Almond Fields Forever: Efficient Agricultural Water Use in California

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Abstract

Agriculture uses about 80% of California's developed water use, and many crops that are considered water-intensive are grown exclusively in California.
Diverting water resources away from agriculture will have dramatic consequences for California's economy and for food production all over the world. Total diversion of water away from agriculture may not be a viable option for the state, but perhaps reevaluating which crops are grown in California could aid in effective water use and management, as well as secure water supplies for the coming years. Our project aims to analyze a selection of water intensive crops grown in California, and create a cost benefit analysis looking at gallons of water used, and money brought into California's economy. In this way, we may be able to assess whether California should grow water intensive crops in the context of a state-wide drought. We will analyze rice, almonds, grapes, alfalfa, and avocados, and assess whether California growers should scale back or limit production of these water intensive crops. We will create a cost benefit analysis for the top water intensive crops grown in California by looking at the value of water used by the crops versus income the crop generates for the state. This analysis may provide California water managers with the information necessary to efficiently distribute water resources across the state to people and industries that need them.

Introduction

With over 80,500 farms and ranches in the state, California is the largest agricultural producer in the United States, earning $44.7 billion in agricultural cash receipts in 2012 alone. However, with California's water resources dwindling in the recent drought, legislators and the public are critically analyzing how agriculture affects the state water supply. In the coming years, the State of California will need to find a way to conserve its water resources for cities and industry while maintaining its agricultural economy and food production. Our project aims to analyze rice, almonds, raisin grapes, alfalfa, and avocados, and assess whether California growers should scale back or limit production of these water intensive crops. We will create a cost benefit analysis for some of the more water intensive crops grown in California by looking at the value of water used by the crops versus income they generate for the state. We will then make a recommendation for policy makers about whether or not to scale back production of these water intensive crops in order to conserve California's water resources.

Objective

The main objective of this project is to create a cost benefit analysis of five water intensive crops that are grown heavily in California. The project has three main tasks:

(1) Data collection: including crop water usage, and income generated by the crops.

(2) Data analysis: e.g. ET=Kc*ETo

(3) Drawing conclusions from the information and considering future policies and regulations for agricultural water use.

Hypothesis

We hypothesize that California could be using its water resources more efficiently in this

time of drought if water intensive crop production were effectively scaled throughout the state.

Data Sources

To determine crop revenue to the State of California, this project used existing data from reports collected by the United States Department of Agriculture (USDA) and the National Agricultural Statistics Services, http://www.nass.usda.gov/Statistics_by_State/California/Publications/California_Ag_Statistics/2013cas-all.pdf.

Crop evapotranspiration rates were calculated using data from the California Irrigation Management Information System (CIMIS) for both the San Joaquin Valley and the Sacramento Valley (http://www.cimis.water.ca.gov/) .

Crop coefficient values (Kc) values were taken from the Food and Agriculture Organization of the United Nations (FAO), (http://www.fao.org/docrep/X0490E/x0490e0b.htm#chapter%206%20%20%20etc%20%20%20single%20crop%20coefficient%20%28kc%29).

A variety of sources were used to determine the number of plants per acre for each analyzed crop. The number of almond trees per acre and the number of avocado trees per acre were determined using reports from the University of California Division of Agriculture and Natural Resources (UCANR), (http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=8539, http://ucanr.org/sites/alternativefruits/files/121267.pdf). The number of alfalfa plants per acre was determined using data from the California Alfalfa and Forage Association from the University of California Davis (http://alfalfa.ucdavis.edu/-

files/pdf/alfalfaFactSheet.pdf). The number of grape vines per acre was estimated using vine spacing recommendations from the San Francisco Chronicle (http://homeguides.sfgate.com/distance-between-concord-grape-vines-planting-56036.html). Lastly, the number of rice plants per acre was determined using rice seeding rate recommendations from the University of Arkansas (https://www.uaex.edu/publications/PDF/FSA-2157.pdf).

The valuation of agricultural water was determined from estimations given in California publications regarding the resale value of water, including NBC News, CBS News, and San Jose Mercury News. The links to these publications will be listed in the References section at the end of this report.

Methods and Assumptions

The cost of growing each crop was determined using annual evapotranspiration rates from the San Joaquin Valley and the Sacramento Valley to determine the amount of water crops use. The reference evapotranspiration rate used for alfalfa, almonds, avocadoes, and grapes was taken from CIMIS data from the San Joaquin Valley. Reference evapotranspiration rate was averaged over 30 CIMIS stations spanning the length of the San Joaquin Valley. The reference evapotranspiration rate used for rice was taken from CIMIS data from the Sacramento Valley, where the majority of California's rice is grown. This reference evapotranspiration rate was averaged over 12 CIMIS stations over the length of the Sacramento Valley.

The amount of water used per crop was determined using crop coefficient (Kc) values specific to each single crop. The amount of water transpired through each crop was calculated using the following equation:

$$ET_c = K_c ET_o$$

Midseason Kc values were used in calculating the daily crop evapotranspiration rates. These rates were then transposed into annual evapotranspiration values. The annual evapotranspiration values were calculated as a worst-case scenario, assuming each plant used the maximum amount of water possible during midseason for the crop year or growing season.

These results were used to determine the total water transpired by each crop throughout the San Joaquin Valley or the Sacramento Valley for rice. In order to determine the total water used, evapotranspiration rates were applied to the total number of single plants grown throughout either valley. The total acreage of agricultural land used by each crop was taken from the USDA. Values for the total number of plants grown by acre were determined using spacing recommendations from various sources, including the University of California and the University of Arkansas (see above). The total number of grapes per acre was determined according to average vine spacing recommendations of 7 foot vine spacing by 9 foot row spacing. The total number of alfalfa plants per acre was determined according to the number of seeds planted per acre (200,000 seeds per acre). Total number of rice plants per acre was also determined using the total number of seeds planted per acre (36 seeds per square foot). Alfalfa and rice calculations were made assuming that every seed planted per acre sprouted successfully. Total number of plants grown throughout the state was calculated by multiplying the total number of acres used per crop in the state and total number of plants per acre.

Statewide evapotranspiration by crop was calculated by multiplying the annual evapotranspiration per plant by the total number of plants grown in the state. This

evapotranspiration rate was converted to acrefeet per year. The cost of this water was valued according to the current resale value of agricultural water in the year 2014 of $700 per acre foot, as well as a past resale value of water in all other non-drought years of $50 per acrefoot.

In order to determine the net benefits of growing each crop in the State of California, a cost-benefit analysis was created according to the monetary value of water from each crop in comparison the revenue brought in to the state from the sale of each crop. The revenue from each crop came from data given from the USDA California Agricultural Statistics report from the 2013 crop year. This resulted in a net monetary value from each of the five crops per year for a drought year and a non-drought year.

Calculations and Results

The performed cost-benefit analysis of the 5 studied crops is summarized in the figures below for both the drought year and the non-drought year water values.

Crop	Value of Water(Current Resale $700)	Total Crop Value	Net Benefits
Alfalfa	$21 trillion	$1.20 trillion	-$19 Trillion
Almonds	$2.02 billion	$6.38 million	$4.36 billion
Avacados	$2.43 billion	$369 billion	$366 billion
Grapes	$4.03 billion	$829 billion	$825 billion
Rice	$133 trillion	$1.00 trillion	-$132 Trillion

Figure 1: Cost-Benefit analysis of California Crops according to the drought resale value of water.

Crop	Value of Water (Prior Resale $50)	Total Crop Value	Net Benefits ($)
Alfalfa	$1.48 trillion	$1.20 trillion	-$283 billion
Almonds	$145 thousand	$6.38 billion	$6.24 billion
Avacados	$173 thousand	$367 billion	$368 billion
Grapes	$28 thousand	$826 billion	$829 billion
Rice	$9.51 trillion	$1.00 trillion	-$8.51 trillion

Figure 2: Cost-Benefit analysis of California crops according to the resale value of water in non-drought years.

Conclusions

According to the cost-benefit analysis, at both the current value of water ($700 per acrefoot) and the non-drought conditional resale value of water ($50 per acrefoot), both alfalfa and rice had net negative benefits for the State of California. This net negative value could imply an economic loss to the state or a monetary loss to individual growers in the state.

The other three crops analyzed, almonds, avocados, and raisin grapes showed overall net gains for the State of California both at the current resale value and the non-drought valuation of water. Though these crops may be water intensive in their own right, the results imply that these crops still bring revenue into the State of California, benefits which may extend to individual growers as well.

The net losses incurred by both alfalfa and rice could be a result of the volume of crops grown rather than the sheer amount of water used. High volume of alfalfa grown for livestock production and the high amount of seeds per acre may increase the water usage of this crop, even at a fairly standard evapotranspiration rate for the alfalfa crop. The high amount of seeds per acre as well as the high volume of water used on rice paddies may have increased the cost of growing rice in our valuation.

This valuation may have great implications for the economy of California and far reaching effects around the world. Ceasing production of rice or alfalfa in the state would affect trade throughout the country, as California is a primary exporter of these crops to several states and countries around the world. Loss of revenue of these crops may incur a loss to the state's economy. Loss of these crops may also affect the lives of growers in the state, as well as decrease the number of available jobs in the San Joaquin and Sacramento Valleys.

Recommendations/ Limitations

Based on our conclusions, we would recommend that the state consider scaling back production of both alfalfa and rice, rather than completely ceasing production. This would allow the state to collect some revenue from these crops while conserving water resources. This would also preserve the lives of the growers and their employees in the San Joaquin Valley and the Sacramento Valley. In order to find the optimal amount of alfalfa and rice to plant in the state, more research must be conducted in order to construct an optimization model for California's growers. Further data collection from individual farms or growers should be conducted in order to monitor the amounts of water used during regular farming operations in addition to water transpired by the plants during the growing season. Continued monitoring of California's water resources, including groundwater, should also be conducted in order to construct an accurate model for alfalfa and rice optimization.

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