Section 4.4 Drought

Drought

Droughts are characterized by periods of abnormally dry weather that diminish natural stream flows and soil moisture. They can come as a result of a lack of rainfall and are exacerbated by human activity that uses more water than an environment can support. Droughts impact local ecosystems and put stress on communities and economic activities.

CHANGES SINCE 2018

+13

Declared Disasters

+3

Multi-year Events

COUNTIES MOST VULNERABLE

Kaua‘i Honolulu Maui Hawai‘i

SOCIALLY VULNERABLE POPULATION

22.3%

Of Total Population

316,257

Persons

HAZARD RANKING

Low Medium High

COMMUNITY LIFELINES

Greatest

CLIMATE PROJECTIONS

Climate change will increase the frequency of meteorological and agricultural droughts

An increase in wildfire events will destroy native plants and support the spread of fire-adapted invasive species

Increased temperatures, nutrient and sediment loads, and decreased dilution of pollutants threaten the availability of fresh water

Drought may directly or indirectly impact these physical state assets.

- Environmental Resources
- State Buildings
- Hawaiian Home Lands
- Cultural Resources
- Miles of State Road

CONTENTS

TABLES

FIGURES

[1] *Section Cover Photo: Drought conditions on leeward Hawai'i Island. Photo courtesy of DLNR*

SECTION 4. RISK ASSESSMENT

4.4 DROUGHT

2023 SHMP Update Changes

- Drought events that occurred in the State of Hawai‘i from January 1, 2018, through December 31, 2022, were researched for this 2023 SHMP update.
- New and updated figures from federal and state agencies are incorporated.
- This section now includes a discussion of how drought impacts socially vulnerable populations and community lifelines.

4.4.1 HAZARD PROFILE

HAZARD DESCRIPTION

A drought is a period of abnormally dry weather. Drought diminishes natural stream flow and depletes soil moisture, which can cause social, cultural, environmental, and economic impacts. In general, the term "drought" should be reserved for periods of moisture deficiency that are relatively extensive in both space and time. While some droughts may seem like extreme and rare events, drought is a normal and recurring part of the climate in Hawai‘i.

Drought Types Defined

Meteorological Drought — When dry weather patterns dominate an area

Hydrological Drought — When low water supply becomes evident in the water system

Agricultural Drought — When crops become affected by drought

Socioeconomical Drought — When the supply and demand of various commodities is affected by drought

Ecological Drought – When natural ecosystems are affected by drought

(National Integrated Drought Information System n.d.)

Lack of rainfall is not the only factor contributing to the impacts of drought. Both natural events and human activities, such as expanding populations, irrigation, and environmental needs, put pressure on water supplies. Lack of rainfall combined with the demands society place on water systems and supplies contribute to drought impacts.

Average Rainfall

The climate, and consequently the amount of rainfall, of the Hawaiian Islands is directly influenced by the northeasterly trade winds. Leeward locations (south and west shores) are much drier and sunnier than windward locations (north and east shores), as depicted in Figure 4.4-1. Within leeward and windward locations, rainfall varies considerably according to elevation. Studies have shown fewer days with northeast trade winds than 40 years ago (Garza, et al. 2012). Fewer days of northeast trade winds leads to more muggy weather and volcanic haze and results in longer-term effects for the state.

Figure 4.4-1. Drought Conditions on Leeward Hawai'i Island

Source: DLNR

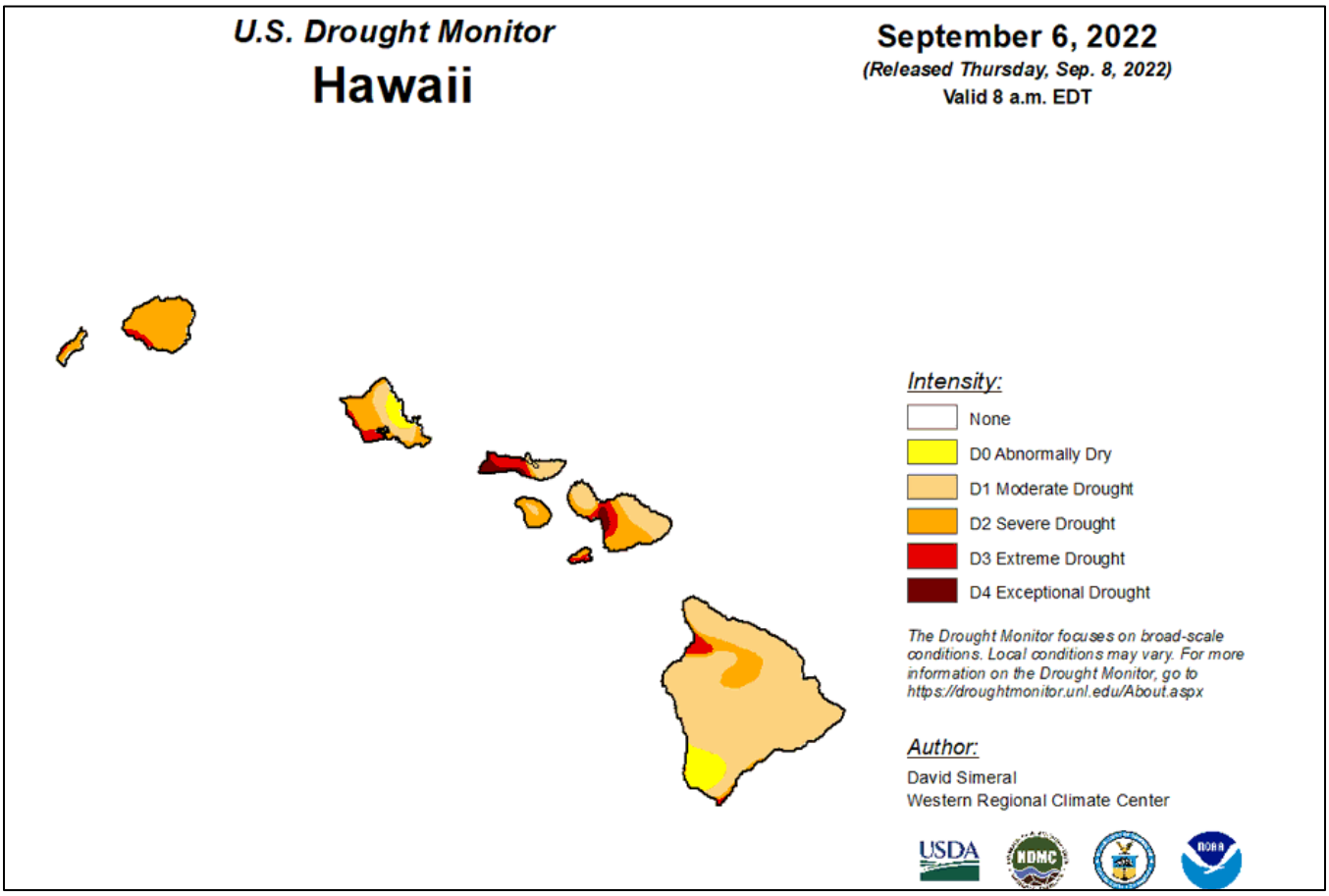
The trade winds are responsible for much of the rainfall, especially in windward areas. As their occurrences decrease, so will the total rainfall, leading to more drought conditions. Over the last 100 years, the State of Hawai'i has experienced longer, more severe, and more frequent droughts (Frazier, et al. 2022). Nearly the entire state experienced some degree of drought in 2022 (Figure 4.4-2).

Figure 4.4-3 shows a map of the main Hawaiian Islands indicating the average annual precipitation for the 30-year period between 1982 and 2011 (Giambelluca, et al. 2013).

LOCATION

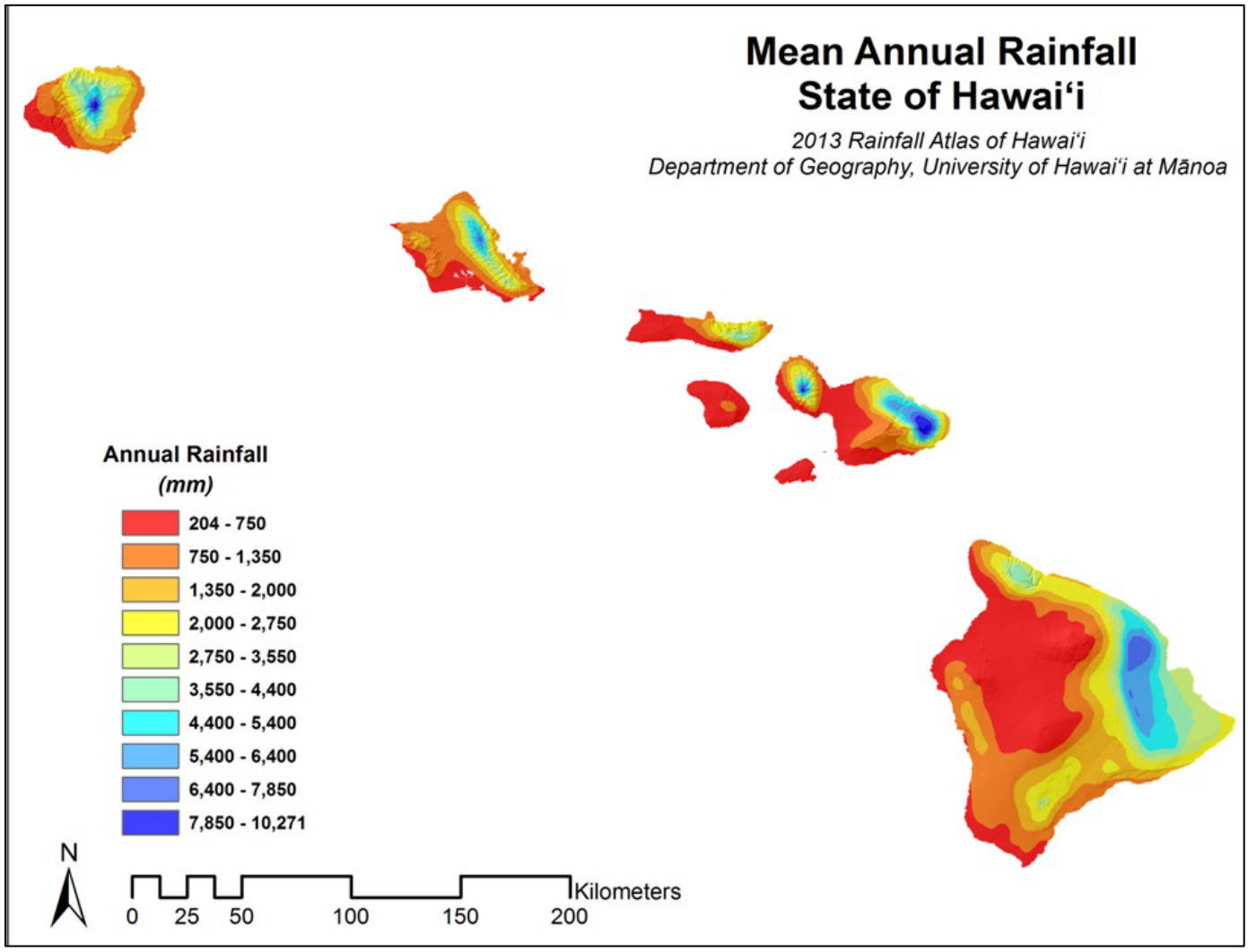
All areas of the state are susceptible to drought, although the extent and severity of the drought will depend on the variance of rainfall throughout the state based on location. The identification of areas that are vulnerable to drought impacts is difficult due to the differences in microclimate and impact sectors. Figure 4.4-4 and Figure 4.4-5 show general risks to the water supply and agriculture and commerce sectors, respectively. For water supply, the 30,000-60,000 residents who rely primarily on rainwater catchment are at the highest risk (shown in red in Figure 4.4-4) to drought because they could run out of water from a week or two of reduced rainfall (Frazier, et al. 2022).

Figure 4.4-2. Drought in the State of Hawai'i, 2022



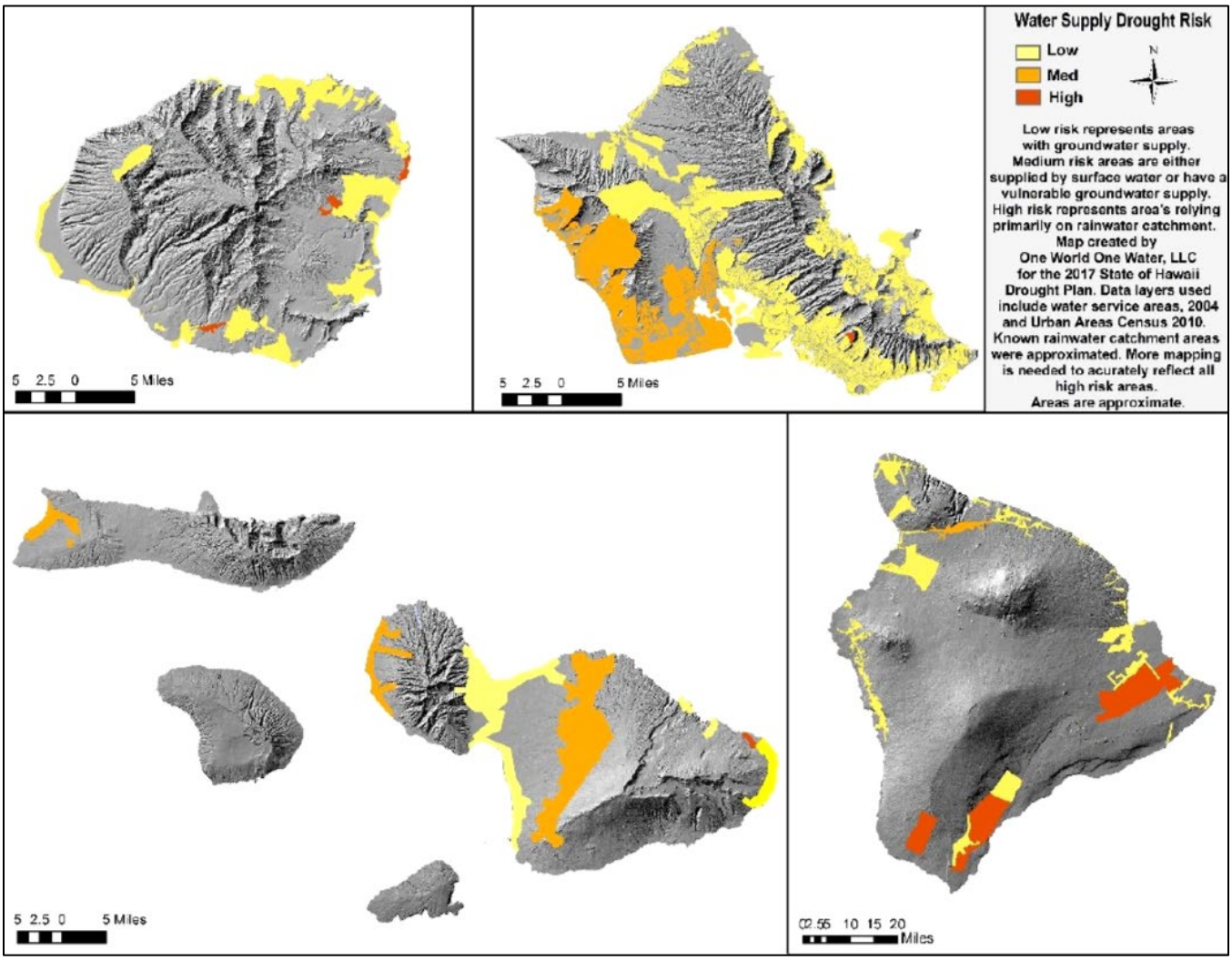
Source: (U.S. Drought Monitor 2022)

Figure 4.4-3. Mean Annual Precipitation Rainfall for the Main Hawaiian Islands



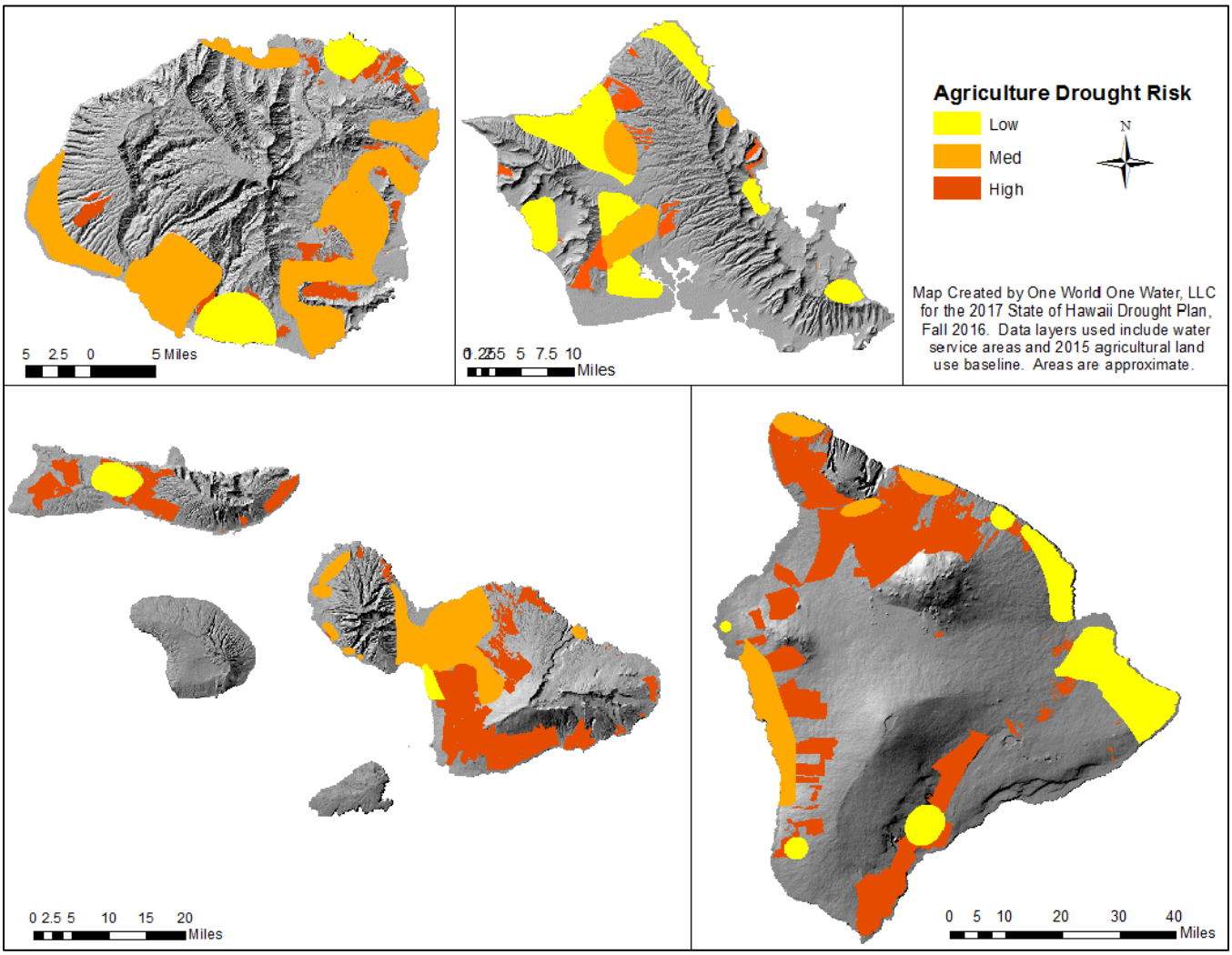
Source: *(Giambelluca, et al. 2013)*

Figure 4.4-4. Water Supply Drought Risk in the State of Hawai'i



Source: (DLNR Commission on Water Resource Management 2017)

Figure 4.4-5. Agricultural Drought Risk in the State of Hawai'i



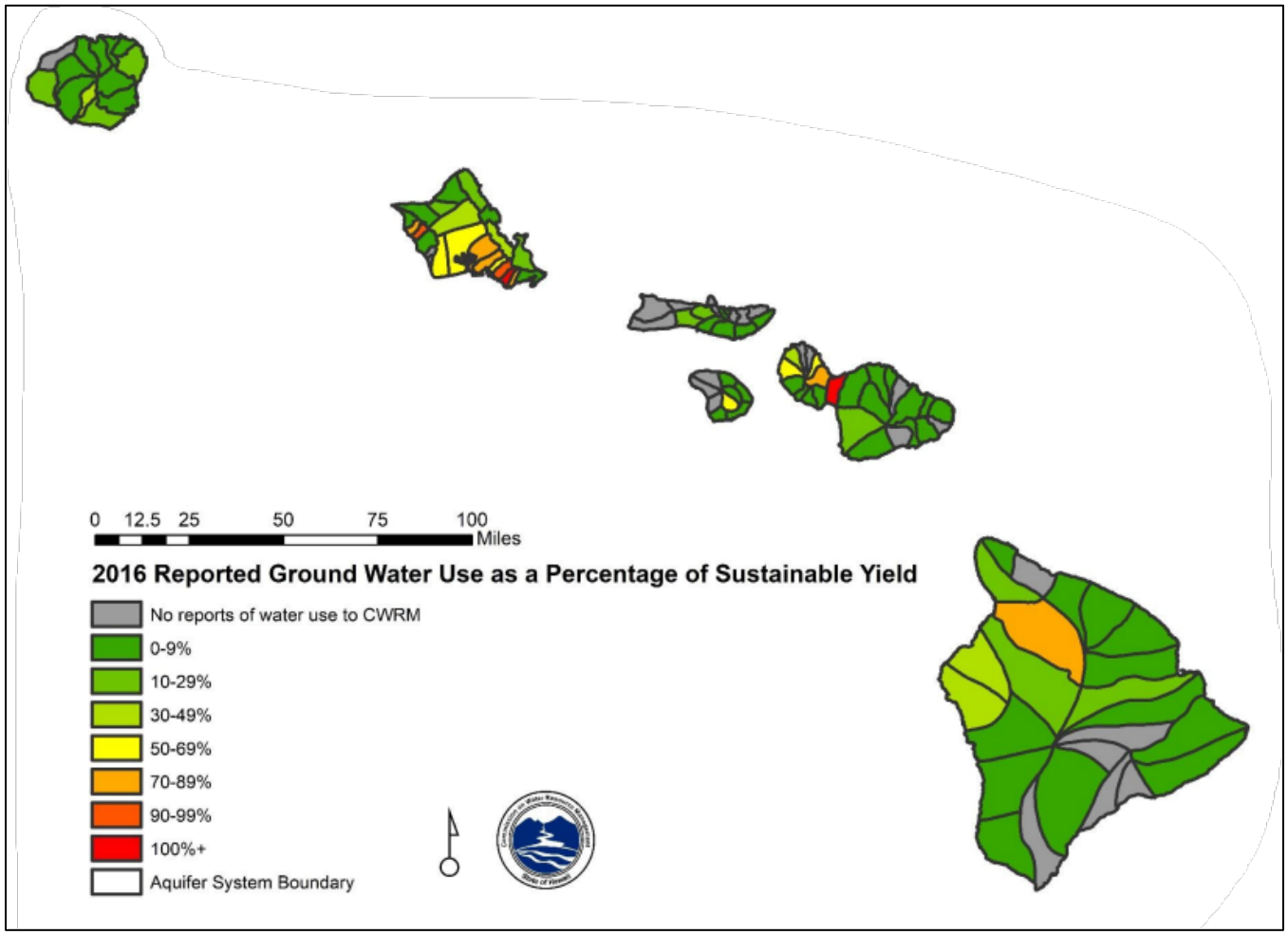
Source: (DLNR Commission on Water Resource Management 2017)

The DLNR Commission on Water Resource Management compiles reports that show groundwater use as a percentage of sustainable yield (Figure 4.4-6). Sustainable yield refers to the rate that groundwater can be pumped without endangering the quality or quantity of the water. Groundwater recharge in areas of the state experiencing drought conditions may not be able to sustain the amount or quality of water pumped for consumer use.

El Niño and La Niña

During El Niño, summers can have above-average rainfall that extends the growing season and increases fuel loads, especially in drier areas where plant growth is limited by lack of rainfall. Extended drought through the winter months then causes vegetation to dry out, which can significantly increase wildfire risk, especially for windward parts of the state that are usually wet year-round. A recent study by researchers in the University of Hawai'i at Mānoa concluded that at least two types of El Niño impact the state. Drought in Hawai'i is associated with the Eastern Pacific El Niño event (Lu, et al. 2020).

Figure 4.4-6. 2016 Reported Ground Water Use as a Percentage of Sustainable Yield



Source: (DLNR Commission on Water Resource Managment 2019)

La Niña is the opposite end of the oscillation. During these events, most of the tropical Pacific Ocean is cooler than average, and surface winds are stronger than normal. Rainfall decreases over the cooler central Pacific Ocean, including the State of Hawai'i. While La Niña is historically associated with wetter than normal rainfall in Hawai'i, drought conditions are still possible during these events. Areas with the lowest risk to drought are water supply areas that have adequate groundwater sources. Only a severe extended period of drought would affect these sources. Water supply sources will only become more vulnerable with climate change. For further information, refer to the Hawai'i Drought Plan 2017 Update. The Impacts on Climate Change subsection below details how climate change will impact drought throughout the State of Hawai'i.

For the environment, public health, and safety sector in the state, refer to the Communities at Risk from Wildfires figure (Figure 4.15-2) found in Section 4.15 (Wildfire). This figure is beneficial for understanding areas at risk from environmental hazards of drought. During periods of drought, vegetation dries out and has an increased susceptibility to wildfire.

Figure 4.4-5 identifies agricultural areas that are more vulnerable to drought conditions. If the water source for a region is groundwater, it has a lower risk during periods of drought as it can likely still withdraw groundwater to irrigate crops. Areas that rely on surface water have a medium drought risk as they typically have some ability to store water but sources can run out in an extended drought period. Unirrigated areas, mostly pastures, are at highest risk because they rely directly on rainfall for productivity. Drought risk may change in the future due to changes in land use, water access, and climate change.

EXTENT

The severity of a drought depends on the degree of moisture deficiency, the duration, and the size and location of the affected area. The longer the duration of the drought and the larger the area impacted, the more severe the potential impacts. Droughts are not usually associated with direct impacts on people or property, but they can have significant impacts on agriculture, which can impact people indirectly. When measuring the severity of droughts, analysts typically look at economic impacts on an area.

The National Drought Mitigation Center developed the Drought Impact Reporter in response to the need for a national drought impact database for the United States. The Drought Impact Reporter maps the effects of drought, based on reports from media, observers, and other sources. Impacts are an observable loss or change at a specific place and time due to drought. The Drought Impact Reporter is not a comprehensive set of data but is useful in tracking drought, if submissions are adequate, to aid in better understanding and response to drought impacts. The main emphasis is for drought planning. Drought impacts in the Drought Impact Reporter are likely under reported since submissions are made on a purely voluntary basis or picked up from media reports.

The Drought Impact Reporter contains information on 39 drought impacts from droughts that affected Hawai‘i between January 1, 2018, and December 31, 2022. All of these impacts are from media reports. Most of the impacts (21) were classified as “agriculture.” Other impacts include “relief, response & restrictions” (20), “water supply & quality” (19), “plants & wildlife” (18), “fire” (6), “society & public health” (5), “business & industry” (3), and “tourism & recreation” (1) (National Drought Mitigation Center 2022).

Between January 1, 2018, and December 27, 2022, the County of Maui had 66 drought-related impacts; the County of Hawai‘i had 25 drought-related impacts; the City and County of Honolulu had 19 drought-related impacts; and the County of Kaua‘i had 1 drought-related impact.

Drought Monitoring and Forecasting

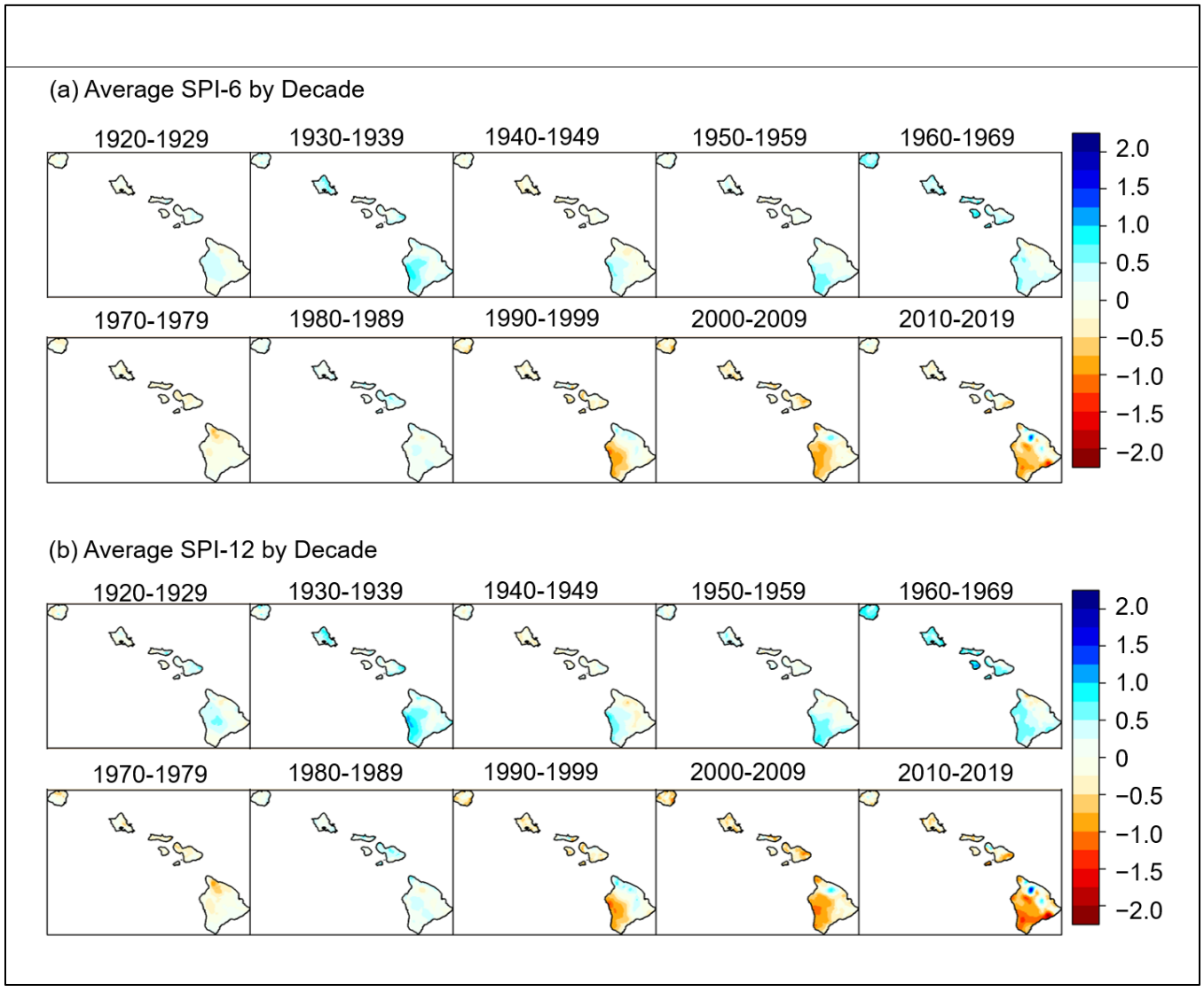
There are two popular drought indices used in Hawai‘i to monitor and forecast droughts: the Standardized Precipitation Index and the Percent of Normal Rainfall Index. A third index, the Keetch-Byram Drought Index, is used by the National Weather Service to track wildland fire fuel conditions and to assess the potential for wildland fire in the State of Hawai‘i.

Standardized Precipitation Index

The Standardized Precipitation Index (SPI) has been embraced by agencies such as the National Drought Mitigation Center (NDMC) and the Western Regional Climatic Center (WRCC) and was adapted for use in Hawai‘i by the National Weather Service Honolulu Forecast Office (National Weather Service n.d.). The SPI considers only precipitation, which makes the index ideal for use in Hawai‘i, where there is a relatively dense network of rain

gauges. The SPI is computed for time scales ranging from 1 to 48 months. Because the SPI values are normalized, the wide range of rainfall conditions across the State of Hawai'i can be assessed on an equal basis. Furthermore, SPI values can be generated for multiple time scales (see Figure 4.4-7). This feature is extremely useful for monitoring purposes because the effects of droughts occur over wide ranges of time scales. Finally, since the SPI uses standard statistical principles, it can also be used to monitor other data such as stream flow, reservoir levels, and ground water levels. Table 4.4-1 displays the different SPI categories and their associated values.

Figure 4.4-7. Average 6-month (a) and 12-month (b) SPI by decade (1920–2019) for the State of Hawai'i



Source: (Frazier, et al. 2022)

Table 4.4-1. SPI Categories

Value	Category
Greater than or equal to 2.00	Extremely Wet
1.50 to 1.99	Severely Wet
1.00 to 1.49	Moderately Wet
0.99 to -0.99	Near Normal
-1.00 to -1.49	Moderate Drought
-1.50 to -2.00	Severe Drought
Less than or equal to -2.00	Extreme Drought

Percent of Normal Rainfall Index

The Percent of Normal Rainfall Index (PNRI) is based on the percentage of current rainfall value compared against the long-term mean. The PNRI is one of the simplest methods of comparing current precipitation amounts to recorded historical averages. The index is calculated by dividing the actual precipitation amount by a 30-year (typically) precipitation mean. Time scales are generally stated in months or a year. The PNRI is effective for comparing a single region or season in easily understood terms.

One of the disadvantages of using the PNRI is that the mean precipitation is often not the same as the median precipitation. The reason for this is that precipitation on monthly or seasonal scales does not have a normal distribution while the PNRI implies a normal distribution where the mean and median are considered being the same. Another disadvantage of the PNRI is that due to the variety in the precipitation records over time and location, there is no way to determine the frequency of the departures from normal or compare different locations inhibiting attempts to mitigate drought based on the departures from normal and form a plan of response.

Keetch-Byram Drought Index

The Keetch-Byram Drought Index (KBDI) is calculated using weather station latitude, mean annual precipitation, maximum dry bulb temperature, previous 24-hour rainfall. The KBDI is used by the National Weather Service and foresters to assess fuel conditions and potential for wildfire. The KBDI describes soil moisture deficit with values ranging from 0 to 800. A value of 800 indicates extreme drought, and a value of 0 reflects saturated soil. KBDI at the Honolulu International Airport fluctuates through the year, while values in excess of 600 represent the highest 34% of values from 1975-2010. A KBDI of greater than 600 is typically encountered by late July and normally persists through late October. The National Weather Service (NWS) issues Red Flag Warnings when all three of the following conditions are met for two hours or more during any part of a day at the Honolulu International Airport (National Weather Service 2022):

- KBDI ≥ 600
- Minimum Relative Humidity ≤ 45 % (2 hours or more)
- Wind ≥ 20 mph (≥ 17 knots) (2 hours or more)

Warning Time

Droughts are climatic patterns that occur over long periods of time. Only generalized warning can take place due to the numerous variables that scientists have not pieced together well enough to make accurate and precise

predictions. Though only generalized warnings can take place, the U.S. Drought Monitor provides current and recent history of areas and populations affected by drought (U.S. Drought Monitor 2022).

El Niño events are strongly correlated with drought in the State of Hawai'i. There is an approximately 70% chance of a drier than normal winter season following the onset of an El Niño event. This can give a lead time of up to 12 months or so for managers and decision makers to prepare for a potential drought. The intensity and duration of drought cannot be predicted, but an El Niño occurrence is one of the only indicators managers have to forecast drought in Hawai'i. It is very difficult to predict an El Niño or La Niña event, but scientists monitor various ocean and atmospheric elements associated with these events and utilize complex computer models to make El Niño/La Niña forecasts. The National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center produces a monthly El Niño/Southern Oscillation (ENSO) Diagnostic Discussion, which provides analysis of current oceanic and atmospheric conditions as well as projection summaries of ENSO prediction models. A La Niña event can also affect rainfall and is historically related to wetter than normal conditions; however, this association is not as consistent as El Niño is to drought.

Drought is a very slow-developing hazard, and depending on the impact sector, it may take anywhere from months to years for the impacts and effects of drought to be felt. Scientists at this time do not know how to predict drought more than one month in advance for most locations. Predicting drought depends on the ability to forecast precipitation and temperature. Anomalies of precipitation and temperature may last from several months to several decades. How long they last depend on interactions between the atmosphere and the oceans, soil moisture and land surface processes, topography, internal dynamics, and the accumulated influence of weather systems on the global scale (Zhou, et al. 2019).

Previous Occurrences and Losses

During the planning for this update, many sources were researched that provided drought information regarding previous occurrences throughout the State of Hawai'i. The 2018 Plan discussed drought events that occurred in the state through 2017. For this 2023 SHMP Update, drought events were summarized between January 1, 2018 and December 31, 2022.

Disaster and Emergency Declarations

The following disaster declarations or emergency proclamations related to drought have been issued for Hawai'i:

- Federal disaster (DR) or emergency (EM) declarations, 1955–2022: no drought events
- Hawai'i state emergency proclamations, 2018–2022: 8 events, classified as drought
- USDA agricultural disaster declarations, 2012–2022: 34 events, classified as drought

Table 4.4-2 and Table 4.4-3 provide the United States Department of Agriculture (USDA) Secretarial disaster declarations in all Hawaiian counties from January 1, 2018, through December 31, 2022. Maui County received the most USDA declarations during this timeframe.

Table 4.4-2. Drought-Related USDA Declarations, 2018 to 2022

Year	Approval Date	Designation Number	Description of Disaster	Counties Affected
2019	July 9, 2019	S4492	Drought	Hawai‘i
2019	July 3, 2019	S4495	Drought	Maui
2019	March 19, 2019	S4490	Drought	Kaua‘i
2020	November 18, 2020	S4870	Drought	Kaua‘i
2020	November 6, 2020	S4863	Drought	Honolulu
2020	March 11, 2020	S4649	Drought	Maui, Hawai‘i
2021	November 19, 2021	S5107	Drought	Kaua‘i
2021	September 10, 2021	S5073	Drought	Honolulu
2021	June 25, 2021	S4991	Drought	Hawai‘i
2021	March 5, 2021	S4918	Drought	Maui
2022	August 15, 2022	S5253	Drought	Kaua‘i
2022	April 8, 2022	S5148	Drought	Maui, Hawai‘i
2022	March 15, 2022	S5185	Drought	Maui, Honolulu

Source: (USDA 2022)

Table 4.4-3. Summary of USDA Secretarial Disasters in Hawai‘i by County, 2018 to 2022

County	2018	2019	2020	2021	2022	5-Year Total
Kaua‘i	0	1	1	1	1	4
Honolulu	0	0	1	1	1	3
Maui	0	1	1	1	2	5
Hawai‘i	0	1	1	1	1	4

Source: (USDA 2022)

Insured Crop Losses

According to the USDA Risk Management Agency (RMA), insured crop losses through the State of Hawai‘i as a result of drought conditions for the five-year period of 2018 to 2022 totaled $780,330. In Table 4.4-4, the USDA RMA insured crop losses through the State of Hawai‘i as a result of drought conditions are shown by year, from 2018 to 2022. It shows the highest year of crop losses as 2022 in this five-year period, followed by 2021. This data only applies to insured crops.

Table 4.4-4. Total Insured Crop Insurance Paid by Year, 2018 to 2022

Year	Crop Insurance Paid
2018	$0
2019	$0
2020	$0
2021	$344,991
2022	$435,339
Total:	**$780,330**

Source: (USDA Risk Management Agency 2022)

Event History

Table 4.4-5 provides a summary of drought events that have impacted the State of Hawai'i between 2018 and 2022. Drought events that occurred prior to 2018 can be found in Appendix E (Hazard Profile Supplement).

Table 4.4-5. Drought Events in Hawai'i, 2018 to 2022

Date(s) of Event	Event Type	Counties Affected	Description
January 1 to February 22, 2018	Drought	All	All portions of the state experienced consecutive weeks of abnormally dry to severe drought conditions, particularly Hawai'i County.
May 31 to October 11, 2018	Drought	All	All portions of the state experienced consecutive weeks of abnormally dry to severe drought conditions, particularly Hawai'i and Maui Counties.
December 6, 2018 to December 22, 2022	Drought	All	All portions of the state experience consecutive weeks of abnormally dry to exceptional drought conditions. During the time span, Maui experience 33 weeks of exceptional drought. A significant lack of rainfall across Maui County resulted in lack of groundwater recharge and surface flow; increase wildfire activity; grasslands dried and were unable to meet the needs of cattle; and thousands of axis deer starved to death from lack of forage. Dry conditions in Honolulu County, coupled with the shutdown of three wells due to Navy fuel tank leaks contaminating the water supply led to voluntary water restrictions. Below normal rainfall in Hawai'i County degraded pastures throughout the island; contributed to the 20,000-acre Leilani and 40,000 Mana Road Fires; and led to residents trucking water to fill catchment tanks. During the 2021-2022 wet season, portions of Kaua'i, Maui, and Hawai'i Counties received 40 percent of average rainfall; portions of O'ahu received 70 percent of average rainfall.

Source: (U.S. Drought Monitor 2022, National Drought Mitigation Center 2022, USDA 2022, Hawai'i Wildfire Management Organization 2022)

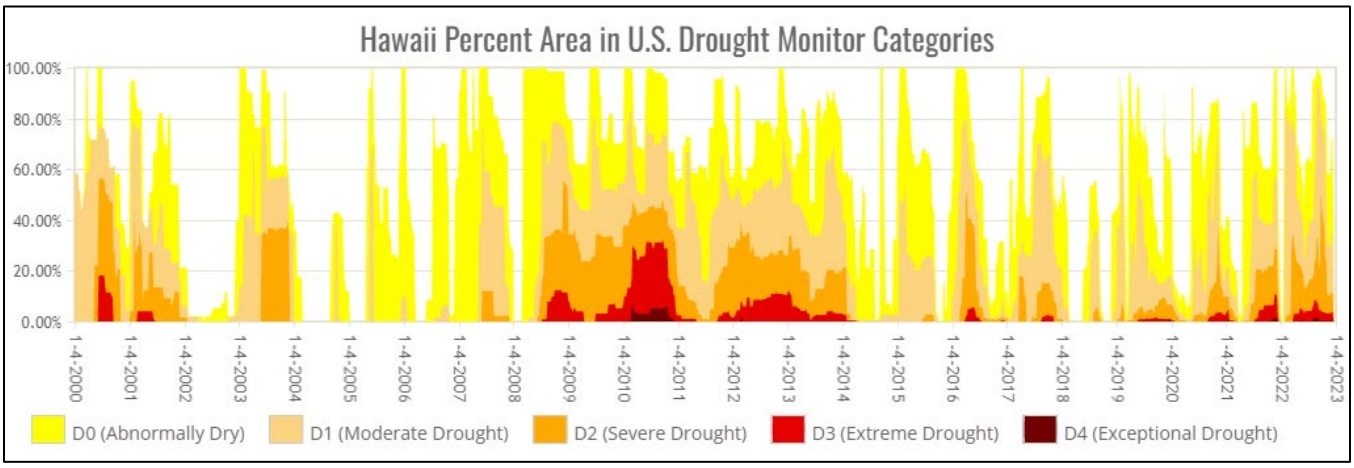
As shown in Table 4.4-2 and Figure 4.4-8, droughts have been and will continue to be a significant concern in the State of Hawai'i. Planning for and coping with recurring, if unpredictable, drought events is complicated by the inherent water resource limitations of the islands and the uneven range of drought-related concerns and relevant priorities across counties. The statewide variability in resources, vulnerability, and risk necessitates a sectoral approach to drought mitigation. Statewide, three sectors were identified as being vulnerable to drought as well as having the potential to be ameliorated through mitigation measures: public water supply; agriculture and commerce; and environment, public health, and safety.

Probability of Future Hazard Events

Overall Probability

During the entire time period for the 2023 SHMP Update, from January 1, 2018, to December 31, 2022, drought conditions existed somewhere in the State of Hawai'i. Based on the history of droughts in the state, the State of Hawai'i can expect drought conditions on an ongoing basis.

Figure 4.4-8 Percent of Hawai'i State Affected by Each USDM Rating, 2000–2022



Source: (U.S. Drought Monitor 2022)

Climate Change Impacts

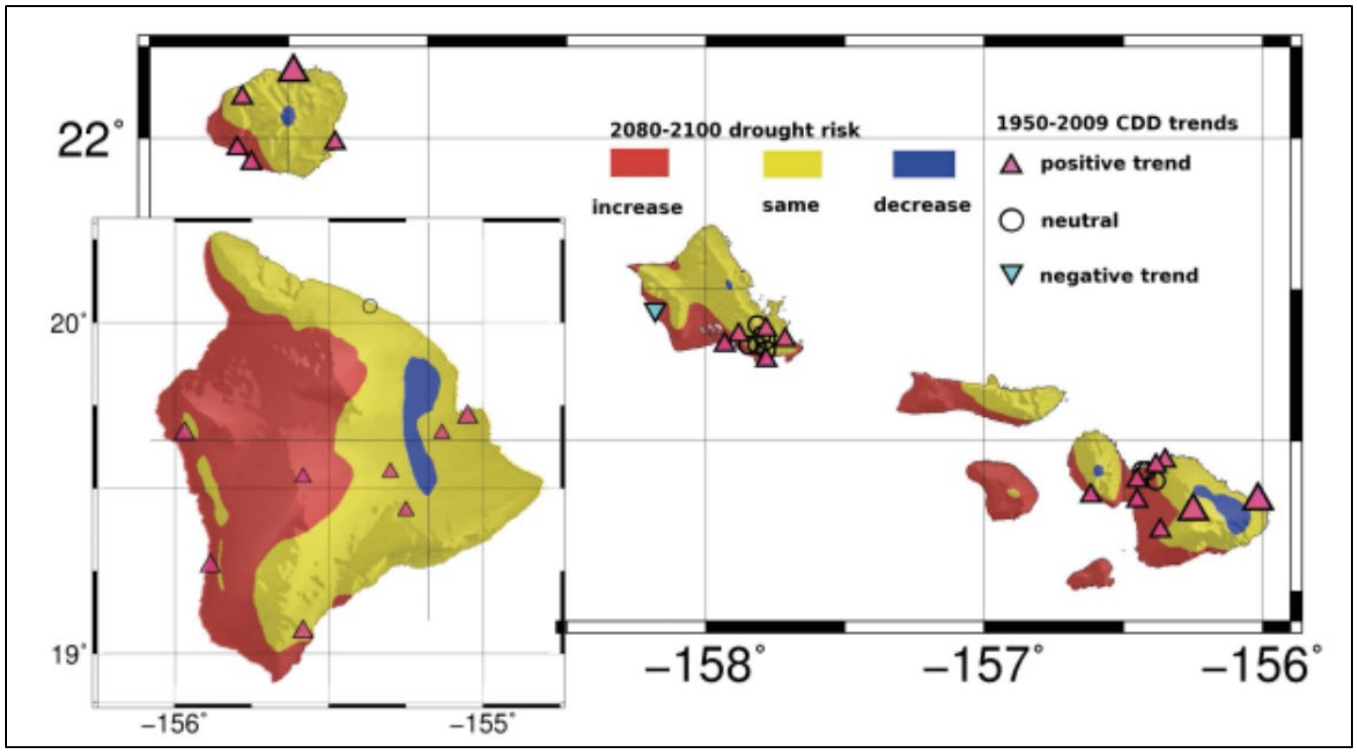
The effects of climate change on the drought hazard in the State of Hawai'i are described in detail in *Hawai'i Drought Plan 2017 Update* (DLNR Commission on Water Resource Management 2017). Climate change threatens the quality and quantity of fresh water available. Increasing temperatures, increased nutrient and sediment loads, and decreased dilution of pollutants during periods of drought threaten the availability of fresh water.

Over the past 100 years, the average annual rainfall has decreased, receiving almost one foot less rainfall today than a century ago. When trends are analyzed seasonally and spatially, much larger dry season declines are found, particularly on the leeward side of islands. Streamflow and base flow have also declined during this period of time, with impacts to groundwater storage, which supplies 99% of the state's domestic water use. In addition, the State of Hawai'i is at risk to sea level rise (see Section 4.2 – Climate Change and Sea Level Rise). Rising sea levels may contaminate fresh water with salt water (Frazier, et al. 2022).

Drought can also increase the likelihood of wildfire. An increase in wildfire events will destroy native plants and support the spread of fire-adapted (and often fire-promoting) invasive species (Hawai'i Wildfire Management Organization 2022, Wessendorf 2022).

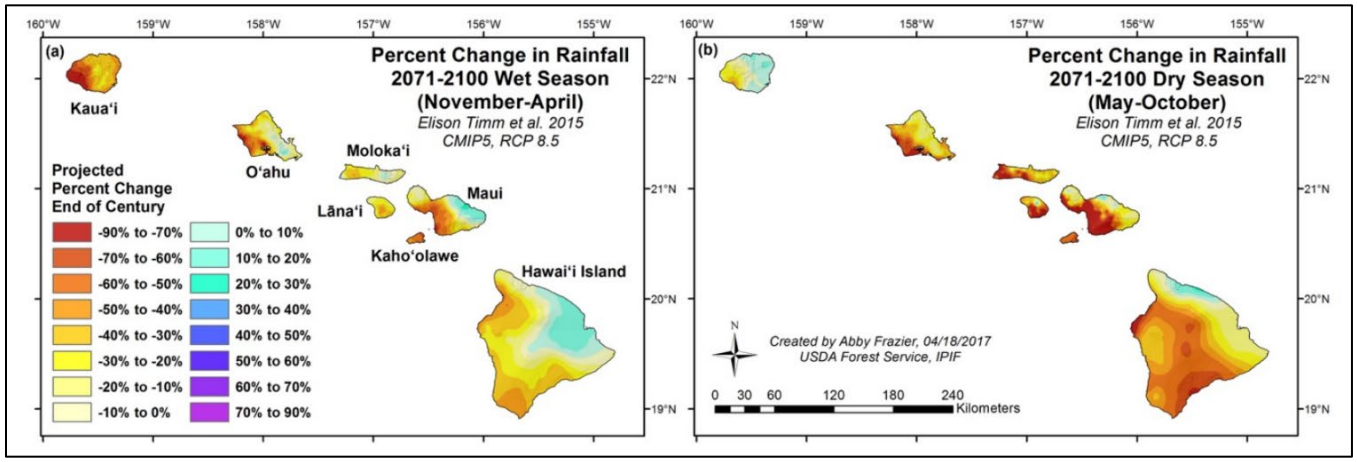
It is anticipated that climate change will increase the frequency of meteorological and agricultural droughts. This will increase the frequency of brief hydrological droughts, and the probability of a long hydrological drought. Figure 4.4-9 shows the potential for increased drought risk in the State of Hawai'i based on historical drought and future projections of climate change. Figure 4.4-10 shows precipitation projections for the 2071 to 2100 wet and dry seasons in Hawai'i based on statistical downscaling methods. There is inherent uncertainty in any global climate model that is downscaled to reflect the intricacies and microclimates of the Hawaiian Islands. These computer models continue to be refined, and research on future rainfall and water availability in Hawai'i is ongoing.

Figure 4.4-9. Future Projections of Drought Based on Historical Data and Future Climate Projections



Source: (DLNR Commission on Water Resource Management 2017)

Figure 4.4-10. Percent Change in Rainfall



Source: (DLNR Commission on Water Resource Management 2017)

4.4.2 VULNERABILITY ASSESSMENT

The Hawai'i Drought Plan 2017 Update lists the different impacts of drought in the state, including decimation of crops and livestock, the creating of dustbowls and erosion of landscapes, damage to terrestrial and aquatic wildlife

habitats, enhanced wildfires, and economic damage. In addition to these impacts, the State of Hawai'i has other issues such as growing conflicts between agricultural uses of surface water and instream uses, surface and groundwater interrelationships, and the effects of growing water demands on traditional and cultural uses of water. Droughts have always been and will continue to be prevalent in the state. Droughts will continue to adversely affect the environment, economy, and the citizens of Hawai'i (DLNR Commission on Water Resource Management 2017).

Assessment of State Vulnerability and Potential Losses

This section discusses statewide vulnerability of exposed state assets (state-owned or state-leased buildings), state roads, and critical facilities and community lifelines to droughts.

State Assets

As reported in the *Hawai'i Water Plan*, the state owns both potable, non-potable, and irrigation water systems that may be impacted by drought (Department of Land and Natural Resources 2020). Impacts to water systems may include loss or severe reduction of water supply, loss of water pressure, or poor water quality. Drought does not directly affect buildings, so no state buildings are considered vulnerable to drought. However, there are secondary impacts that state buildings would be vulnerable to as a result of drought: wildfires and expansive soil effects on concrete and structure foundations.

Drought conditions may make structures more vulnerable to wildfires, which are more likely during a prolonged drought. Risk to life and property is greatest in areas where forested areas adjoin urbanized areas known as the wildland urban interface (WUI). Therefore, all state buildings and critical facilities (discussed below) in and adjacent to the WUI zone and located in high wildfire risk areas are considered vulnerable to wildfire. Section 4.15 describes the state's vulnerability to the wildfire hazard.

State buildings could be affected by the shrink-swell cycle that occurs as soils swell during wet periods and shrink during drought periods can cause damages to concrete components and structure foundations. Bridges and roads are especially vulnerable to damages as a result of the shrink-swell cycle. The Hawai'i Department of Transportation (HDOT) monitors this type of damage and is responsible for the repairs of those roads and bridges that are state-owned/maintained.

Community Lifelines and Critical Facilities

As stated previously, drought does not directly impact structures. However, water-dependent community lifelines and critical facilities may be impacted. Under extreme drought conditions, where local water supplies are depleted and water utilities are unable to supply adequate water pressure, fire stations and healthcare facilities could be impacted. Healthcare facilities, including hospitals, clinics, and nursing homes, rely on water for heating, cooling, and ventilation systems as well as for equipment sterilization, sanitation, water-based patient treatments, fire suppression, and hazmat decontamination.

Community lifeline and critical facility elements such as landscaping may not be maintained due to limited resources, but the risk to the facilities inventory will be largely aesthetic. For example, when water conservation

measures are in place, landscaped areas will not be watered and may die. These aesthetic impacts are not considered significant.

Secondary impacts from drought include an increased risk of wildfires which could threaten community lifelines and critical facilities and the concrete components and structure foundations from the shrink-swell cycle of expansive soils, as discussed above. Tertiary impacts include sediment runoff during severe rainfall events in areas where the vegetation and ground cover have been burned by wildfire. Sediments can damage and kill Hawaii's fragile coral reef systems. Uninhibited runoff could reduce recharge of the underlying aquifers.

Assessment of Local Vulnerability and Potential Losses

Drought impacts cross jurisdictional boundaries and primarily impact the population's water supply and the agricultural/aquacultural industry. The state is vulnerable to drought, both statewide and county-specific, because it has limited groundwater resources and is isolated. Buildings are not anticipated to be directly affected by a drought, and all are expected to be operational during a drought event. As discussed above, droughts can create conditions conducive to wildfires, and therefore local populations and buildings in and adjacent to the wildfire hazard areas are considered vulnerable to wildfire.

The unique terrain and orography of the Hawaiian Islands produce extremely variable microclimates and drought may impact limited geographical areas or affect large portions of an island. Where some areas on an island may be experiencing drought, other areas may be free of drought conditions. Drought conditions and impacts in Hawai'i may vary greatly both temporally and spatially, and this is an important factor to consider when planning for drought mitigation and preparedness.

Drought events impact the economy, including loss of business function and damage and loss of inventory. Industries that rely on water for business may be impacted the hardest (e.g., agriculture/aquaculture). Even though a majority of businesses will still be operational, they may be impacted aesthetically. These aesthetic impacts are most significant to the recreation and tourism industry which is an important part of each county's economy.

Economic impacts may include:

- Losses from crop, livestock, timber, and aquaculture production and associated businesses
- Losses from tourism industry, recreation providers and associated businesses
- Losses related to the increased costs resulting from increased energy demand and from shortages caused by reduced hydroelectric generation capacity
- Revenue losses for federal, state, and local governments from a reduced tax base and for financial institutions from defaults and postponed payments
- Long-term loss of economic growth and development

The size of the agriculture industry varies from county to county. A prolonged drought event could have significant impacts to the state's economy, particularly in counties that have large amounts of agricultural lands. Additionally, damaged and dead crops are also vulnerable to wildfires which can spread easily during periods of drought. Additional information about the potential exposure areas to drought in each county are discussed further below.

Based on past information, during a long-term drought (several months to years) drought first affects unirrigated agriculture and pasture operations. As the drought continues, surface water-supplied water systems are impacted due to lowered stream flows, there is an increase in wildland fire occurrence, and residences that rely on rainwater catchment may need to purchase drinking water from water delivery companies (water haulers). If the drought continues, ground water supplies and drinking water utilities may be affected due to decreases in aquifer recharge, which is replenished by rainfall during normal conditions.

The local HMPs were reviewed to integrate risk assessment results into the 2023 SHMP Update; a summary of information available is below.

- County of Kaua'i – The County of Kaua'i HMP included Drought and Extreme Heat as one hazard. The County utilized the U.S. Drought Monitor to identify past drought events and the geographic areas most impacted by drought. The County also identified planning issues around drought, including a lack of drought-tolerant landscape designs; a failure to utilize groundwater recharge techniques; a lack of active water conservation; and a need for cooling centers(County of Kaua'i 2020).
- City and County of Honolulu – The City and County of Honolulu studied the impact of drought on three different sectors: the water supply sector, the agricultural and commerce sector, and the environment, public health and safety sector. The City and County used the 2017 Hawai'i Drought Plan to identify risk to these sectors. There is little risk to the City and County's water supply; moderate risk to the agricultural enterprises in the central area of the island; and drought risk in the wildland urban interface near the Mililani/Waipio region (City and County of Honolulu 2020).
- County of Maui – The Maui County HMP includes a risk assessment of both drought and extreme heat. The county utilized rainfall records to identify areas prone to drought, finding that leeward-facing areas such as Maui's Upcountry are particularly vulnerable to drought. The County HMP included a discussion of how drought would impact Maui's socially vulnerable residents, identifying communities that would be especially at risk from drought impacts, including single-parent households, households including dependent individuals, low-income households, households living in properties built prior to 1950, and households with mobility and transportation constraints (County of Maui 2020).
- County of Hawai'i – The County of Hawai'i used the Standardized Precipitation Index (SPI) and the U.S. Drought Monitor to identify areas of drought risk within the county. The county also integrated Hawai'i's Drought Risk and Vulnerability Assessment and GIS Mapping Project into the risk assessment; the Assessment found areas of concern for drought in Hawai'i County are located on the western side of the island, coinciding with low rainfall zones (County of Hawai'i 2020).

Socially Vulnerable and Total Populations

Directly or indirectly, the entire population of the State of Hawai'i is vulnerable to drought events. Drought can affect people's health and safety as well as other impacts. Health problems related to low water flows, poor water quality, or dust could arise. Additional possible impacts include recreational risks; air quality reduction; diminished living conditions related to compromised, local hydroelectric power sources; compromised food and nutrition; and increased incidence of illness and disease. Vulnerable populations who rely on rainfall catchment for residential water supply may be especially impacted if they do not have the physical or financial ability to obtain

imported water to refill dry catchment tanks. How and to what degree drought affects the state's population does vary.

Overall, there are primarily three drought impact sectors that are critical to the health and welfare of the state's population in terms of social, economic, and environmental aspects. These impacts include: the Water Supply Sector; the Agriculture and Commerce Sector; and the Environment, Public Health, and Safety Sector. These sectors are not mutually exclusive, and as such, impacts in one sector may result in secondary or cumulative impacts in other sectors. The following describes these sectors:

Water Supply Sector

The water supply sector includes public and private urban and rural drinking water systems, agriculture water systems, and rainwater catchment systems. Since the availability of freshwater is crucial to human survival in both direct and indirect ways, minimizing the impact of drought to the state's freshwater is a significant priority. In the State of Hawai'i, most public water systems (PWS) are supplied by groundwater sources, but there are seven surface water supplied systems and four rainfall catchment water systems that are considered PWS by the Department of Health (DLNR Commission on Water Resource Management 2017).

Agricultural and Commerce Sector

The Agriculture and Commerce Sector experiences severe negative drought impacts due to dependence upon both surface water and rainfall. Rainfall shortage-induced impacts are often exacerbated by the limits placed on ground water pumping during drought periods. A persistent shortage of rainfall and the resultant lack of soil moisture can result in reduced ground cover and lower agricultural yields. Reduced ground cover and pasture can result in the reduction of livestock herd sizes and is also associated with an increased rate of erosion. Drought impacts to the agriculture sector are highly dependent on whether or not the crops are irrigated since unirrigated pasture, orchards, or other fields are most vulnerable to droughts. Irrigated agricultural areas become more vulnerable when water supplies become more threatened. Commerce sectors such as tourism will also experience negative drought impacts since tourism directly depends on healthy, thriving Hawaiian ecosystems (DLNR Commission on Water Resource Management 2017).

Environment, Public Health, and Safety Sector

The Environment, Public Health, and Safety Sector mainly focuses on the increased incidence of wildfires due to drought conditions. Wildfires are described in Section 4.15 (Wildfire). However, there are environmental impacts of drought conditions that are also an important component of this sector. Stressed water supplies exacerbate already vulnerable island ecosystems and can result in impacts to wildlife habitats, water quality, land quality, and biodiversity and can contribute to erosion (DLNR Commission on Water Resource Management 2017).

General Building Stock and Economy

As stated previously, drought does not directly impact structures, including the general building stock. The general building stock, as defined for this plan, would continue to be functional during a drought. The only secondary impacts from drought would be an increased risk of wildfires which could threaten buildings located close to WUI areas, and to the concrete components and structure foundations from the shrink-swell cycle of expansive soils, as discussed previously.

Drought causes the most significant economic impacts on industries that use water or depend on water for their business, most notably in the State of Hawai'i, agriculture and aquaculture as well as landscaping businesses. In addition to losses in yields in crop and livestock production, drought is associated with increased insect infestations, plant diseases, and wind erosion. Drought can lead to other losses, including reduced income for farmers and reduced business for retailers and others who provide goods and services to farmers.

According to the 2021 USDA Agriculture Overview for the State of Hawai'i, statewide there are 1,100,000 acres in agricultural use (U.S. Department of Agriculture 2023). Each county varies in the acreage of agricultural land and the overlapping risk from drought. Table 4.4-6 shows the most recent compiled USDA Census of the State of Hawai'i and the total value of agricultural products sold totaled nearly $564 million that are exposed to drought conditions.

Table 4.4-6. State of Hawai'i Agriculture Market Value

Agricultural Products Sold	Market Value
Value of crops, including nursery and greenhouse	$417,069,000
Value of livestock, poultry, and their products	$146,733,000
Total value of agricultural products sold	**$563,803,000**

Source: (U.S. Department of Agriculture 2017)

During drought, ranchers lose pasture and forage resources. Ranchers may have to purchase expensive supplemental feed and reduce herd size. This can lead to large revenue losses with impacts to livelihoods and industry sustainability. After a severe multi-year drought, it may take a decade or more of normal rainfall conditions to financially recover to pre-drought ranching revenue levels (Frazier, et al. 2022).

Environmental Resources and Cultural Assets

Environmental losses from drought are associated with damage to plants, animals, wildlife habitat, and air and water quality; forest and range fires; degradation of landscape quality; loss of biodiversity; and soil erosion. Some of the effects are short-term and conditions quickly return to normal following the end of the drought. Other environmental effects linger for some time or may even become permanent.

Watersheds are critical to replenishing Hawaii's groundwater aquifers, which supply most of the state's drinking water. Healthy watersheds also reduce polluted runoff into our nearshore waters and support healthy stream ecosystems. Watersheds impacted by drought-induced ecosystem damage or wildfires result in decreased ground and surface water supplies and damage to nearshore waters and reef ecosystems.

Wildlife habitat, for example, may be degraded through the loss of wetlands, lakes, and vegetation. However, many species will eventually recover from this temporary condition. The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological productivity. The impacts to vegetation and wildlife can include death from dehydration and the spread of invasive species or disease because of stressed conditions. Invasive species pose problems for the ecosystems in which they are introduced. Like many hazards that affect the State of Hawaii's environment, invasive species have both direct and indirect impacts.

One fairly recent but pervasive consequence of drought is the impact to the wild axis deer population in the County of Maui. Axis deer are considered an invasive species in Hawai'i, and one estimate places the population in Maui County at 60,000 animals (Maui Now 2022). During drought, the natural food and water sources of axis deer in

forested and upland areas are severely reduced, which causes the animals to move into agricultural and urban areas. Seeking food and water, the deer decimate agricultural crops, residential vegetable gardens, and irrigation systems in areas where deer normally do not inhabit. Deer have also been involved in automobile collisions on highways and roads, causing a dangerous traffic hazard. Severe drought is also associated with game mammal die-offs on Molokaʻi and Lānaʻi Islands.

When groundwater is not replenished over a period of time, aquifer and well water levels diminish, making irrigation and drinking water difficult to obtain. In addition, contamination of surface water sources can occur during drought conditions. Surface water reservoirs (although there are few in Hawaiʻi) may experience increased pollutant levels and lower levels of oxygen, contributing to higher concentrations of illness-causing bacteria and protozoa as well as toxic blue-green algae blooms. Further, reduced aquifer recharge and depletion of aquifer storage may affect the discharge of groundwater to the coastal nearshore waters. This may negatively impact the groundwater dependent ecosystems, which rely on coastal discharge of groundwater to flourish.

Growing public awareness and concern for environmental quality has required that public officials focus greater attention and resources on these effects. Since the tourism industry accounts for a significant portion of the state's economy, adverse effects on the natural environment could have serious effects on this important sector (DLNR Commission on Water Resource Management 2017).

The primary impacts on cultural assets from drought would be an increased risk of wildfires which could threaten these assets, and to structure foundations from the shrink-swell cycle of expansive soils.

Droughts may impact Native Hawaiian traditional and customary practices, which rely on healthy terrestrial, marine, and groundwater dependent ecosystems. These practices may include the collection of plants, animals, and minerals and other practices. As discussed above, drought and its secondary impacts can damage watersheds and nearshore waters may impair, diminish, or impede the exercise of traditional and customary practices.

Future Changes that May Impact State Vulnerability

Understanding future changes that impact vulnerability in the state can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. The state considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in population
- Availability and vulnerability of water supplies
- Other identified conditions as relevant and appropriate, including the impacts of climate change

As the resident and visitor populations in the State of Hawaiʻi continue to increase, the stresses on the state's water sources will increase as more resources will be needed for human use and consumption and these resources are further taxed by changing climate conditions. Drought conditions and development are interrelated – as water is drawn down from increased rates of use, drought can occur more readily than from lack of precipitation alone. In addition, newly developed land or expansion into upland forested areas may reduce groundwater recharge as more land in the state becomes impermeable.

Native Hawaiian cultural practices are closely tied to the natural environment. Together, drought, wildfire, and invasive species threaten many of Hawaii's iconic plants and animals. When coupled with land use change and the spread of diseases facilitated by warming temperatures, impacts to native species and their habitat may incur (McGinn 2022)

Drought Hazard Mitigation Success Story

Credit: Hawai'i Climate Data Portal

The 2018 SHMP included an action to enhance the Hawai'i State Rain Gauge Network. In late 2021, the project was funded by the National Science Foundation to deploy 84 new Mesonet meteorological stations across the State. These Mesonet stations collect and produce real time weather data. Measurements include rainfall, air temperature, relative humidity, wind speed and direction, air pressure, solar radiation, reflected solar radiation, incoming and outgoing longwave radiation, net radiation, soil heat conduction, soil temperature at three depths, and soil moisture at three depths.

In addition to increasing understanding of drought conditions across the state, data from the Hawai'i Mesonet increases the State's capacity to forecast the weather, issue flood and wildfire warnings, and provides resources for emergency management, water resource management, agriculture and ranching.

University of Hawai'i students help install, calibrate and maintain the weather data.

For more details on the Mesonet project, please see Hawai'i Mesonet – Hawai'i Climate Data Portal (hawaii.edu)