Is Alfalfa Integral to the Colorado Agriculture Industry?
(an assessment of Colorado Crop Yield during an active drought)

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Business, Economics, and Society

Abstract

The Colorado River Basin (CORB) is an integral water source in the Southwestern United States. It supplies water to over 40 million people and irrigates approximately 5.5 million acres across the basin. This water system is currently under extreme stress due to an ongoing drought that has persisted since 2000. This historic drought is causing severe depletion of key reservoirs like Lake Powell and Lake Mead. This study evaluates how Colorado's agricultural water demand, specifically for the livestock feed crops alfalfa and corn, impacts the Colorado River's water levels alongside drought conditions. Using regression analysis and data over the period of time from 2000 to 2020, the study models the relationship between water demand as a function of crop-specific irrigation needs, temperature, precipitation, and water levels at Lake Powell against Colorado River levels. This study will highlight how water intensive alfalfa farming may exceed regional water supply, with corn presenting as a potentially more sustainable alternative due to its lower irrigation demand. The findings will also show the importance for adaptive agricultural practices and resource allocation. This will help to manage water security within the CORB as climate pressures intensify. This research provides information into balancing agricultural productivity with water sustainability in drought times for the CORB.

KEYWORDS: (Alfalfa, Colorado River Basin, Drought)

On my honor, I have neither given nor received unauthorized aid on this assignment.

William Hanson
Signature

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Introduction

The Colorado River Basin (CORB) is located in the southwestern United States. It occupies an area of about 250,000 square miles and supplies water resources to seven basin states (Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming), 29 different Tribal Reservations, and some of Mexico. The Colorado River is approximately 1,400 miles long and originates along the Continental Divide in Rocky Mountain National Park, Colorado, and ends where it meets the Gulf of California in Mexico. The head of the river originates in the Colorado Rocky Mountain snowpack which consequently, river levels are very dependent on. The two largest and most important reservoirs are Lake Powell and Lake Mead. They are both an integral part in the delivery of water downstream as well as the creation of energy to the surrounding areas (Kelly A, 2023). The Colorado River and its tributaries provide water to nearly 40 million people for municipal use and supply water to irrigate nearly 5.5 million acres of land. It is the lifeblood of many differing people and practices across the basin (Bureau of Reclamation, 2012). Furthermore, the United States also has a delivery obligation to Mexico which includes some of the Colorado River waters according to a 1944 Treaty with Mexico. In 2012, the treaty was redefined to include regulations to the required delivery if Lake Mead levels were to fall.

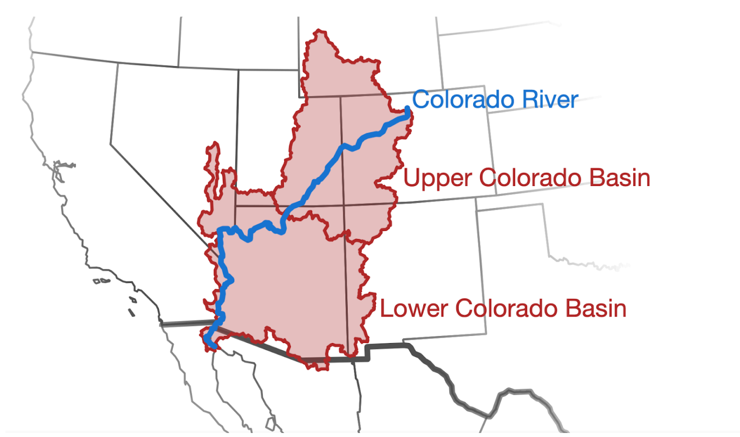


Figure 1: The Entirety of the Colorado River Basin [U.S. Geological Survey OWDI]

This Western river basin is currently facing an active drought as declared by the Bureau of Reclamation, Interior. In 2007, the Bureau of Reclamation issued a final environmental impact statement that proposed specific shortage guidelines and management strategies to help address the lower basin shortages in the Lake Powell and Mead reservoirs. The department proposed that these guidelines stay in effect until 2026 when the drought will then be reevaluated. Furthermore, in 2023, the Biden and Harris administration advanced all long term planning efforts to protect the stability of the Colorado River Basin and strengthen water security in the West. This shows how critical of a drought the Colorado River Basin is experiencing. The interim guidelines from 2007 are under review and new guidelines are said to be released in 2027 (Bureau of Reclamation, Interior, 2007/2023).

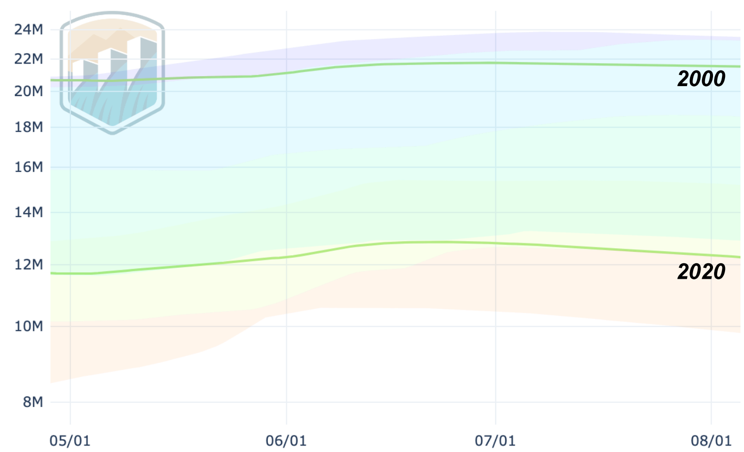
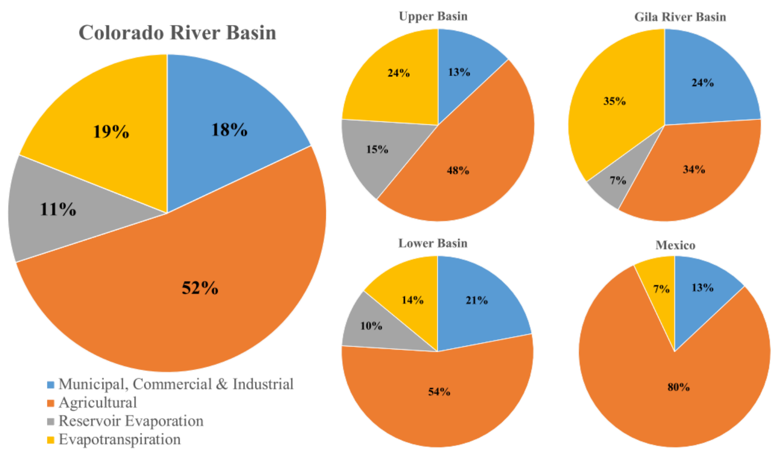
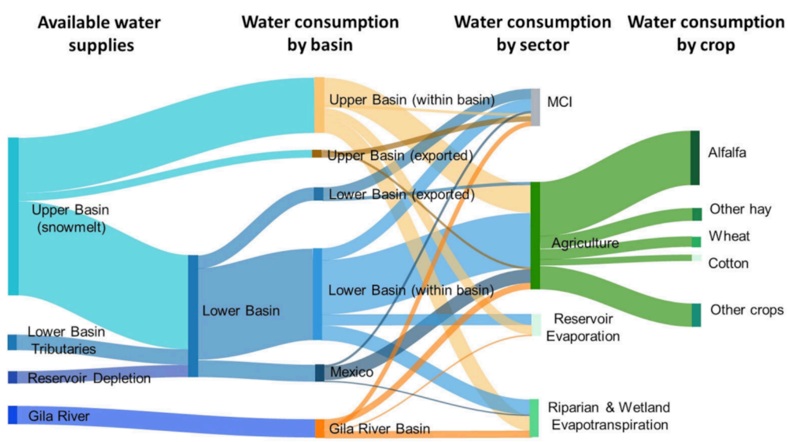


Figure 2: Bureau of Reclamation Water Operations Lake Powell Storage in Acre-Feet (millions)

A Colorado River Basin Water Supply and Demand Study was conducted in 2012 by the Bureau of Reclamation to help put into perspective the crisis on our hands. In their executive study, they describe four future model predicted scenarios that were conducted. The most likely outcome is that "future climate will continue to warm with regional precipitation and temperature trends" (Bureau of Reclamation, 2012). The Bureau also conducted a study in 2011 that gathered ideas from people on varying areas regarding the vulnerability of the river basin and categorized them based on their ability to increase the water supply, decrease the water supply, modify operations, and governance and implementation. In light of the active drought, basin states have made solid headway on developing other water resources and programs. No one solution will solve the problem for the entirety of the Colorado River Basin so many people will have to take accountability and work together to do their part (Bureau of Reclamation, 2012).





Figures 3 & 4: Colorado River Accounting Basics and Model of Water Resources and their Uses on the Colorado River Basin (Richter and Lamsal, 2024)

According to the Colorado Division of Homeland Security and Emergency Management, drought is one of the few environmental hazards with the potential to impact the entire population of Colorado. This can lead to an array of restrictions on water use in highly affected communities. It can also cause low water quality, sharp increase in prices, and limited access to recreational areas. Furthermore, severe droughts can also impact the state's agriculture industry and greatly limit readily available produce. In 2022, Colorado brought in over $2.5 billion in field crops according to the USDA.

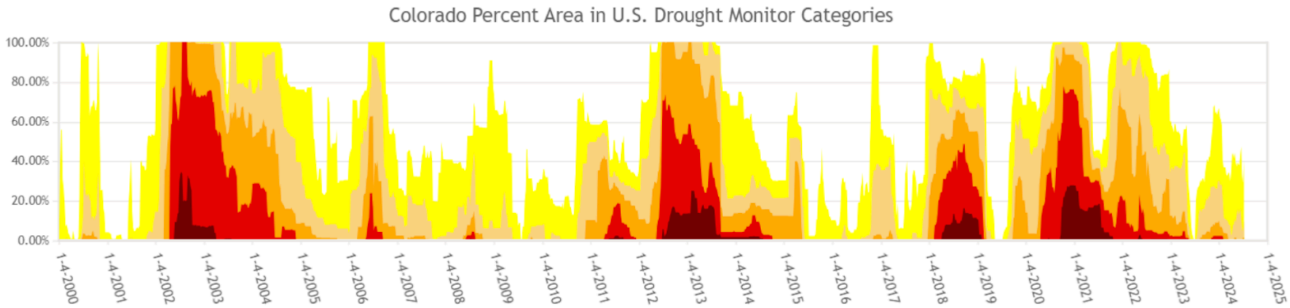


Figure 4: Historical Drought Conditions 2000-2024 [US Drought Monitor]

The Colorado River has a considerable agricultural industry statewide that depends on its water use. Its top producing farms consist of the Northeast region of the state. A few of its top revenue producing counties are Weld and Yuma which bring in just under $3 billion annually (Census of Agriculture USDA, 2017). Alfalfa is an essential agriculture crop grown in Colorado, especially across the northeast. It is a feed crop similar to hay and its value is in providing feed for Colorado's beef and cattle industry. Alfalfa is a perennial crop noted for improving soil health and having a higher potential yield than any other forage crop in Colorado. It can tolerate certain levels of drought and counters the effects by having deep roots in the soil but in turn this leads to alfalfa being a very water intensive crop. Its growing season is the summer months of May to August and is abundantly grown in the Northeast region of Colorado. According to the 2021 Colorado Agricultural Statistics, alfalfa brought in just under $500 million in 2020. Furthermore, alfalfa requires 3 to 6 acre feet of water annually to irrigate an entire acre. An acre foot is a unit of volume used to measure the amount of water needed to cover one acre of land to a depth of one foot. In 2022, alfalfa consumed more than 2 trillion gallons of irrigated water in Colorado.

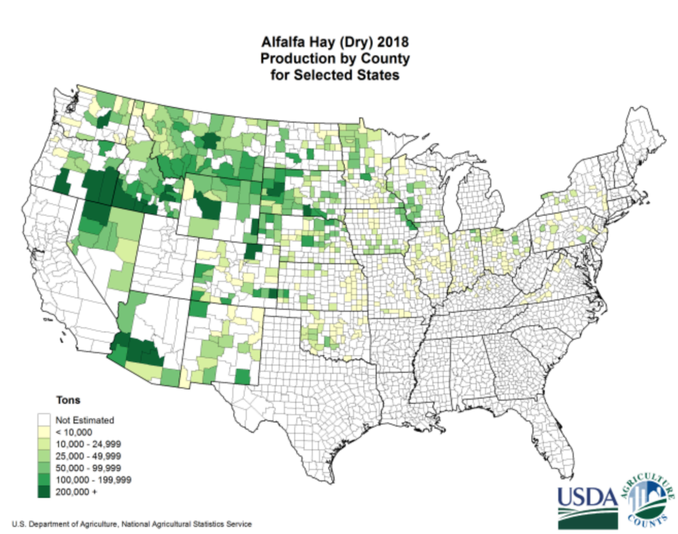


Figure 6: Alfalfa Production Across The US [United States Department of Agriculture]

Alfalfa and other forage grasses cover more than half of the farmland in the Colorado River Basin. A study found that alfalfa and other cattle feed crops consume 46% of the water that is diverted from the river (Fu, 2022). Another cattle feed crop that can be used as an alternative to alfalfa is grain corn grown for silage. It is also grown over the summer months of May to August but unlike alfalfa, corn is not a perennial but an annual crop. Most corn acreage is irrigated, either by furrow or sprinkler systems. Furthermore, corn is a less water intensive crop and only requires 2 acre feet of water (Woods, 1988). Alfalfa and corn are Colorado's largest cattle feed additive crops and provide good sources of protein for muscle support and energy for sustained health. The effects of increased temperatures lead to a larger decrease in yield on grain, such as corn, than on vegetative growth, such as alfalfa, because of the overall increased minimum temperatures (Hatfield, 2015). This study hopes to examine the relationship between these two feed crops and weather parameters against the Colorado River levels to determine the best crops to grow for sustaining crop yield during an active drought.

Literature Review

With an ever growing population, the challenge of meeting the projected double in global food demand by 2050 is ever so difficult. The agriculture industry will always need to be innovative if it wants to keep up with food demand in regards to populations all around the world. Some studies have analyzed promising strategies for increasing crop yields per unit of land. One specifically has concluded that irrigation and watering systems need to be improved upon such as desalination. Irrigation with desalinated water improves yields and saves water (Assouline, 2015). They focused on maintaining levels of output while looking for ways in managing a marginal resource such as fresh water regardless of its restrictions.

Approximately 80% of the Colorado River's water is used for agriculture. The remaining water then has to supply the rest of the basin with other resources such as hydropower or municipal supplying drinking water to 40 million people daily. The largest user of that 80% portion is the Imperial Irrigation District located in Southern California. Even without any pressure of ongoing drought the IID uses 20% of the rivers flow, usage trends approach system criticality. Furthermore, there is a substitute relationship between water quality and water quantity. There is a steady decline in the productivity of irrigated water as salinity levels increase in the soil (Moore, 1974). To any downstream water user in the CORB, in this study it pertains to anyone below Lees Ferry, income can be viewed as an external loss due to upstream developments such as over watering. Now add that to the accumulating number of years the CORB has been in this drought.

According to water year precipitation accumulations in the 2024 Colorado Climate Assessment Report, four of the five driest years for the Colorado river Basin have occurred since 2000. Northwest Colorado summer precipitation has decreased 20% in years from 1951 to 2000. Southwest Colorado spring precipitation has decreased 22% in that same time frame. The future change in annual precipitation is much less clear than that of temperature and the spring snowpack is expected to decrease in the coming years. This will result in an earlier runoff timing coming from the Rocky Mountains which can lead to a lower streamflow throughout the river basin (Bolinger, 2023).

The statewide annual average temperatures in Colorado warmed by 2.3°F from 1980 to 2022 and significant further increases are expected in the future across all seasons (Bolinger, 2023). For lower elevation areas in Colorado such as the plains, elevations around 5,000 feet or less, average temperatures (°F) are observed in the teens for winters and often reach high nineties in the summer months. Some studies have used climate projections combined with hydraulic models to simulate future systematic changes in the Colorado River Basin and elsewhere. The main findings is that April 1 SWE (snow water equivalent) is likely to decline across the Colorado River due to impacts of warming temperatures. Snow water equivalent determines the amount of water available in the snow. The Rocky Mountains act as a natural reservoir by collecting snow in the winter and releasing it in the spring as temperatures increase. Snow is a key source of water for ecosystems and people in the Northwest and helps water and resource managers plan for water use across categories such as municipal use, agriculture, and hydropower (Climate Hubs, USDA).

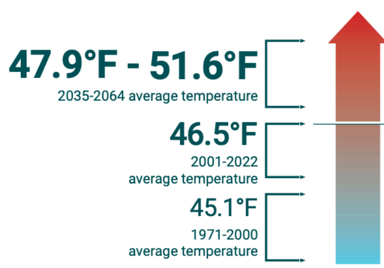


Figure 7: 2023 Colorado Climate Assessment Report

Outcomes such as crop yield and profits have always been linked to independent factors such as weather, climate or precipitation according to many studies. The importance of feed crops lies in its ability to provide for Colorado's beef and cattle industry. These studies also span several different disciplines and methods to reach their results. Agronomic studies focus on a crop's yield and emphasize the dynamic physiological process of the plant's growth as well as the complex system that is farming and agriculture as a whole. This process is known to be quite complex and dynamic in nature and thus not easily put into a regression framework. Instead, some studies use intense theoretical frameworks to simulate crop yield models to better understand the question they are asking. These simulations are strong in assessing a large distribution of weather outcomes over a growing season. A weakness to this approach is the uncertainty about the function farming process of the crops. Some agronomists seem to worry about possible misspecification and omitted variable biases since there is no certain account for behavioral response on behalf of farmers (Long et al. 2005). Evenso, this approach is the predominant tool used to evaluate likely effects from climate change on crop yields (Schlenker, 2008).

The other drawback that comes with crop simulation models is that they are unable to account for a whole agriculture sector; rather, they focus on an individual crop. Several economic studies use hedonic models to link land values to land characteristics: including climate (Mendelsohn et al, 1994). This approach or adaptation can also account for behavioral responses in the data or model. Cooler area crop yields have the potential to mimic that of warmer areas if farmers are conscientious of their crops choice, management, and land values changing in accordance with the cross-section of climate (Schlenker, 2008).

Some other studies choose to focus on the importance of the growing stage of crops and put their efforts into understanding the value proposition that irrigation and other water management brings to agriculture and ultimately to crop yield. Furthermore, droughts are greatly considered seeing that they affect more people globally than any other natural hazard (Bryant, 2005). One study used the Water Resource System for the United States (WRS-US) model version 2.0 within the MIT Integrated Global System Model-Community Atmosphere Model (IGSM-CAM) modeling framework. This framework allowed them to track the effect of irrigation during water shortage on crop yields. This study predicted a decrease in crop production is caused due to climate stress and increase in water demand elsewhere (Blanc E, 2017). Using this model the researchers determined future water allocation across multiple sectors and found that in the Western part of the United States, water demand for irrigation is the highest.

The Murray-Darling Basin in southeast Australia is also experiencing one of the most severe recently observed droughts. The Colorado River and Murray-Darling Basins are roughly the same size. This drought is driven by several years of deficit rainfall as well as an increase in temperatures (Leblanc, 2009). Nearly 67% of the basin is agricultural land which is used for pasture and cropping (Australian Bureau of Rural Sciences). Just like the Colorado River Basin, the Murray-Darling Basin is struggling to meet its water needs because of the sheer amount of water required by the agriculture industry as well as all the other functions that need water such as energy or municipal. In terms of the current Colorado River Basin, the drought has been active since the year 2000 and live updates are posted by location and are provided by the NDMC, USDA, and NOAA.

Methodology

The intention of the analysis conducted in this study is to assess agricultural decisions during an active drought in the Upper Colorado River Basin. The study consists of two regressions that will measure the relationship between Colorado alfalfa and corn, both as livestock feed, against the ever decreasing water levels of the Upper Colorado River Basin. The results hope to shine light on certain decisions behind Colorado's agricultural industry and offer a more sustainable option for farmers during an active drought. The time frame that this study occurs in is during the years from 2000 to 2020. Colorado is still in this drought as stated by the Bureau of Reclamation and further drought expectations have been posted for review in 2026. The sample size in this multivariable regression analysis is small due to the fact that Colorado is still in the midst of this drought and observed data for recent years has not been released yet. The results of this study will act only as a suggestion derived from experimental results as I am not an agronomist.

All observed data in this multivariable regression analysis have been collected annually from the years 2000 to 2020 during the growing season (summer) of Colorado alfalfa and corn. Colorado River levels are easily determined by discharged water flowing downstream and is collected all across the state at different intervals of the river. The interval at Lees Ferry, Arizona was chosen for this study because it is the lowest point in the Upper River Basin and is frequently used to measure water allocations for downstream regions. The dependent variable in this study is Colorado River levels as described by average discharge in cubic feet per second annually between the months of May and August. This regression contains two basic independent variables. The first being year over year change in temperature (°F) and the second being precipitation (inches) each year across the specified summer months. Both values have also been collected annually over the years 2000 to 2020. I also included an independent variable tracking Lake Powell water levels in millions of acre feet. This data was taken from the Bureau of Reclamation and is used to sustainably provide water to those on the CORB.

The last independent variable in regards to crop yield in each equation has been modified so that crop yield is a function of irrigation water demand ($10^8 m^3$) for each crop because irrigation is more directly related to river levels than actual yield. In other words, the amount of water required for growth is more directly related to river levels than the output of the crop after harvesting. In order to accomplish this, measures such as net irrigation quota, effective precipitation, and sown crop area have all been collected across the desired years and made into a formula (Hua, 2023). The expression for water demand represents a function, where the variable W is determined by three key factors. ET_c is the combined amount of water lost from the soil through evaporation and from plants through transpiration. In this study, ET_c for alfalfa is 942.34 and for corn 589.28 is which represents their water requirement to combat evapotranspiration which is measured in millimeters found on the USDA's agriculture website. It is critical in measuring water needs as higher rates indicate more water is required for crop growth. P_{ann} represents the annual average growing season precipitation and D is sown acre in acres of the two crops each year.

In 1991, the Land and Water Development Division of the Food and Agriculture Organization of the United Nations created this irrigation water demand model called CROPWAT to understand irrigation, planning, and management. This model is also used to predict schedules; however, I have taken the basics of the formula to solely acquire the water demand data for both the alfalfa and corn variable respecting the two regressions. The variables for this equation are located below and will be incorporated as the fifth variable in each regression equation. I only modified the monthly precipitation to annual to match the parameters of this study as shown below (Hua, 2023). The irrigation utilization coefficient (η, eta)) is .85 and is the measurement of the amount of water actually being used by the crops divided by the water applied in total (San Diego, 2010).

ET_c = is the crop water requirement (mm) P_{eff} = is the effective precipitation (mm)
P_{ann} = is the annual precipitation (mm) I = net crop irrigation quota (mm)
W = is the irrigation water demand D = sown area of the crop (hm^2)
η = irrigation utilization coefficient (.85) (eta)

$W = f(ET, P_{ann}, D)$ $W = (ET - 125 + .01xP_{ann})D$

$W = \frac{1}{1000}((ET - 125 + .01xP_{ann})D)/\eta$ $P_{eff} = 125 + 0.01 * P_{ann}$

$$I = ET_c - P_{eff}$$

To find out if alfalfa and corn have a strong negative relationship with the CORB I plan to run two regressions and compare the results. I will begin by developing two separate equations that describe the impact of crop production on Colorado River Levels. The first being the effect of Colorado alfalfa yield, temperature, and precipitation, on Colorado River levels and the second being the effect of Colorado corn yield, temperature, and precipitation, on Colorado River levels where sown area (D) of crop will be defined as the sown area of alfalfa year over year from 2000 to 2020. The second equation will match that of the first except the sown area of the crop will be represented by the sown area year over year of corn. The sown area is represented in acres and is taken from the annual Colorado Agricultural Statistics Bulletin. These results will help determine which crop, a vegetative hay or corn grain, is more sustainable to grow in the Colorado Northeast during an active drought. The regression equation was taken and modified from a study conducted on crop yield's response to dry versus irrigated lands (Lu, 2017). I have taken this equation and switched the dependent variable with Colorado River levels. I then inserted my own independent variables that I believe have some consequence to CORB and its water resources. I estimated a river levels response function by specifying fixed variables for a model where y is the annual discharge of the Colorado River in year k. Figures α_0, α_1, α_2, α_3, and α_4 are all parameter estimates and t and p are temperature and precipitation variables respectively in year k. The parameters estimates in the second regression are represented by the β figure. The other variables l and w represent Lake Powell water levels in acre feet and the water demand function with respect to the two different crops with e as the error term. The equation as well as the two separate regressions are as follows:

$$y_k = \alpha_0 + \alpha_1 t_k + \alpha_2 p_k + \alpha_3 l_k + \alpha_4 w_k(i) + e$$

Colorado River Levels = α_0 + α_1(Temp) + α_2(Precip) + α_3(LP)+ α_5(Water Demand(Alfalfa yield)) + e

Colorado River Levels = β_0 + β_1(Temp) + β_2(Precip) + β_3(LP)+ β_4(Water Demand(Corn Yield)) + e

The regressions should show the strength of the relationship between Colorado River levels amongst the independent variables and the switched variables of alfalfa and corn. In light of the study, the relationship, or coefficients in the equation, between alfalfa and river levels should be greater due to the fact that alfalfa requires an average of 4.5 acre feet of water to irrigate an acre against corn's average of 2 acre feet as specified earlier.

Results and Analysis

The regressions were run on the computer program R Studio to measure the statistical relationships between the observed data. A few prerequisite tests were also run in order to determine validity and significance. The tests were run for both regressions used in this study. First, I tested for heteroskedasticity which checks if the variance of errors is not constant across all observations. There was no significant p-value so using the Breusch-Pagan Test I was able to cancel out any heteroskedasticity. Secondly, I used the Durbin-Watson test to find if there was any autocorrelation amongst the observations. Autocorrelation refers to the degree of correlation of the same variables between two successive time intervals. This also has no significant p-value; therefore, I can rule this out. I also tested for multicollinearity and found that the observed data has a very moderate amount and no two variables are over correlated, which is perfectly adequate for such a method. Using R Studio, I was also able to test for normality of residuals among the observed data using a QQ Plot. I was able to determine that the distributions do not deviate from the theoretical. Finally, I was able to run the two regressions, the results are shown below:

Table 1: First Alfalfa Regression - Multiple R-squared: 0.139, Adjusted R-squared: -0.076
F-statistic: 0.646

Coefficients	Estimate	Std. Error	T-Value
Intercept	1.351e+04	6.134e+03	2.203
Average Rain	4.061e+02	3.478e+02	1.167
Change in Temperature (YoY)	1.754e+02	3.260e+02	0.538
Lake Powell Water levels	-7.501e+01	2.597e+02	-0.289
Water Demand	-4.786e-03	1.442e-02	-0.332

Table 2: First Corn Regression - Multiple R-squared: 0.1348, Adjusted R-squared: -0.081
F-statistic: 0.6233

Coefficients	Estimate	Std. Error	T-Value
Intercept	1.181e+04	4.163e+03	2.837
Average Rain	3.625e+02	3.375e+02	1.074
Change in Temperature (YoY)	1.682e+02	3.537e+02	0.476
Lake Powell Water levels	-1.247e+02	1.952e+02	-0.639
Water Demand	3.763e-06	2.126e-05	0.177

The multiple r squared suggests that only a small amount variation in the dependent variable can be explained by the independent variables (average rain, temperature change, Lake Powell water levels, and water demand). The adjusted R squared value accounts for the number of predictors in the model. The multiple r-squared for the corn model is 0.3118, which is higher than the alfalfa model's 0.139. This could be that about 31.18% of the variability for corn is explained by the model, compared to only 13.9% in the alfalfa model. However, with an adjusted r-squared of -0.1, it still shows that the model may not be the best fit for the data. It also means that I have to reject such results because the negative value indicates the predictors aren't contributing useful information in predicting the dependent variable. Since the two adjusted r-squared values are negative, relevant predictors or alternative modeling approaches could improve the model. The two intercept values in the tables above predict the value of the dependent variable when all other variables are zero. For every unit increase in average rain, change in temperature, Lake Powell levels, or water demand for the two crops the dependent variable is estimated to increase by the value in the respective estimated value, holding all other variables constant. The low t value for Lake Powell water levels suggest a weak effect. Furthermore, change in temperature and water demand also have low to negative t values so this effect is minimal suggesting no significant impact. In the context of sustainable water systems, the lack of strong, predictive relationships may highlight how tough it is to accurately model water needs for alfalfa or corn in such drought conditions. An f-statistic of 0.646 and

0.6233 is quite low, indicating that the whole models do not significantly explain the variation in the dependent variable. After some further research, a common approach to such issues is taking the natural log of all variables present in the regression dependent variable too (Pathak,2022). The results to the two modified regression can found below:

Table 2: Second Alfalfa Regression - Multiple R-squared: 0.296, Adjusted R-squared: -0.1734
F-statistic: 0.6305 - Taking the Natural Log of all variables

Coefficients	Estimate	Std. Error	T-Value
Intercept	13.19201	10.51054	1.225
Average Rain	0.22686	0.39162	0.579
Change in Temperature (YoY)	-0.02065	0.11029	-0.187
Lake Powell Water levels	-0.08797	0.40639	-0.216
Water Demand	-0.29653	0.85545	-0.347

Table 2: Second Corn Regression - Multiple R-squared: 0.3118, Adjusted R-squared: -0.1
F-statistic: 0.6796 - Taking the Natural Log of all variables

Coefficients	Estimate	Std. Error	T-Value
Intercept	9.50345	1.38735	6.850
Average Rain	0.08653	0.41477	0.209
Change in Temperature (YoY)	-0.04997	0.11468	-0.436
Lake Powell Water levels	-0.18869	0.32677	-0.577
Water Demand	0.01936	0.03790	0.511

Even after transforming the variables into natural logs, the model still does not explain much of the variability in the dependent variable. The multiple r-squared for the alfalfa model is only slightly lower than for corn. This shows that both models explain a similar percentage of the variance in the dependent variable. Similarly, the negative adjusted r-squared in both regressions suggests that the models might be overfitted or that the variables selected do not explain any variability in the outcomes for these two crops. Similarly to before, the low f-statistics suggest the predictor variables collectively do not significantly explain the variance in the outcomes for either crop as well. The intercept for alfalfa is higher than that for corn. This means that there is a higher baseline production or value for alfalfa when all predictors are at zero. Both models show a positive coefficient for average rain; however, with low t-values in both situations this effect is not statistically significant for either crop. The temperature change coefficient is negative, but very small, for both models. This indicates that year-over-year temperature changes have a minimal impact on either crop's outcome in this model. For Lake Powell water levels, higher water levels may correlate with slightly lower outcomes in both crops except the low t-value shows the low significance. Lastly, the water demand coefficient is negative for alfalfa and positive for corn. The difference in signs could suggest that increased water demand might negatively impact alfalfa production while having a slightly positive effect on corn. However, the significance is also negligible here. These two models show minimal explanatory power for both alfalfa and corn when using the natural log transformation on all of the variables.

The inconclusive results could also be due to an interaction term. This does not isolate the impact of crop production. That could mean that a lack of rain, or heat extremes during the growing season could also have some amount of impact on Colorado River water levels. Following the results I completed a sample t test on R Studio as well. It is a statistical hypothesis test that compares a sample mean to a specific value to determine if they are different. The test also measures the probability of the null and alternative hypotheses. The null being the predicted water demand for alfalfa is equal to the mean predicted water demand for corn. On the other side, the alternate hypothesis is that the mean predicted water demand for alfalfa is not equal to the mean predicted water demand for corn. The test proved that the average demand for alfalfa is the same as the average demand for corn in the sample with a $t = 0$ value. The degrees of freedom for the test is just barely under 40. This value is then used in the test statistic to determine how much variability is expected in the data. Lastly, the p-value of 1 says that there is no significant difference between the two means of the groups. If the p-value is less than a significance level, which in this case it is, we reject the null hypothesis, suggesting that the predicted water demand differs significantly between alfalfa and corn.

Conclusion

This study aimed to assess the relationship between water demand, average rainfall, temperature changes, and Lake Powell water levels on the production of two crops, alfalfa and corn, using regression analysis. The analyses were conducted in order to measure the statistical relationships and test for validity and significance in the data. The results, unfortunately, highlight that the regression models used in this study provide limited explanatory power. In all models, the t-values associated with most of the predictors were low, showing that the individual variables (average rainfall, temperature changes, Lake Powell water levels, and water demand) had a very small impact on crop outcomes if not at all. Moreover, the water demand coefficient showed different signs for the two crops: negative for alfalfa and positive for corn. Although the difference means that increased water demand may slightly decrease alfalfa production while having a small increased effect on corn, the insignificance of the coefficients says that this is unlikely.

Progress is better than no progress at all; therefore, it is important to remember the sheer size of the Colorado agriculture industry and how there can be many factors that result in lower river levels. While the regression results were inconclusive, it is important to recognize the broader implications of water usage, particularly during the ongoing Colorado River Basin drought. The CORB is facing unprecedented low water levels due to prolonged drought conditions exacerbated by climate change. These conditions directly interfere with agricultural productivity in the upper basin, particularly for crops like alfalfa and corn, which have high irrigation water demands. Despite the lack of definitive results in this study, progress has been made in understanding the relationship between water resources and crop production. As the CORB continues to face water shortages, advancing sustainable agricultural practices is integral in preserving the balance between agricultural productivity and the need for long term water conservation. Both alfalfa and corn for silage are integral to the cattle and beef industry in Colorado. In order for that industry to grow and thrive during an active drought some farmers may have to make an executive decision to switch to a more water sustainable crop and do their part in saving the Colorado

River Basin. Please see the Bureau of Reclamation's website for drought control for further updates and live drought information in the CORB.

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