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.

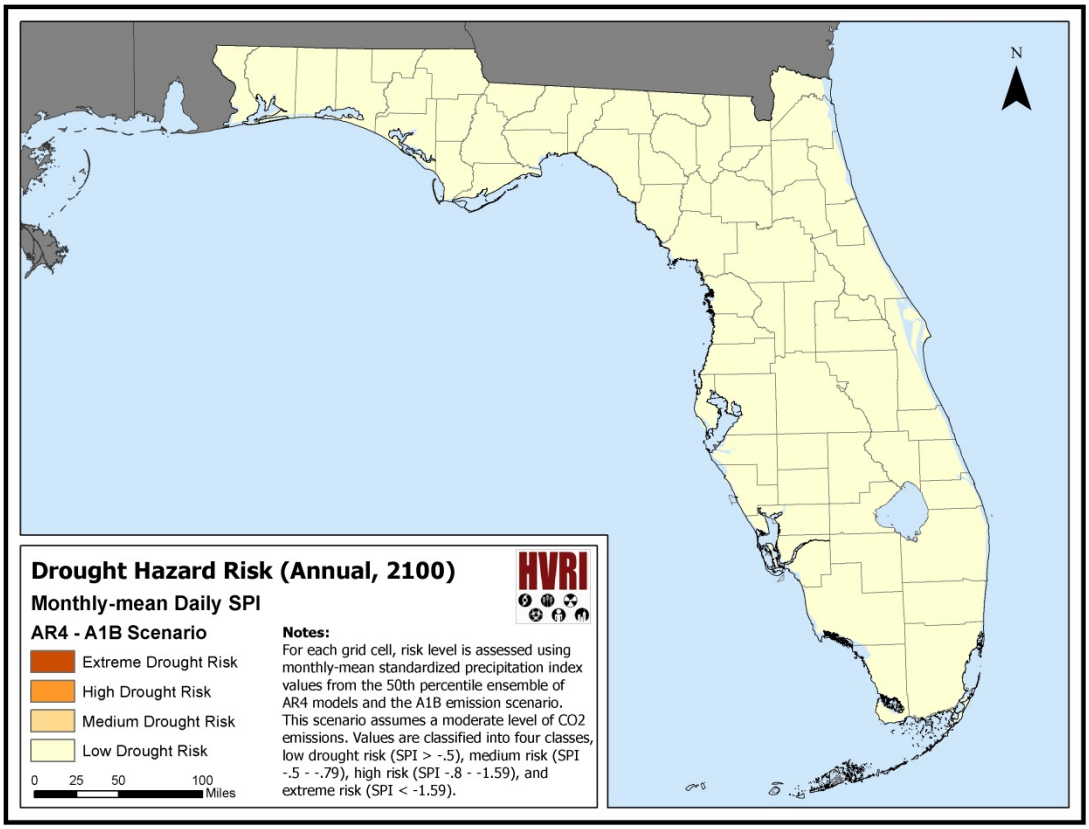

Figure 56: Monthly-mean daily SPI for A1B scenario in Florida, 2100.

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).

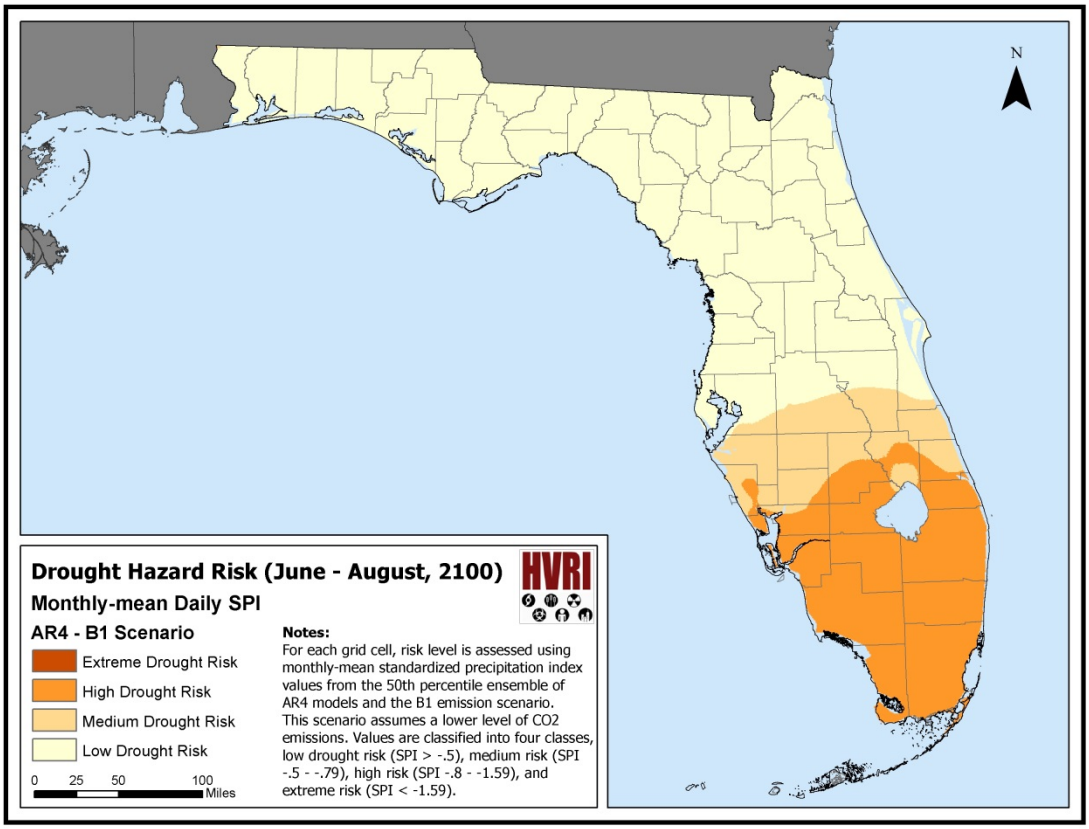

Figure 57: Monthly-mean daily SPI for B1 scenario in Florida – June-August, 2100.

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).

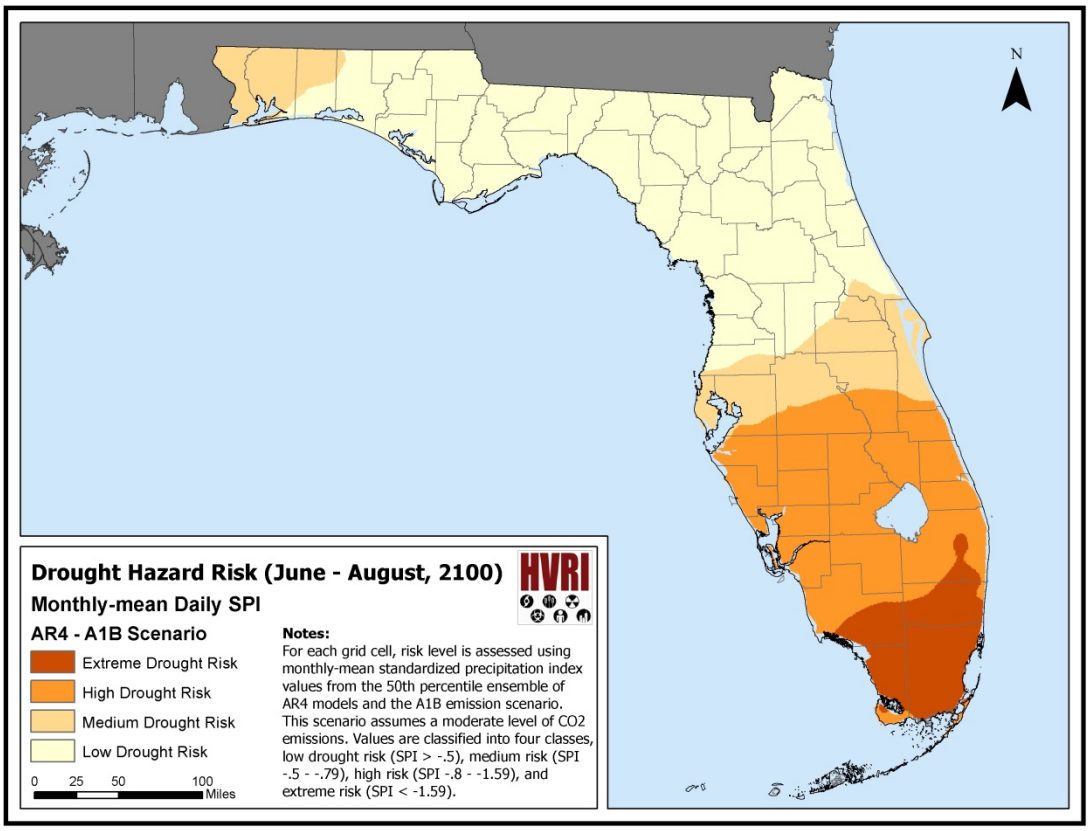

Figure 58: Monthly-mean daily SPI for A1B scenario in Florida – June-August, 2100.

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					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	-	-	-	247,336	-	Lee	-	618,754	-	-	-
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	1,528,246	219,820	-	-	-	Manatee	-	314,944	7,889	-	-
Calhoun	-	-	-	14,625	-	Marion	-	-	-	331,298	-
Charlotte	-	159,978	-	-	-	Martin	-	146,318	-	-	-
Citrus	-	-	-	141,236	-	Miami-Dade	2,407,836	85,291	-	-	-
Clay	-	-	-	190,865	-	Monroe	-	73,090	-	-	-
Collier	-	321,520	-	-	-	Nassau	-	-	-	73,314	-
Columbia	-	-	-	67,531	-	Okaloosa	-	-	48,091	132,731	-
DeSoto	-	34,862	-	-	-	Okeechobee	-	39,996	-	-	-
Dixie	-	-	-	16,422	-	Orange	-	-	1,022,004	123,952	-
Duval	-	-	-	864,263	-	Osceola	-	-	268,685	-	-
Escambia	-	-	297,619	-	-	Palm Beach	140,316	1,179,146	-	-	-
Flagler	-	-	-	95,696	-	Pasco	-	-	223,993	240,704	-
Franklin	-	-	-	11,549	-	Pinellas	-	-	916,542	-	-
Gadsden	-	-	-	46,389	-	Polk	-	47,749	551,831	2,515	-
Gilchrist	-	-	-	16,939	-	Putnam	-	-	-	74,364	-
Glades	-	12,884	-	-	-	Santa Rosa	-	-	110,258	41,114	-
Gulf	-	-	-	15,863	-	Sarasota	-	379,448	-	-	-
Hamilton	-	-	-	14,799	-	Seminole	-	-	368,050	54,668	-
Hardee	-	27,731	-	-	-	St. Johns	-	-	-	190,039	-
Hendry	-	39,140	-	-	-	St. Lucie	-	277,789	-	-	-
Hernando	-	-	-	172,778	-	Sumter	-	-	-	87,023	-
Highlands	-	98,786	-	-	-	Suwannee	-	-	-	41,551	-
Hillsborough	-	29,874	1,199,352	-	-	Taylor	-	-	-	22,570	-
Holmes	-	-	-	19,927	-	Union	-	-	-	15,535	-
Indian River	-	138,028	-	-	-	Volusia	-	-	89,896	404,697	-
Jackson	-	-	-	49,746	-	Wakulla	-	-	-	30,776	-
Jefferson	-	-	-	14,761	-	Walton	-	-	-	55,043	-
Lafayette	-	-	-	8,870	-	Washington	-	-	-	24,896	-
Lake	-	-	-	297,052	-	**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).

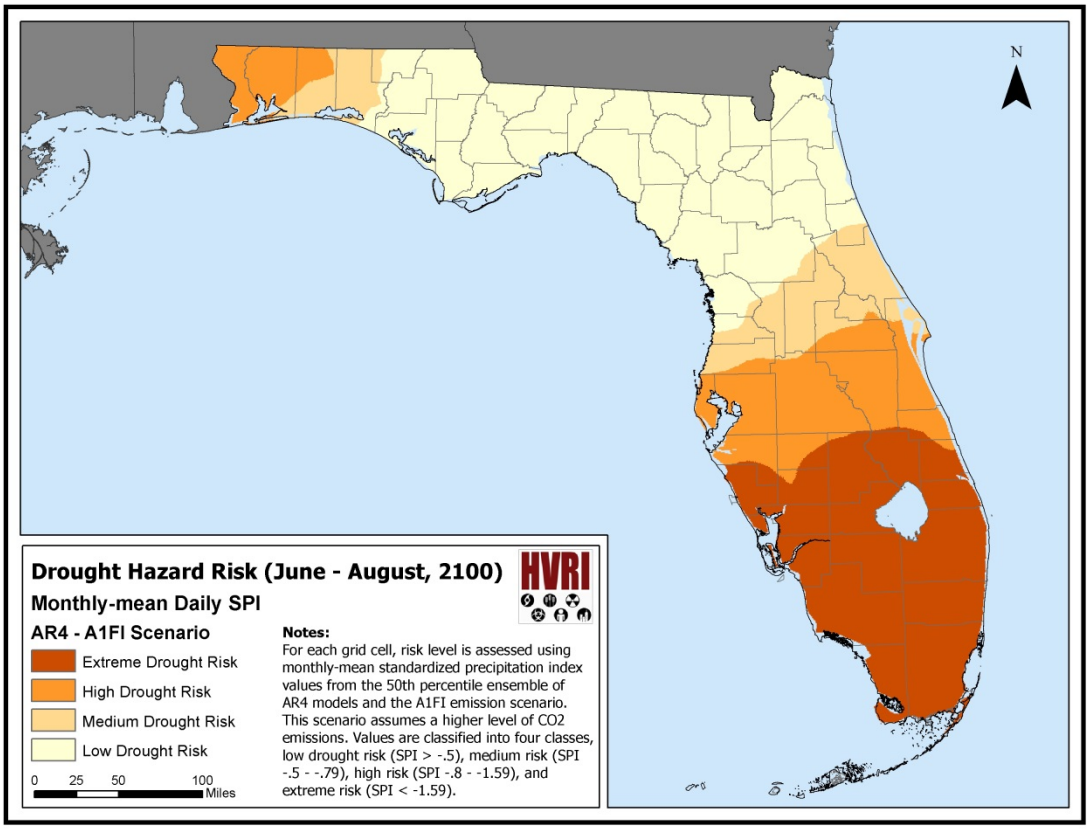

Figure 59: Monthly-mean daily SPI for A1FI scenario in Florida – June-August, 2100.

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%	-	Lewy	-	-	-	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.

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	-	-	-	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.

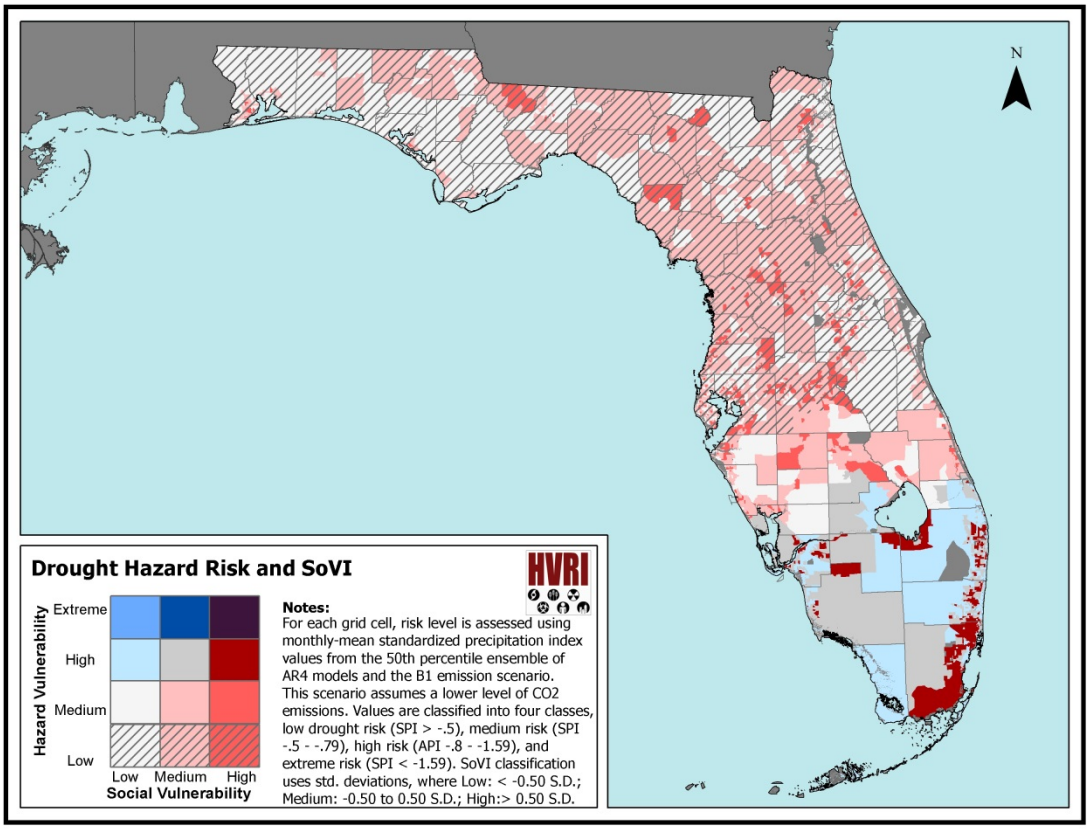

Figure 60: Bivariate representation of SoVI and drought hazard risk for B1 scenario in Florida.

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.

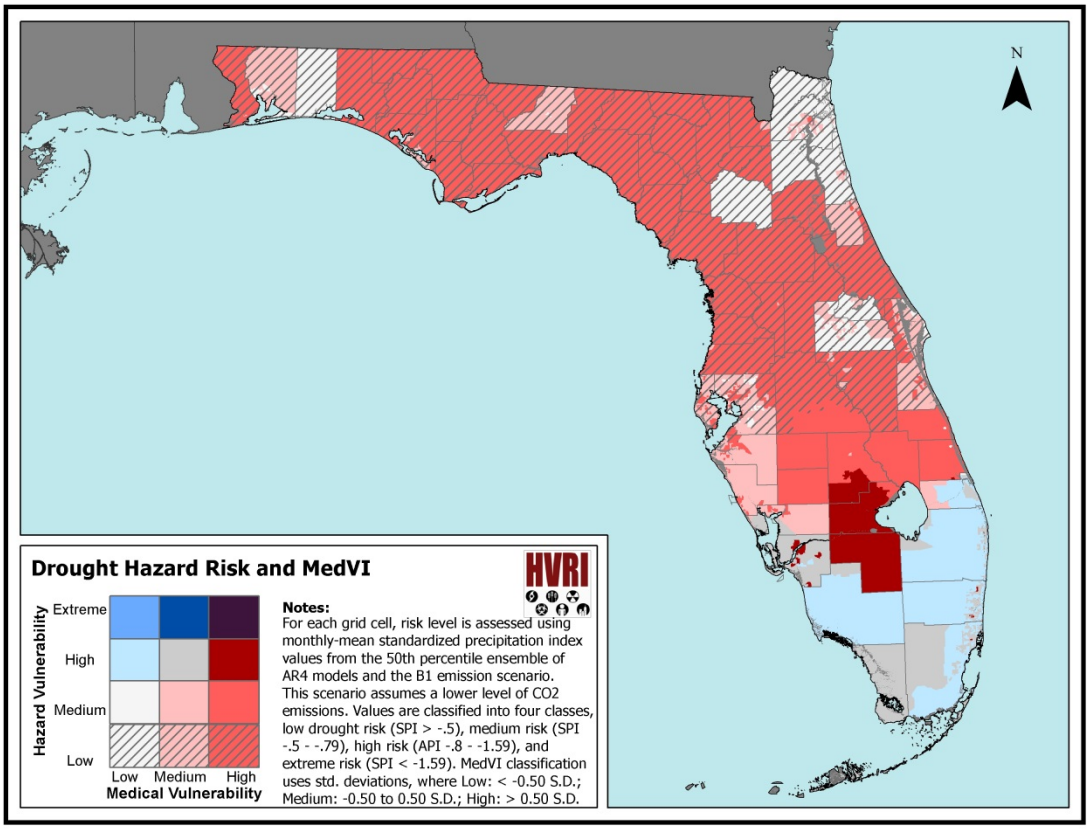

Figure 61: Bivariate representation of MedVI and drought hazard risk for B1 scenario in Florida.

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.

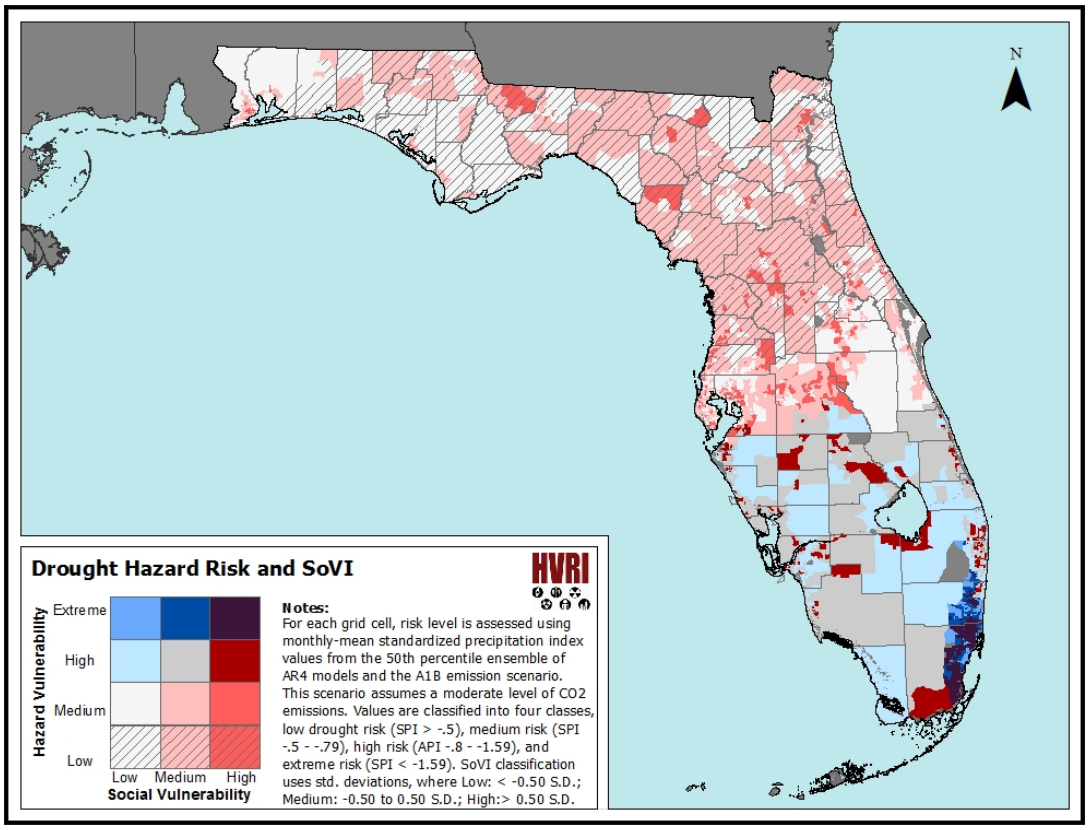

Figure 62: Bivariate representation of SoVI and drought hazard risk for A1B scenario in Florida.

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.

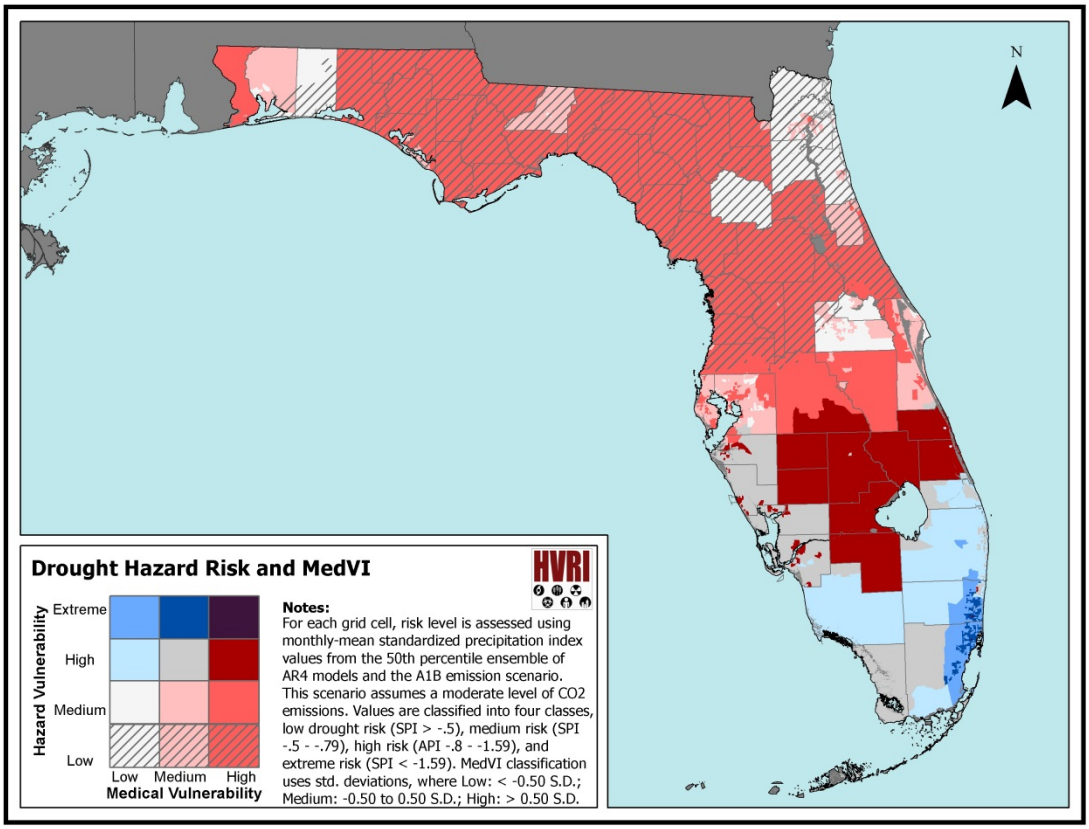

Figure 63: Bivariate representation of MedVI and drought hazard risk for A1B scenario in Florida.

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.

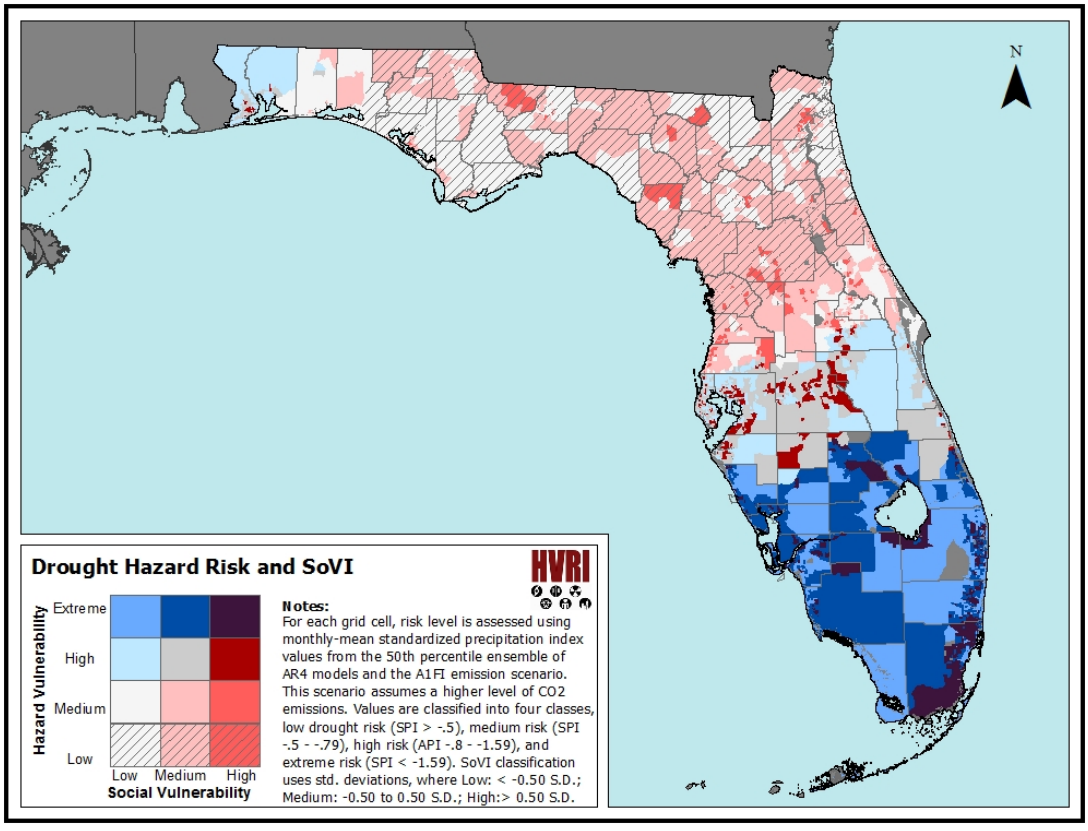

Figure 64: Bivariate representation of SoVI and drought hazard risk for A1FI scenario in Florida.

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).

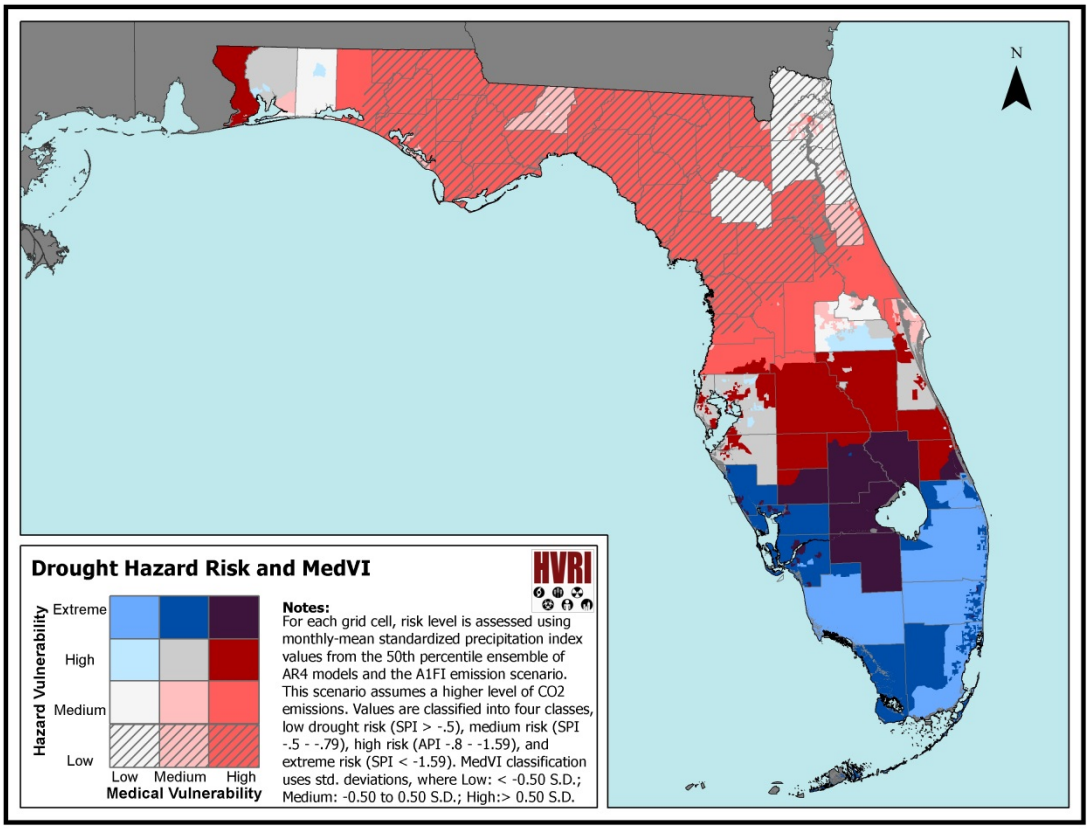

Figure 65: Bivariate representation of MedVI and drought hazard risk for A1FI scenario in Florida.

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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