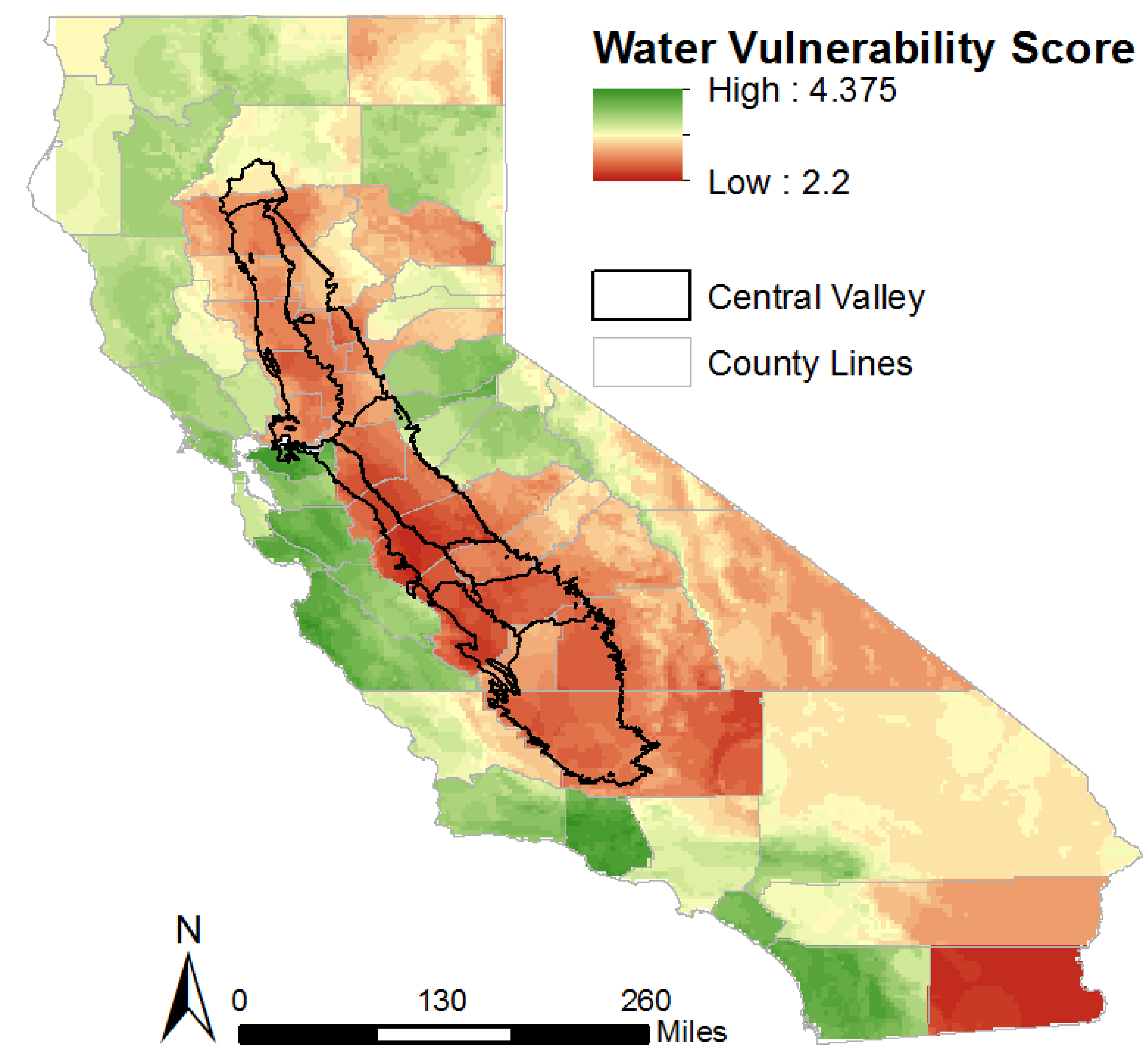
All Dried Up — A Vulnerability Analysis of California's Water

Water Vulnerability in California

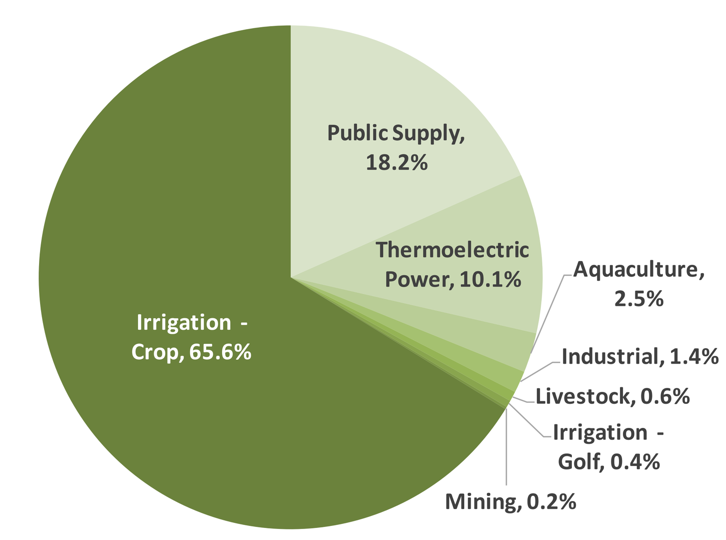


Introduction

With climate change widely accepted as one of the most pressing issues of our time, exhaustive scientific research has shown that it is most likely the result of human interventions such as land use change and industrialization. In particular, water scarcity is expected to grow as climate change increases the prevalence of droughts and extreme weather events. In California, a severe drought from 2012 to 2016 highlighted the precariousness of its water supply. California's largest water consumer, the agricultural sector, stands to be heavily impacted by water scarcity. Although only 5% of the land is used for agriculture, it accounts for roughly 65% of the California's total water use (USGS, 2015).

Agriculture primarily occurs in the Central Valley, one of the most productive agricultural regions in the world that produces one third to one half of all fruit, nuts and vegetables grown in the United States (Bittman, 2012). The Central Valley is extensively irrigated with man-made canals and reservoirs to divert snow-fed rivers to farmland. The water is allocated based on arcane laws that give senior water rights to the first users and, in many cases, has resulted in extreme overallocation of most of the rivers. Groundwater extractions from private wells has also come under recent regulation to replenish depleted aquifers, limiting the potential water supply available to farmers (PPIC, 2017).

Water Use by Sector



Population growth, expanded irrigation and a shift in crop production to perennial crops has added to the water stress of agricultural sector. In order to address the impending water crisis, sustainable water management practices such as low-flow irrigation and conservation practices will help alleviate water stress during times of uncertainty.

The project aims to graphically illustrate water scarcity through the application of a water vulnerability index made up of ten indicators. This allows for the identification of Californian communities most at-risk and can give insight into the contributing factors like climate, agriculture and population growth.

Methods

After identifying the spatial question, a list of potential indicators were selected and data collection began. Once ten variables were identified, they were uploaded and projected into a common coordinate system. Precipitation and Evaporation were already rasters and only needed to be clipped before reclassifying. The dam location and almond acreage data were geocoded and attached to the county boundaries using spatial join. Point density was then used to derive a density map of the dam locations. Almond acreage was summed by county to create a choropleth map. The data from USGS was tabulated and calculations were made to determine changes between 2000-2015 as indicated. Following data scrubbing, the excel was joined to the county shapefile and it was exported and saved to make a new chart for each indicator.

Indicator	Inclusion Reasoning	Weighting	Data Year	Source
Almond Acreage	Water Use - Irrigation	20.0%	2019	Esri
Change in Ground Water Use	Water Consumption	10.0%	2000-2015	USGS
Change in Surface Water Use	Water Consumption	10.0%	2000-2015	USGS
Dam Density	Storage Capacity	7.5%	2019	NID
Irrigation/ Total Withdrawal	Water Use - Irrigation	7.5%	2015	USGS
Population Change	Domestic demand	5.0%	2000-2015	USGS
Potential Evapotranspiration	Environmental	7.5%	2019	CGIAR
Precipitation	Environmental	10.0%	2019	PRISM
Sustainable Irrigation	Water savings	15.0%	2015	USGS
Total Withdrawals/Population	Water Consumption	7.5%	2015	USGS

The vector maps were then converted to rasters using the feature to raster conversion tool. Once all ten variables were converted to rasters, each one was reclassified using quantile categorization and 1-5 rankings. "1" was associated with highest water vulnerability, whereas, "5" meant low water vulnerability. Precipitation, Dam Density and Sustainable Irrigation were ranked in reverse as they decrease water vulnerability. The idea is that more precipitation and more dams would mean there was wider availability of water and, thus, less risk. Sustainable Irrigation was included because it meant that conservation practices were already in place to manage for water stressed years. After all maps were reclassified, the layers were overlaid using raster calculator and the weights in the chart above. The resulting water vulnerability map is shown in the top right-hand corner.

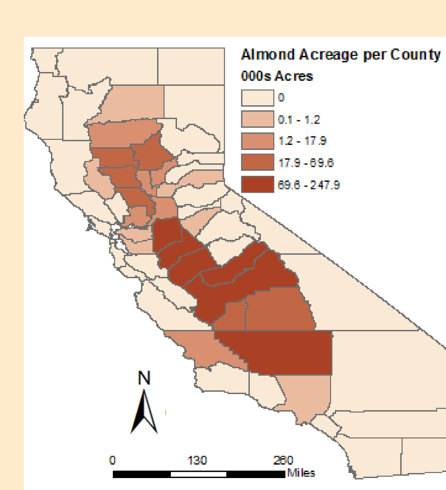
Analysis & Conclusion

The resulting map from the weighted raster analysis demonstrates a spatial trend that agriculturally focused regions of California are most susceptible to water vulnerability. Over the past twenty years, irrigation as a percentage of overall agriculture has greatly increased and the shift towards perennial crops has sharply raised water consumption. Should these current trends continue, the agricultural areas face worsening prospects in terms of a water shortage, ultimately creating massive economic ramifications at both the individual and state level.

California's Central Valley is particularly at risk due to a combination of climatic, demographic and economic related factors. At the southern border of California, the Imperial Valley, perhaps faces an even greater water shortage as it relies on water from the Colorado River instead of runoff from the Sierra Nevada Mountains. Outside of the State's agricultural areas, the north has less water vulnerability than the south, likely a result of less population and more precipitation. Meanwhile, the coasts to the west and mountains to the east of the valley experience much less risk than the valley.

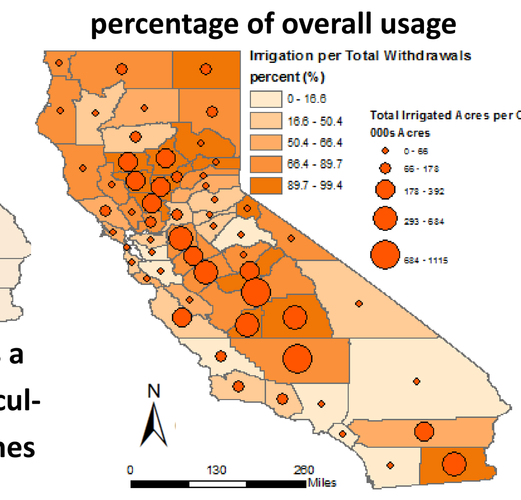
Water vulnerability in California is a pressing and urgent concern for many. Using spatial analysis, policymakers can determine where the highest risk lies and respond in a methodical and targeted way. In this case, there is evidence that that the irrigation and population growth increases susceptibility. As such, ongoing management of California's water resources should prioritize sustainable water use within agricultural communities. Solutions to promote water conservation and reduce the impact of future droughts include regulation of water diversions and extractions, infrastructure development of water re-use treatment and new technologies such as micro irrigation or bio-char for soil moisture improvements.

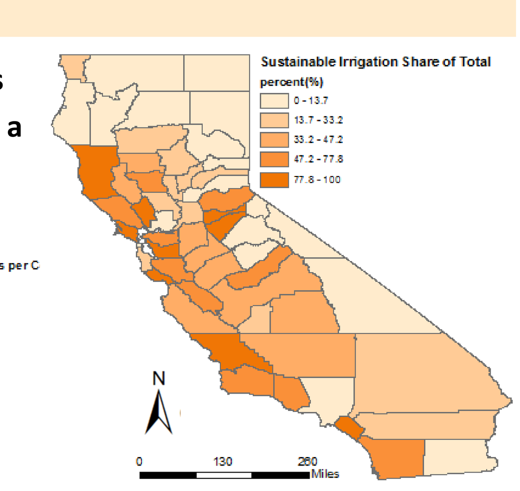
Water Use—Irrigation



Using total almond acreage as a proxy to determine within agricultural regions where high volumes of water use

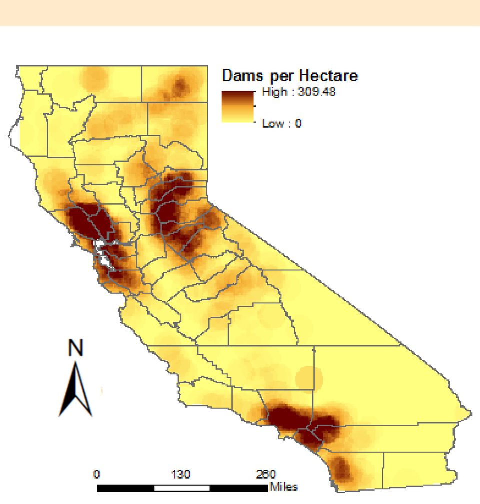
Using irrigation to identify areas with large water consumption as a percentage of overall usage





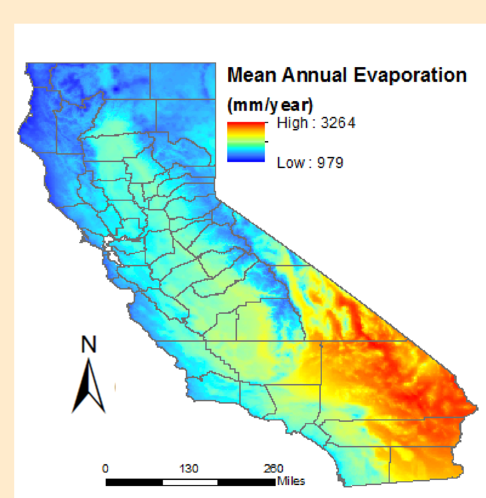
Adoption of low-flow irrigation indicates location of current water conservation practices

Storage Capacity



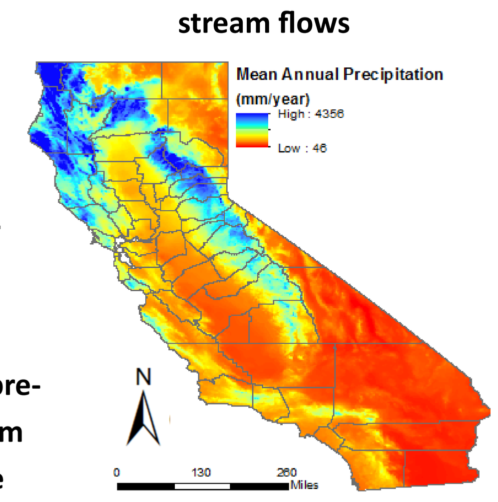
Higher volumes of storage capacity within reservoirs allow for flexibility of water supply as water be drawn down as needed

Environmental Factors

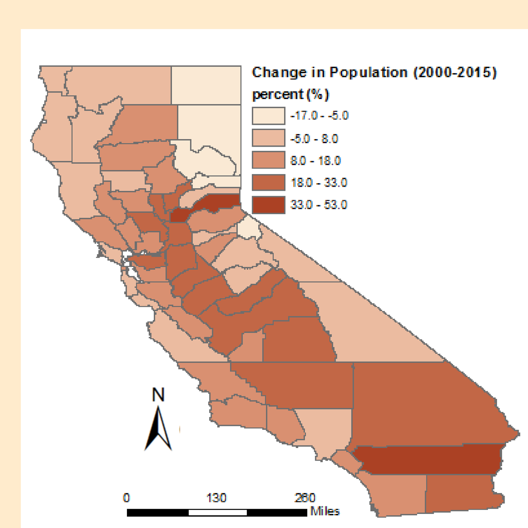


The Mean Annual Evaporation represents the potential water loss from surface water and soil moisture

Precipitation is essential for the water balance as it contributes to groundwater recharge and instream flows

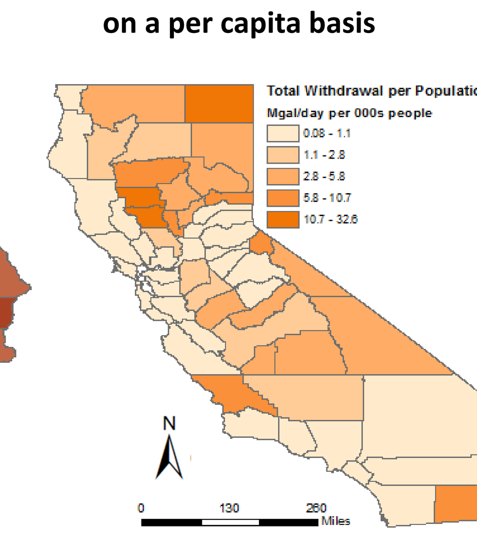


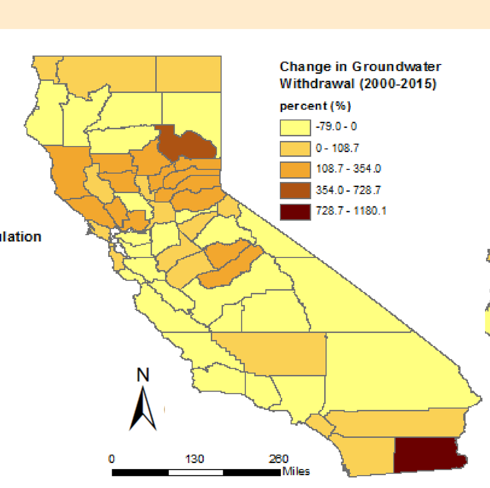
Water Consumption & Population



Higher population growth will increase water stress in an area

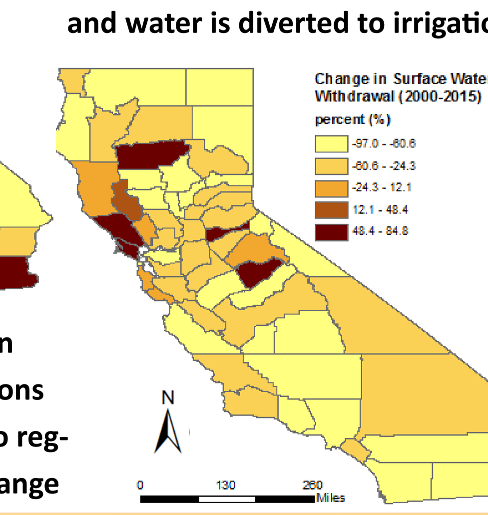
Can we used as a proxy to estimate water consumption on a per capita basis





Determine trends in groundwater extractions overtime in response to regulation and climate change

Determine trends in surface water usage as instream flow levels fluctuate with climate change and water is diverted to irrigation



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Sources: USGS, PRISM, CGIAR, ESRI & NID
Projection: NAD 1983 California (meters)
Coordinate System: GCS North American 1983