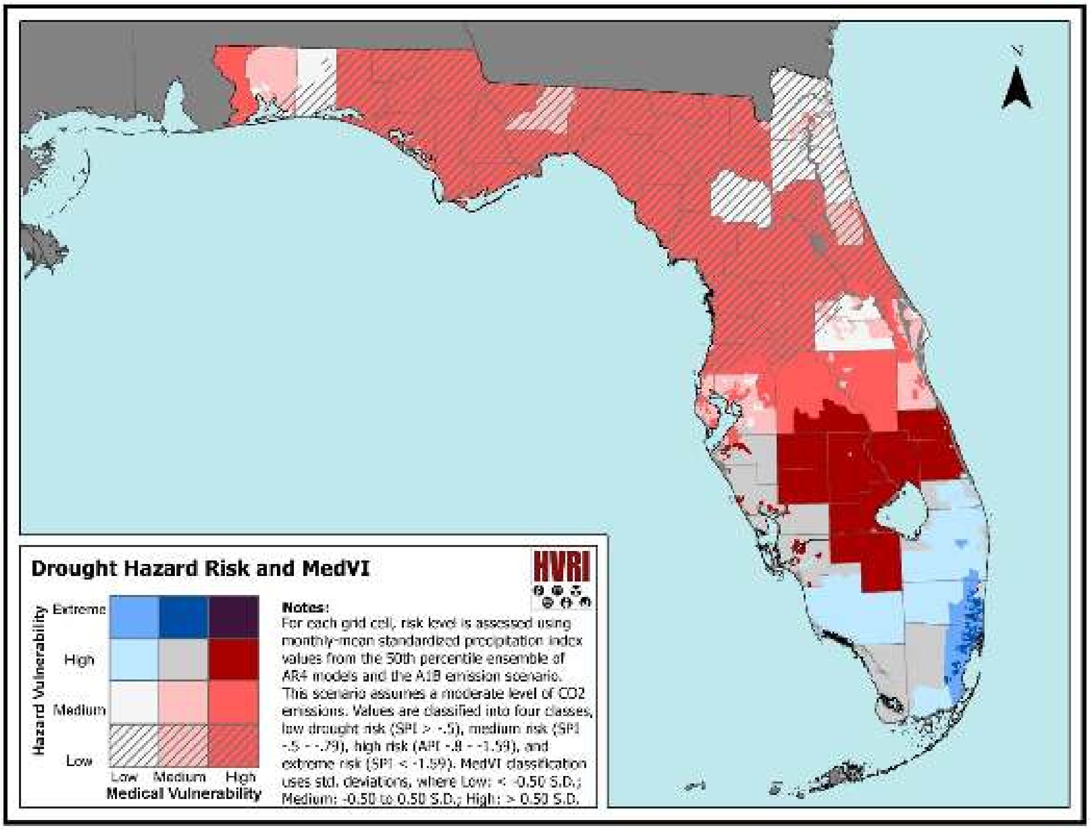

Figure 63: Bivariate representation of MedVI and drought hazard risk for A1B scenario in Florida.

Table 78: Tract and population summary for counties with high MedVI and medium or greater drought hazard risk using the A1B scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Drought Hazard Risk								
Broward	3	18,422	Miami-Dade	4	12,514		-	-
State Total	**7**	**30,936**		-	-		-	-
High Drought Hazard Risk								
Broward	1	8,694	Charlotte	7	32,234	DeSoto	9	34,862
Glades	3	12,884	Hardee	6	27,731	Hendry	6	39,140
Highlands	26	98,785	Indian River	29	138,028	Lee	32	136,588
Manatee	16	69,028	Okeechobee	11	39,996	Polk	17	47,749
Sarasota	16	63,596	St. Lucie	43	277,789		-	-
State Total	**222**	**1,027,104**		-	-		-	-
Medium Drought Hazard Risk								
Brevard	27	158,238	Escambia	70	294,396	Hillsborough	85	307,926
Manatee	1	4,497	Osceola	39	264,577	Pasco	61	220,393
Pinellas	68	272,992	Polk	135	551,828	Volusia	16	89,896
State Total	**502**	**2,164,743**		-	-		-	-

Integrating A1FI (High) Scenario Extreme Heat with SoVI and MedVI

When combining drought hazard risk from the A1FI scenario with social vulnerability, central and southern Florida stand out as areas with high or extreme drought hazard risk and medium or high social vulnerability (Figure 64). Conversely, most of the northern part of the state, as well as the panhandle, is characterized by low hazard vulnerability and medium social vulnerability. In this scenario, 7.7 million people live in areas with extreme drought hazard risk and high social vulnerability, with Broward, Lee, Miami-Dade, and Palm Beach Counties providing most of the census tracts and population in this risk category (Table 79). In areas characterized by high drought hazard risk and high social vulnerability, an additional 5 million people and 1,200 tracts are spread across 17 counties.

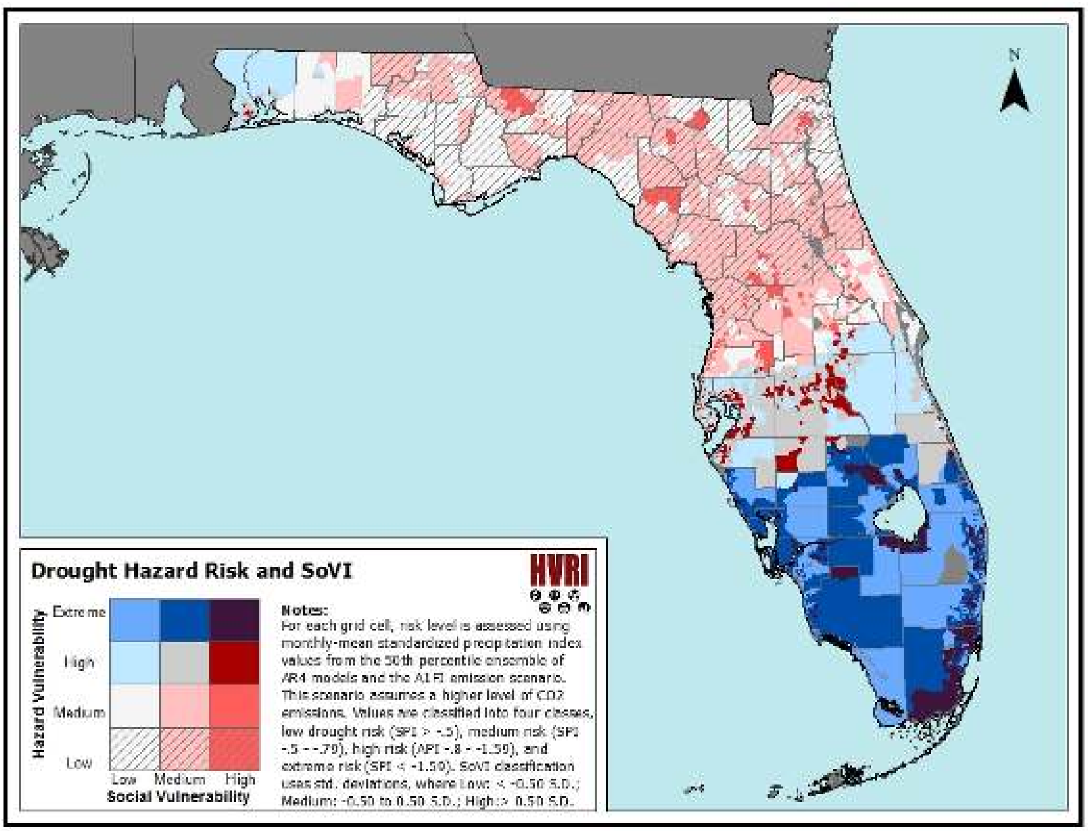

Figure 64: Bivariate representation of SoVI and drought hazard risk for A1FI scenario in Florida.

Table 79: Tract and population summary for counties with high SoVI and medium or greater drought hazard risk using the A1FI scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Drought Hazard Risk								
Broward	111	549,548	Charlotte	5	17,905	Collier	15	76,682
DeSoto	3	13,900	Hendry	3	21,846	Highlands	5	19,272
Lee	32	100,752	Martin	2	4,091	Miami-Dade	359	1,900,621
Okeechobee	3	10,116	Palm Beach	104	378,320	Sarasota	13	46,430
St. Lucie	8	29,699						
State Total	**663**	**3,169,182**		0	0		0	0
High Drought Hazard Risk								
Brevard	5	17,615	Escambia	12	39,923	Hardee	2	10,630
Highlands	3	15,844	Hillsborough	73	279,785	Indian River	5	14,670
Manatee	19	84,453	Orange	24	114,941	Osceola	14	103,651
Pasco	8	21,550	Pinellas	37	132,662	Polk	52	219,460
Santa Rosa	1	6,115	St. Lucie	2	7,416			
State Total	**257**	**1,068,715**		0	0		0	0
Medium Drought Hazard Risk								
Brevard	1	3,232	Hernando	13	54,195	Lake	9	40,805
Orange	26	137,407	Pasco	20	65,692	Seminole	7	25,901
Sumter	1	4,314	Volusia	18	83,236			
State Total	**95**	**414,782**		0	0		0	0

When looking at drought risk in comparison with medical vulnerability, however, different areas of the state are highlighted. Counties most at risk for high or extreme drought in combination with high medical vulnerability are located in the central part of the peninsula, north and west of Lake Okeechobee (Figure 65). Census tracts in south Florida are at extreme hazard risk, but are mostly placed in the low or medium category of medical vulnerability. The westernmost part of the panhandle (Escambia County) shows a high hazard risk combined with high medical vulnerability, while the rest of the panhandle displays a medium or low drought risk. In addition, the total population at extreme risk and high medical vulnerability is less than a tenth of the population at extreme risk when compared to high social vulnerability, totaling only 720,000 people (Table 80).

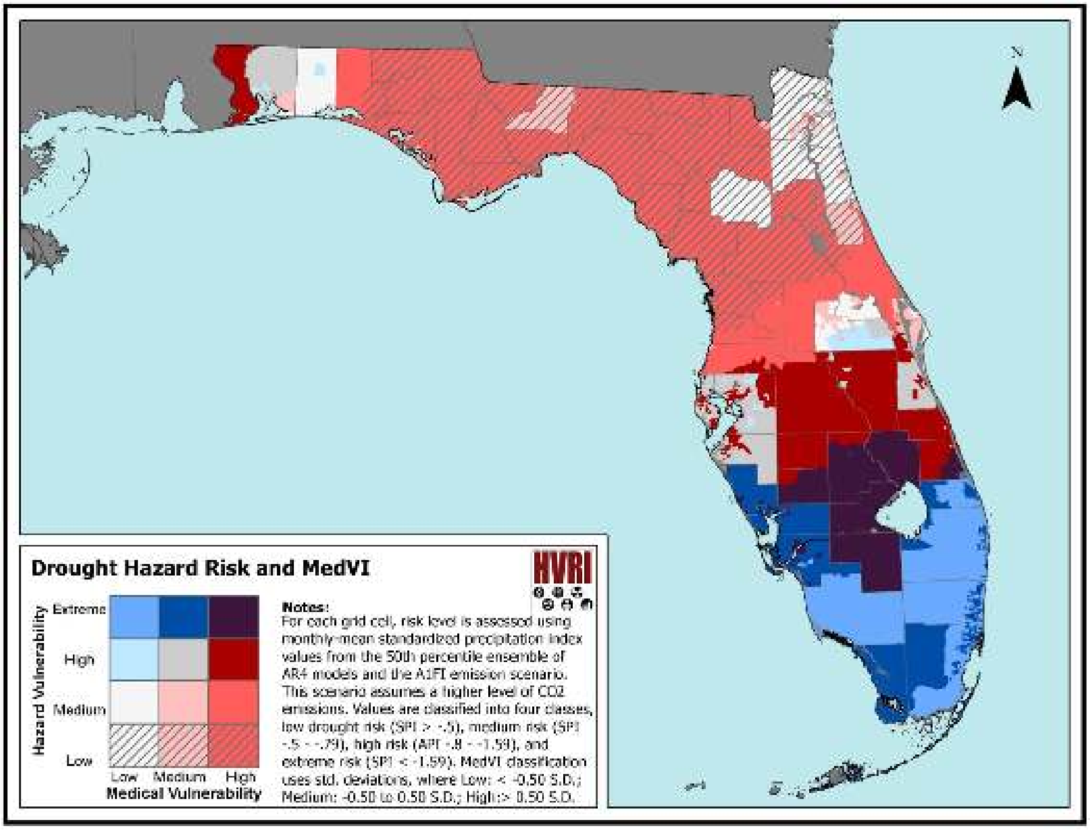

Figure 65: Bivariate representation of MedVI and drought hazard risk for A1FI scenario in Florida.

Table 80: Tract and population summary for counties with high MedVI and medium or greater drought hazard risk using the A1FI scenario.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Extreme Drought Hazard Risk								
Broward	4	27,116	Charlotte	7	32,234	DeSoto	8	31,592
Glades	3	12,884	Hendry	6	39,140	Highlands	20	79,279
Lee	32	136,588	Miami-Dade	4	12,514	Okeechobee	11	39,996
Sarasota	16	63,596	St. Lucie	35	244,517		-	-
State Total	**146**	**719,456**		-	-		-	-
High Drought Hazard Risk								
Brevard	23	141,734	DeSoto	1	3,270	Escambia	70	294,396
Hardee	6	27,731	Highlands	6	19,506	Hillsborough	85	307,926
Indian River	29	138,028	Manatee	17	73,525	Osceola	39	264,577
Pasco	37	128,278	Pinellas	68	272,992	Polk	151	589,656
St. Lucie	8	33,272		-	-		-	-
State Total	**540**	**2,294,891**		-	-		-	-
Medium Drought Hazard Risk								
Brevard	4	16,504	Hernando	36	140,102	Lake	55	293,540
Marion	1	-	Pasco	94	330,432	Polk	2	12,436
Sumter	11	34,586	Volusia	111	486,362	Walton	7	37,295
State Total	**321**	**1,351,257**		-	-		-	-

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10. Vulnerability to Wildland Fires

Methods

States in the South hold a unique set of urban and environmental characteristics, making the region susceptible to wildfire ignition. An abundance of wildland forest combined with a steady influx of new residents in Florida has created a landscape of urban settlements and infrastructure within or near to forested land across the state. Furthermore, wildfire ignition risk is compounded in Florida by the frequent occurrence of cloud-to-ground lightning (Buckley et al., 2006). With drier and warmer temperatures projected for Florida in the mid-late 21st century, the risk of wildfires is increased, particularly in the spring season through June (Bedel et al., 2013).

To quantify wildfire ignition risk throughout the state, data were obtained from the Florida Division of Forestry. The dataset used for analysis, the Wildland Fire Susceptibility Index (WFSI), represents a subset of the Southern Wildfire Risk Assessment Project, initially produced for the Southern Group of State Foresters in 2006. Spatially, the WFSI is illustrated as a 30x30 m grid with cell values ranging from zero to one representing the likelihood of an acre of land burning if ignited (Buckley et al., 2006). As Buckley et al. (2006) describe, WFSI integrates the probability of an acre igniting and the expected final fire size based on the rate of spread in four weather percentile categories into a single measure of wildland fire susceptibility. The WFSI is comprised of three component data streams: 1) probability of fire occurrence, 2) fire behavior, and 3) fire suppression effectiveness. Figure 66 illustrates the components of the final WFSI model.

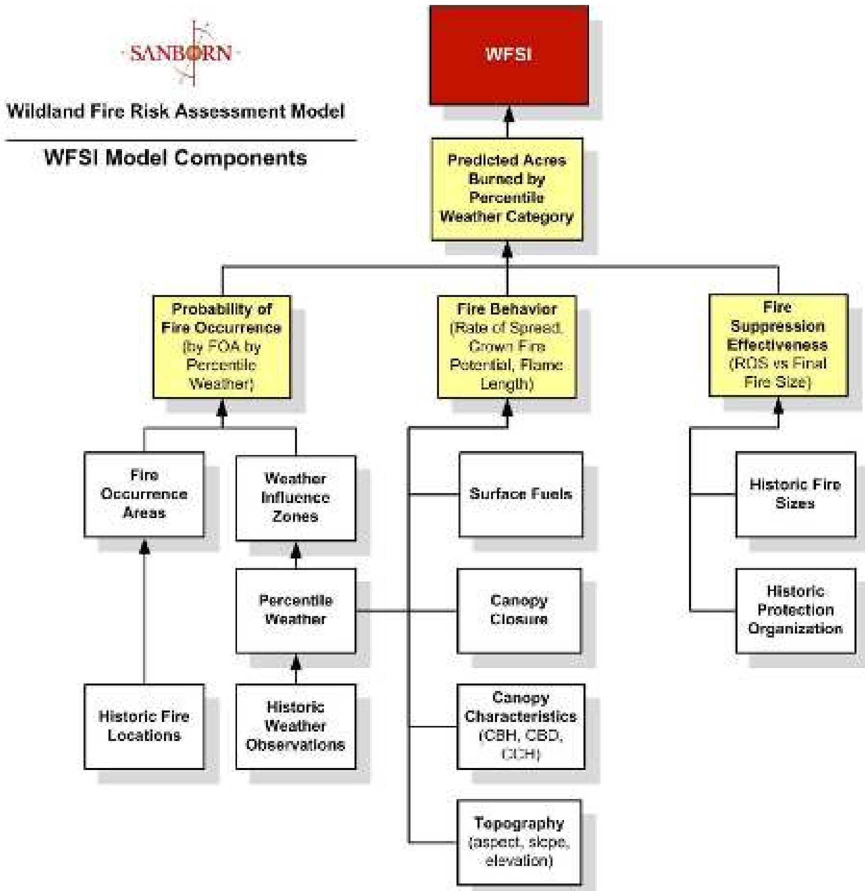

Figure 66: WFSI model components.

Source: Buckley et al., 2006: 41

The WFSI grid was imported into ArcMap for GIS processing. The raster grid was overlaid with Florida census tract boundaries. Wildfire ignition risk for each tract was approximated by extracting the maximum WFSI value inside each tract boundary. Maximum WFSI was selected over the average value because averaging values for each tract resulted in extremely low and misrepresentative values. Using maximum probability of an acre or more burning provides the highest risk faced in any tract in much the same way that tract coincidence with other hazard zones indicates higher risk (Figure 67). Each census tract was then categorized into one of five classes based on the maximum WFSI score coinciding with it using the following equal interval classification scheme so that future changes in risk at the tract-level can be easily seen in comparison to the current risk level:

- Low = Less than 25% probability of an acre or more burning if ignited
- Medium = Between 25% - 50% probability of an acre or more burning if ignited
- High = Between 50%-75% probability of an acre or more burning if ignited
- Extreme = Greater than 75% probability of an acre or more burning if ignited

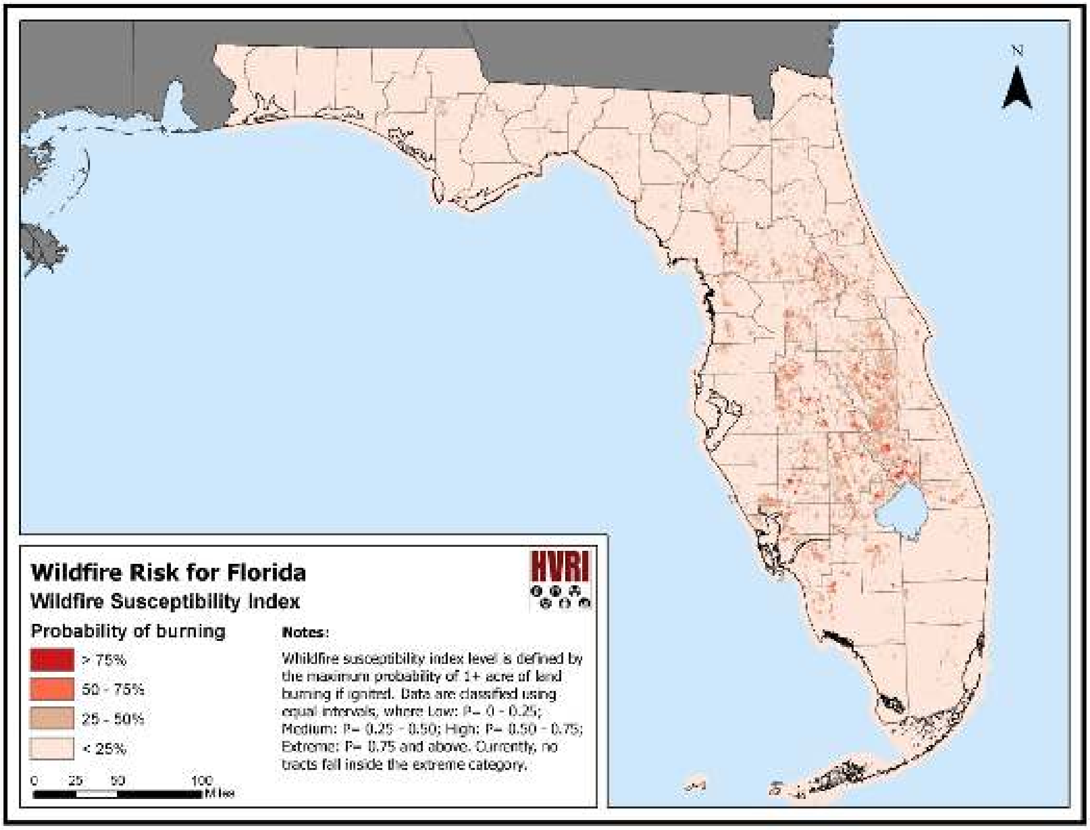

Figure 67: Wildland Fire Susceptibility Index (WFSI) scores for Florida.

State Summary

Wildfire threat is greatest across the central portion of the state where vast fields of livestock and citrus, along with numerous federal, state, and county parks and scenic areas are located (Figure 68). Among the most at-risk counties are Charlotte with 18% of its tracts in a medium threat category, Highlands (15%), Lee (9%), Marion (10%), Osceola (15%), and Polk (19%) (Table 81). There are no counties with census tracts in the extreme wildfire threat category and only two counties (Okeechobee and Polk) with high risk areas, when classifying tracts based on maximum probability of an acre or more burning if ignited. There are, however, many more counties containing populated census tracts characterized by medium wildfire threat. Here, more than 500,000 people live within areas of medium wildfire risk (Table 82).

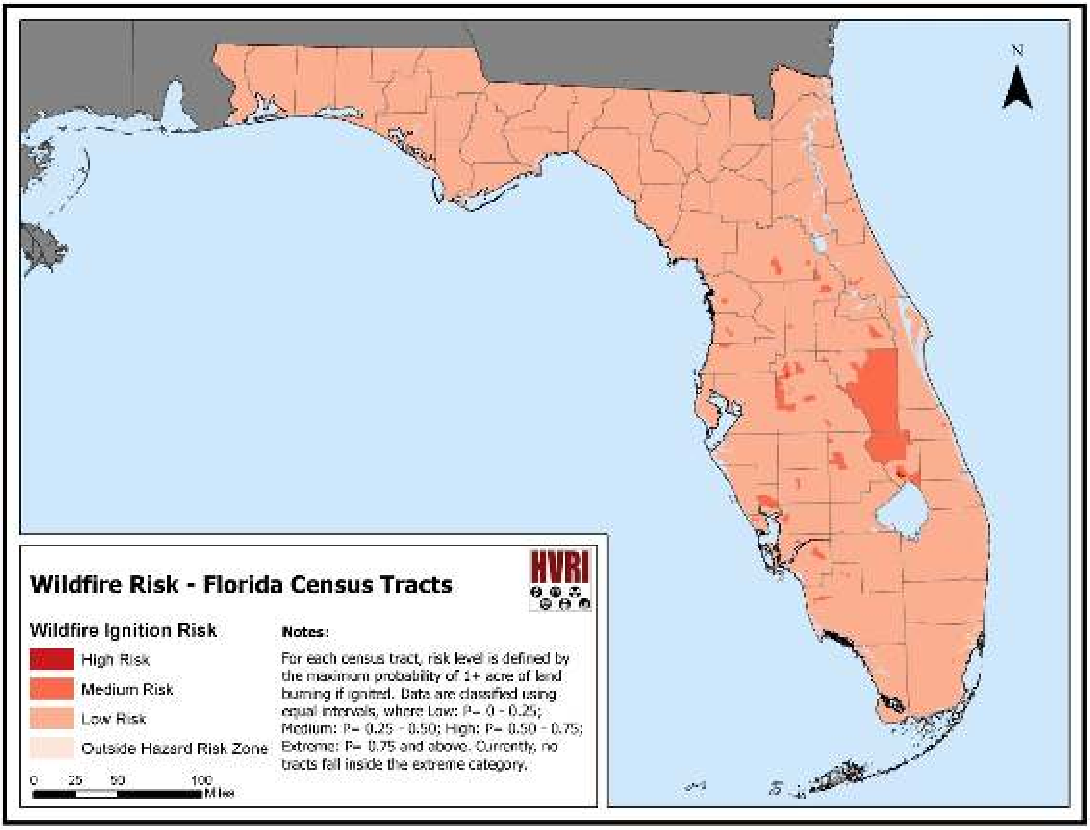

Figure 68: Wildfire ignition risk in Florida.

Table 81: Census tract summary for wildfire risk.

County Name	Widlfire Hazard Risk					County Name	Wildfire Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out		Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	100.00%	-	Lee	-	-	8.98%	89.82%	1.20%
Baker	-	-	-	100.00%	-	Leon	-	-	-	100.00%	-
Bay	-	-	-	97.73%	2.27%	Levy	-	-	-	90.00%	10.00%
Bradford	-	-	-	100.00%	-	Liberty	-	-	-	100.00%	-
Brevard	-	-	-	100.00%	-	Madison	-	-	-	100.00%	-
Broward	-	-	-	96.12%	3.88%	Manatee	-	-	-	100.00%	-
Calhoun	-	-	-	100.00%	-	Marion	-	-	9.52%	90.48%	-
Charlotte	-	-	17.95%	79.49%	2.56%	Martin	-	-	-	100.00%	-
Citrus	-	-	3.57%	96.43%	-	Miami-Dade	-	-	0.19%	83.82%	15.99%
Clay	-	-	-	100.00%	-	Monroe	-	-	-	96.77%	3.23%
Collier	-	-	5.41%	93.24%	1.35%	Nassau	-	-	-	100.00%	-
Columbia	-	-	-	100.00%	-	Okaloosa	-	-	-	100.00%	-
DeSoto	-	-	22.22%	77.78%	-	Okeechobee	-	9.09%	63.64%	27.27%	-
Dixie	-	-	-	100.00%	-	Orange	-	-	1.45%	98.55%	-
Duval	-	-	-	100.00%	-	Osceola	-	-	14.63%	85.37%	-
Escambia	-	-	-	100.00%	-	Palm Beach	-	-	-	97.62%	2.38%
Flagler	-	-	5.00%	95.00%	-	Pasco	-	-	1.49%	97.76%	0.75%
Franklin	-	-	-	100.00%	-	Pinellas	-	-	-	99.59%	0.41%
Gadsden	-	-	-	100.00%	-	Polk	-	0.65%	18.83%	80.52%	-
Gilchrist	-	-	-	100.00%	-	Putnam	-	-	-	100.00%	-
Glades	-	-	-	75.00%	25.00%	Santa Rosa	-	-	-	100.00%	-
Gulf	-	-	-	100.00%	-	Sarasota	-	-	4.26%	95.74%	-
Hamilton	-	-	-	100.00%	-	Seminole	-	-	-	100.00%	-
Hardee	-	-	-	100.00%	-	St. Johns	-	-	-	100.00%	-
Hendry	-	-	-	100.00%	-	St. Lucie	-	-	-	100.00%	-
Hernando	-	-	4.44%	93.33%	2.22%	Sumter	-	-	-	100.00%	-
Highlands	-	-	14.81%	85.19%	-	Suwannee	-	-	-	100.00%	-
Hillsborough	-	-	0.31%	99.07%	0.62%	Taylor	-	-	-	100.00%	-
Holmes	-	-	-	100.00%	-	Union	-	-	-	100.00%	-
Indian River	-	-	3.33%	96.67%	-	Volusia	-	-	4.39%	94.74%	0.88%
Jackson	-	-	-	100.00%	-	Wakulla	-	-	-	100.00%	-
Jefferson	-	-	-	100.00%	-	Walton	-	-	-	100.00%	-
Lafayette	-	-	-	100.00%	-	Washington	-	-	-	100.00%	-
Lake	-	-	5.36%	94.64%	-	**State Total**	**-**	**0.05%**	**2.47%**	**94.66%**	**2.82%**

Table 82: Census tract population summary for wildfire risk.

County Name	Widlfire Hazard Risk						County Name	Wildfire Hazard Risk				
	Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out			Extreme (75%)	High (50%-75%)	Medium (25%-50%)	Low (<25%)	Out
Alachua	-	-	-	247,336	-		Lee	-	-	56,200	559,452	3,102
Baker	-	-	-	27,115	-		Leon	-	-	-	275,487	-
Bay	-	-	-	168,852	-		Levy	-	-	-	40,801	-
Bradford	-	-	-	28,520	-		Liberty	-	-	-	8,365	-
Brevard	-	-	-	543,369	-		Madison	-	-	-	19,224	-
Broward	-	-	-	1,697,082	50,984		Manatee	-	-	-	322,833	-
Calhoun	-	-	-	14,625	-		Marion	-	-	38,869	292,429	-
Charlotte	-	-	34,885	125,093	-		Martin	-	-	-	146,318	-
Citrus	-	-	6,488	134,748	-		Miami-Dade	-	-	-	2,141,010	352,117
Clay	-	-	-	190,865	-		Monroe	-	-	-	73,090	-
Collier	-	-	19,622	301,898	-		Nassau	-	-	-	73,314	-
Columbia	-	-	-	67,531	-		Okaloosa	-	-	-	180,822	-
DeSoto	-	-	11,592	23,270	-		Okeechobee	-	4,568	23,634	11,794	-
Dixie	-	-	-	16,422	-		Orange	-	-	19,504	1,126,452	-
Duval	-	-	-	864,263	-		Osceola	-	-	43,025	225,660	-
Escambia	-	-	-	297,619	-		Palm Beach	-	-	-	1,295,766	23,696
Flagler	-	-	7,274	88,422	-		Pasco	-	-	8,869	455,828	-
Franklin	-	-	-	11,549	-		Pinellas	-	-	-	916,542	-
Gadsden	-	-	-	46,389	-		Polk	-	3,685	113,750	484,660	-
Gilchrist	-	-	-	16,939	-		Putnam	-	-	-	74,364	-
Glades	-	-	-	12,884	-		Santa Rosa	-	-	-	151,372	-
Gulf	-	-	-	15,863	-		Sarasota	-	-	53,103	326,345	-
Hamilton	-	-	-	14,799	-		Seminole	-	-	-	422,718	-
Hardee	-	-	-	27,731	-		St. Johns	-	-	-	190,039	-
Hendry	-	-	-	39,140	-		St. Lucie	-	-	-	277,789	-
Hernando	-	-	8,422	164,356	-		Sumter	-	-	-	87,023	-
Highlands	-	-	17,281	81,505	-		Suwannee	-	-	-	41,551	-
Hillsborough	-	-	5,287	1,223,939	-		Taylor	-	-	-	22,570	-
Holmes	-	-	-	19,927	-		Union	-	-	-	15,535	-
Indian River	-	-	5,354	132,674	-		Volusia	-	-	24,702	469,891	-
Jackson	-	-	-	49,746	-		Wakulla	-	-	-	30,776	-
Jefferson	-	-	-	14,761	-		Walton	-	-	-	55,043	-
Lafayette	-	-	-	8,870	-		Washington	-	-	-	24,896	-
Lake	-	-	8,595	288,457	-		**State Total**	**-**	**8,253**	**506,456**	**17,846,318**	**429,899**

Analyzing Wildfire in Combination with SoVI and MedVI

About Bivariate Classifications

Here, we keep the exposure constant by using the same hazard threat surface but use different vulnerability perspectives (Social and Medical) in bivariate representations to create an easily understood depiction of not only increased threat but also a limited ability to adequately prepare for and respond to these threats. In doing so, we are able to quickly identify three specific geographic areas of interest:

1. Areas where the hazard itself should be the focus of planning and mitigation,

2. Areas where understanding the underlying socioeconomics and demographics would prove to be the most advantageous input point to create positive change, and

3. Areas where a combination of classic hazard mitigation techniques and social mitigation practices should be utilized in order to maximize optimal outcomes.

The following maps utilize a three by three bivariate representation in which one can easily identify areas of limited to elevated SoVI in relation to areas with low to extreme hazard classifications. Places identified in item number one in the preceding list are shaded in the blue colors and can be understood as locations where hazard susceptibility is higher than SoVI or MedVI. Areas identified in item number two above, indicating where socioeconomics and demographics play an important role, are shaded in the pink/red colors and can be conceived as locations where SoVI or MedVI are greater than physical hazard threats. Places identified in item number three above are shaded either in gray-tones or in a dark burgundy color and can be understood as areas that have equal vulnerability and hazard classification scores.

The pattern of wildfire threats combined with social vulnerability (Figure 69) shows mostly low levels of wildfire threat coupled with medium to high social vulnerability throughout central Florida, especially in Polk, Okeechobee, and Marion Counties. There are no census tracts with high or extreme wildfire threat coupled with high social vulnerability. Only 38 tracts in 13 counties exhibit high social vulnerability coincident with medium wildfire risk, representing 186,000 people (Table 83).

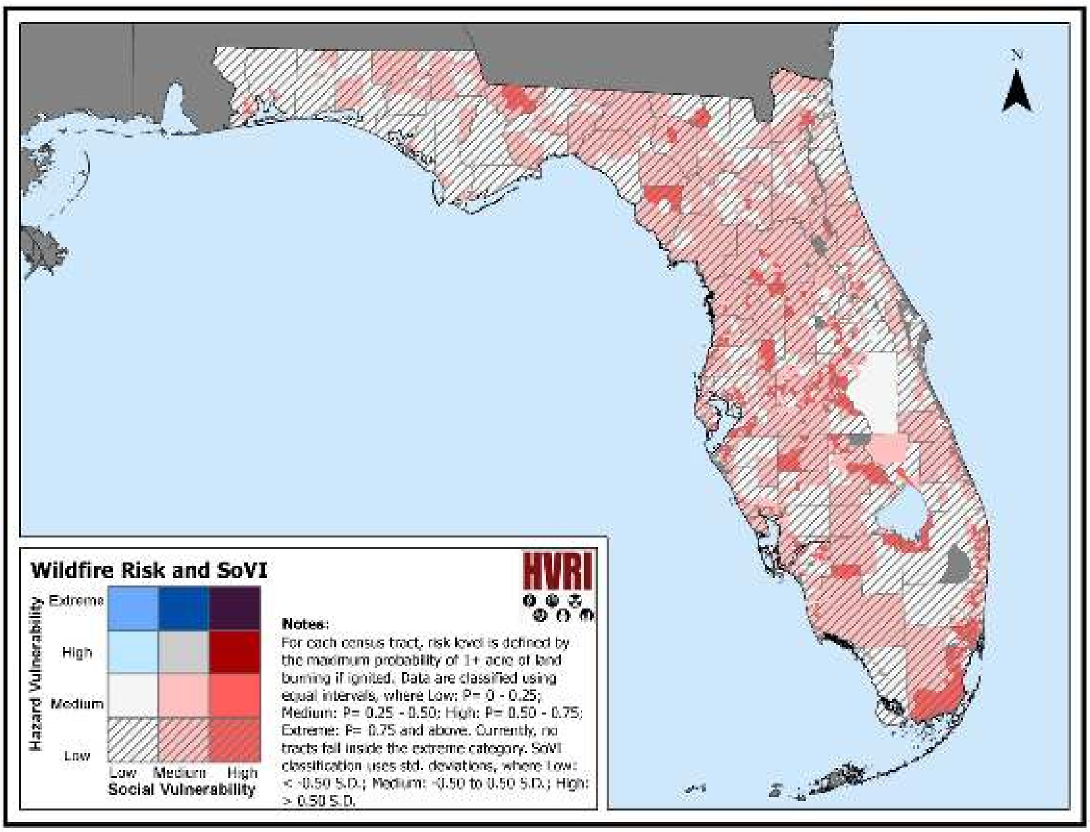

Figure 69: Bivariate representation of SoVI and wildfire risk in Florida.

Table 83: Tract and population summary for counties with high SoVI and medium or greater wildfire risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
Medium Wildfire Risk								
Charlotte	3	10,175	Collier	2	9,033	DeSoto	2	11,592
Hernando	1	3,686	Hillsborough	1	5,287	Indian River	1	5,354
Lee	9	39,201	Marion	3	28,805	Okeechobee	3	10,116
Orange	2	10,263	Polk	9	45,762	Sarasota	1	2,755
Volusia	1	4,055		-	-		-	-
State Total	**38**	**186,084**		-	-		-	-

The pattern is quite different when we take into account MedVI. Here, a large portion of Osceola County exhibits medium medical vulnerability coupled with medium wildfire threat (Figure 70). Seminole County, as a whole, does not exhibit as high MedVI or wildfire threat as its neighboring counties. There are, however, more than 300,000 people residing in 72 tracts across 15 counties with both high MedVI and medium to high wildfire threat (Table 84). Included here are 29 tracts in Polk County where more than 100,000 people reside and over an additional 40,000 people across six tracts in Osceola County.

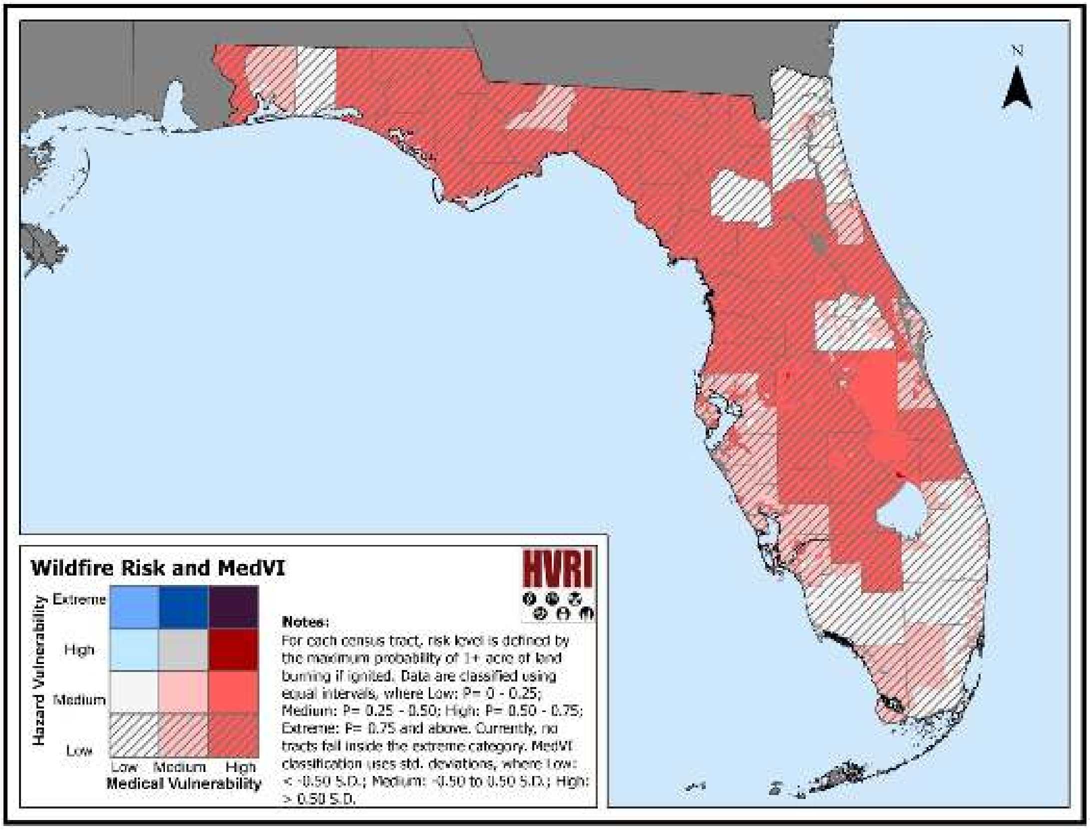

Figure 70: Bivariate representation of MedVI and wildfire risk in Florida.

Table 84: Tract and population summary for counties with high MedVI and medium or greater wildfire risk.

County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts	County Name	Number of Tracts	Total Population of Tracts
High Wildfire Risk								
Okeechobee	1	4,568	Polk	1	3,685		-	-
State Total	**2**	**8,253**		-	-		-	-
Medium Wildfire Risk								
Charlotte	1	5,498	Citrus	1	6,488	DeSoto	2	11,592
Hernando	2	8,422	Highlands	4	17,281	Indian River	1	5,354
Lake	3	8,595	Lee	5	21,194	Marion	5	38,869
Okeechobee	7	23,634	Osceola	6	43,025	Pasco	2	8,869
Polk	29	113,750	Sarasota	2	12,103	Volusia	5	24,702
State Total	**75**	**349,376**		-	-		-	-

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