California Water Quality: The Role of Agriculture

Hossein Farzin and Kelly Grogan

While California's agriculture has been vibrant and growing, the quality of the state's water bodies has weakened. However, despite the common perception that agricultural production is a principal culprit, our study shows that this is not generally true. It shows that only a very small portion of water pollutants attributed to agricultural production are actually positively correlated with agricultural production while the majority of the pollutants have *no* relationship, and some of them are even *negatively* correlated.

A 2004 assessment by the U.S. Environmental Protection Agency (Table 1) found that about 93 percent of the state's water is "impaired," a term that means the body of water cannot be used for at least one of its designated uses. These uses may include recreation, commercial fishing, agricultural water supply, drinking water supply, and wildlife habitat, among others. About five percent of assessed bodies of water are "threatened," meaning that there is a high probability that their designated uses will no longer be viable in the future. Only about three percent of the bodies of water assessed in the state are labeled "good," which means that the body of water can be used for all of its designated uses and none of these appear to be threatened. A variety of causes underlie these impairments, of which agriculture is commonly perceived to be a principal one. We have conducted a study to measure the relationship between a county's intensity of agricultural production and its water quality. A variety of water pollutants come from both agricultural and non-agricultural sources. Table 2 summarizes these sources.

As is apparent from Table 2, common water pollutants come from a variety of sources of which agriculture is only one. To complicate things further, all water within a watershed gets pooled together so it is not easy to know from which source the pollution is coming. Furthermore, different industries may have more effective mitigation of pollutants than other industries. Industry *A* may emit ten units of the pollutant each year but abate seven units, implying that only three units reach a body of water. Industry *B* may emit eight units but only abates two units, allowing six units of the pollutant to reach water bodies. As a result, industry *B* is responsible for a larger share of the water pollution even though industry *A* looks like a larger polluter.

To efficiently improve the state's water quality while facing budget constraints, policymakers should target the main sources of the pollutants instead of targeting any and all possible sources. As discussed, however, knowing the actual source can be difficult. One way to overcome these difficulties is to use regression analysis to see which factors are most highly correlated with levels of pollution.

Data

The water quality data for the study came from the EPA's STORET database. This database collects water quality data from a wide variety of sources such as the California Department of Water Resources, the EPA National Aquatic Resource Survey, the California Surface Water Monitoring Program, the California State Water Resources Control Board, and the National Park Service. Each sample in the STORET database represents one water sample that was taken from a specific location. Since most of the socioeconomic data are available at the county level, all samples were aggregated up to the county level by water body type and pollutant. For example, if county x had fifteen samples of nitrate levels in rivers, the mean, median, maximum, and standard deviation of these 15 samples were calculated. Similarly, if county y had 32 samples of sulfate levels in lakes, the mean, median, maximum, and standard deviation of these 32 samples were calculated. Each observation in the analysis that is reported below captures the underlying samples in this manner.

Agricultural production data came from the National Agricultural Statistics Service's County Agricultural Commissioners' Data, an annual report that contains the value of production by crop or animal product. The monetary values of crop and livestock production at the county level were obtained from these reports. To measure the intensity of production, these values were divided by the total land area of each county.

Unfortunately, measures of other economic activity, such as mining and industry, were not readily available at the county level. To make up for this, we included measures of a county's ethnic, gender, and age compositions. If an industry tends to employ a higher proportion of any of these groups, these variables will pick up those effects. We also included a measure of population density which will account for household sources of pollutants. Since the local population's demand for water quality influences local water pollution levels, we included measures of education and income. As important determinants of demand for environmental quality in general, these variables may

Table 1: Attainment Status of California's Water Bodies		
Attainment Status	**Miles**	**Percent of Assessed**
Good	910.21	2.78
Threatened	1,507.16	4.61
Impaired	30,287.89	92.61
Total Miles Assessed	**32,705.26**	**100.00**

Source: U.S. EPA. 2004. National Assessment Database. *http://www.epa.gov/waters/ir/*

affect water quality. We included a time trend to account for statewide improvements or deterioration due to, for example, changes over time in water pollution standards, monitoring, enforcement, or related technologies. Finally, we account for naturally occurring variation of pollutants between different types of bodies of water such as rivers, oceans, lakes, and estuaries. All data is at the county level for 1993 to 2006.

Empirical Analysis

To determine the relationships between agricultural intensity and water pollution, we estimated three regression models for each of the agricultural pollutants listed above. These three models examined the statistical relationship between the mean, median, or maximum level of a pollutant and variables that one might expect to affect the pollution level. For example, we estimated the relationship between the mean level of ammonia and various measures of county and water body characteristics that might affect ammonia levels.

Table 3 presents the relationships between measures of agricultural production and water quality indicators. As hypothesized, only a portion of pollutants associated with

Table 2: Water Quality Indicators and Agriculture

Pollutant	Natural (Non-human) Sources	Industrial Sources	Agricultural Sources	Household Sources
Ammonia	no major sources	coke plant emissions and effluent, ceramic production, mining	fertilizer runoff, animal waste runoff	septic systems, cleaning products, sewage treatment plants
Arsenic[a]	erosion of natural deposits	glass and electronics production runoff	orchard runoff	no major sources
Copper	erosion of natural deposits	no major sources	Insecticide runoff	plumbing system erosion
Dissolved Oxygen	warm weather, runoff from forests	thermal pollution	runoff from pastures, cropland	fertilizer runoff, wastewater treatment plants
Magnesium	erosion of natural deposits	construction and electronic industry runoff	fertilizer runoff	no major sources
Mercury[b]	erosion of natural deposits	refinery and factory discharge	cropland runoff	landfill runoff
Nickel[c]	erosion of natural deposits	power plant and metal industry emissions	fertilizer runoff	waste incinerator emissions
Nitrate[d]	erosion of natural deposits	no major sources	fertilizer runoff	fertilizer runoff, septic tank leaching, sewage
Nitrite[e]	erosion of natural deposits	no major sources	fertilizer runoff	fertilizer runoff, septic tank leaching, sewage
Phosphorus	erosion of natural deposits	industrial effluent	fertilizer and manure runoff	sewage effluent
Specific Conductivity	erosion of natural deposits	industrial inputs	agricultural runoff	road salt
Sulfate	erosion of gypsum, volcanoes	mining runoff, fossil fuel combustion	fertilizer runoff	no major sources
Total Coliform	naturally present, animal fecal matter	none	animal waste	human and animal waste
Total Suspended Solids	natural soil erosion	industrial wastewater	soil erosion	soil erosion from construction sites, sanitary wastewater
Zinc	erosion of natural deposits	alloys, paints, batteries, car parts, electrical wiring	insecticide runoff	sewage sludge

Source unless otherwise noted: EPA. 2008. Drinking Water Contaminants. *www.epa.gov/safewater/contaminants/index.html*

[a] *Texas Cooperative Extension. 2008.* Dissolved Oxygen. *http://aquaplant.tamu.edu/contents/dissolved_oxygen.htm.*

[b] *Water on the Web. 2008.* Glossary. *http://waterontheweb.org/resources/glossary.html.*

[c] *USGS. 2006.* The Effect of Urbanization on Water Quality: Phosphorous. *http://ga.water.usgs.gov/edu/urbanpho.html.*

[d] *Michigan Department of Environmental Quality.* Total Suspended Solids. *www.deq.state.mi.us/documents/deq-swq-npdes-TotalSuspendedSolids.pdf.*

[e] *Central New York's New Real-Time Surface Water Quality Network. 2008.* Specific Conductivity. *www.ourlake.org/html/specific_conductivity.html.*

Figure 1: The Percent Increase in Water Pollutant Given a 20 percent or 40 percent Increase in Animal Production Intensity

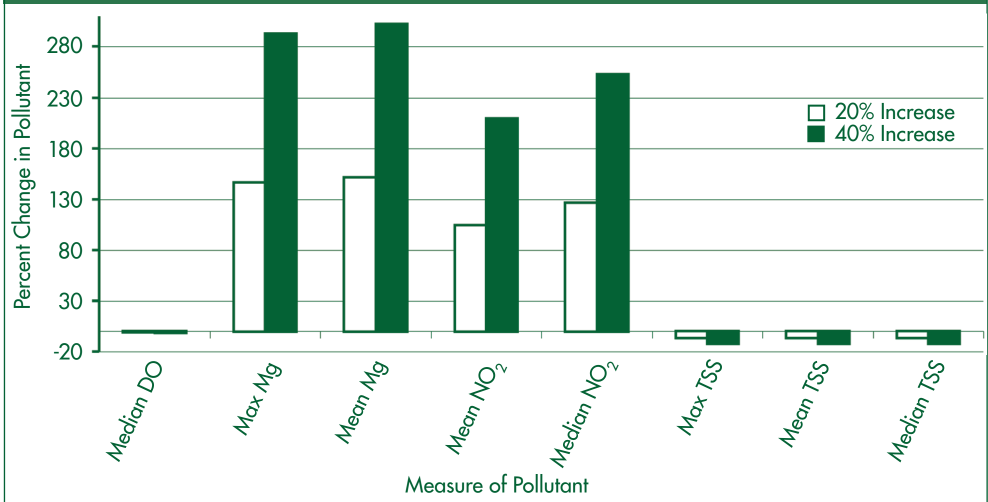


Figure 2: The Percent Increase in Water Pollutant Given a 20 percent or 40 percent Increase in Crop Production Intensity

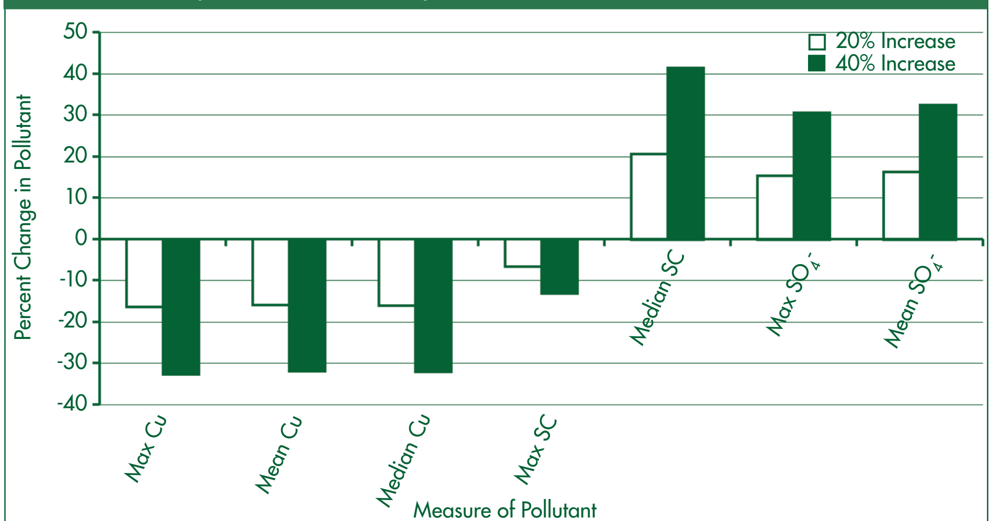
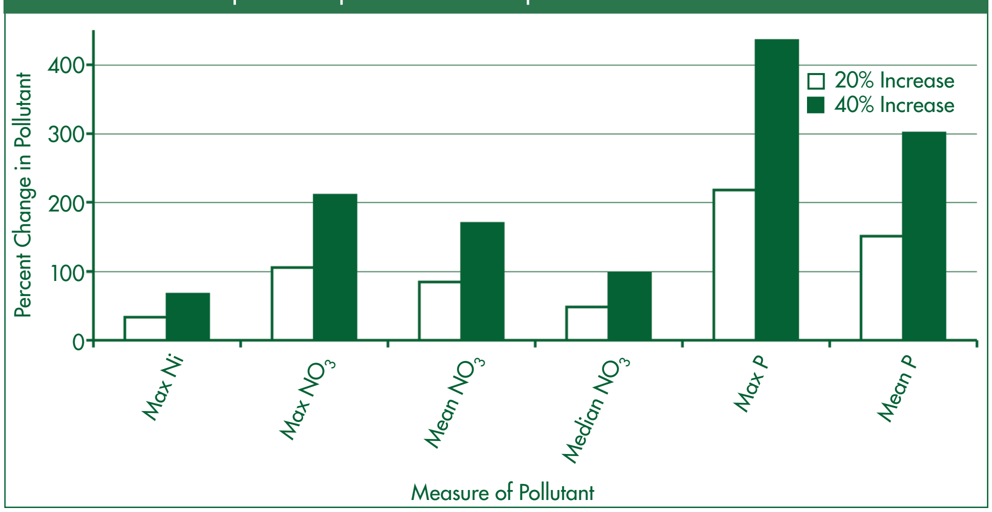


Figure 3: The Percent Increase in Water Pollutant Given a 20 percent or 40 percent Increase in the Hispanic Proportion of the Population



agricultural production are actually correlated with agricultural production in a statistically significant way.

We found that nitrites (NO_2^-) and dissolved oxygen (DO) depletion were positively correlated with the value of animal production per acre of county land. These correlations picked up the effect of animal-waste runoff. Animal waste contains nitrites, increasing the concentration of these nitrogen-containing ions in surrounding water. The nitrites, as well as other nutrients found in animal waste, encourage algal growth which decreases the concentration of oxygen in water. In areas with median levels of dissolved oxygen and nitrates, increasing the intensity of animal production by one percent decreases the quantity of dissolved oxygen by 0.02 percent and increases the concentration of nitrites by 5.23 percent.

While animal production is associated with worsened water quality with regards to dissolved oxygen and nitrites, total suspended solids (TSS) are negatively correlated with the value of animal intensity. This pollutant is associated with urban and suburban construction. Population density was positively correlated with this pollutant, suggesting that construction is a main source. It is possible that areas with high animal production such as Fresno and San Bernadino Counties are less likely areas for new development projects, perhaps due to the unpleasant odors of such operations. Thus, the negative impact of the animal-intensity variable may be picking up that effect.

The value of crop production per acre of county land was positively correlated with sulfate (SO_4^-) and specific conductivity (SC), a measure of the water's salt content. Increased sulfate concentrations in counties with high agricultural production are due to fertilizer runoff. Increasing the intensity of crop production by one percent is associated with a 0.81 percent increase in sulfate concentrations. Areas with high levels of agricultural activity like Tulare and San Joaquin counties have elevated specific conductivity due to the irrigation water applied to crops. All water, even fresh sources, contains some quantity of salts. Plants take up

Table 3: Correlation between Water Quality Indicators and Measures of Agricultural Activity

Pollutant	Impact of Crop Intensity	Impact of Animal Intensity	Correlation with Hispanic Population
Ammonia			
Arsenic			
Copper	-		
Dissolved Oxygen		-	
Magnesium		+	
Mercury			
Nickel			+
Nitrate			+
Nitrite		+	+
Phosphorous			+
Specific Conductivity	+		
Sulfate	+		
Total Coliform			
Total Suspended Solids		-	
Zinc			

** Blanks indicate no statistically significant correlation.*
*** (-) and (+) indicate statistically significant correlation at the 90 percent confidence level or more.*

the water, but leave the salts behind. With each irrigation application, more salts are added to the region's soil and surface water. In areas with median-specific conductivity values, increasing the intensity of crop production by one percent is predicted to increase specific conductivity by 1.03 percent.

Interestingly, value of crop production per acre of county land is negatively correlated with copper (Cu), a common ingredient in miticides. In California, mites are more common pests of some of the relatively lower-valued crops such as cotton and alfalfa than the higher-valued fruit and vegetable crops, so our value-weighted crop intensity measure likely picks up this phenomenon. It is also possible that farms growing higher-valued crops tend to implement mitigating measures, preventing the need for miticide use.

As a cautionary reminder while interpreting these results, it should be noted that the measure of agricultural activity used in the study weighs high-valued crops more heavily. As a result, if a certain pollutant is more heavily associated with lower-valued crops, or equally associated with all crops, the value measure will not pick up the effect of agriculture on the pollutant's level. One of the socio-economic variables we included in the analysis was the percent of a county's population that is of Hispanic ethnicity. Since this ethnic group makes up a large portion of the agricultural workforce, it is natural to suppose that this variable may be picking up the effect of agriculture. Interestingly, we found that this variable is positively correlated with nitrates, nitrites (NO_3^-), nickel (Ni), and phosphorous (P), pollutants often found in fertilizer runoff. Fertilizer is an input one expects to be used in all agricultural production and which might not vary as much with value of production as does something like irrigation.

Importantly, we find that ammonia, arsenic, mercury, total coliform, and zinc are all *uncorrelated* with measures of agricultural intensity. This suggests that due to health hazards of these toxins, mitigatory measures already in place work adequately, and policy should address the *non-agricultural* sources of these pollutants as possible.

Conclusions

While agriculture can be an easy target for those looking to place the blame for poor water quality, this study shows that agriculture is *not* the main culprit of some typical agricultural pollutants found in surface water. People commonly associate *soil erosion* with agriculture, and soil erosion leads to increased total suspended solids (TSS). We find that crops do not contribute to total suspended solids, and that animal production even appears to decrease TSS. Ammonia is another pollutant commonly associated with agricultural production, but we find no connection between the two when considering surface water. Some of the misconception with regard to agriculture and surface water quality may stem from agriculture's impact on *groundwater* quality. However, practices like agricultural buffers can prevent much surface water contamination, while few mitigative measures exist to protect groundwater.

Surface water pollutants like nitrites, nitrates, sulfates, phosphorous, and specific conductivity are, however, significantly positively correlated with agricultural production. This suggests that agriculturally targeted surface water quality programs should focus on these pollutants in counties with high agricultural intensities, while groundwater quality programs may need to target a wider range of pollutants.

Hossein Farzin is a professor in the Department of Agricultural and Resource Economics at UC Davis. He can be contacted by e-mail at farzin@primal.ucdavis.edu. Kelly Grogan is a Ph.D. student in the ARE department at UC Davis who can be reached at grogan@primal.ucdavis.edu.