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Changing Water Supplies and Solutions to the Water Crisis: An Earth Systems Analysis of the American Southwest

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Abstract

The pressing issue of water scarcity in the Southwestern United States has been a topic of increasing concern in recent years. To address this critical problem, this research-driven essay aims to conduct an in-depth earth systems analysis to evaluate the complexities and implications of water shortages in the region. The study centers on three main objectives: (1) identifying the underlying reasons for water deficits, (2) assessing the specific impacts of these shortages on the Southwestern United States, and (3) proposing potential solutions to mitigate the crisis.

To achieve the first objective, a comprehensive investigation into the root causes of water shortages in the Southwestern United States will be undertaken. This analysis will encompass a multi-faceted approach, incorporating climatic, hydrological, ecological, and socio-economic factors. Through the utilization of advanced modeling techniques and extensive data collection, this research aims to uncover the intricate interactions between natural and human systems that contribute to the scarcity of water in the region.

Subsequently, the study will focus on a case-by-case examination of the impacts that water shortages have had on the Southwestern United States. By adopting a localized perspective, the research will delve into specific regions within the Southwestern United States, enabling a nuanced understanding of the varying consequences faced by different communities and ecosystems. The analysis will encompass diverse aspects such as agricultural productivity, urban water supply, ecosystem health, and societal

resilience to illuminate the multifaceted repercussions of water deficits in the region.

Finally, this research will propose potential solutions to address the water crisis in the Southwestern United States. Drawing upon the knowledge gained from the earth systems analysis, a range of strategies will be presented, including innovative water management practices, conservation efforts, policy interventions, and technological advancements. By exploring these mitigation options, the study aims to foster sustainable water management practices that can serve as effective remedies for the prevailing water shortages in the American Southwest.

The essay’s ultimate goal is to demonstrate the power and efficacy of conducting an earth systems analysis in comprehending and addressing complex water scarcity challenges. By shedding light on the intricate interplay of various components within the Southwestern United States, this study endeavors to serve as a valuable reference for scientists, policymakers, and stakeholders dealing with water-scarce regions worldwide. Emphasizing the significance of adopting a holistic approach in water resource management, this research endeavors to inspire further investigations and encourage the implementation of earth systems analyses in other regions facing similar water scarcity concerns.

Research Question

This essay asks the question, “To what extent has the American Southwest’s water crisis affected interactions between Earth’s spheres?”

Justification

I chose this research topic because it combined my interests in earth and environmental sciences with my passion for sustainability. With most of my extended family living in water-scarce regions, I’ve grown a deep appreciation for water’s versatility. From cleaning and cooking my favorite foods to transporting some of my most desired products, water has played an essential role in my life. My motivation to pursue this research project stems from precisely my appreciation and respect for water. Consequently, I studied the causes of the Southwest’s water crisis and brainstormed potential solutions such that similar exploratory investigations could be conducted in other regions that also experience water scarcity. In doing so, hopefully, one day, we all live in a world where water is not seen as a resource but as a universal commodity.

Project Goals

The central objective of this research project is to evaluate the Southwestern United States water shortage through an earth systems analysis. This will be done by first determining why water shortages are occurring in this region. Afterward, an analysis will be done to see how these water shortages have affected the Southwestern United States on a case-by-case basis. Finally, potential solutions to this crisis will be presented. Ideally, this research paper will illustrate the power of conducting an earth systems analysis and encourage other scientists to apply similar investigations in other water-scarce regions.

Causes of the Crisis

A. The American Southwest

Often, the American Southwest is pictured as a hot, dry landscape with a plethora of rocks, canyons, and deserts, all baked by the sun. While much of the region is characterized by a desert climate, the region supports numerous plants and animals, and millions of individuals (Cayan, 2010). However, all this life comes with immense annual water demands, which are already scarce in the Southwest.

The Southwest primarily depends on surface water supplies such as Lake Mead, which are especially vulnerable to evaporation. Consequently, small increases in temperature or decreases in precipitation can seriously threaten natural systems and societies in this already arid region. Thus, droughts can have exceptionally disastrous consequences in this region.

B. Drought in the Southwest

Every part of the Southwest has experienced warming since 1895. In some areas, warming has exceeded 2 degrees Fahrenheit. This is due to the overall warming trend caused by greenhouse gas emissions, which has resulted in a drought that has enveloped the American Southwest for the past twenty years (NOAA, 2022).

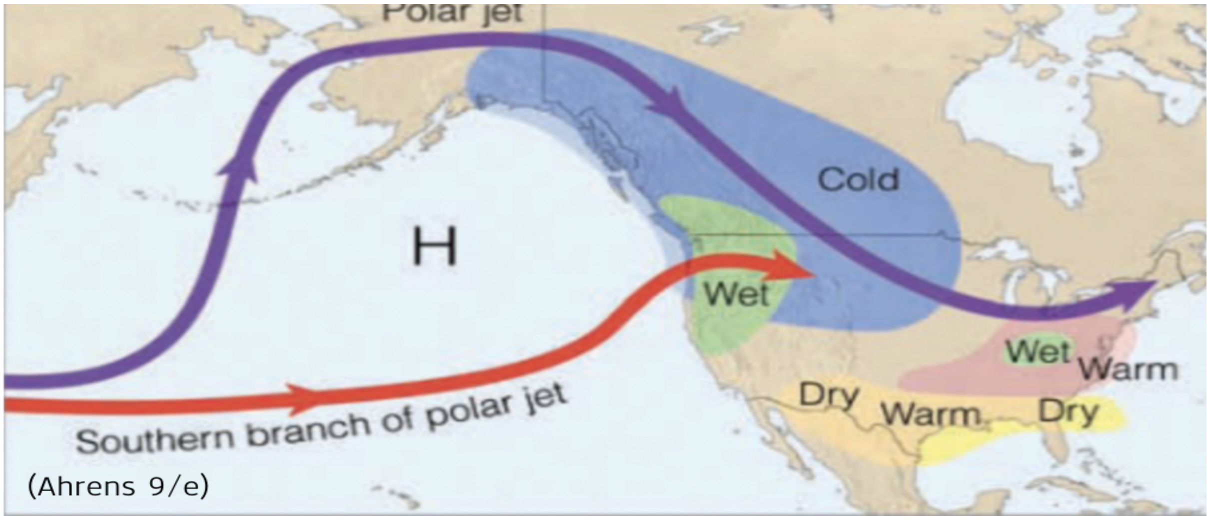
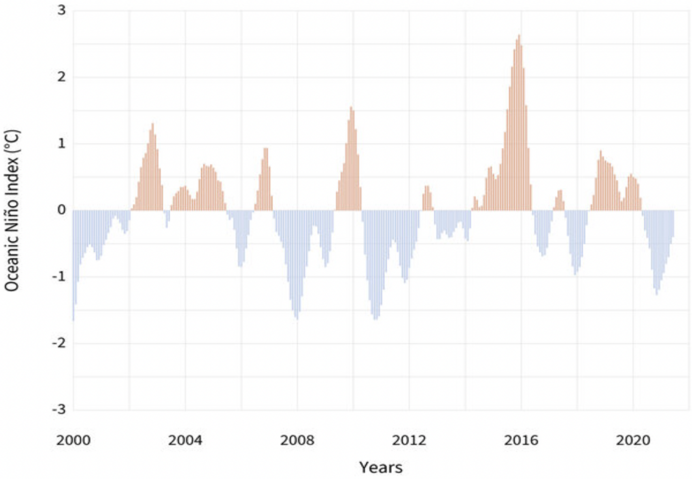


Figure 1: Schematic representation of La Niña

However, over the past three years, the situation has grossly intensified. This is mainly due to low precipitation and high temperatures that continue to plague these areas. Two sources dominate precipitation in this region: the movement of low-pressure systems from the Pacific in the winter and the activation of the North American Monsoon system during the summer. However, in 2020 precipitation decreased drastically. This is primarily due to the intensification of La Niña, which has weakened the northern winter low-pressure system, resulting in drier conditions during the winter (US EPA, 2020).



Graph 1: La Niña events intensifying over time

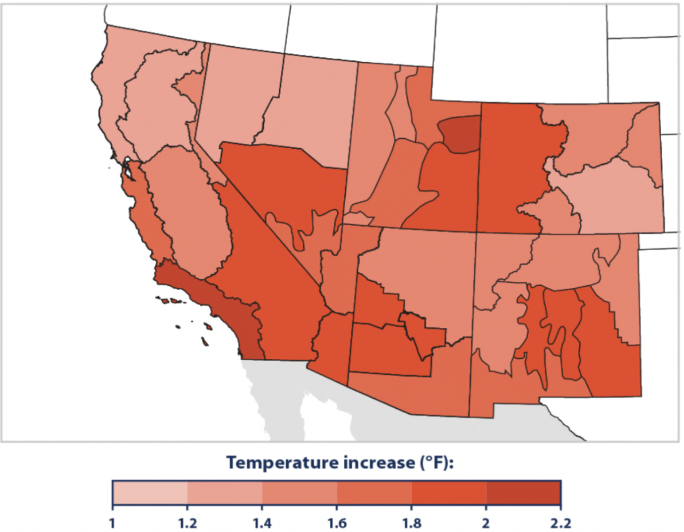


Figure 2: Temperature increase in the Southwest

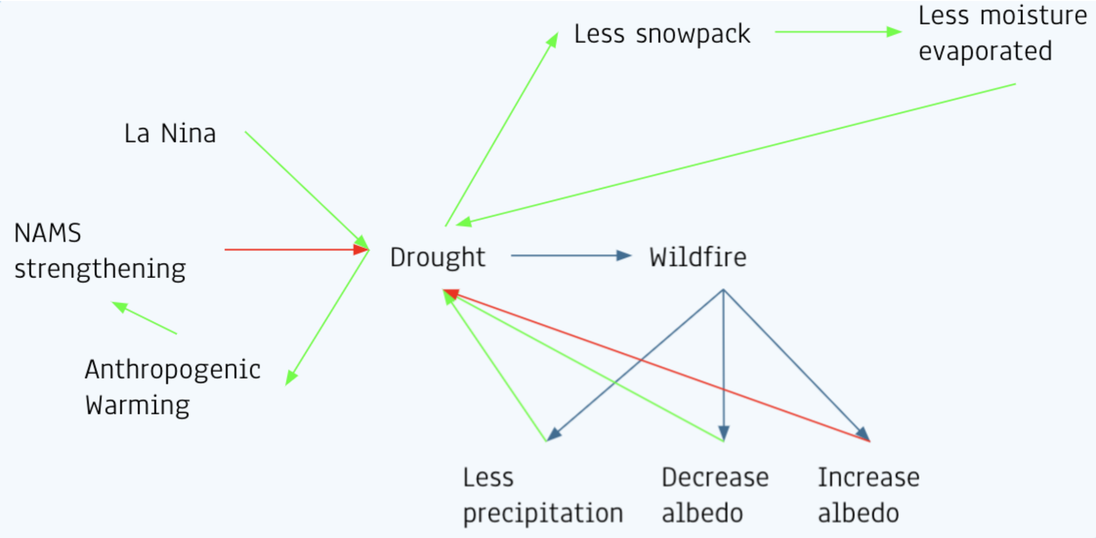
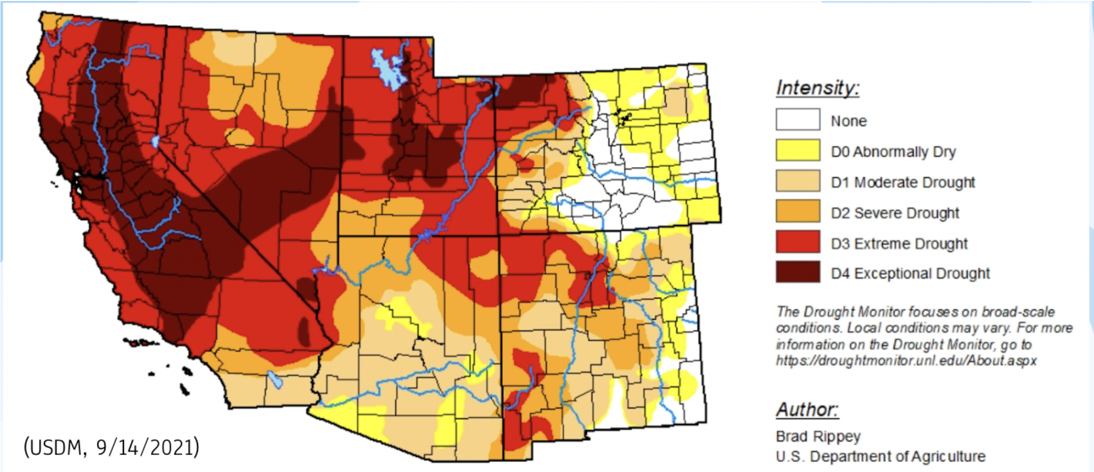


Diagram 1: Earth systems analysis of the effect La Niña has on drought in the Southwest

On the other hand, the geographic location of the Southwest has been the main contributor to high temperatures in the region. Located between the mid-latitude and subtropical atmospheric circulation regimes, its positioning results in year-round warm temperatures and clear skies. The intensification of La Niña, combined with increased fossil-fueled emissions, has contributed to significant droughts in 2020 and 2021 and has perpetuated the Southwest's longer "megadrought" that has dominated the region since the early 2000s (James, 2021).



The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to https://droughtmonitor.unl.edu/About.aspx

(USDM, 9/14/2021)

Figure 3: Map displaying areas in the Southwest that are experiencing drought and its intensity

C. Particulate Matter (PM) Influence on Weather

Particulates, also known as atmospheric aerosol particles, are microscopic particles of solid or liquid matter suspended in the air. Reports indicate that variations in particulate matter (PM) concentrations over short period cause abnormalities in weather patterns (Tiwari et al., 2012). Wet weather conditions often indicate lower concentrations of PMs than dry weather conditions, with better air quality in urban and rural lands typically associated with frequent light precipitation events (Yadav, 2020). During wet weather conditions, concentrations of PM_{10} $PM_{2.5}$ are generally reduced by 46% and 18%, respectively (Yadav, 2020). This is explained by the fact that diffusion conditions in the atmosphere govern particulate matter concentrations. Atmospheric diffusion is defined as the motion of relatively small numbers of different gas molecules in the medium of the atmosphere. These diffusion conditions are by the concentrations of PM in the atmosphere. Thus, the formation and development of many weather events are a result of tremendous changes in the mass of suspended particulate aerosols in any given region (Wrobel, 2000). This especially pertains to the Southwestern United States, which has been experiencing significant aerosol variability over the past decade (Sorooshian et al., 2013).

D. Other Positive Feedback Loops

Unfortunately, the story does not end with just low precipitation, high temperatures, and pollution. Once drought sets in, atmospheric feedback loops amplify and weaken initial conditions. At the surface, soot forms and decreases surface albedos which produce a warming effect, initiating a positive feedback loop. This process also occurs at high altitudes. When fire aerosols enter the atmosphere, they increase the number of vacant cloud condensation nuclei, resulting in smaller cloud droplets when water coalesces onto these atmospheric particles. As a result, less precipitation is produced due to the deficiency of large droplets, creating another positive feedback loop (Jiang, 2020).

Furthermore, a lack of winter storms because of La Niña has substantial impacts. Namely, it has led to a reduction in the Southwest's total snowpack, resulting in less water evaporating during the summer. This decrease in atmospheric water moisture content during the summer and fall months further insinuates drought in the Southwest.

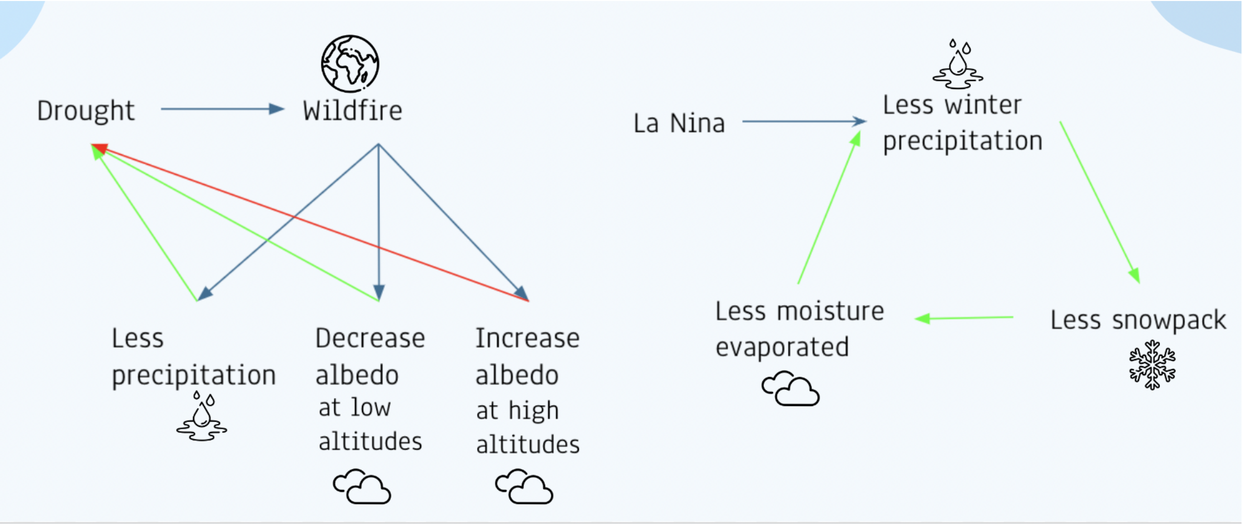


Diagram 2: Other feedback loops

E. Economic Impacts

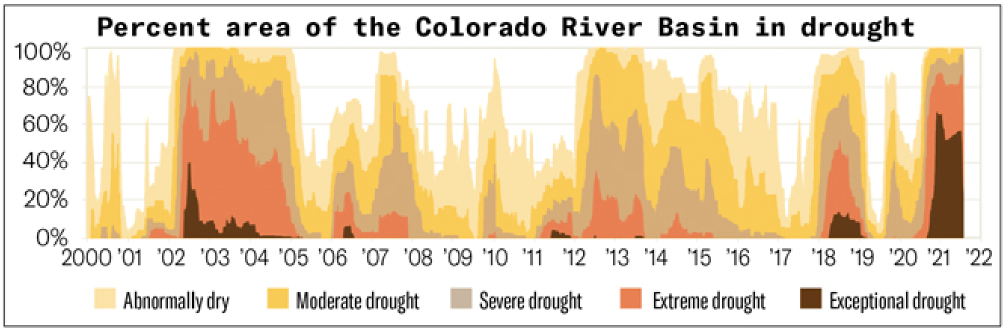
Droughts also substantially impact the economy of this region. They are associated with increased pest outbreaks and wildfires, damaging local economies and reducing the amount of water available for producing energy. Thus, it is clear that the Southwest's drought crisis is not only limited to the hydrosphere, geosphere, or atmosphere but affects the anthroposphere as well.

Case Studies

Decreasing the pervasiveness of drought in the Southwest requires humans to break the positive feedback loops they have created without altering the environment substantially, which is a complex task. However, analyzing how substantial changes in climate have affected areas in the Southwest may provide a clearer vision of potential methods to solve this crisis.

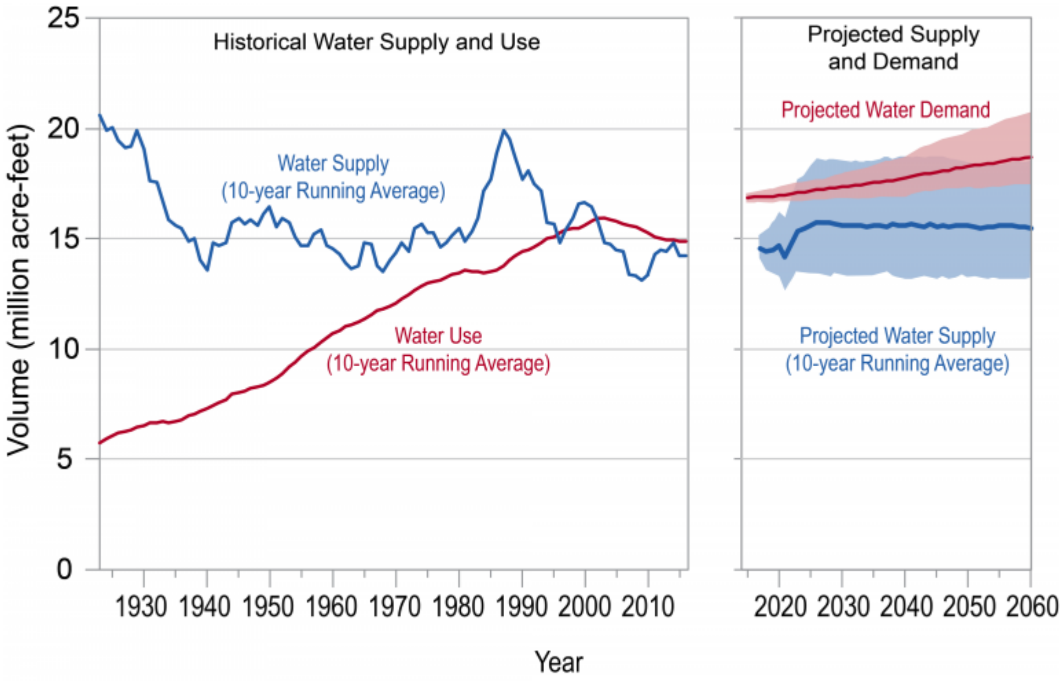
A. Colorado River Basin

The Colorado River basin is one of the most important of its kind. Spanning the entire southwest region, it is estimated to supply water to forty million people.



Graph 2: Percent area of the Colorado River basin that experiences drought over time, each color represents a different drought severity.

As seen in graph 2, the Colorado River has been experiencing drought conditions since the year 2000. In 2021 and 2022, the entirety of the Colorado River basin experienced drought, largely due to the low precipitation conditions created by La Niña. Furthermore, during 2021 and 2022, approximately 60% of the basin experienced exceptional drought conditions. This is due to anthropogenic-induced climate change combined with the basin's growing demand for water.



Graph 3: Water demand and supply of the Colorado River

Graph 3 shows the historic and projected water supply and demand of the Colorado River. From the graph, it is apparent that water supply is decreasing rapidly, whereas demand is dramatically increasing. This demonstrates there is simply not enough water in this region to support anthropogenic water demands.

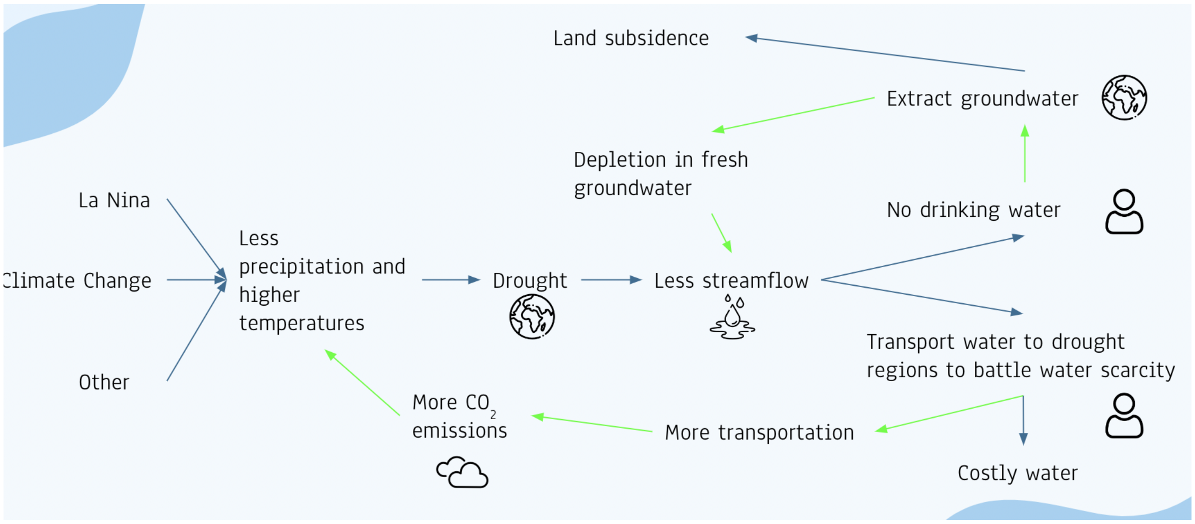
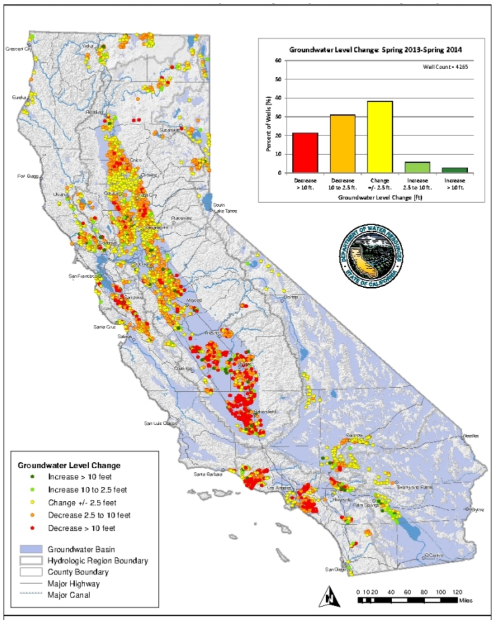


Diagram 3: Earth systems analysis of the Colorado River basin

From diagram 3 it is clear that drought in the Colorado River basin has had numerous impacts on associated earth systems. Firstly, less streamflow has led to fewer available surface freshwater drinking sources, which has resulted in greater pumping and extraction of groundwater sources. Secondly, a decrease in streamflow places a greater emphasis on the vehicular transportation of water in places exceptionally affected places affected by droughts. This increase in transportation in more CO_2 emissions which further aggravates and worsens drought in this region.

B. San Joaquin Valley

The San Joaquin Basin is located in the Central Valley of California. With over 4 million residents and producing roughly a quarter of the nation’s food supply, farmers rely heavily on groundwater to irrigate their crops when they don’t receive enough water from surface water sources.



*Groundwater level change determined from water level measurements in wells. Map and chart based on available data from the DWR Water Data Library as of 04/28/2014. Document Name: S2014-S2013_20140428 Updated: 04/28/2014 Data subject to change without notice.

Figure 4: Groundwater level change from spring 2013 to spring 2014

As depicted in figure 4, just one year of excessive groundwater pumping (from 2013 to 2014) caused a significant decrease in the water table in many areas of the San Joaquin Basin.

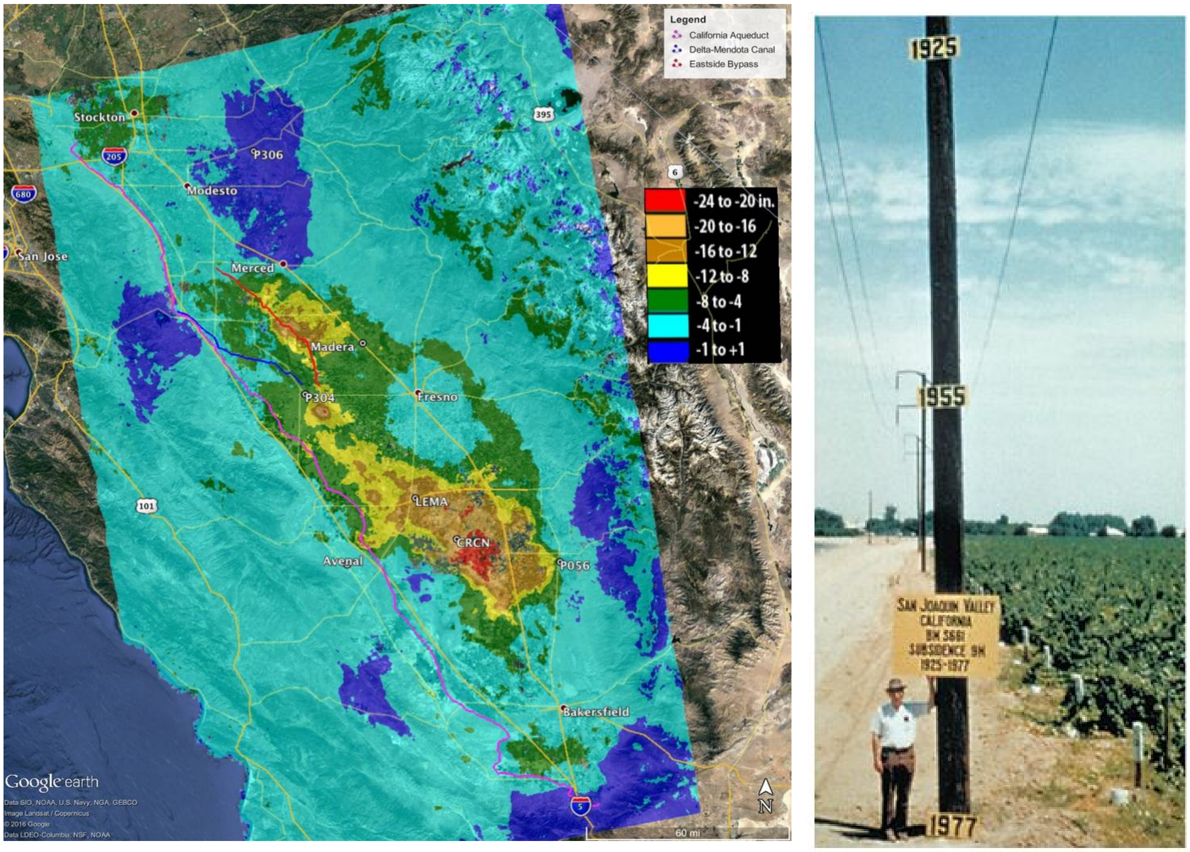


Figure 4: Amount of land subsidence in the San Joaquin Basin over the course of a year (left), over the course of fifty-two years (right)

Thus, one major effect of groundwater pumping is land subsidence. Figure 4 is a satellite image that shows the amount of subsidence in the San Joaquin Basin ranged from a couple of inches to two feet over the course of a year. As a result, excessive groundwater pumping has had a significant impact on the San Joaquin Basin's topography.

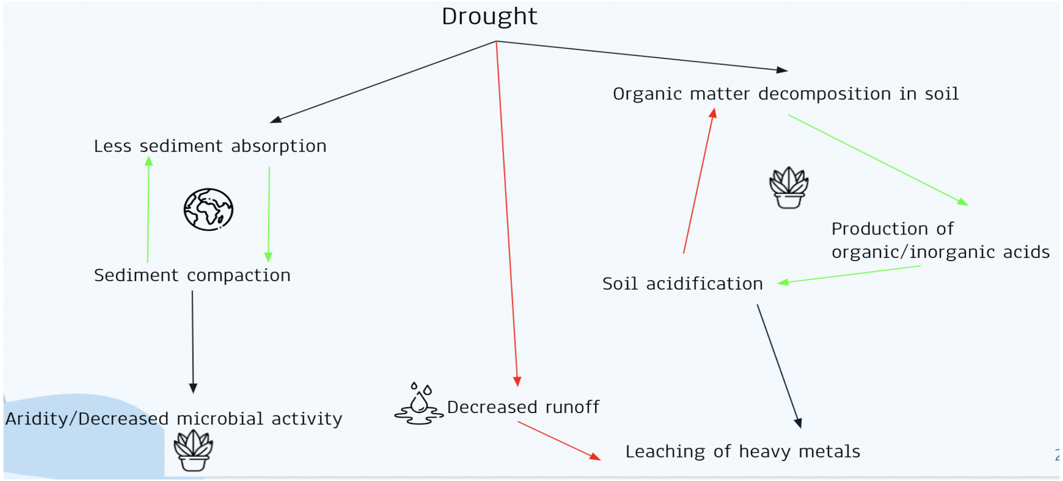


Diagram 4: Earth systems analysis of the San Joaquin Valley

Furthermore, the lowering of the region’s water table has led to the drying up of wells. This forces water mining companies to tap into deeper and deeper groundwater sources which significantly increases groundwater pumping costs. Secondly, less water in lakes and rivers (whose main source of water comes from the seepage of groundwater) causes significant loss in riparian vegetation and wildlife. This has resulted in a long-term decline in carbon fixation and sequestration within the region, leading to higher concentrations of pollutants, which has affected the hydrosphere, biosphere, and anthroposphere.

Changing Water Supplies

If drought in the Southwest persists in the future, what are some ways to solve and mitigate this crisis? Securing long-term access is the first step, but this requires the research and development of alternative and sustainable water sources.

A. Artificial Recharge

One ongoing solution to the water crisis is the artificial recharge of aquifers. This process involves the human-controlled spread, impound, or injection of water in order to replenish underground aquifer sources. As seen in figure 5, aquifers are widespread across the Southwest. As a result, artificial recharge is commonly used to replenish groundwater sources in the Southwest. This process prevents land subsidence and saltwater intrusions by keeping the water table at a healthy level. Additionally, less water is lost through the evaporative processes surface waters are victim to.

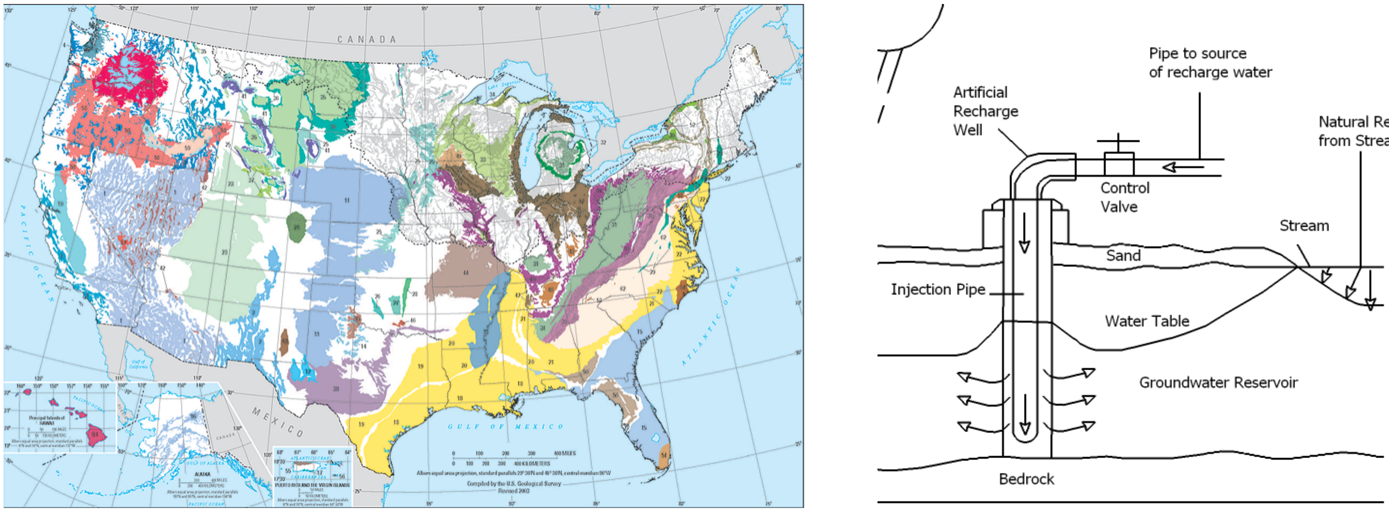
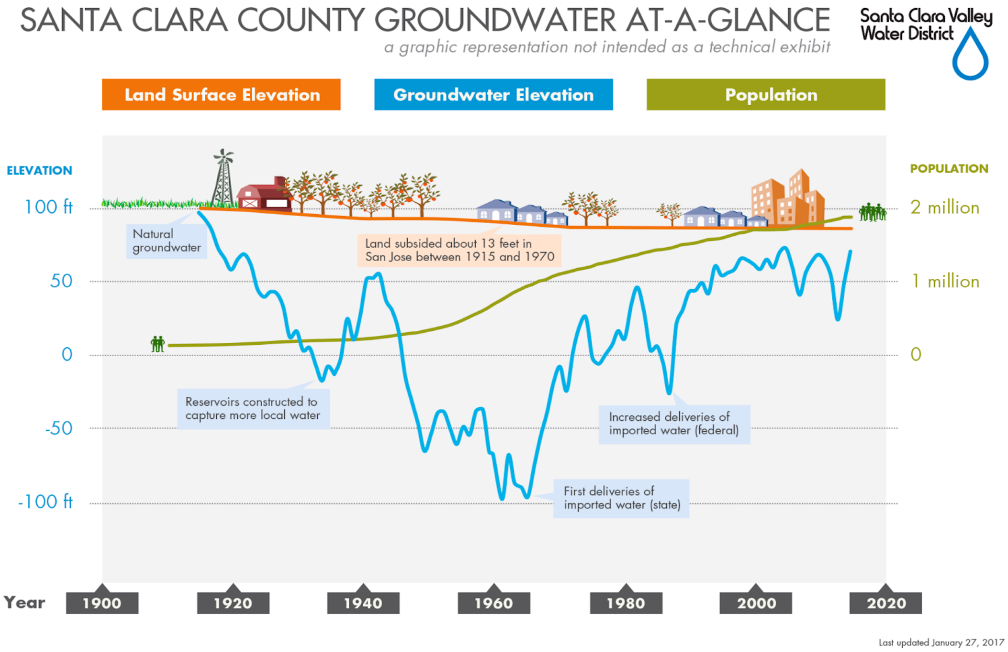


Figure 5: (Right) United States underground aquifer system, each color represents an independent aquifer system. (Left) Schematic of a typical artificial recharge system.

Artificial recharge has been shown to be most effective in regions that are able to take advantage of already-established infrastructure. For this reason, many urban communities in New Jersey and India have already adopted artificial recharge as part of their environmental and economic policies.



Graph 4: Santa Clara county's groundwater and land surface elevation over time

Graph 4 displays a success story of artificial recharge in Santa Clara, a county adjacent to the San Joaquin Valley. The orange line on the graph depicts ground level starting from 1900, which steadily declined up until the 1970s, where it has remained relatively consistent since. This is due to shifts in groundwater elevation (blue line) brought by Santa Clara's artificial recharge program. With groundwater elevation at its lowest in the 1960s, Santa Clara county opted to finance a massive artificial recharge policy in order to preserve its aquifer. Since then, water tables have risen back dramatically, and land subsidence has halted (Public Policy Institute of California, 2022).

However, artificial recharge does come with its disadvantages. Namely, excess water must be preserved and stored during wet seasons so it can be pumped back into aquifers during dry seasons. Unfortunately, there are not enough natural sources (lakes/rivers) in the Southwest that can hold water. As a result, many artificial recharge plants are forced to import water which is a costly and inefficient process. Additionally, artificial recharge processes can contaminate groundwater sources, often occurring when pollutants are leached from unmaintained metal pipes and equipment.

B. Recycling Wastewater and Rainwater

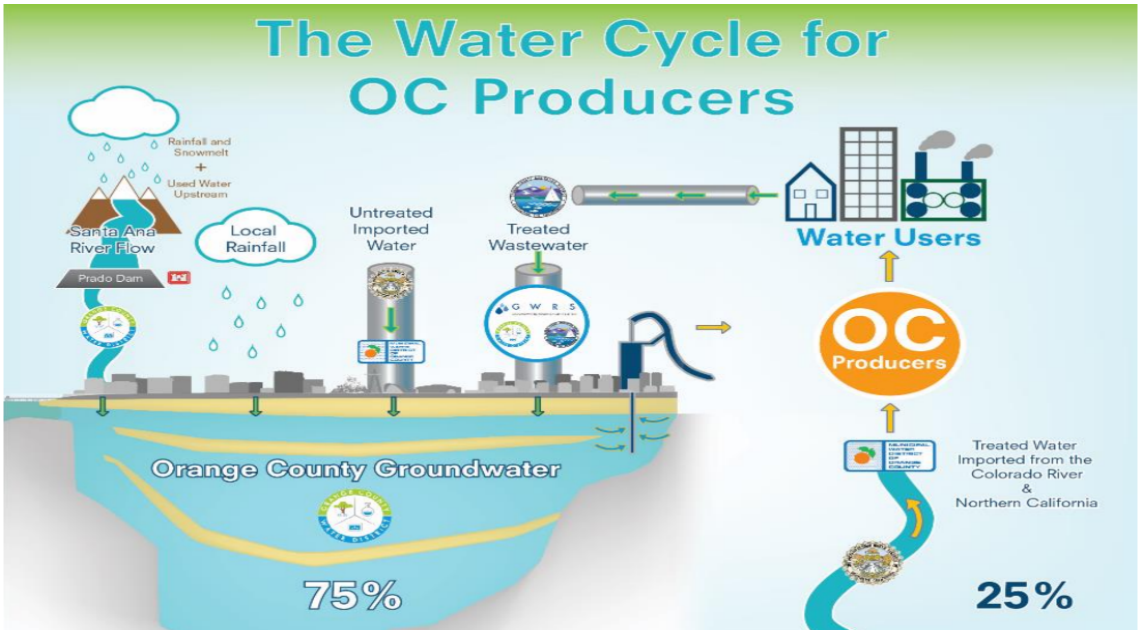


Figure 7: Wastewater recycling process

Many places worldwide are planning to or are currently practicing wastewater, rainwater, and runoff recycling strategies to reuse water supplies and optimize the overall usage of water before it is reintroduced to outside environments. One successful example is the Groundwater Replenishment System (GWRS) in Orange County, California, the world's largest wastewater purification system. This system produces up to 100 million gallons of high-quality water daily and supplies nearly 850,000 residents in north and central Orange County.

Furthermore, many townships have adopted rainwater recycling policies. These policies typically have residents of the area collect rainwater that falls onto their property (through barrels or nets) which then gets distributed to local municipalities (Radonic, 2019). However, such techniques may not be effective in the Southwest. For one, rainfall varies by location across the Southwest. Different regions receive different amounts of precipitation at different times; this makes centralized collection difficult. Additionally, precipitation values have been dropping in the Southwest compared to other areas of the United States. As a result, rainwater recycling is not a sustainable solution.

C. Atmospheric Water Generators

12,900 cubic kilometers. That is the average amount of water suspended in the atmosphere at any given moment, more than the largest lake in North America. Accessing this water would greatly benefit individuals from arid regions of the world; however, doing possesses many challenges. Atmospheric and climate engineers have approached this issue by creating atmospheric water generators (AWGs), which condense water vapor and then store it for later use.

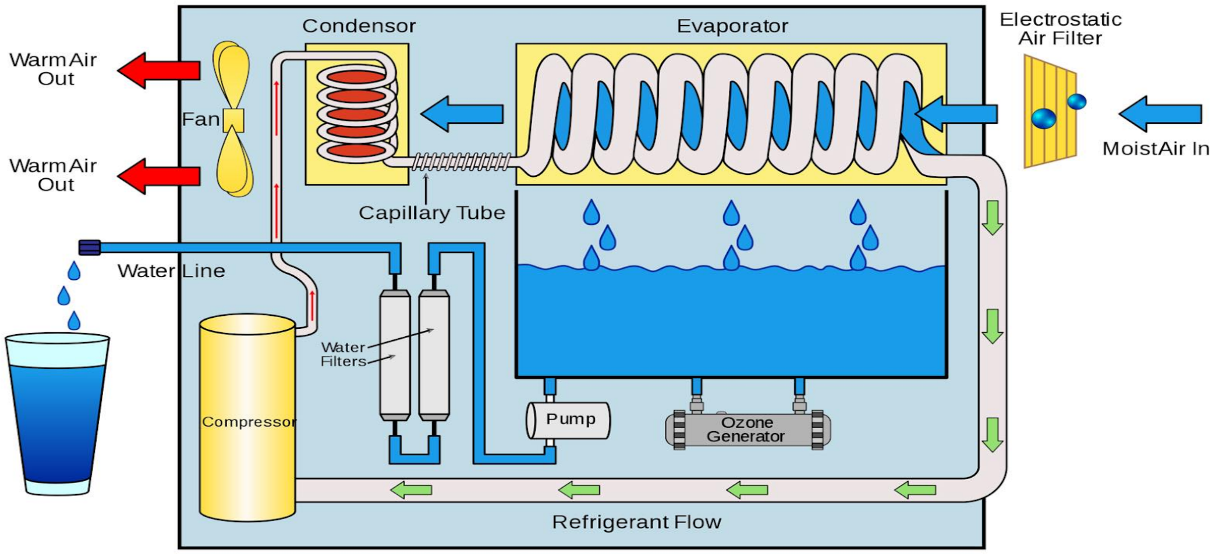


Figure 8: Schematic of a typical atmospheric water generator

Figure 8 outlines this process. Moist air first flows through a filter to extract particulate matter. The condenser then circulates refrigerant and an evaporator coil cools the surrounding air. This causes the vapor to condense, allowing it to be collected easily. Lastly, a fan removes the filtered air while the water undergoes purification and filtration.

The production rate of this process depends on the humidity of the air. In some circumstances, where the air has a relative humidity as low as 15%, liters of water can be extracted; however, such processes require significant energy sources. As a result, atmospheric water generators are currently best suited for personal use rather than for large-scale operations.

D. Desiccant Materials

A desiccant is a hygroscopic material that promotes moisture retention on a surface, and is often used to absorb water particles suspended in the air.

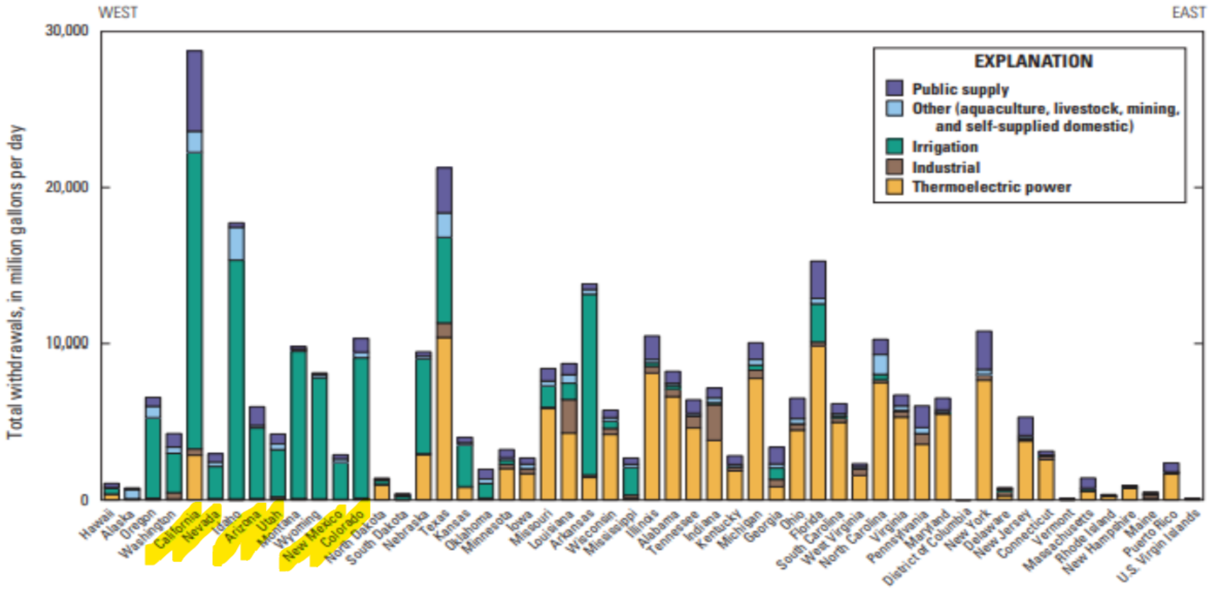
Figure 9: SOURCE hydropanels in the Sonoran Desert

SOURCE hydropanels (Figure 9) use solar energy and the properties of desiccants to extract pure drinking water from the air. Since this technology only requires solar energy, it is highly accessible in places in the Southwest with limited electricity, water, and energy resources. However, despite these limited energy requirements, each panel produces three to five liters of water per day; this significantly limits large-scale operations of SOURCE hydropanels.

Water Use in the Southwest

As illustrated so far, users demand significantly more water than natural and artificial water sources in the Southwest can adequately supply. In the classic demand vs. supply battle, demand appears to be winning. But studying and analyzing the largest water consumers in the Southwest may provide valuable guidelines and criteria sustainable freshwater solutions should follow.

A 2015 USGS survey found that irrigation and thermoelectric power were the most significant water consumers, with irrigation leading total freshwater use at 42%.



Graph 5: Total water withdrawals by State in 2015

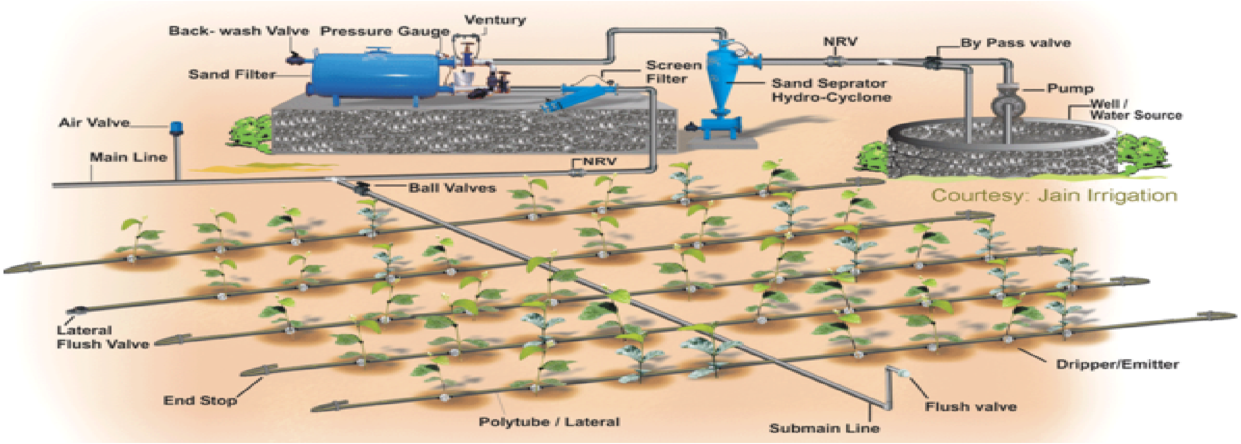
Graph 5 visualizes total water withdrawals by state. In the Southwest (defined as California, Nevada, Arizona, Utah, Colorado, and New Mexico by the graph), nearly 80% of freshwater was drawn for irrigation use, vastly more than the rest of the continental United States. Moreover, this trend does not appear to slow as over the past twelve years, the use of freshwater for irrigation purposes has increased by two percent.

With this said, it’s important to note that Earth isn’t going to run out of water. Water rarely leaves or enters the atmosphere. As a result, the amount of water Earth currently has is the same as Earth had thousands of years ago (Devis, 2022). The only issue is that clean freshwater is not always available when and where humans need it. Thus, if the Southwest can reduce irrigation’s total freshwater expenditure, it may help solve its water crisis.

Sustainable Irrigation Methods

Solving the water crisis doesn’t necessarily mean finding new water sources but rather conserving the water resources already accessible to us. Doing so is especially vital in the agricultural sector since it is one of the biggest consumers of freshwater in the Southwest.

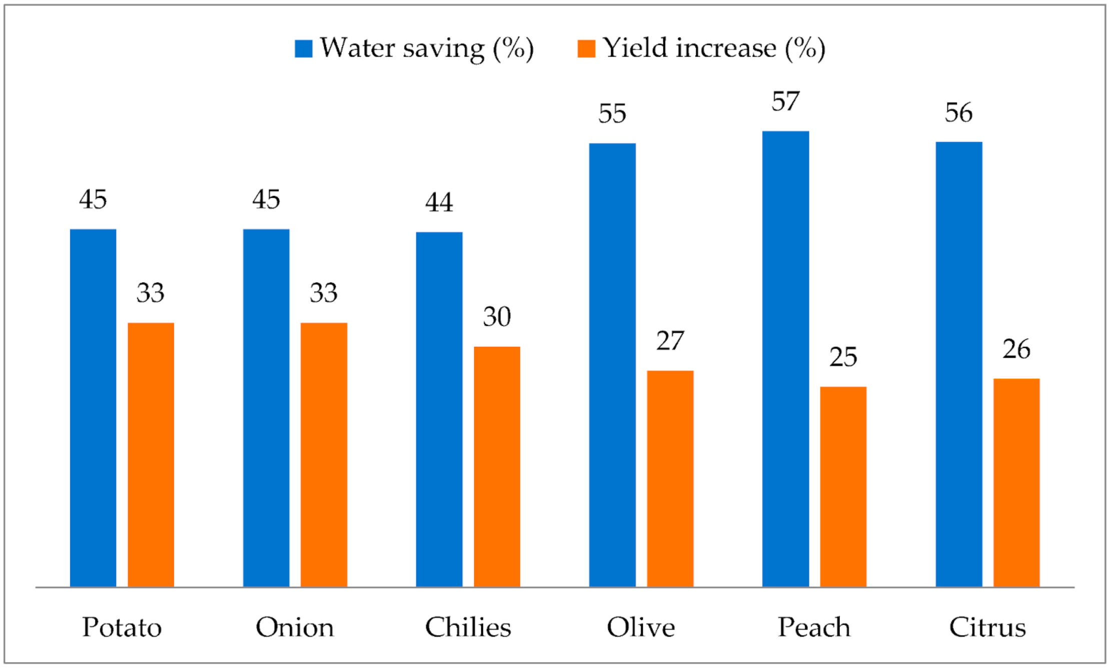
A. Drip Irrigation



Courtesy: Jain Irrigation

Figure 10: Schematic illustrating a typical drip irrigation system

One potential solution is drip irrigation. My first experience with drip irrigation came from my experience at my grandfather's farm in India. It was here that I noticed my grandfather's use of drip irrigation as a means of water conservation. Rather than flooding his entire farm as most Southwestern farmers do, he constructed a field of pipes across his farm. These pipes slowly dripped water and nutrients directly into his cardamom plants' roots.

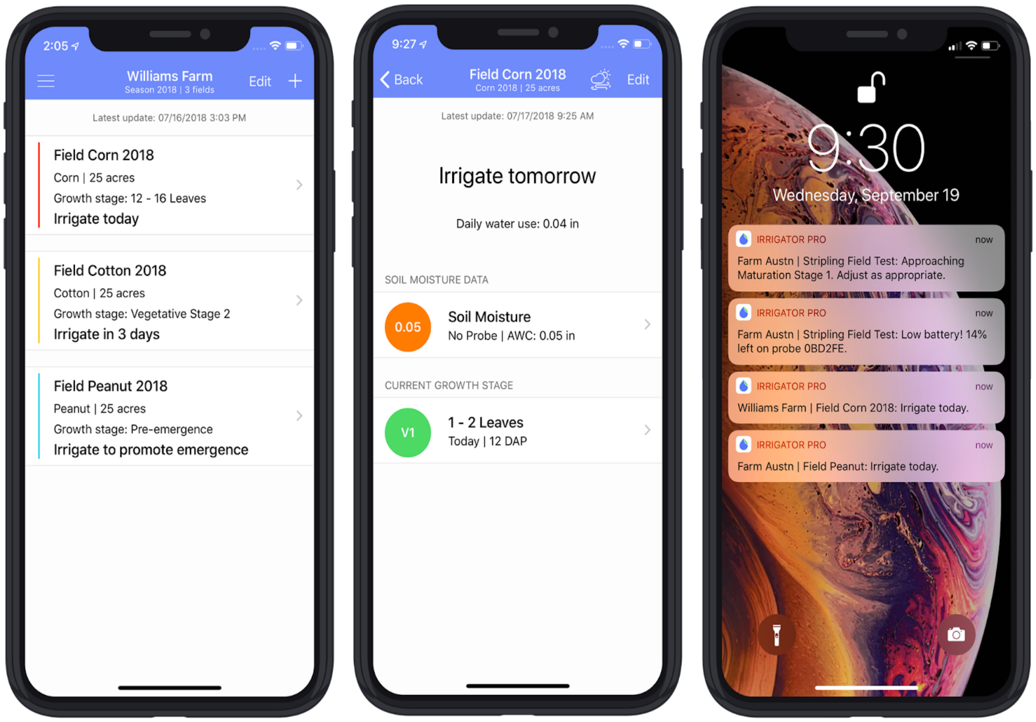


Graph 6: Percentage of water that was saved and change in net yield after using drip irrigation

Drip irrigation preserves water in the long run. A study in Punjab, Pakistan, found that drip irrigation reduced water consumption by 50% in small landholdings and increased net crop yield by 28% when compared with traditional furrow irrigation systems (Aziz, 2021). These findings are likely replicable in the Southwest, which shares similar climate and weather patterns as Pakistan.

B. Irrigation Monitor/Scheduler

Another way to make irrigation more sustainable in the Southwest is through the use of irrigation monitoring apps. Such apps record soil moisture, temperature, and crop growth stage and use this data to notify farmers when to irrigate their crops. If farmers base their irrigation schedules solely on their farm’s soil physiology, it avoids excessive irrigation, making the process more efficient. So far, irrigation monitoring apps have been used during peanut, cotton, and corn cultivation; however, these technologies may also be applied to other crops in the Southwest, such as grain cultivation (Irrigation scheduling aids and tools, 2022).



Williams Farm
Season 2018 | 3 fields

Latest update: 07/16/2018 3:03 PM

Field Corn 2018
Corn | 25 acres
Growth stage: 12 - 16 Leaves
Irrigate today

Field Cotton 2018
Cotton | 25 acres
Growth stage: Vegetative Stage 2
Irrigate in 3 days

Field Peanut 2018
Peanut | 25 acres
Growth stage: Pre-emergence
Irrigate to promote emergence

Field Corn 2018
Corn 2018 | 25 acres

Latest update: 07/17/2018 9:25 AM

Irrigate tomorrow

Daily water use: 0.04 in

SOIL MOISTURE DATA

0.05 Soil Moisture
No Probe | AWC: 0.05 in

CURRENT GROWTH STAGE

V1 1 - 2 Leaves
Today | 12 DAP

IRRIGATOR PRO now
Farm Austn | Stripling Field Test: Approaching Maturation Stage 1. Adjust as appropriate.

IRRIGATOR PRO now
Farm Austn | Stripling Field Test: Low battery! 14% left on probe 0BD2FE.

IRRIGATOR PRO now
Williams Farm | Field Corn 2018: Irrigate today.

IRRIGATOR PRO now
Farm Austn | Field Peanut: Irrigate today.

Figure 11: Mock-up of potential irrigation monitoring/scheduling app

C. Vertical Farming

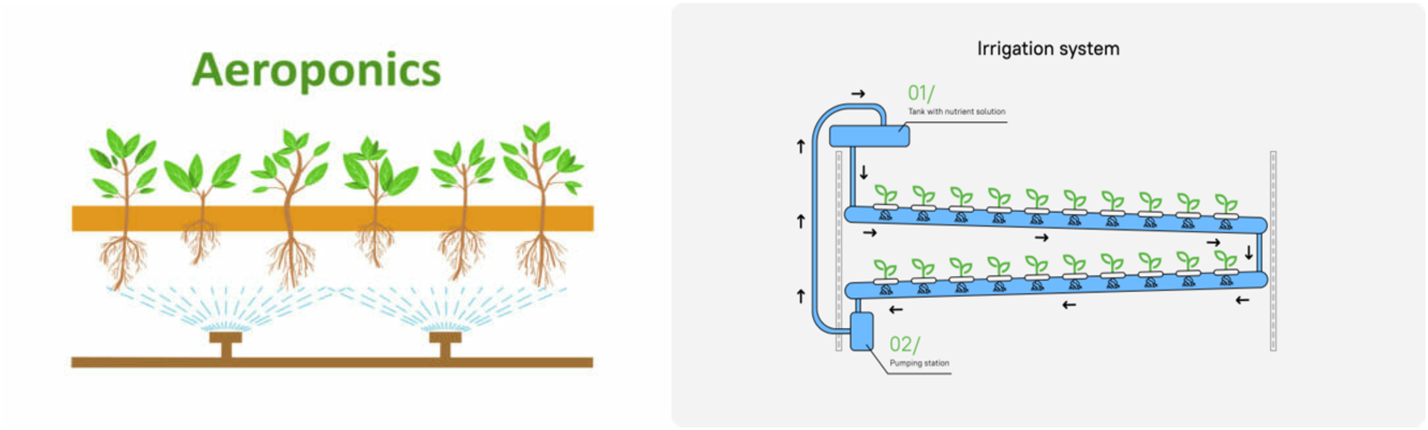


Figure 12: (Right) Schematic of an aeroponics irrigation system. (Left) Schematic of a hydroponics irrigation system.

In addition to novel irrigation technologies (such as drip irrigation and irrigation scheduling apps), vertical farming has been used for decades to extend the reach of conventional farming methods (Banerjee, 2014). Vertical farming involves stacking crops vertically and growing them indoors in controlled environments (Asseng, 2020). Figure 12 illustrates other applications of this method, such as aeroponics and hydroponics which use soilless nutrient mediums to nourish plants.

According to iFarm, a company that develops vertical farming and hydroponic technologies, vertical farming uses 95% less water and yields hundreds of times more produce than conventional farming techniques (iFarm, 2022). Because agriculture is the largest expenditure in the Southwest's annual water budget, a significant reduction in irrigation's total water use would allow for the gradual restoration of aquifers over time. Furthermore, since vertical farming techniques reduce the need for fertilizers, pesticides, or herbicides, vertical farming ensures fewer pollutants enter freshwater systems through runoff.

D. Limitations

However, these sustainable irrigation technologies come with their fair share of limitations. For one, crops produced through vertical farming are typically two to three times more expensive than crops grown through regular irrigation systems due to vertical farming's high maintenance and labor costs. Additionally, vertical farming requires artificial light systems to allow plants to perform photosynthesis indoors. These artificial light systems increase a farm's energy consumption and present many farmers with an unfeasibly high overhead cost. Finally, vertical farming and drip irrigation are often only economically profitable in small landholdings due to their high costs per square foot. Combining these factors results in a product that is promising environmentally but not necessarily financially feasible or competitive in the agricultural industry. Thus, more research is needed to optimize the design of these drip irrigation and vertical farming systems.

Agricultural Solution

The technologies and techniques discussed so far have sought changes in agriculture's physical characteristics (water, land, etc.); however, it is essential to discuss solutions that change the chemistry of agriculture—specifically, the soil.

A. SMAG Soil

Figure 13: SMAG soil hydrogel

SMAG soil is a super moisture-absorbing gel that harvests water from the air and supplies it to plants. SMAG soil is a combination of water-absorbing hydrogels and regular sandy soil. SMAG soil absorbs water in the nighttime when the air is cool and moist. This passively causes water to be stored in the soil. The hydrogels then dry in the afternoon (due to the evaporative processes solar radiation initiates), releasing captured water into the soil.

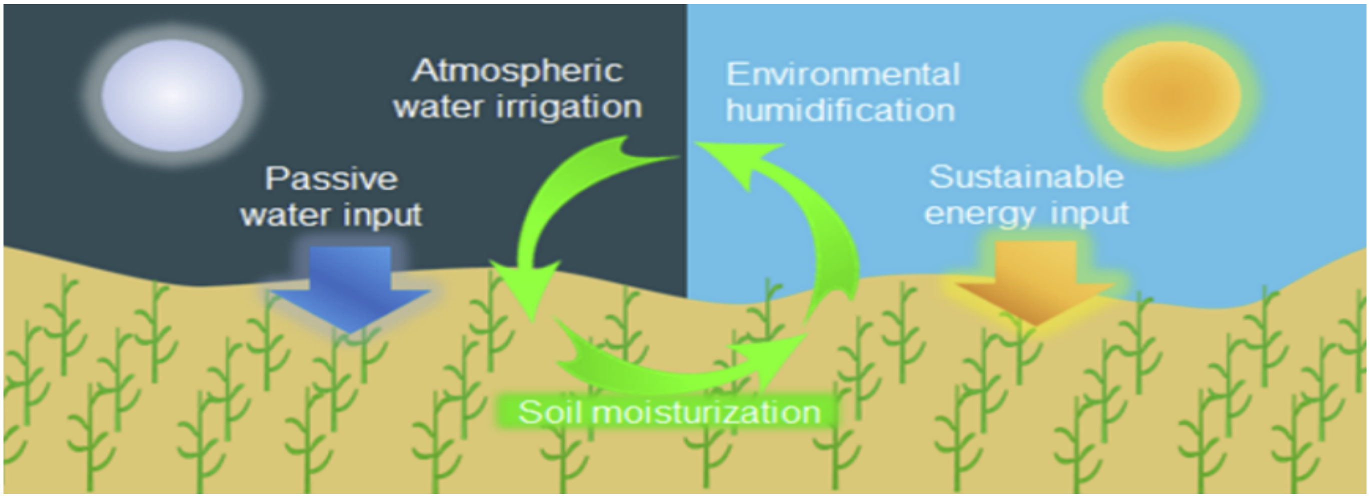
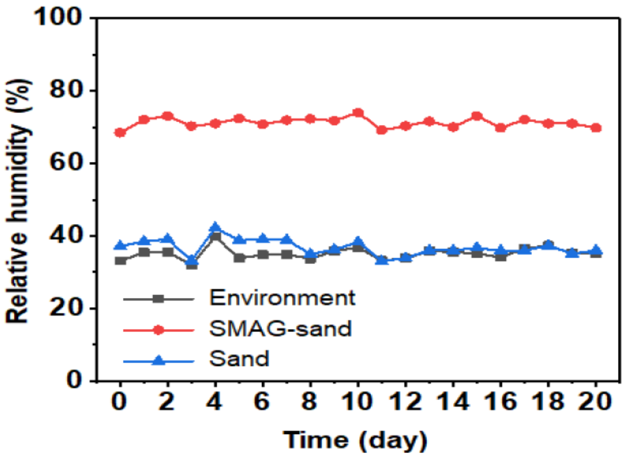
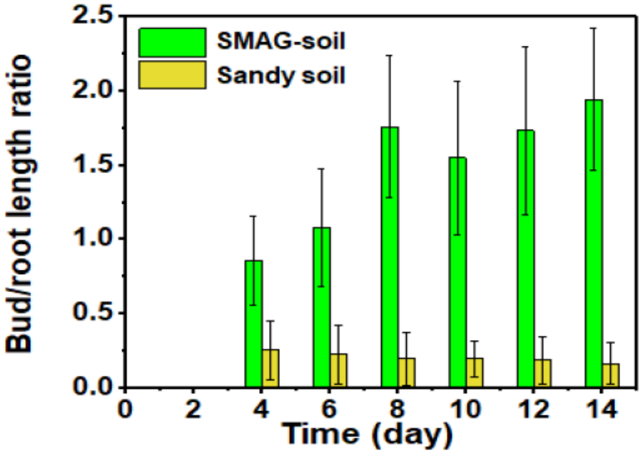


Figure 14: Schematic of SMAG soi’s atmospheric water irrigation process

This process is outlined in Figure 14. At night, SMAG soil absorbs water from the atmosphere. And then, in the afternoon, it releases stored water into the surrounding soil. Since this process utilizes water stored in the atmosphere, SMAG soil can be used in any location, regardless of its accessibility to liquid water sources. Furthermore, SMAG soil can retain water in areas that experience moderately low relative humidities and periodic droughts. This makes it a particularly effective solution in the American Southwest, which is known for encountering such conditions (as seen with the Colorado River basin and San Joaquin Valley case studies).

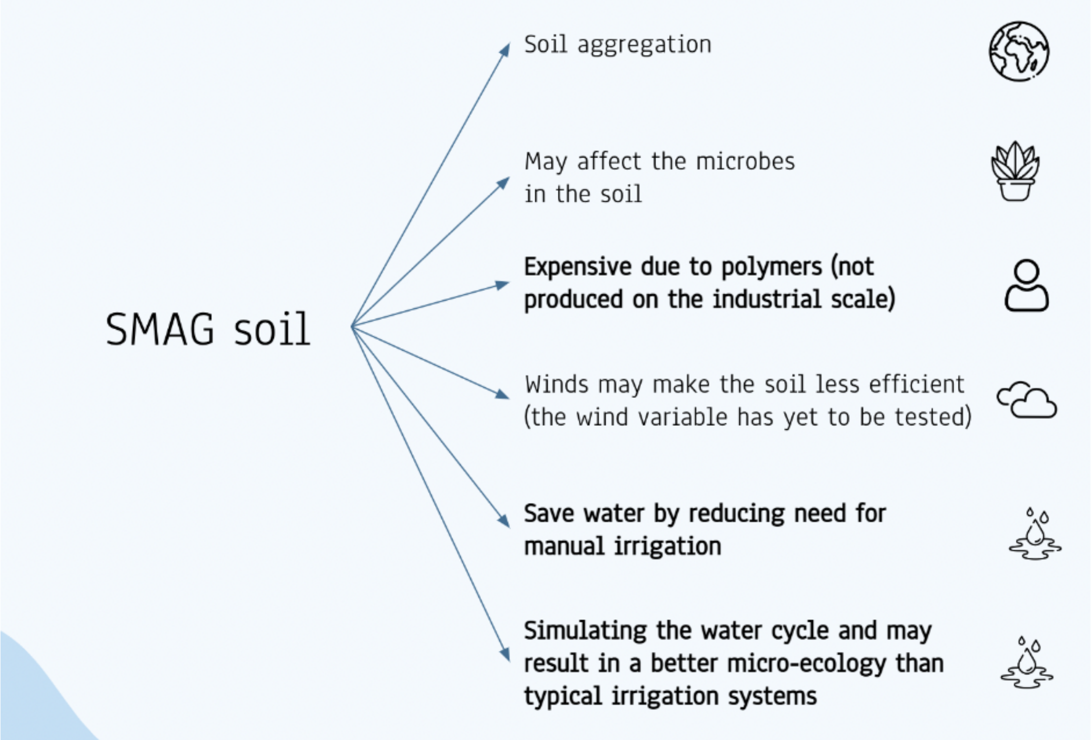




Graph 7: (Right) Relative humidities of plants grown in SMAG-soil and sandy soil environments. (Left) Growth of plants in SMAG-soil and sandy soil environments over time.

The University of Texas conducted a research study to see if SMAG soil was more effective than regular sandy soil. As shown in graph 7, which depicts the relative humidity, the air in the SMAG soil container typically had a relative humidity of 70%. In comparison, the average relative humidity in the sandy soil container was 40% (Zhou et al., 2020). This indicates that SMAG soil is more effective in trapping and preserving water than ordinary sandy soils. Furthermore, SMAG soil improves plant growth over time. In the same University of Texas research study, radishes were grown in both SMAG and sandy soil, with the plant's height recorded every two days. Graph 7 demonstrates that plants grew faster in SMAG soil, whereas plants growing in sandy soil grew at a much slower rate (Zhou et al., 2020). Overall, the University of Texas found that if a farmer adopted SMAG soil onto their farm, it would not dramatically impact their crop rotations and increase crop production per cycle. Additionally, SMAG soil has been shown to prevent erosion and runoff due to its ability to aggregate and clump soil.

With this said, SMAG soil does come with its limitations. Namely, it is costly since it is made from polymers that are not produced on an industrial scale. Additionally, certain SMAG soils have been shown to impact native soil microbiota environments. In general, scientists must conduct more research to see if SMAG soils are conducive to the American Southwest's environment.



SMAG soil

Soil aggregation

May affect the microbes in the soil

Expensive due to polymers (not produced on the industrial scale)

Winds may make the soil less efficient (the wind variable has yet to be tested)

Save water by reducing need for manual irrigation

Simulating the water cycle and may result in a better micro-ecology than typical irrigation systems

Diagram 5: Advantages and disadvantages of SMAG soil

Conclusion

Throughout this research paper, we have seen how humans have exacerbated droughts because of climate change. We've discussed solutions relating to changing the Southwest's water supply, irrigation methods, and agricultural techniques. However, all these fixes are temporary, and each has its own unique limitations. There is no one perfect solution to solving the Southwestern United States water crisis, but there are certain steps individuals can take to conserve the water we already have.

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