Western Drought Conditions Overview and Adaptation Strategies

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Climate Change (MPDM 730)

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The climate of Earth is changed. The civilizations of the world are scrambling to adapt. While the earth is 71 percent water, 96.5 percent of that water is in the salty oceans, seas, and bays, not directly usable for support of human life. (USGS, 2021). How must humans adapt to overcome this problem of shifting freshwater availability? How much will it cost, and who stands to win or lose? These are among the key questions of our generation, and in some parts of the western United States, the answers are being shown to us in real time. In this paper, I will examine the status of climate change affected areas of the United States, with a focus on the western states and California. I will address several questions- what policies were in place historically? How have they affected the current situation? What more can be done? In this space, I will focus on what technologies and practices have proven effective or ineffective locally and around the world and discuss why these practical and technological changes must be employed immediately.

The western United States have a history of dryness. The data shows that moderate drought is prevalent throughout historical record, severe to extreme drought periods have been increasing in the last 50 years, water usage continues to increase in certain areas despite limited supply, and water management is heavily influenced by political and corporate interests. Figure (1) below shows the historical record of rainfall in the State of California from 1895 to present.

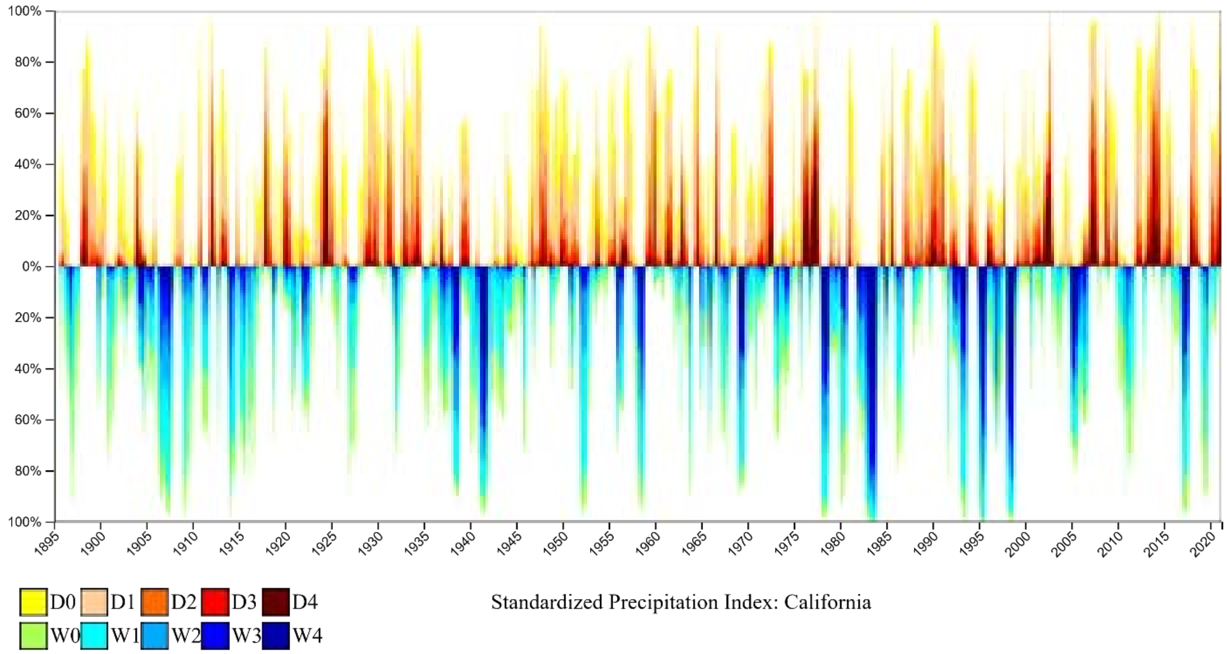

Fig. (1) Drought.gov, 2021.

While this graphic does show a pattern of both drought and floods, the more recent years have seen an increased prevalence of more extreme drought conditions, as shown below in Figure (2).

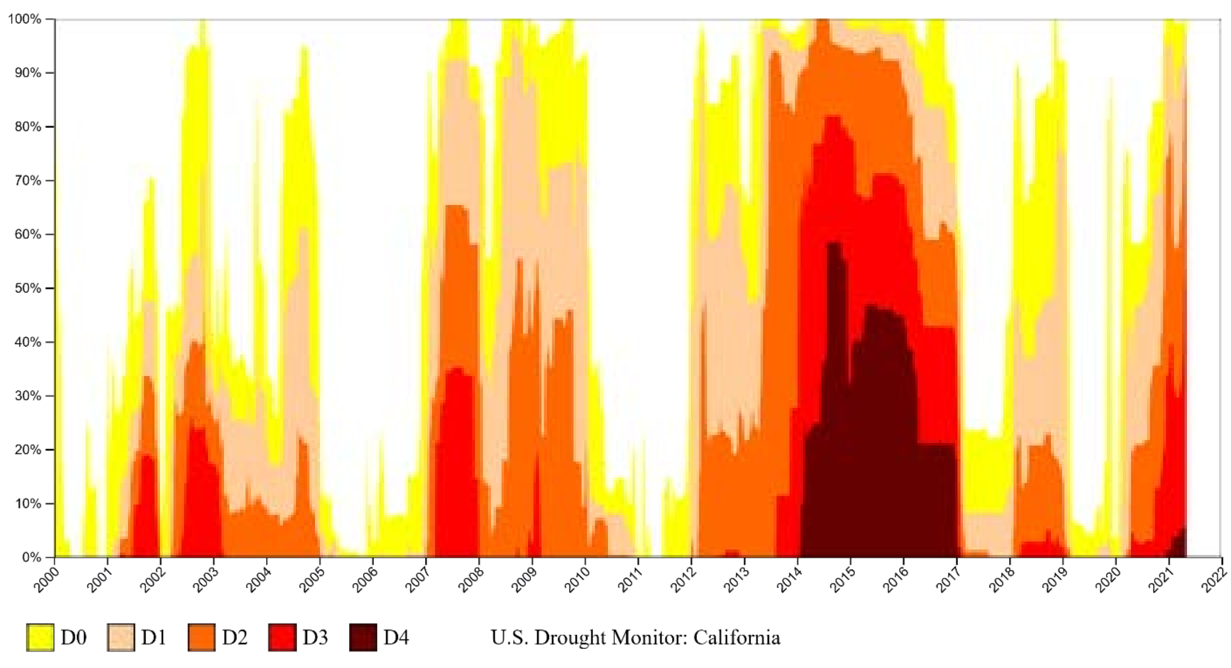

Fig. (2) Drought.gov, 2021.

Notably, from 2014-2017, California experienced the most extreme drought conditions across approximately 50% of the state, with only a few years of recovery between that point and now. During those few years, wildfires and ecological catastrophes have exponentially increased.

> *"Sparked by lightning strikes, extreme wildfire conditions and an unrelenting heatwave, California's unprecedented 2020 fire season set a new state record with more than 2.5-million acres burned, doing so by early September, and also accounted for three of the state's top four largest wildfires ever."* (CALOES, 2021).

This has left the State of California with fuel loading in the forests that is unlike any conditions we have seen since the 1895 data collection began. The brief 2–3-year respites between extreme drought conditions have not been enough to restore forests and wildlands to a better state of natural resiliency, resulting in a "stacking" of bad fire conditions over time. Bark beetle proliferation continues, killing entire swaths of trees and adding dry fuel to an already dry forest. This fire condition stacking and ecological damage is not explainable by natural cycles shown in the past. (Drought.gov, 2021). Unfortunately, each fire season that turns out to be bad, releasing thousands of tons of carbon into the atmosphere, exacerbates the problems of climate change and global warming. Another aspect of climate change and fires is the lengthening of the "season" as patterns of rainfall frequency and location shift. Fire season in California is already underway in mid-May and is expected to last until early November, a shift from the July through September seasons of the past. The California Office of Emergency Services (CALOES) has been forced to create new budgets, structures, and policies to incorporate operating an incident within an incident within an incident, and so on, due to the ongoing COVID-19 pandemic, lengthened fire season, and the "normal" emergency response posture. (CALOES, 2021). Although fires are extremely destructive and costly, it would seem that there is little that can be done on such a vast scale to prevent wildland fires from spreading in the face of the climate today. California and much of the west is being forced to pivot from traditional techniques of forest management and urban to rural interface safety to a more adaptable and nimble set of principles from which to operate. Examples include identifying urban to rural interfaces and creating large fire breaks ahead of time to slow or prevent wildfires from rushing into urban or suburban areas and completely destroying whole neighborhoods and towns, such as in the 2018 Camp Fire or the 2017 Tubbs Fire. Identification of areas for adaptability projects like brush reduction and shifting of zoning approvals at these interface areas also help make communities more resilient. Finally, management of water in rivers, watersheds, lakes, and reservoirs helps to allow for irrigation in communities and areas downstream where it can do the most good and keeps valuable resources from being squandered watering areas that should be better left alone. Fires will continue to be one of the most devastating effects of climate change in the west for decades to come. It will require governmental and community adaptation to put into place the policies necessary to become resilient enough to thrive in these new conditions.

Water usage in the western states varies by location, and by season. The wet “el nino” and dry “la nina” weather patterns, are collectively known as the El Nino-Southern Oscillation (ENSO) cycle. (NOAA, 2021). These patterns are irregular but are constantly affecting the Jetstream and thus the weather we experience in the western United States. Figure (3) shows what a la nina year can do to the atmospheric conditions, shifting the Jetstream north and causing southern states to experience drought conditions. These la nina cycles may last two to seven years (NOAA, 2021) and have been wreaking havoc on western states in the last ten years.

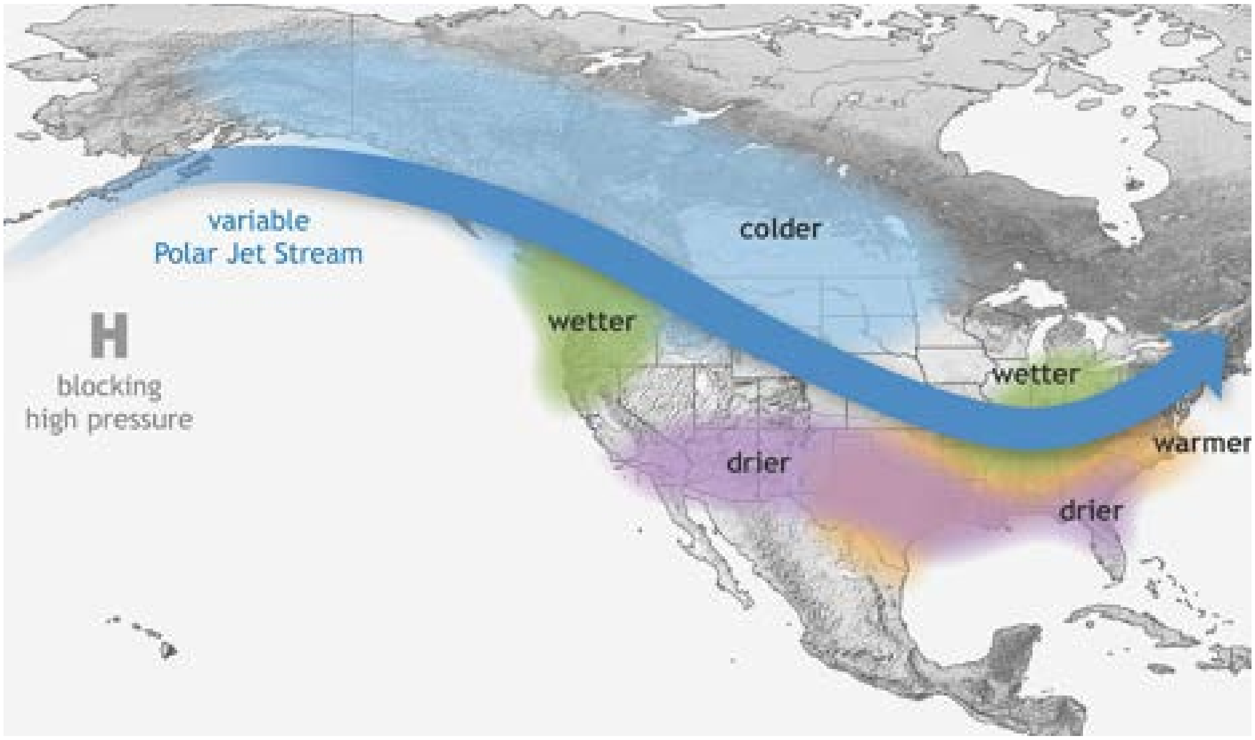

Fig (3) (NOAA, 2021)

Unfortunately, in terms of water management, this natural phenomenon complicates the desired practice of putting a system in place that a government can "set and forget." There are three main areas in which water is used: environmental, agricultural, and urban. Figure (4) shows how the effects of variability and location may affect how water can be effectively allocated over time. In more wet years, it is preferable to retain water in the environmental sector, allowing rivers, lakes, and streams to replenish their vitality and ecological abundance. In drier years, water must be shifted towards agriculture, to support diminished water tables from being over pumped while allowing for continued output of needed crops.

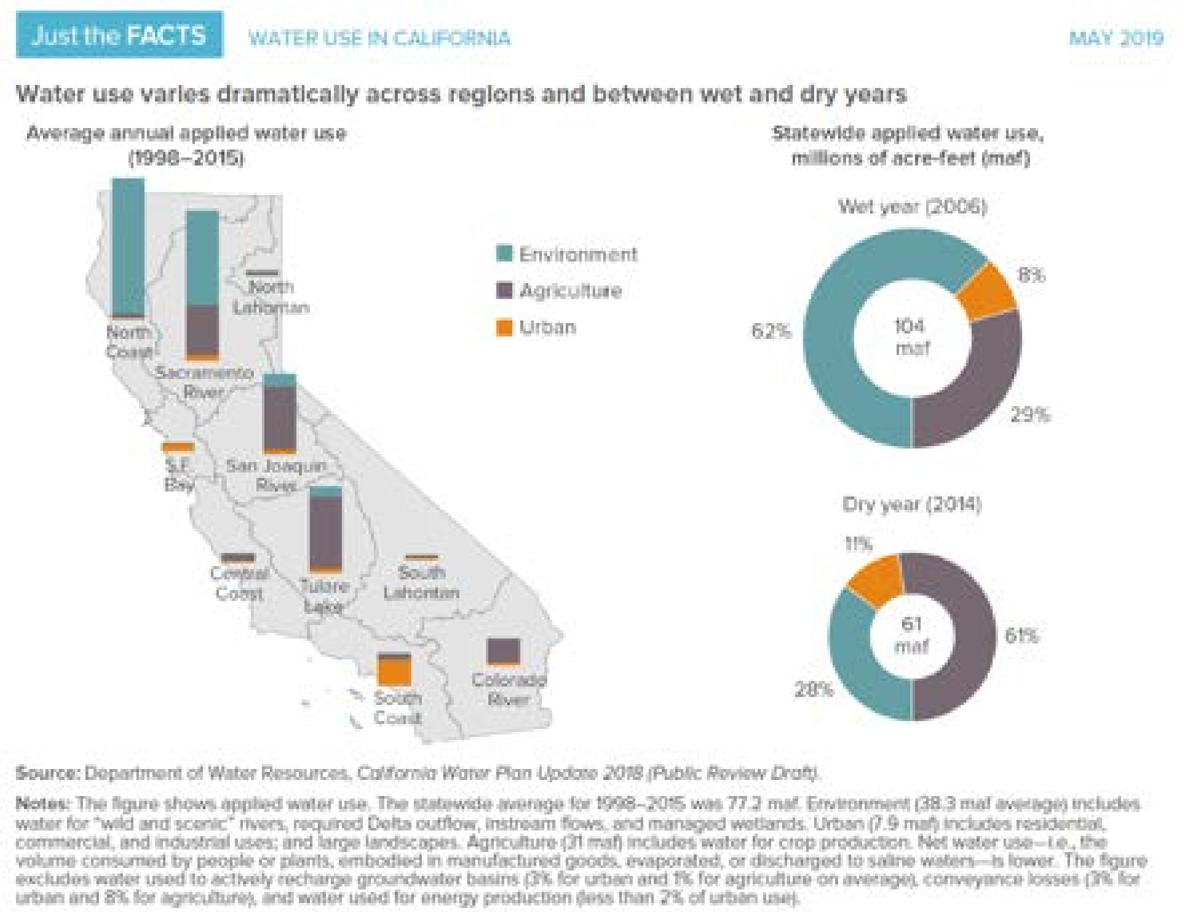

Fig (4) (Drought.gov, 2019)

Despite knowing the dynamics necessary to manage the water inventories effectively, changes in climactic weather patterns have varied inputs to the equation drastically, making management near impossible without a change in priorities and use of new technology. Manmade reservoirs are currently at or near historic lows due to low inflows from rivers and streams. Control of outflows is necessary for downstream users and wildlife habitat; maintaining minimum flowrates is necessary but, in many cases, now not achievable. With reduced capacities for storage or needed reductions to downstream flowrates, electrical power from hydroelectric generation will be reduced, causing more reliance on nuclear and fossil fuels and additional carbon input to the atmosphere.

There are some glimmers of hope floating on the sea of bad news. Population increases annually in the west, and one would expect water usage to increase proportionally. In fact, after peaking in 1995, due mostly to infrastructure improvements and building code updates, water usage has declined annually in California from 41 to 37 million acre-feet while population increased from 31 to 39 million people, as shown in figure (5) below.

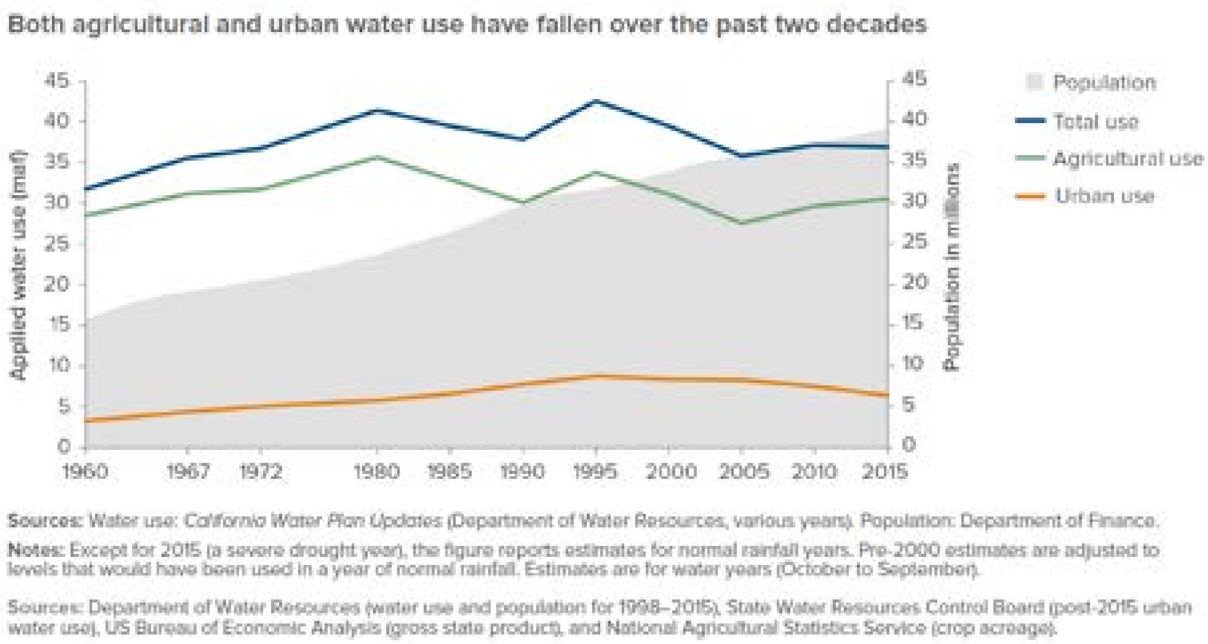

Fig (5) (Drought.gov, 2019)

California Governor Gavin Newsom recognizes the severity of the water problem and has requested $5 billion for state spending on water and water related expenses. Specifically, $1.3 billion for drinking water and wastewater systems, prioritizing smaller and poorer communities. $2 billion to help pandemic affected families pay their water bills. $200 million would go to repair canals damaged when the ground beneath them sank as more groundwater was pulled from wells. Other projects would address groundwater cleanup, water recycling, fish and wildlife habitat, flood preparedness, weather forecasting, and agricultural water use. Unfortunately, there is extraordinarily little money allocated or identified that will go towards improvement of existing practices and technologies. This approach will address current conditions and treat their symptoms, but the underlying health of the system must be addressed.

There are several technologies available that can be put in play in the west to improve resilience, by increasing inventories of potable water for human consumption and by increasing inventories of water available for general use wherever needed. These technologies are used around the world today, they are not experimental or fringe theories. However, many are costly in dollars or in ecological impact without implementing new controls, new laws, or extraordinarily complex strategies. Available technologies include dams and reservoirs, open or closed top canals, pumping stations, improved flow monitoring device feedback systems, desalinization plants, water recycling and reuse programs, reduction of corporate and business-related use through monitoring and limitations or taxation, and reduction of agricultural use and proper management of agricultural pumping and water tables. All of these are areas to be examined for current best practices and lessons learned to broaden application of technological improvements where needed.

The water allocated for environmental use is the first inventory raided to go towards agricultural use in a dry year. We have seen the devastating effects this can have on our forests and watersheds, with fires and water shortages in reservoirs downstream. Most fresh water is used in the agricultural areas, so these areas should be prioritized for improvements above all others. Marginal gains should also be tactically planned for in local municipalities, through building code improvements, zoning ordinances, and infrastructure upgrades. Examining the best areas to implement these changes shows the following candidates.

The first such technology is use of desalinization plants. There are many positives and negatives associated with these plants, however, they can be exceptionally useful in reducing overall loading of a reservoir system for an urban area and can act as a dampener when the system is stressed by drought. Some positive aspects include: local municipalities have greater ability to control supplies and set costs for end users, they solve problem of water loss during transport in open canals by moving operations to local area, and they are proven to work well in many countries, with the largest concentration in the Middle East. Some are capable of over 1 million cubic meters per day. (AquaTech, 2021). They can be used in conjunction with power plants or solar. One negative aspect of desalinization plants is that the salty brine byproduct must be pumped back out to sea, causing environmental impact through increased local salinity. A recent Massachusetts Institute of Technology study shows brine can be used to make needed chemicals on site, reducing amount of byproduct needing disposal. (Kumar, et al, 2019).

The next promising technology or practice is water reuse and recycling. Indirect Potable Reuse (IPR) has been accepted since 1978 and is in many state processes for ground injection. Direct Potable Reuse (DPR) is gaining traction, with California and Texas leading the way. There have been no instances documented by the EPA of health concerns stemming from DPR treated to potable standards. Membrane and Ozone technologies are in use now and becoming more common. Some drawbacks include potentially higher capital costs, limited lifespan of membranes, the complexity of the operation, and potential irreversible membrane fouling that reduces productivity. Unlike conventional media filters, membrane systems require more maintenance and good strategies for optimal performance.

Agricultural water use is the majority of all surface and sub-surface fresh water consumed. Making headway in this area is the top priority. Historically, agriculture has been prioritized as the highest for water, for obvious reasons; humans need to eat food. However, blanket acceptance of irrigation techniques is a luxury that we can no longer afford. Figure (6) shows that moving toward precision irrigation and away from older flood irrigation techniques can reduce consumption drastically.

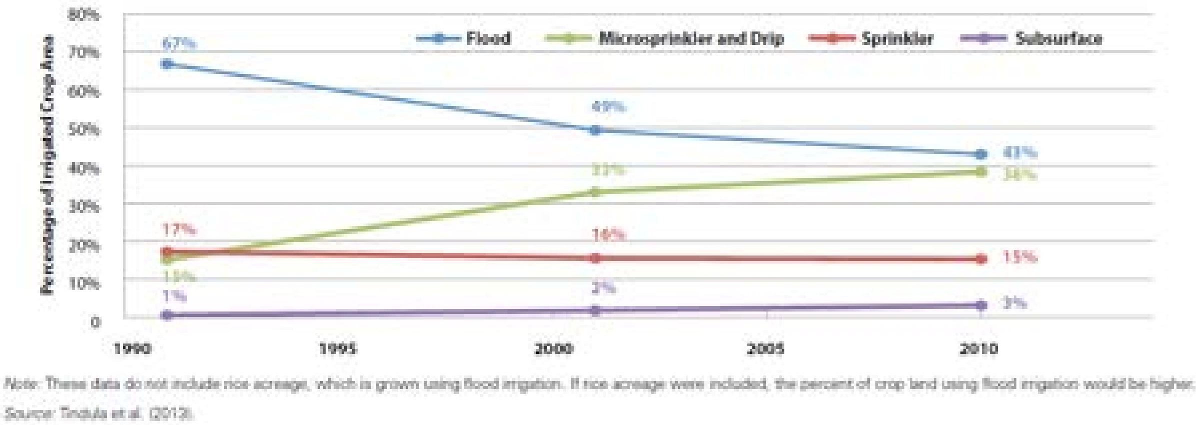

Fig (6) (Cooley et al, 2014)

Agricultural controls and water table management can improve the ability to monitor and replenish water tables to avoid over pumping during drought conditions. Use of regulated deficit irrigation techniques have proven exceptionally effective for certain plant species. These certain species thrive with deficits of hydration followed by rehydration, such as wine grapes and many types of nuts. Use of weather dependent irrigation timing is certainly not only achievable in today's world but must be considered mandatory. This kind of weather sensing equipment can be tied into networked data on the internet of things or can be a simple rain sensor locally attached to sprinkling controllers. All these techniques will yield an estimated reduction of 5.6 million to 6.6 million acre-feet per year, or by about 17 to 22 percent, while maintaining productivity and total irrigated acreage (Cooley et al, 2014). Allowing fields of crops that are high water usage but low economic return to fallow, or go dead, or replacing these with lower water use and high economic return crops is another key example of common-sense business decisions that must be incentivized by local and state governments.

The ideas above are just part of the equation that must be solved by local communities and larger governments. The drought concept itself has changed in the west, such that we are no longer experiencing a temporary shortage of rainfall and water stored, we are experiencing a new normal; the climate is changed. For humans to have needed resources, water, food, clean air, etc., we must adapt. Local communities must develop climate adaptation and resiliency plans to continue working on progressive approaches to recognize the changed climate for what it is and to plan for approaches that have not been incorporated before. Allocating billions of dollars to construct a new reservoir in a suburban or rural area to serve an urban area is an outdated, and unfortunately politically useful, approach to water management. Those billions, if applied correctly to agricultural improvements and targeted urban improvements, will gain back exponentially more water inventory. If the inputs are no longer there, new reservoirs will not have water to hold. Priorities must be clearly identified and relayed to the public, so that the understanding is widespread and ready when voting in policymakers. Identifying stakeholders within the community, vulnerable populations affected by water shortages, and engaging with these groups effectively to develop needed adaptations and foster community resiliency is crucial now and moving forward for success with water.

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