Supporting CA Human Right to Water: Assessing Statewide Water Quality Monitoring Tools and Promoting Accountability ofGovernment Monitoring

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ABSTRACT

California Human Right to Water Act declares that every person in California has the right to accessible clean water. Despite the act, millions of people continue to lack access to clean drinking water, among those are well water users. The state of California does not monitor or clean private domestic well water, leaving many unknowingly drinking contaminated water. To provide well water users and policy makers with accurate data on well water quality the Water Equity Science Shop developed a digital drinking water tool where people can access ground water quality data in California. I analyzed the effectiveness of the model in terms of nitrate and arsenic contamination by comparing the model to an independent data set of water quality samples taken in Sonoma and Monterey county. I conducted correlation tests and performed nonparametric linear regressions in RStudio. I used ArcMap to visualize the differences between the WESS model and the independent data set. I looked at who is affected by nitrate and arsenic contamination and who effective modeling would aid by analyzing the correlation between nitrate and arsenic contamination and the percentage of people of color (POC), percentage Latinx and percentage renters. I found the model to be initially effective, but that more sampling is needed to verify its effectiveness. POC, Latinx and renters are disproportionately affected by nitrate contamination, but not by arsenic contamination. The WESS model is a good tool but the state of California must institutionalize monitoring and cleaning of well water to protect Californians from hazardous water quality.

KEYWORDS

well water quality, nitrate and arsenic contamination, GIS modeling, environmental justice

INTRODUCTION

In California an estimated 1.5 million people rely on private domestic wells for drinking water (Johnson and Belitz 2015). Private domestic well water is not monitored or regulated for contamination by the state ("Bill Text - SB-200 Drinking water." n.d.). The lack of monitoring is especially concerning for communities that live in agricultural and industrial areas due to the high risk of contamination from agricultural and industrial sources (Singh and Sekhon 1979). Pesticides and fertilizers used in agriculture are full of arsenic and nitrates which, without proper management, can run off of agricultural lands into local rivers and ultimately seep into groundwater reservoirs. In groundwater samples taken across the central valley and coast of California arsenic and nitrate levels have been found above the maximum contaminant level (MCL) (Balazs Carolina et al. 2011). Well water users then pull their water from these polluted groundwater reservoirs, unknowingly exposing themselves and their families to hazardous levels of arsenic and nitrates. Without monitoring and regulating private domestic well water, the state is unable to identify contamination and furthermore protect well water users from contaminated waters.

The health impacts of nitrate and arsenic exposure are long term if not fatal, and especially dangerous for the development of children (Fan and Steinberg 1996, Temkin et al. 2019). Nitrate specifically restricts the flow of oxygen in the body and this has been seen in the Central Valley in the spike of blue baby syndrome, a condition where babies turn blue due to a lack of oxygen. Likewise, nitrate has been linked to reproductive issues and cancers (Temkin et al. 2019). Arsenic exposure has been linked to skin lesions, cardiovascular disease, diabetes, delays in cognitive development in children and cancers (Huang et al. 2015). Given that in the Central Coast and Central Valley area of California, private domestic well water users are primarily Latinx, low income and undocumented, access to clean drinking water is a social justice issue (Schaider et al. 2019, Méndez et al. 2020). Many of the most marginalized communities in California are still lacking access to clean water (Phillips 2018). If California does not monitor and regulate contaminants in groundwater, children's health is put at risk from exposure to high levels of nitrate and arsenic, a multitude of health risks are experienced by the larger community and the state is institutionalizing environmental racism.

In 2012 the state of California passed AB 685, a landmark bill affirming access to clean water as a human right for all Californians ("Human Right to Water | California State Water

Resources Control Board" n.d.). To uphold the Human Right to Water Act, private domestic well water contaminants must either be accurately modeled or measured and regulated by the state. Recent efforts by the UC Berkeley Water Equity Science Shop (WESS) have mapped domestic well communities throughout California and estimated their water quality and demographics (Pace et al. 2020). This is a valuable resource that can help support community members with water quality concerns, provide valuable information to social justice advocacy groups, support decisions made by groundwater sustainability agencies, and inform policymakers in their efforts to achieve the human right to water (Miao and Fry 2018, Latchmore et al. 2020). Publicly available water quality monitoring data for domestic wells is limited, and current models estimating water quality in domestic well areas rely on samples collected predominantly from untreated public supply wells and monitoring wells. It remains to be seen how estimates, such as those available through the efforts of the WESS, compare to independent samples collected from domestic well households in California. Accurate models, such as the WESS model, would allow for effective action and informed policy to protect well users.

The objective of this study is to understand how accurate existing models of groundwater quality are in terms of arsenic and nitrate estimation and if these models can be reliably used to inform policy to protect well water users. To answer the question, I will consider 1) How does the WESS model's nitrate predictions compare to an independent dataset of water quality collected from domestic wells? 2) How does the WESS model's arsenic predictions compare to an independent dataset of water quality collected from domestic wells? 3) What are the environmental justice implications of effective modeling? The present study will compare arsenic and nitrate concentrations from a dataset of approximately 300 water samples collected from households with private domestic wells in the Central Coast and San Juaquin valley to estimates developed for these areas by the WESS model. This will provide valuable information on the accuracy of currently accepted modeling parameters. I will also consider the environmental justice implications of basing policy decisions on modeling data and highlight the need for more comprehensive statewide sampling efforts.

METHODS

Study System

The San Joaquin Valley and Central Coast are the agricultural heartland of California. These areas are characterized by some of the most productive lands in the world due to aggressive cultivation with fertilizer and pesticides (Burow et al. 2013). A mass workforce is necessary for the ¼ of the nation's food produced in the 20,000 square miles of the Central valley and Coast ("California's Central Valley | USGS California Water Science Center" n.d.). Of the farmworkers in the region 88% are Latinx (Núñez 2019). This population is vulnerable to oppression and exploitation as they face issues of immigrant rights, environmental racism and undocumented labor discrimination (Daftary 2018). An estimated 1.5 million people are reliant on well water in rural California with the majority of them residing in the Central Coast and Valley (Johnson and Belitz 2015). The mass fertilizer and pesticide use in the region create an environmental justice issue as the majority of people left vulnerable to chemical contamination of drinking water from agricultural runoff are Latinx farmworkers.

Water Equity Science Shop Model

UC Berkeley's Water Equity Science Shop (WESS) developed a drinking water tool that allows Californians to understand their water quality through a simple interactive website (Pace et al. 2020). Users can visualize potential nitrate, arsenic, hexavalent chromium and 1,2,3 trichloropropane exposures, drought susceptibility and demographic information through the tool. The tool breaks California into counties, census block groups and townships for clear visualization. Private domestic well locations in the model were determined by using the Department of Water Resources' Online System for Well Completion. Water quality values from the Office of Environmental Health Hazard Assessment (OEHHA) CalEnviroScreen (CES 3.0, 2017) along with water quality values from Sacramento State's Office of Water Programs (OWP) California Groundwater Contamination Risk Index (GRID) tool were used to determine nitrate, arsenic, hexavalent chromium and 1,2,3 trichloropropane concentrations for the WESS model. CalEnviroScreen data is primarily used to predict the majority of private domestic well water contaminant concentrations while GRID tool data is used to fill in any missing data for the WESS model. CalEnviroScreen data is given priority over GRID because it includes more data inputs including measurements taken from deep and shallow groundwater reservoirs allowing for a wider more representative scope of contamination levels. The WESS model provides policy makers and community members with water quality information that can inform and protect people from dangerous chemical exposure.

Groundwater Ambient Monitoring and Assessment (GAMA) Dataset

I used the State Water Resources Control Board's Groundwater Ambient Monitoring & Assessment (GAMA) dataset to ground truth the accuracy of the WESS model. The GAMA dataset contains water sample data from over 290,000 wells in California. Water samples are taken in wells across California by different groups including community groups and the Department of Water Resources. The data contains samples of over 100 chemical contaminants including nitrate, arsenic, hexavalent chromium and 1,2,3 trichloropropane from the previous 20 years.

Preparing and Cleaning Data

To compare the modeled and measured nitrate and arsenic concentrations I used ArcMap (ESRI v. 10.8, 2020) to visualize differences and RStudio (RStudio Team (2020). RStudio: Integrated Development Environment for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com/) to perform correlation assessments and non-parametric linear regressions. I acquired GAMA water quality data for nitrate and arsenic for domestic wells from the previous 3 years in Monterey and Sonoma counties (Figure 1, Step 1). I also acquired the WESS nitrate and arsenic concentrations for Monterey and Sonoma county census block groups. I then produced one time-weighted concentration average per well-ID for both nitrate and arsenic (Figure 1, Step 2). I then joined the cleaned GAMA data with the WESS data in RStudio (Figure 1, Step 3). Lastly, I averaged the GAMA well water samples to produce one nitrate and arsenic concentration value for each WESS census block group (Figure 1, Step 4).

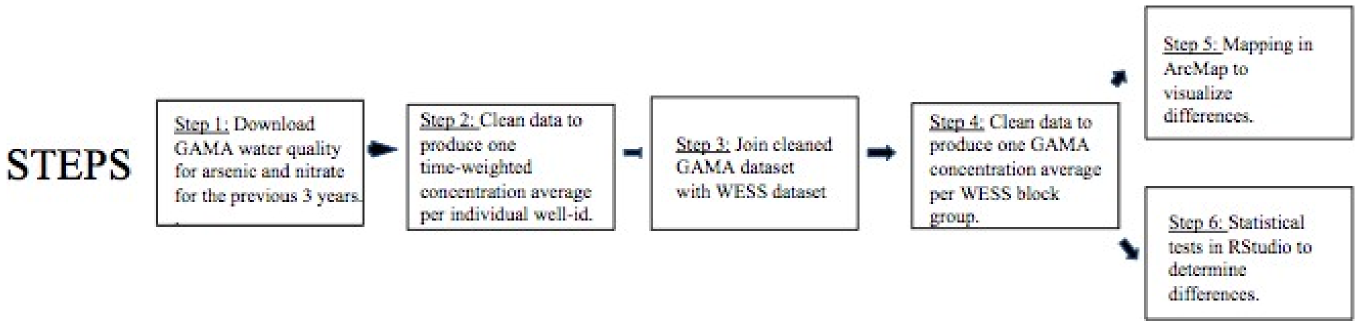


Figure 1: Methods Flow Chart

Nitrate Analysis

To compare the modeled and measured nitrate concentrations I performed correlation tests and non-parametric linear regressions in RStudio. I calculated the r^2 value to understand the overall correlation between the WESS model and GAMA dataset nitrate concentrations. The r^2 value informed how well the model is correlated with the GAMA measurements. To understand if the differences between the datasets are statistically different, I performed a non-parametric linear regression. The assumptions of the nonparametric linear regression are randomness and independence. The P-value produced from the non-parametric linear regression determines the statistical significance of the difference between the WESS model nitrate values and the GAMA measurements.

To visualize the differences in the WESS model and the GAMA measurements nitrate concentrations I used ArcMap to create comparative maps. I created 2 maps for each county: WESS model nitrate concentrations per census block group and GAMA nitrate concentrations per census block group. Giving both the modeled and measured concentrations the same classes and color scheme I was able to look for which census blocks contained discrepancies between the modeled and measured values. I specifically looked for where the WESS model predicts concentrations below the maximum contamination limit of 10 mg/L (MCL) and where GAMA measurements identify concentrations above the MCL.

Arsenic Analysis

I repeated the same analysis as with nitrate but with arsenic data in Sonoma and Monterey County. The MCL for arsenic is 10 ug/L.

Environmental Justice Analysis

To identify the demographics of communities affected by high nitrate and arsenic exposure in drinking water and who is left unprotected by the WESS model I mapped demographic data from the WESS model and performed nonparametric linear regressions in RStudio. I downloaded demographic data from the WESS model which relies on U.S. Census Bureau data (U.S. Census Bureau). Using ArcMap, I created two maps for each county looking at % Latinx, % People of Color (POC) and % renters in Monterey and Sonoma County. I classified % Latinx and % POC in 5 equal intervals and looked for where high percentages of % Latinx, % POC and % renters correlated with high nitrate and arsenic concentrations. I then uploaded the data into RStudio to perform a non-parametric linear regression. The non-parametric linear regression allowed me to understand if % POC is a significant predictor of nitrate and arsenic concentrations. I combined Sonoma and Monterey county nitrate concentrations for GAMA and WESS separately to look at the correlation and P-value of GAMA nitrate concentrations and % POC, WESS nitrate concentrations and % POC. I repeated the same analysis for arsenic. Overall, the non-parametric linear regression is useful in understanding if groundwater contamination is significantly correlated with communities of color.

RESULTS

Nitrate Analysis

Monterey County

The modeled and measured nitrate concentrations in Monterey were found to be well correlated with no statistically significant difference. The correlation tests produced a r^2 value of 0.69 for nitrate (Figure 2). The P-value of the nonparametric linear regression was $8.35\text{x}10^8$, showing the model is a significant predictor of nitrate concentrations in Monterey county. Looking at the correlation graph, although the modeled and measured nitrate concentrations are well correlated, the GAMA measurement concentrations trend to be slightly higher than the WESS model estimate concentrations.

Census block groups with nitrate concentrations above the MCL in the model closely follow the pattern of the measured nitrate concentrations above the MCL (Figure 3). In Monterey county there was missing data for the measured nitrate concentrations in 11 census block groups due to lack of sampling on GAMA's part. There are 7 census block groups in Monterey county where the GAMA measurements of nitrate concentrations are above the MCL and the WESS model does not predict the nitrate concentrations to be above the MCL. Those 7 census block groups would be left unprotected to hazardous nitrate concentrations under the model. The WESS model also inaccurately predicts 3 census block groups to be above the MCL when the GAMA measurements show those three census block groups on average have nitrate concentrations below the MCL. The GAMA measurements found the highest nitrate concentration to be 38.1 mg/L, almost 4 times higher than the MCL. Despite the differences seen visually, the WESS model is a fairly accurate representation of nitrate contamination in well water in Monterey county.

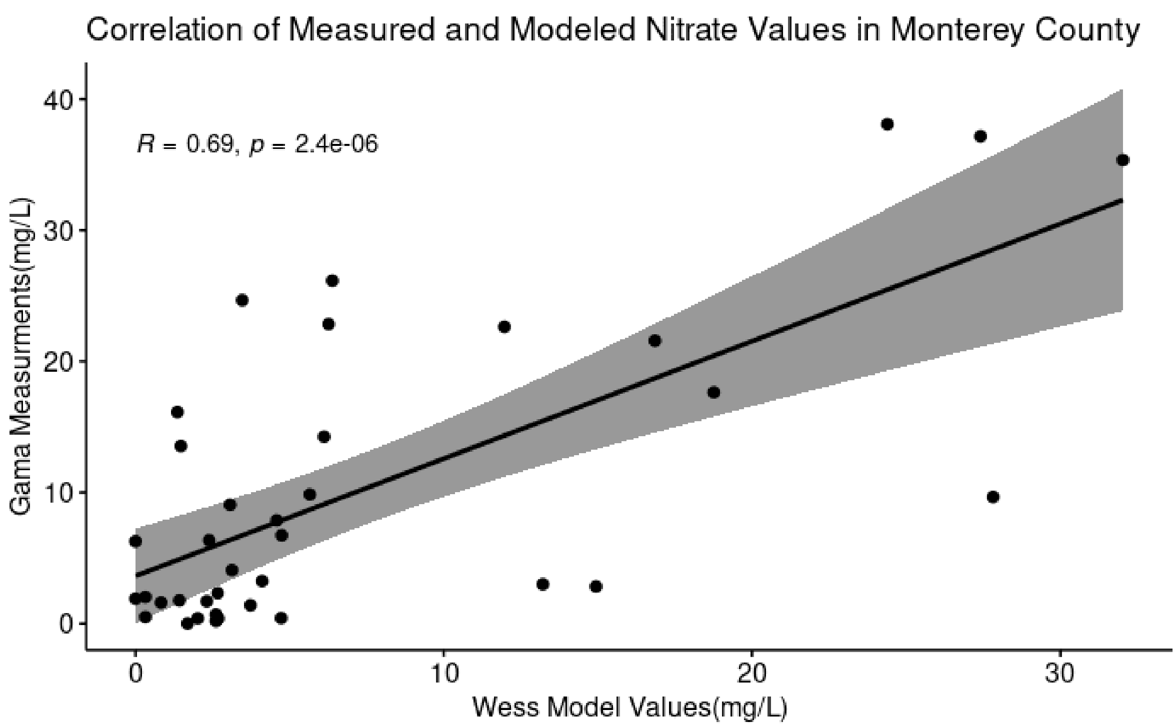
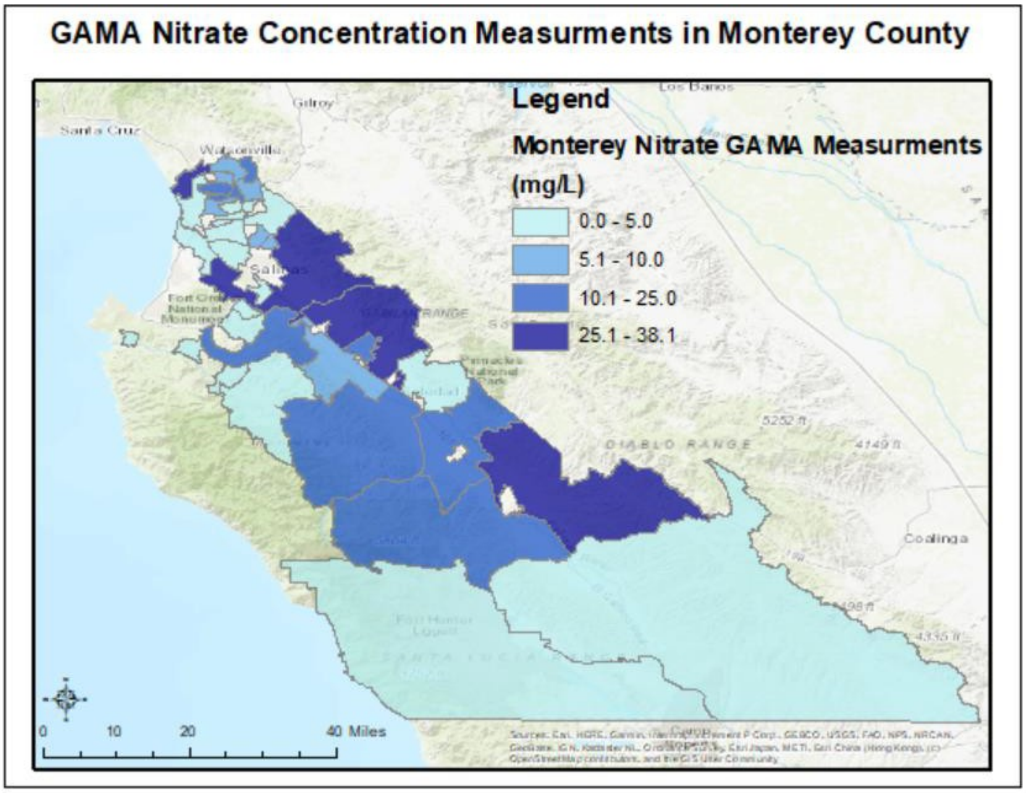


Figure 2. Correlation of measured and modeled nitrate values in Monterey county. Correlation plot visualizing the correlations, the trend line and r^2 value.

(a)



(b)

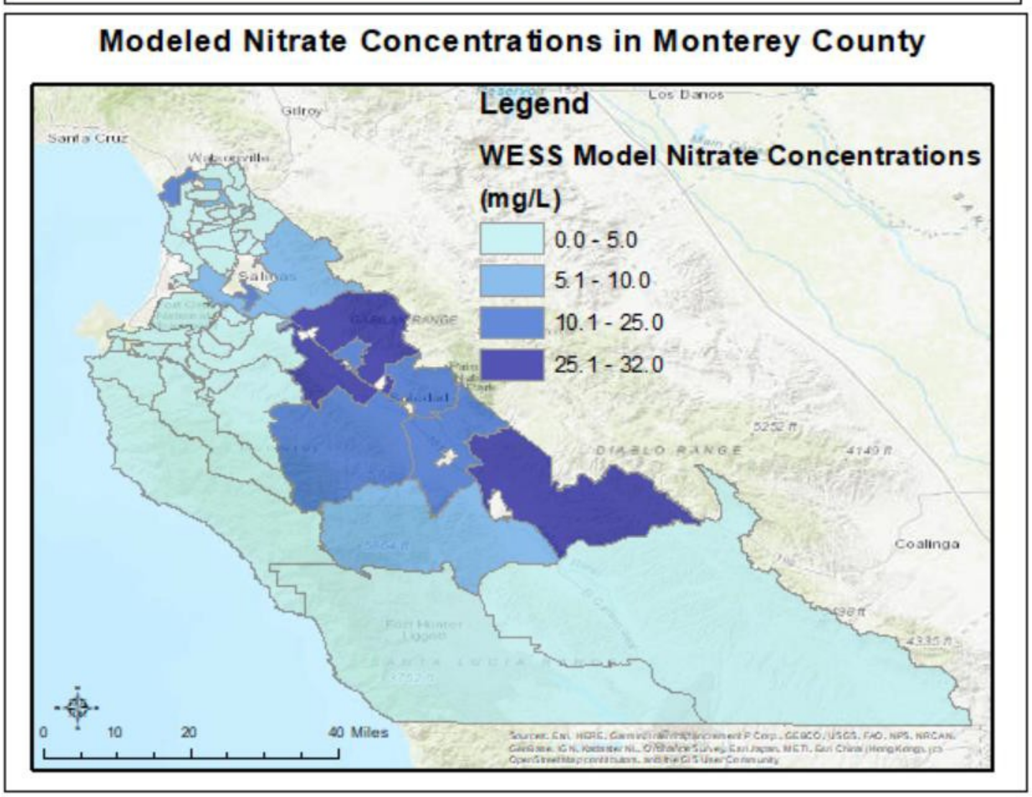


Figure 3. Nitrate Concentrations Maps, Monterey County. Visual display of nitrate concentrations (a) visualizing GAMA measurements and (b) visualizing WESS model nitrate concentration predictions.

Sonoma County

There was only 1 GAMA data nitrate measurement taken in Sonoma County, therefore any analysis was invalid and incomplete. I was unable to perform a proper correlation assessment or a non-parametric linear regression (Figure 4). The 1 GAMA nitrate measurement was 0.4 mg/L, safely below the MCL. Overall, the WESS model predicts the nitrate concentrations to be much lower in Sonoma than in Monterey county (Figure 5). Based on the WESS model, there is only 1 census block group that is predicted to have nitrate concentrations above the MCL.

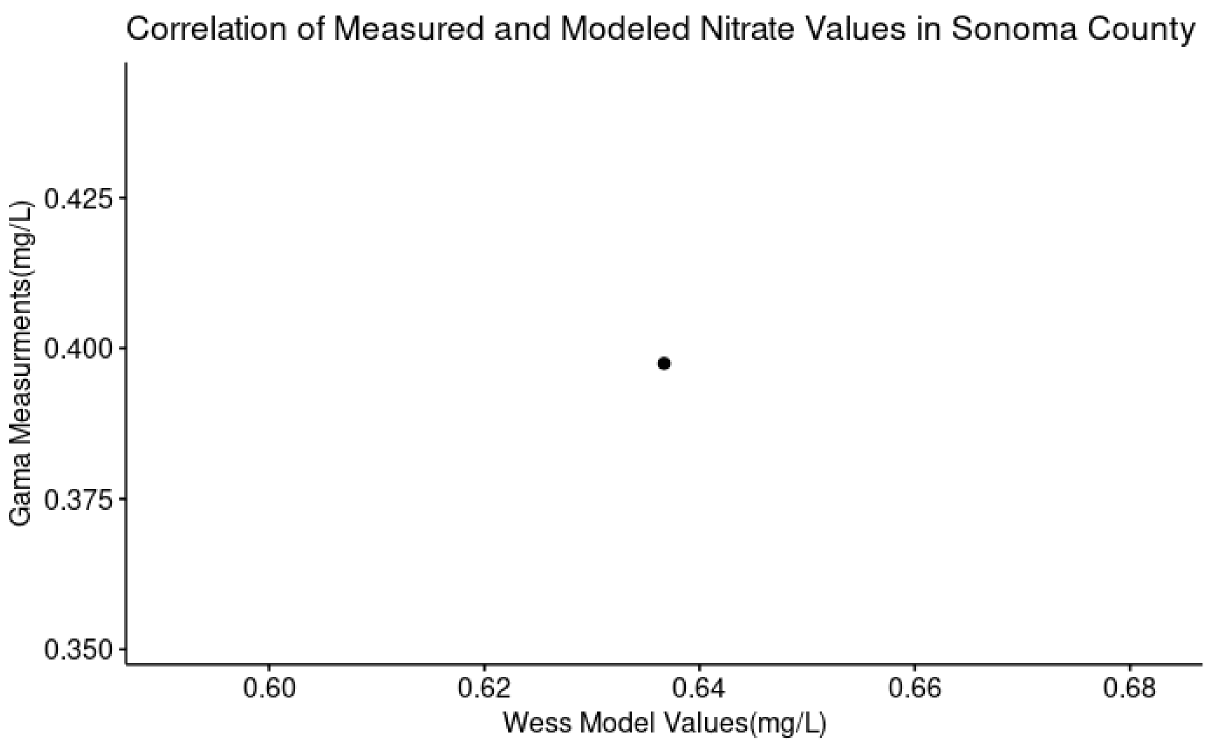
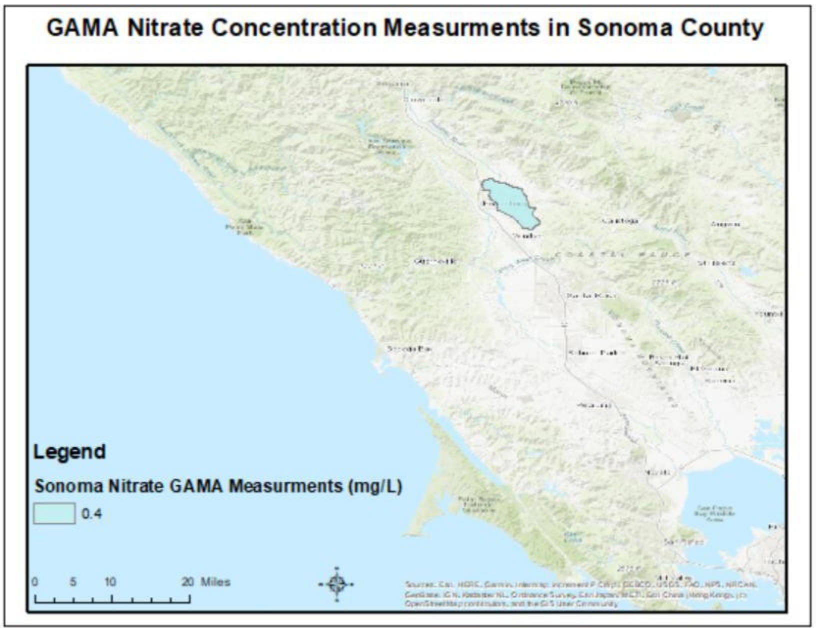


Figure 4. Correlation of measured and modeled nitrate concentrations in Sonoma county. Correlation plot visualizing the correlations, insignificant data therefore unable to display a trend line and r^2 value.

(a)



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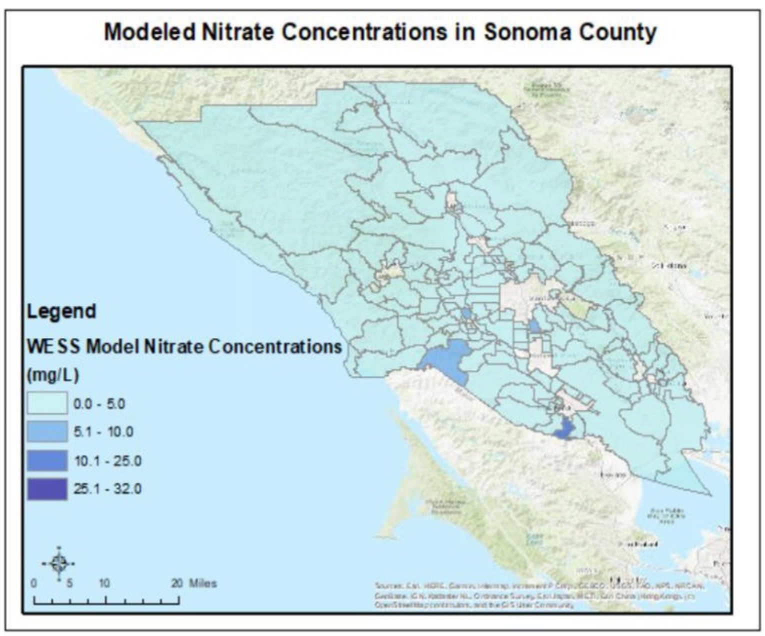


Figure 5. Nitrate Concentrations Maps, Sonoma County. Visual display of nitrate concentrations (a) visualizing GAMA measurements and (b) visualizing WESS model nitrate concentration predictions.

Arsenic Analysis

Monterey County

The modeled and measured arsenic concentrations in Monterey were found to be well correlated with no statistically significant difference. The correlation tests produced a r^2 value of 0.73 (Figure 6). The P-value of the nonparametric linear regression was 0.00209, showing the model is a significant predictor of nitrate concentrations in Monterey county.

The GAMA dataset had missing data for over half of Monterey county. Census block groups with arsenic concentrations above the MCL in the model mostly follow the pattern of the measured nitrate concentrations above the MCL (Figure 7). There are 2 census block groups in Monterey county where the GAMA measurements of arsenic concentrations are above the MCL while the WESS model predicts the concentrations to be below the MCL. Those 2 census block groups would be left unprotected to hazardous arsenic concentrations under the model. The GAMA measurements found the highest nitrate concentration to be 21.2 ug/L, over two times higher than the MCL. More arsenic samples must be taken in Monterey county in order to make an accurate assessment of the accuracy of the WESS model. Based on the limited data and analysis here, the WESS model thus far shows to be a fairly accurate representation of arsenic contamination in well water in Monterey county.

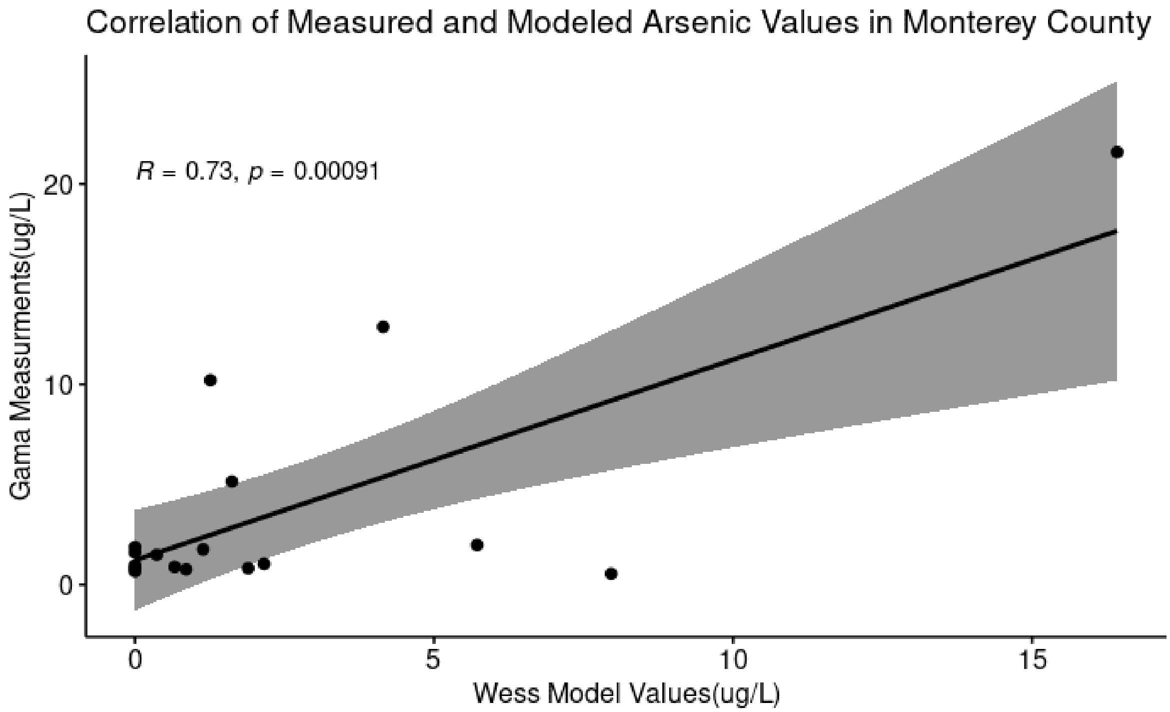


Figure 6. Correlation of measured and modeled arsenic values in Monterey county. Correlation plot visualizing the correlations, the trend line and r^2 value.

(a)

(b)

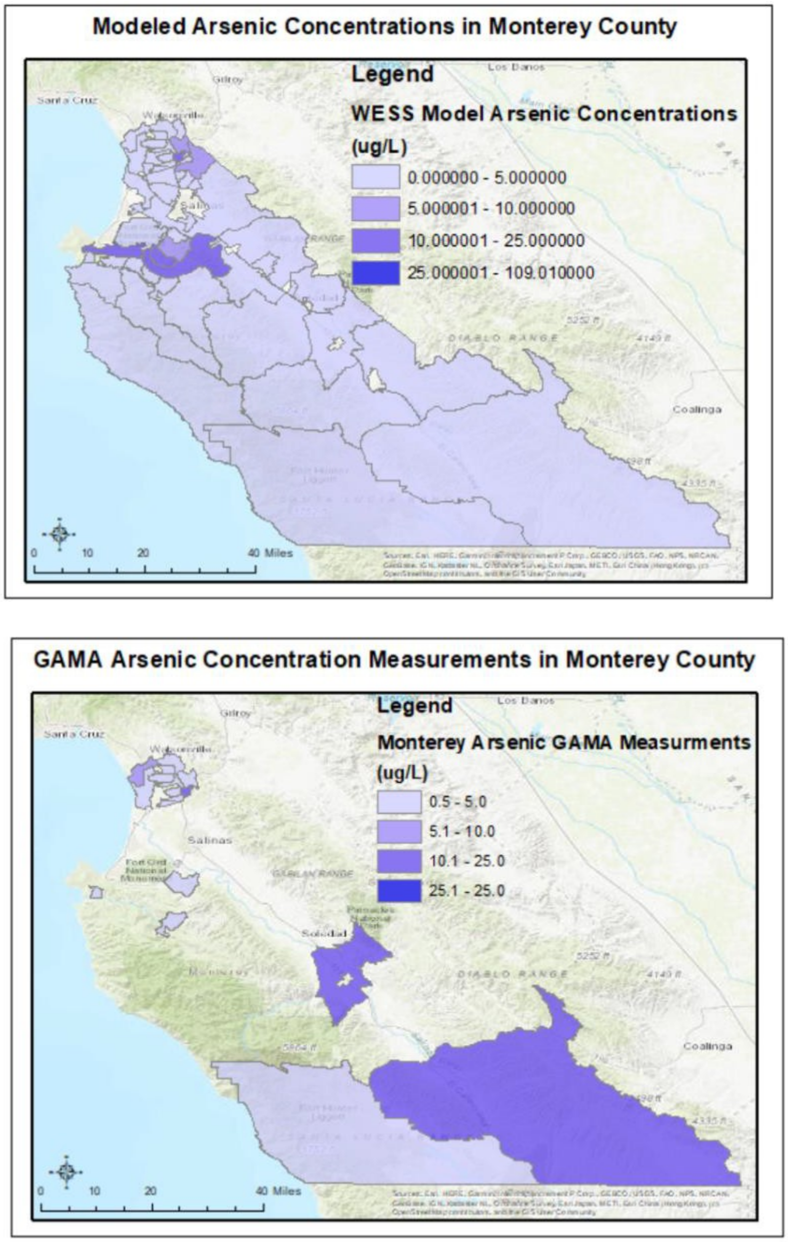


Figure 7. Arsenic Concentrations Maps, Monterey County. Visual display of nitrate concentrations (a) visualizing GAMA measurements and (b) visualizing WESS model nitrate concentration predictions.

Sonoma County

There were only 3 GAMA data arsenic measurements taken in Sonoma County, therefore any analysis was invalid and incomplete. I was unable to perform a proper correlation assessment and a non-parametric linear regression (Figure 8). The highest GAMA arsenic measurement was 5 ug/L, safely below the MCL. Overall, the WESS model predicts the arsenic concentrations to be higher in Sonoma than in Monterey county (Figure 9). Based on the WESS model, there are 10 census block groups that are predicted to have arsenic concentrations above the MCL. More arsenic samples in Sonoma county are needed to make an accurate assessment of the WESS models accuracy.

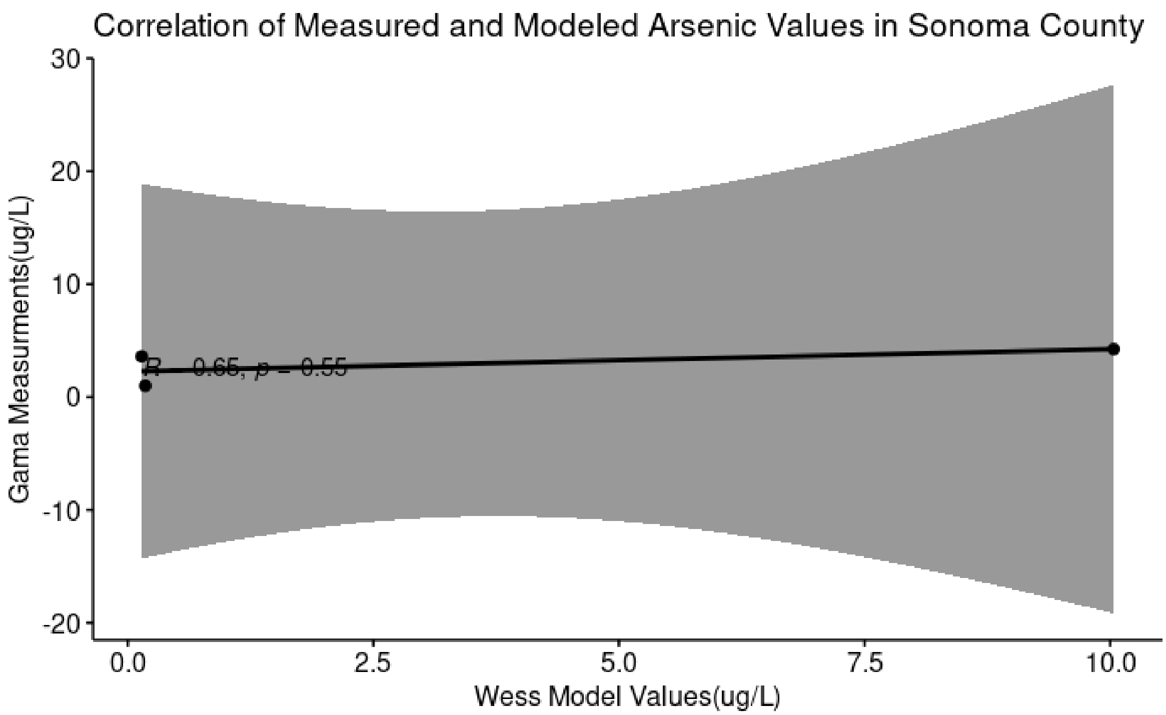
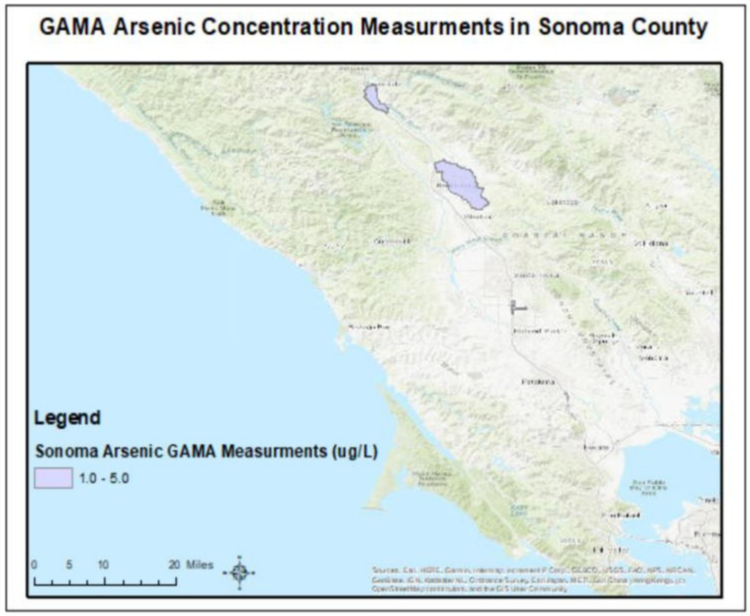


Figure 8. Correlation of measured and modeled arsenic values in Sonoma county. Correlation plot visualizing the correlations, the trend line and r^2 value.

(a)



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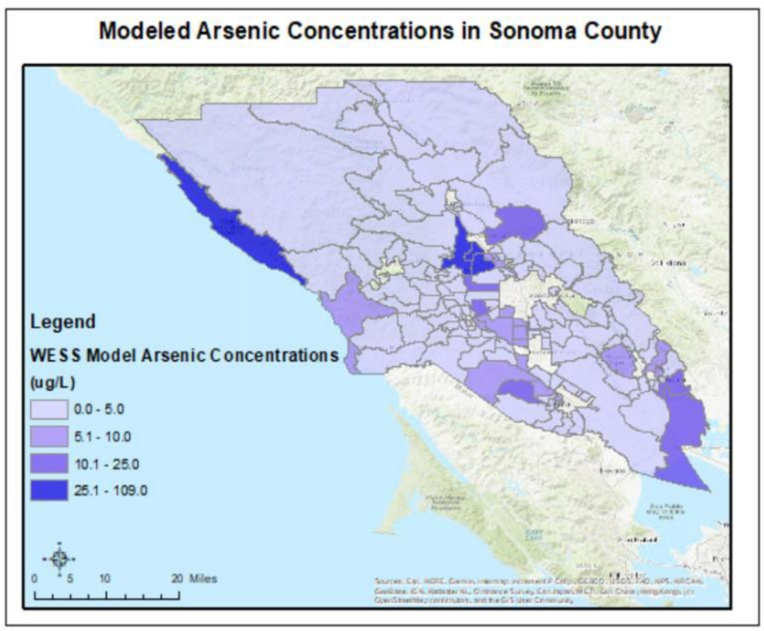


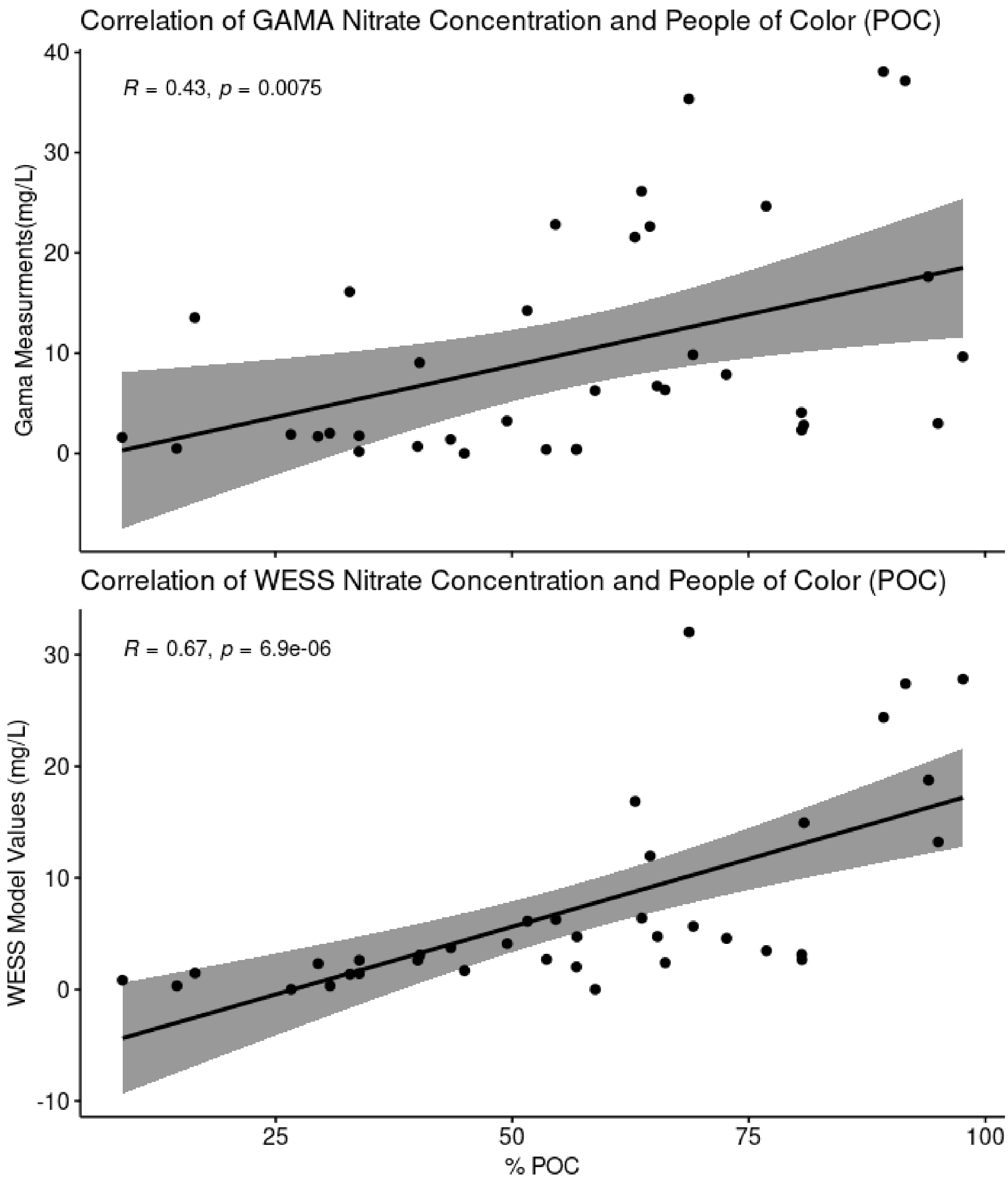
Figure 9. Arsenic Concentrations Maps, Sonoma County. Visual display of nitrate concentrations (a) visualizing GAMA measurements and (b) visualizing WESS model nitrate concentration predictions.

Environmental Justice Analysis

Nitrate Analysis

Nitrate contamination occurs at higher rates in Latinx and communities of color. Nitrate contamination for both the WESS model and the GAMA measurements are well correlated with percent people of color. The correlation tests produced a r^2 value of 0.43 for the GAMA measurements and 0.67 for the WESS model (Figure 10). The P-values of the nonparametric linear regression was $1.45\text{x}10^{-7}$ for GAMA measurements and $2.91x10^{-11}$ for the WESS model, showing the percentage of people of color in Monterey and Sonoma county is a significant predictor of nitrate concentrations. The higher the percentage of people of color, the higher the nitrate concentrations are. The 5 census block groups with the highest measured nitrate concentrations across Monterey and Sonoma county have Latinx populations and communities of color above 60% and renters above 20% (Figure 12,13). Nitrate contamination is a bigger risk for people of color, Latinx people and the poor in Monterey and Sonoma counties.

(a)



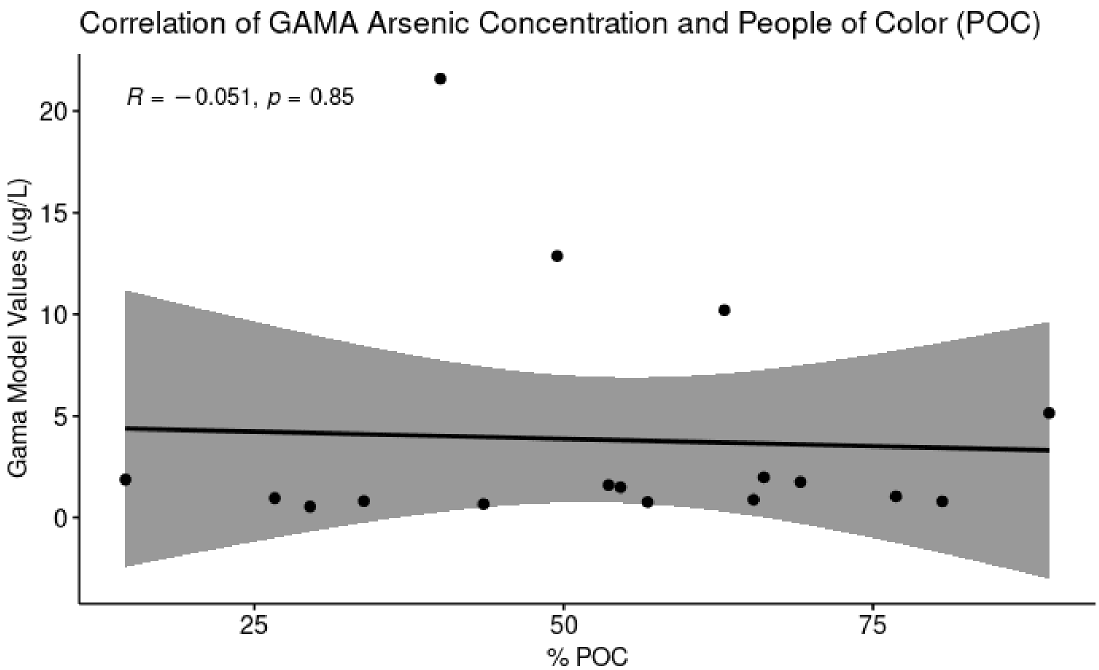
(b)

Figure 10. Correlation of percentage People of Color (POC) and nitrate concentrations. Correlation plot visualizing the correlations, the trend line and r^2 value (a) GAMA measurements correlation to %POC (b) WESS model correlation to %POC.

Arsenic Analysis

There is not a clear correlation between arsenic contamination and People of Color, Latinx populations or renters. Arsenic contamination for both the WESS model and the GAMA measurements are very slightly negatively correlated with percent people of color. The correlation tests produced a r^2 value of -0.051 for the GAMA measurements and -0.18 for the WESS model (Figure 11). The P-values of the nonparametric linear regression was 0.225 for GAMA measurements and 0.054 for the WESS model, showing the percentage of people of color in Monterey and Sonoma county is not a significant predictor of arsenic concentrations. The census block groups with the highest measured arsenic concentrations across Monterey and Sonoma county show no correlation with POC%, Latinx% or Renters % (Figure 12, 13).

(a)



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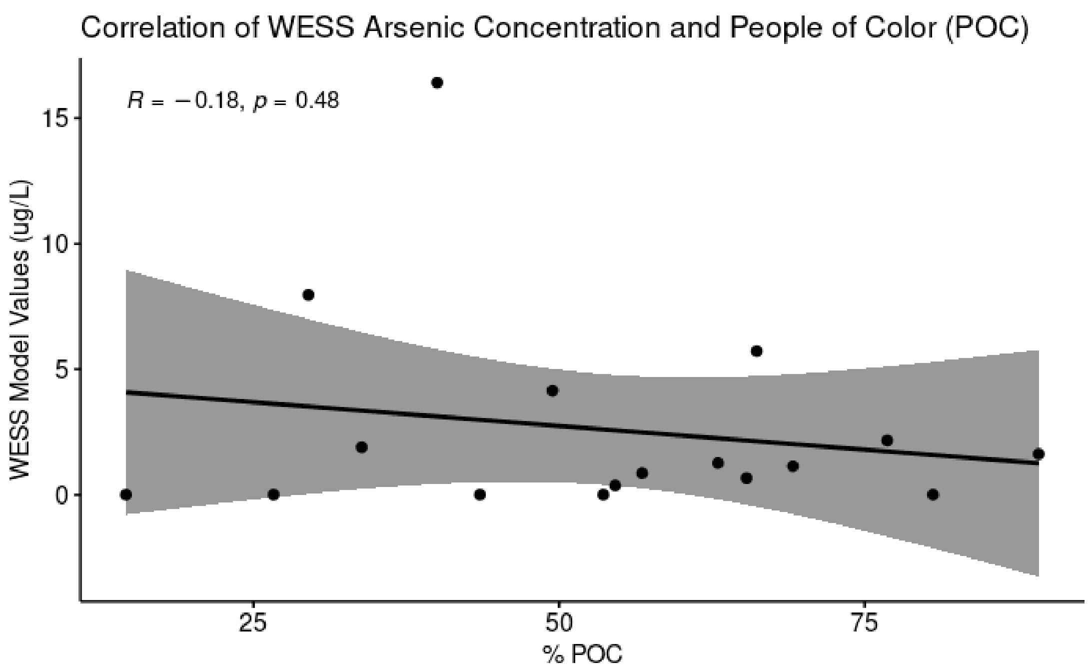
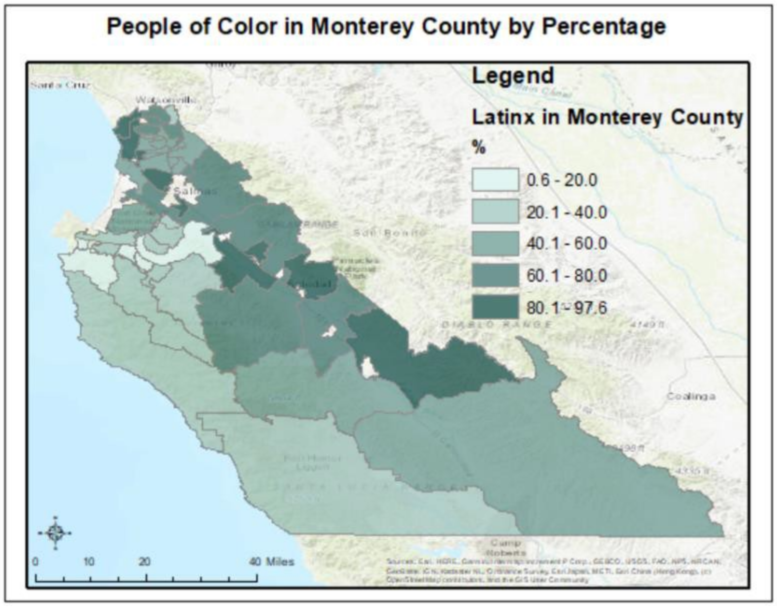
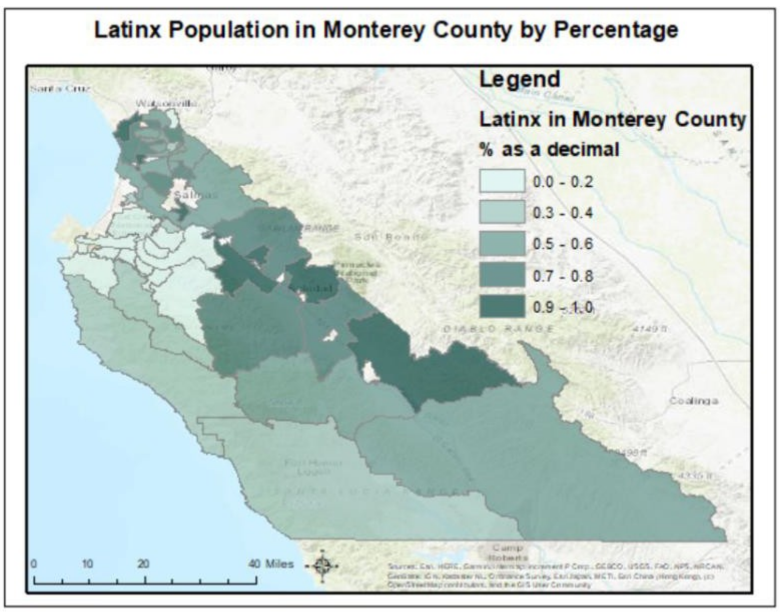


Figure 11. Correlation of percentage People of Color (POC) and arsenic concentrations. Correlation plot visualizing the correlations, the trend line and r^2 value (a) GAMA measurements correlation to %POC (b) WESS model correlation to %POC.

(a)


People of Color in Monterey County by Percentage
Legend
Latinx in Monterey County
%
0.6 - 20.0
20.1 - 40.0
40.1 - 60.0
60.1 - 80.0
80.1 - 97.6
0
10
20
40 Miles
Salinas
Coalinga

(b)


Latinx Population in Monterey County by Percentage
Legend
Latinx in Monterey County
% as a decimal
0.0 - 0.2
0.3 - 0.4
0.5 - 0.6
0.7 - 0.8
0.9 - 1.0
0
10
20
40 Miles
Salinas
Coalinga

(c)

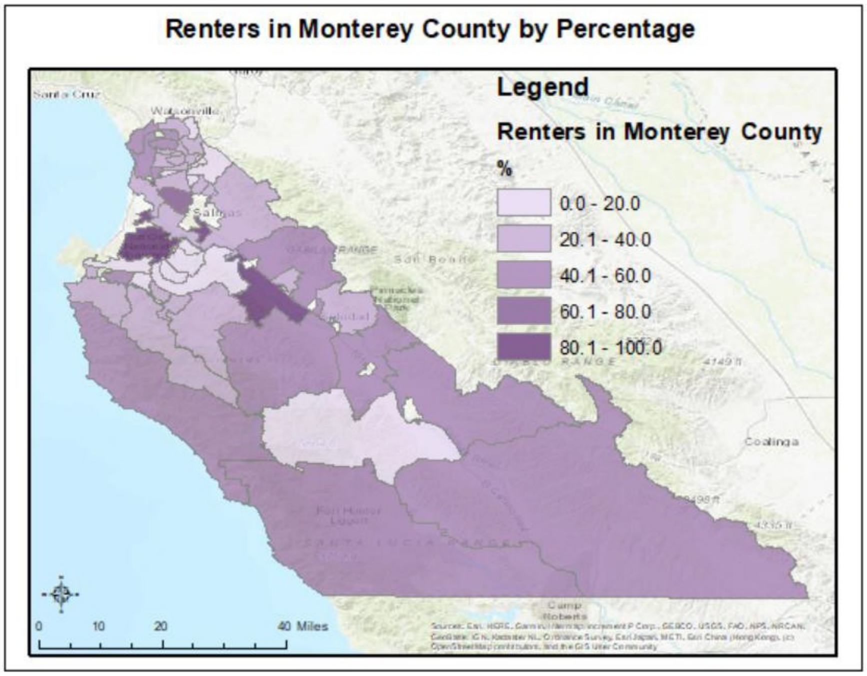
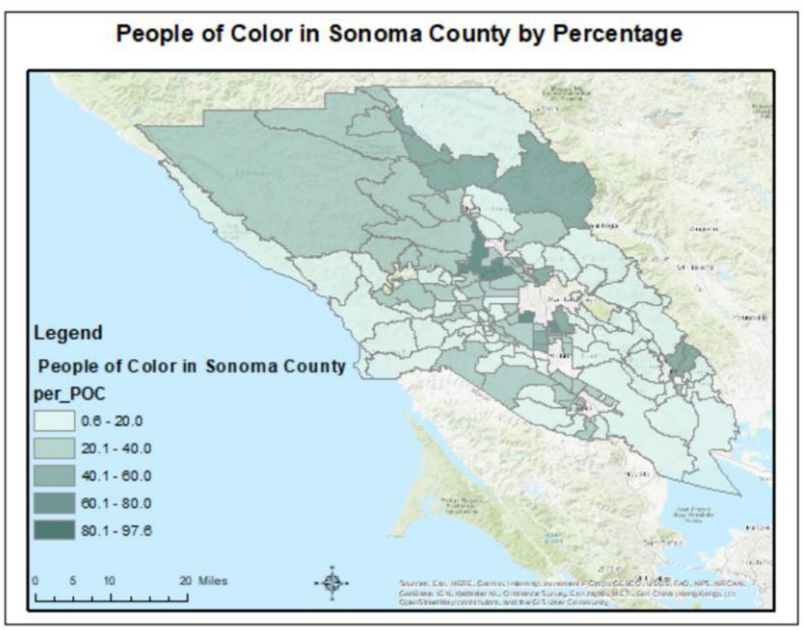


Figure 12. Demographics Maps, Monterey County. Visual display of demographic data (a) visualizing percentage POC (b) visualizing Latinx populations and (c) visualizing percentage renters.

(a)



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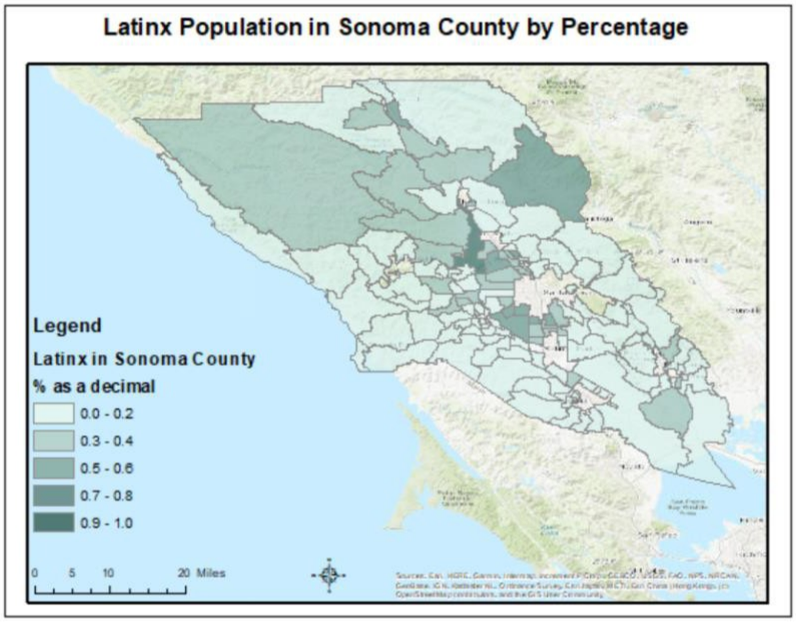

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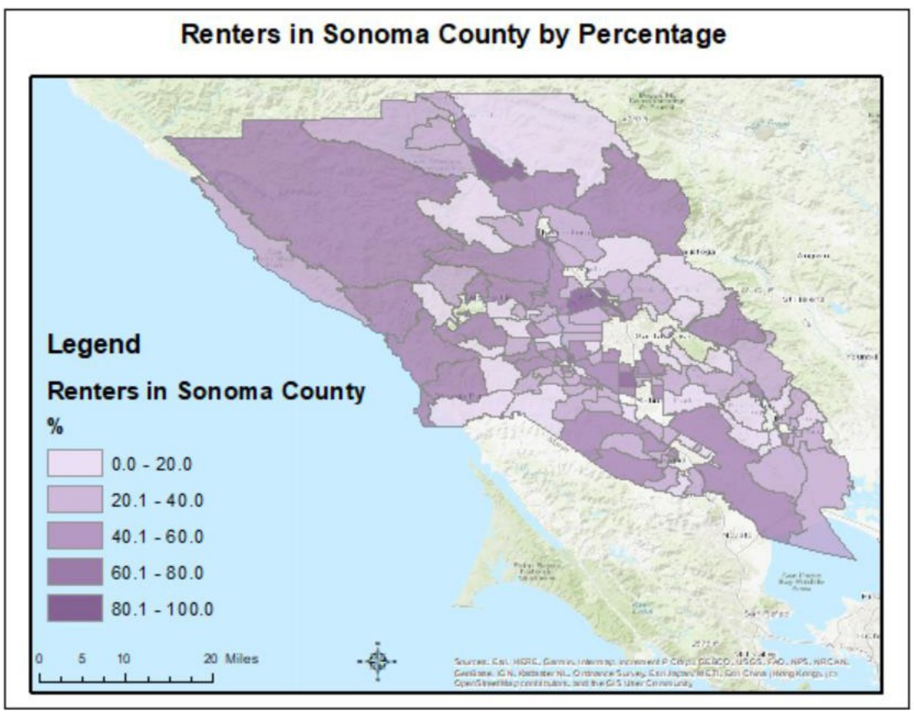

Figure 13. Demographics Maps, Sonoma County. Visual display of demographic data (a) visualizing percentage POC (b) visualizing Latinx populations and (c) visualizing percentage renters.

DISCUSSION

Californians reliant on well water are at high risk for nitrate and arsenic exposure. The WESS model shows to be an accurate predictor of arsenic and nitrate contamination risk given my limited analysis. More sampling and analysis are needed to fully understand the accuracy of the model. While there are clear environmental justice issues with the distribution and burden of nitrate contamination in well water, there are not clear environmental justice issues with arsenic contamination. More sampling is needed to understand the accuracy of the WESS model, but the initial analysis shows that People of Color, specifically Latinx and low-income people, carry a larger burden of nitrate contamination. The WESS model may be an effective tool for informing policy and the public on well water quality, but more sampling and analysis is needed before it can be widely implemented.

Nitrate Exposure Implications

In terms of nitrate concentrations, the WESS model is accurate and effective. While the WESS model accurately predicted nitrate concentrations in well water, the GAMA measurements tended to be higher than the WESS model predictions. The WESS model uses deep and shallow groundwater reservoir data to create its nitrate predictions. Wells draw water from shallow reservoirs, which tend to have higher concentrations of contaminants due to their proximity to the surface. It is easier for nitrates to seep into shallow reservoirs, therefore shallow groundwater reservoirs tend to have higher nitrate concentrations than deep reservoirs (Seidmohammadi et al. 2020). The correlation test showed the GAMA measurements to be slightly higher than the WESS model due to the fact that the WESS model used shallow and deep reservoir data to create its model while the GAMA measurements draw directly from the shallow reservoirs used for wells. The WESS model would be more accurate if it only used shallow reservoir data to create its predictions. I also found that the nitrate concentrations were higher in Monterey county than in Sonoma county. This is most likely caused by differences in agricultural practices in Sonoma and Monterey counties. Sonoma county is dominated by vineyards, where it is common practice to grow nitrogen absorbing plants under the grape vines in the winter to reduce nitrogen runoff (The Land Stewardship Division of the Sonoma County Department of Agriculture/Weights & Measures, 2018). Monterey county is dominated by the production of leafy green vegetables grown with high levels of nitrogen rich fertilizers ("Monterey County Farm Bureau - Facts, Figures & FAQs" n.d.). For this reason, I found the nitrate concentrations to be higher in Monterey county than Sonoma county.

Models can be effective and efficient tools for monitoring and understanding nitrate concentrations (Valivand and Katibeh 2020, Seidmohammadi et al. 2020)**.** The WESS model has the potential to be an effective tool for monitoring nitrate and influencing policy changes to protect well water users' health. Based on the results from my Monterey county nitrate analysis I found that the WESS model is effective, but much more sampling is needed.

Arsenic Exposure Implications

Based on the limited data available with the GAMA dataset, the WESS model shows to be an accurate predictor of arsenic concentrations. There was not significant data available in the GAMA dataset to make an accurate analysis of the WESS models' ability to predict arsenic contamination in well water. From my analysis I found that there are three census block groups in Monterey county where residents are exposed to hazardous levels of arsenic in their water, showing that arsenic is a threat to people's health (Chandio et al. 2021). The WESS model could be an effective tool for monitoring arsenic and influencing policy changes to protect well water users' health. My analysis shows that there is a large need for extensive testing and monitoring of well water arsenic contamination. Models can be efficient tools for the short term, but infrastructure to provide well water users with consistent monitoring is needed to ensure that people are not exposed to harmful levels of arsenic (Flanagan et al. 2016).

Environmental Justice Implications

Well water contamination is environmental racism as it affects communities of color, Latinx people and the poor at much higher rates (Flanagan et al. 2016). Specifically nitrate contamination in Monterey county is disproportionately impacting communities that have been historically marginalized and oppressed. Disadvantaged rural communities consist of predominantly BIPOC Californians. The history and systems of oppression in the United States have caused divides in wealth, resources and toxic environmental exposure (Nigra 2020). My analysis found that nitrate contamination is strongly correlated with POC, showing that the burden of nitrate exposure is being put onto communities of color. I did not find the same correlation for arsenic exposure; therefore, arsenic contamination does not need to be addressed as an environmental justice issue the same way that nitrate must. Exposure to nitrates in drinking water cause a multitude of health issues, some of which are fatal (Temkin et al. 2019). This disproportionate burden of health effects from nitrate exposure falls onto communities that do not have the same access to healthcare as white and wealthier Californians (*2020 California Children's Report Card* 2020). The WESS model can help address environmental and health inequities as it effectively shows where contamination is occurring. Government and community action on the findings of the WESS model would protect thousands of disadvantaged communities from nitrate and arsenic exposure. Groundwater contamination is an environmental justice issue and must addressed as one.

Synthesis

The WESS model thus far shows to be an accurate resource for determining arsenic and nitrate contamination in groundwater. More data is needed to definitively state if the model can be reliably used to inform policy to protect well water users. The model accurately found where nitrate and arsenic concentrations are above the MCL in groundwater in Monterey county and more data is needed to see if it is accurate in Sonoma county. It is clear that nitrate contamination is disproportionately affecting people of color, creating an environmental justice issue for the state. The states attempt to ensure clean drinking water is a right to all Californians has been disastrous. Not only do many Californians not have access to clean drinking water, but POC continue to disproportionately carrying the burden of toxic drinking water. To ensure long-term success in protecting the water and health of Californians, the state government must ensure protections to the most vulnerable and susceptible groups (Swistock et al. 2013). The WESS model can be temporarily used to inform policy and protect well water users, but more is needed to protect Californians.

Limitations and Future Directions

The biggest limitation of my analysis is the lack of data in the GAMA dataset. More data is needed to not only understand the accuracy of the WESS model but to protect well water users in California. Based on my nitrate analysis, the WESS model should not use deep groundwater reservoir data to inform their model because the deep reservoirs are not representative of the contamination in the shallow reservoirs, where well water is drawn from. The WESS model predicts the nitrate and arsenic groundwater concentrations for entire census block groups, not individual wells. Some wells in census block groups where the arsenic or nitrate concentrations are predicted to be below the MCL may actually have concentrations above the MCL. For this reason, the WESS model should look to create estimates on a smaller scale than census block groups. Above all, more is needed for well water users in California than accurate modeling. As California claims the Human Right to Water Act, the state must act to protect all Californians, not just those living in cities. Infrastructure should be created that allows for consistent and reliable statewide monitoring of well water contamination. GAMA and other groups should continue taking data samples to ground truth the model and to provide better data for well water users. As California is one of the only states to have a Human Right to Water Act, other states should begin efforts to pass similar policy and create infrastructure to protect all people in the United States from hazards in their drinking water.

Conclusion

Well water users in California are at a high risk for exposure to hazardous concentrations of arsenic and nitrate in their drinking water. The state of California is not following the Human Right to Water act. They are practicing environmental racism in their lack of monitoring and cleaning of well water. The WESS model is an efficient tool for community organizers to use to protect their communities. The WESS model can be used to inform policy in the beginning steps of addressing well water contamination, but the state needs to invest money and resources to build infrastructure to protect all well water users. The WESS model can be used as a starting point to protect well water users in California. The state of California must be held accountable for contamination of drinking water and must be responsible for creating statewide infrastructure that allows for the monitoring and protection of well water.

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