Title
Analysis of California Drought Effects on Freight Movements

Author
Carrillo, Alma

Publication Date
2015

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA,
IRVINE

Analysis of California Drought Effects
on Freight Movements

THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF SCIENCE

in Civil and Environmental Engineering

by

Alma Carrillo

Thesis Committee:
Professor Stephen G. Ritchie, Chair
Professor R. (Jay) Jayakrishnan
Professor Michael G. McNally

2015

DEDICATION

To

my parents

in recognition of their love and support.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

ACKNOWLEDGMENTS

I would like to express my sincere appreciation to my advisor, Dr. Stephen Ritchie, and to Dr. Andre Tok whose guidance made this project possible. Thank you for taking the time to discuss my progress and review my work.

ABSTRACT OF THE THESIS

Analysis of California Drought Effects
on Freight Movements
By

Alma Carrillo

Master of Science in Civil and Environmental Engineering

University of California, Irvine, 2015

Professor Stephen Ritchie, Chair

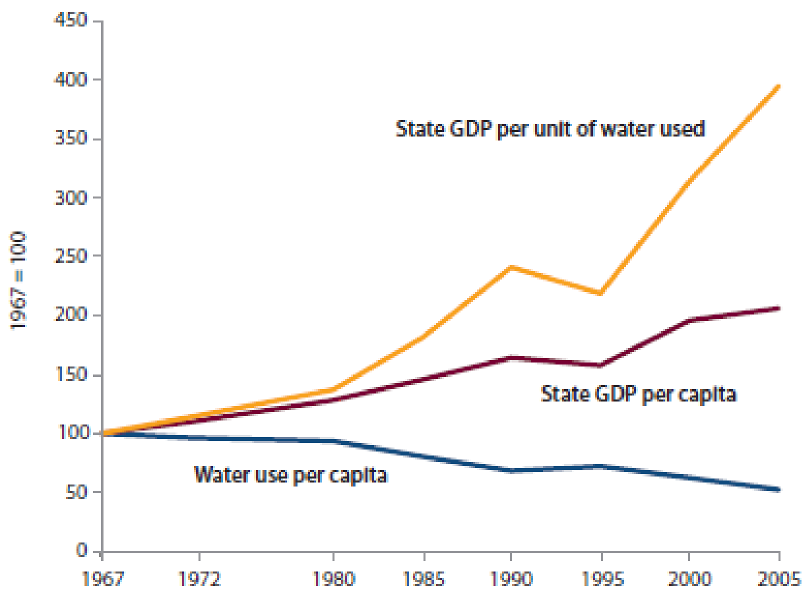
California has been on state of emergency for almost two years as a result of the continued drought. This has caused a decrease or more costly production for many water intensive industries. In addition, it has caused a reduction in crops harvested in the Central Valley and other regions within the state. These productivity issues could lead to potential changes in freight movements within the state which can affect future planning. A freight forecasting model developed by the University of California, Irvine Institute of Transportation Studies is used to forecast any possible changes in freight movements for the year 2020 assuming a continued drought. This model has several characteristics that allow it to be applied under various socioeconomic conditions such as with varying employment, number of establishments per industry type, and harvested acreage per freight analysis zone (FAZ). Four different scenarios are developed. Two assuming drought conditions and two assuming no drought. Results indicate changes in VMT up to a maximum of 3% percent in some regions and emissions reductions up to 2.4% in the San Joaquin Valley air basin. Most effects are visible in the Central Valley region which is home to the largest agricultural production in the state.

CHAPTER 1: Literature Review

1.1 Introduction

As California faces its fourth year of drought, the California Water Resources Control Board has taken initiative by reducing water deliveries and taking control of water rights. To this point, the California drought has not caused significant economic effects. The state's GDP continues to grow at a fast pace as shown in Figure 1 and nonfarm employment continues to increase. This has mainly been accomplished through California's reliance on groundwater and improvements in water conservation techniques.

Figure 1: California GDP and Water Use (Hanak et al., 2012)



However, according to Hanak et al. (2015) two to three more years of drought will lead to larger issues and challenges, making it more difficult for the state to adapt. These types of changes could, for example, lead to a greater reduction in crops harvested, especially in areas with low groundwater resources.

Just within 2014, farmers fallowed approximately 5% of cropland and this is subject to increase in years to follow (Hanak et al. 2015). Fallowed farm land includes land that has been plowed, but left unseeded for the season, thus reducing yearly crops harvested. In addition to affecting agriculture, the drought could potentially create changes in employment within water intensive industries. Considering the fact that California is ranked among the states with the highest number of manufacturing plants in the nation, employment reductions could lead to productivity losses and potentially to changes in good movements throughout the state (U.S. Census Bureau 2010). Several studies have analyzed climate change and drought direct effects at a physical, economic, social, and environmental level (Howitt et al. 2009, Wilson et al 2003, Caldwell et al. 2002). However, very few have analyzed the indirect effects such as the potential changes in freight movement patterns.

Understanding future freight movements is important as the state of California is one of the largest freight importers in the nation accounting for the highest share in value of freight shipments by state of origin and among the largest in ton-miles (USDOT 2014). The state's location makes it a prime importer and exporter of goods nation and worldwide covering over 180,000 million of ton-miles per year (USDOT 2014). Domestic freight movements have been forecast by the Federal Highway Administration to grow by more than 65% from 1998 to 2020 and volumes of goods shipped by trucks and railroads are projected to increase by 98% and 88% respectively by 2035 (FHWA 2002; US-GAO 2007). These projections often assume normal growth conditions, but as climate change and the current California drought become of rising concern, it is important to factor these type of issues into future freight movement estimates.

This study forecasts the indirect effects of the California drought on freight movements within the state of California for the year 2020. Four different scenarios are developed in this analysis. The first assumes that the drought continues to the year 2020 and there is no decrease in cropland use. The second assumes that the drought continues, but there is a reduction in cropland within the state of California. The third scenario is used as a base for comparison with the first scenario. This scenario demonstrates freight movements without the effects of the drought and without a decrease in cropland use. The fourth scenario is used as a base for comparison with the second scenario. It assumes no drought effects but a decrease in cropland use. Truck volumes, vehicle miles traveled (VMT), and emissions are used as performance measures for the analysis.

The following chapter presents the model used for the basis of the analysis and the background on other studies that have analyzed drought and climate change effects on transportation systems.

1.2 Previous Studies

As climate change and drought become a rising issue worldwide several studies have begun to look into the effect it has at different levels in the transportation system. Most studies have recognized the fact that climate change can cause infrastructure loss and deterioration issues and some have come as far as estimating future costs and associated economic losses. However, very few have analyzed indirect effects such as changes in travel patterns and freight movements.

1.2.1 Direct Effects of Climate Change and Drought on Transportation Systems

In 1998, the U.S Department of Transportation created the Center for Climate Change and Environmental Forecasting. Since its inauguration, several studies have begun to further analyze climate change impacts on transportation systems. Drought issues are often included even though different opinions exist on the association of drought with climate change. Many of the studies have addressed the challenge that climate change presents to transportation infrastructure. For example extreme temperatures could lead to higher highway stress, quicker asphalt deterioration, rail track stress and buckling (Krajick & Lee 2008). In the northern parts of the nation, thawing permafrost could lead to higher operations and maintenance costs as road and runways can no longer depend on frozen permafrost as a base (Shwartz & Meyer 2014). In addition, rising sea levels could present threats to many of the nation's largest sea ports. Drought could also affect movement of freight through rivers due to low water levels as it has in the past in the Mississippi River (Caldwell et al 2002). Some studies such as Larsen et al (2008) have projected future costs associated with infrastructure at risk due to climate change. Although potential problems have been identified, very few have been analyzed for future prevention. According to Caldwell et al (2002), these are all issues that can be mitigated by incorporating them into future planning.

1.2.2 Indirect Effects of Climate Change and Drought on Transportation Systems

In 2011, Attavanich et al analyzed the effect of climate change on transportation flows due to shifts in grain growth production. Various climate change scenarios were created using climate forecasting models to predict crop changes for the years of 2045-2055. This study linked two large scale models to forecast grain movements at the regional level throughout the United States. The first model used in the study was the Agricultural Sector Model (ASM). The ASM is a spatial equilibrium mathematical program of the US agricultural sector that analyzes climate change effects on grain crops, specifically corn and soybeans. The results from the ASM model were used as inputs to an International Grain Transportation Model (IGTM), which analyzed grain transportation flows due to climate induced shifts in crop production patterns. The IGTM uses a spatial equilibrium mathematical program that predicts transportation flows by different modes across 303 US regions and allows for mode change through 42 intermediate shipping points, while considering foreign imports and exports from 118 different countries. Results from this study indicate changes in growth patterns for corn and soybeans along with changes in modes of shipment.

A second study from Yevdokimov (2008), assessed climate change impacts in Atlantic Canada on volumes of ground freight transportation in the region for 2050. Three different climate change scenarios were analyzed to assess its impacts on the regional economy and transportation systems. The change in cost of major industrial products due to climate change was used as an indicator of the effects of future production, consumption and trade flows in the Atlantic Canada economy. Vector auto-regression was used to develop a dynamic relationship between the regional economy and freight flows. For each scenario, two projections from 2010 to 2050 were generated to reflect regional gross domestic product and volume of freight transportation. One projection took into consideration climate change related shocks while the other did not. Results indicate a very minimal difference between these two projections and it is not evident until the year 2035.

1.3 Literature Review Analysis/ Conclusion

Most of the current literature indicates that climate change and drought present potential future problems. However, many focus on the effects of climate change in general and it cannot be assumed that this takes into consideration droughts. The most relevant pieces of literature for the purpose of this study are those of Attavanich (2011) and Yevdokimov (2008). The main benefit of Attavanich's model is that it takes into consideration reductions of freight in affected areas and its shift to other regions. In addition, the model allows for representation of changes in shipping mode. However, a major drawback is that projections are at a very broad level. As for Yevdokimov's analysis that modeled future freight volume changes in Atlantic Canada, changes in gross domestic product (GDP) are not always correlated with changes in freight volumes. For example in California, even though the drought has been severely affecting the agriculture sector, the state's GDP continues to steadily grow.

Neither of these modeling techniques would be applicable for the purposes of this study. Therefore, a different modeling technique is used as will be discussed in the following chapter.

CHAPTER 2: California State Freight Forecasting Model (CSFFM)

The California State Freight Forecasting Model (CSFFM) is used to study four drought scenarios for the state of California for the year of 2020. The CSFFM was developed with the purpose of forecasting multi-modal vehicle and commodity flows within the state of California. It has several characteristics that allow it to be applied under various socioeconomic conditions, freight and environment related land use policies, and multimodal infrastructure investments. Among these characteristics include: sensitivity to various commodity groups, sensitivity to scenarios and policies, and the inclusion of multiple modes and truck classifications. The CSFFM model is separated into six modules that allow for freight commodity generation, commodity distribution, commodity mode choice, temporal distribution of commodities, conversion between commodity and vehicle flows, and assignment of vehicles to networks. Therefore, this model allows for drought effects to reach the link volume level as will be further discussed.

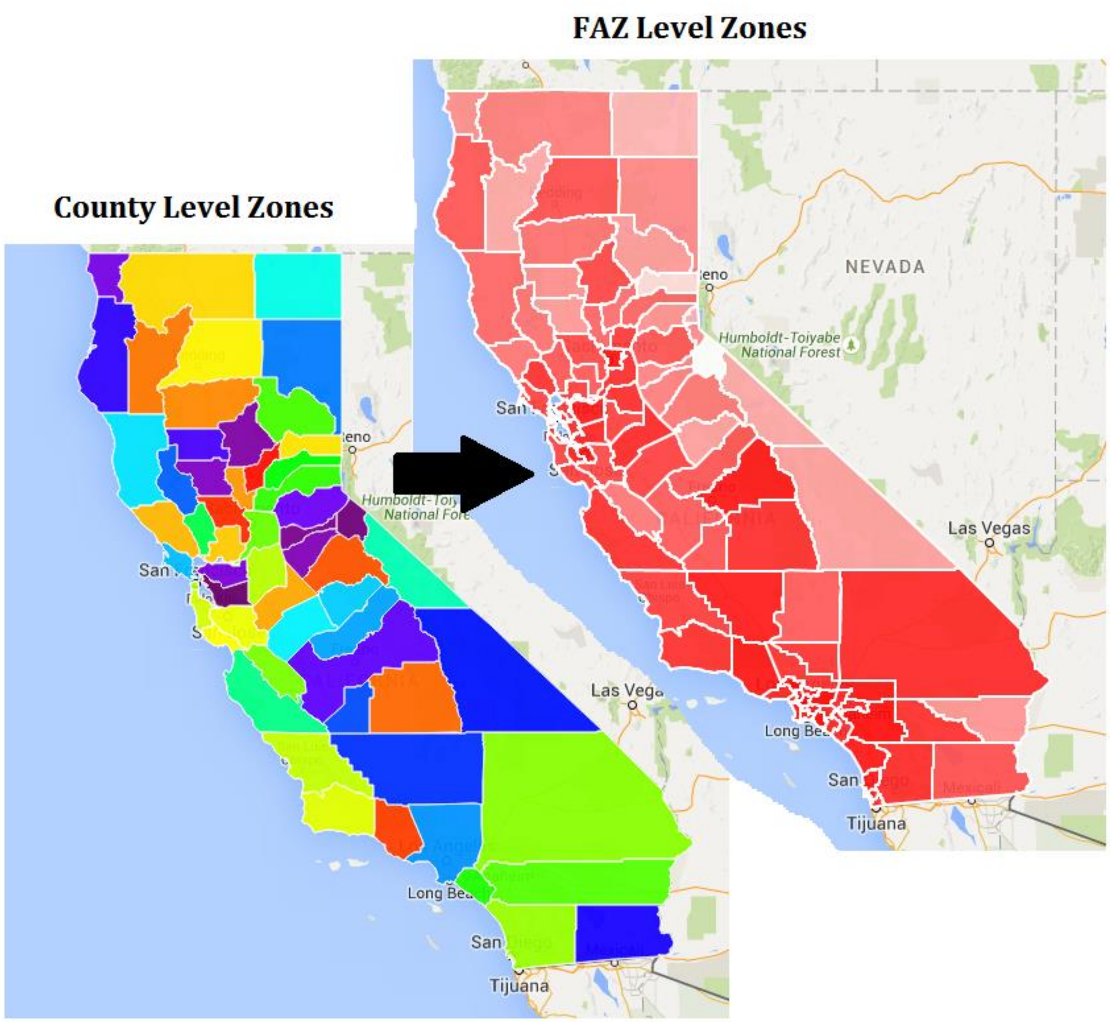
2.1 FAZ Zones and Gateways in CSFFM

The CSFFM model divides California into 97 freight analysis zones (FAZ) that are composed of county level and sub-county level groups. Out of the 58 California counties, the 16 counties summarized in Table 1 are investigated in the model as these account for more than 80% of California's freight movements (CSI, 2009). The remaining counties are aggregated into the "other counties" category to form one FAZ. Figure 2 demonstrates the boundaries of California's 58 county level zones and 97 FAZ zones. In addition, the model is composed of 38 import/export gateways, 118 domestic freight analysis framework (FAF) regions, and 8 international FAF regions. This allows for changes in inbound and outbound shipments to be reflected in the results.

Table 1: Counties Investigated in CSFFM and Number of FAZ's

County	Number of FAZ's per County
Contra Costa , El Dorado , Fresno, Kern, Sacramento, San Francisco , San Joaquin ,San Mateo , Solano, Sonoma	2
Alameda , Santa Clara, Placer, San Bernardino	3
Orange , Riverside	4
San Diego	5
Los Angeles	12
Other 40 counties	1
Total FAZs	97

Figure 2: Division of California's 97 Freight Analysis Zones



2.2 Commodity Groups and Variables

The CSFFM uses 15 commodity groups that are aggregated from the 42 FAF commodities represented by the 2-digit Standard Classification of Transported Goods (SCTG) codes found in Table A.1 under Appendix A. Table 2 summarizes the 15 commodities used in the model analysis.

Table 2: Association of SCTG codes with Commodity Groups

Commodity group	SCTG Codes
CG-1 Agriculture products	1-4
CG-2 Wood, printed products	26-29
CG-3 Crude petroleum	16
CG-4 Fuel and oil products	17,18,19
CG-5 Gravel/ sand and non-metallic minerals	10-13
CG-6 Coal / metallic minerals	14-15
CG-7 Food, beverage, tobacco products	5-9
CG-8 Manufactured products	24,30,39,40,42,43
CG-9 Chemical/ pharmaceutical products	20-23
CG-10 Nonmetal mineral products	31
CG-11 Metal manufactured products	32-34
CG-12 Waste material	41
CG-13 Electronics	35,38
CG-14 Transportation equipment	36-37
CG-15 Logs	25

The total future productions and attractions for each of these 15 commodities are forecasted by the freight generation model within the CSFFM for each of the 97 FAZ zones. The direct demand model then estimates the origin-destination (OD) flows for all commodity groups. A structural equation modeling framework is applied to both the freight generation and direct demand model using spatial, social, economic, demographic, and industrial characteristics of each zone. Three digit employment and establishment codes from the North American Industry Classification System (NAICS) are used to identify the various industry types located in each of the FAZ zones. These codes range from values between 113 to 813 as summarized in Table 3. Ultimately, these characteristics form the variables in the trip generation and direct demand model; therefore, these variables are studied for drought sensitivity.

Table 3: Characteristics of Trip Generation and Direct Demand Model (CSFFM 2015)

Field	Description
EMP113	3 digit NAICS employment 113
EMP114	3 digit NAICS employment 114
…	…
EMP813	3 digit NAICS employment 813
EMPTOT	Total employment
EST113	3 digit NAICS Establishment 113
EST114	3 digit NAICS Establishment 114
…	…
EST813	3 digit NAICS Establishment 813
ESTTOT	Total establishments
POP	population
HARVTLAND	Acreage of harvested land (1000 acres)
REFINCAP	Sum of capacities of all refineries in the zone
MGDP	Manufacturing GDP (million dollars)
LIVSTOK	Ktons of livestock sold in the zone
OILPROD	Million barrel of oil production
EMP23	Construction employment
EMP313_6	Sum of employment in categories 313 to 316
EST322_3	Sum of establishments in categories 322 and 323
G1P …G15P	Total production of commodity group xx if available at FAF data base for that scenario , 0 otherwise
G1A… G15A	Total Attraction of commodity group xx if available at FAF data base for that scenario , 0 otherwise

CHAPTER 3: CSFFM Variables Affected by the California Drought

In order to determine how the state's freight movements are affected by the drought, each of the variables in the freight generation and demand model were investigated for water shortage sensitivity. This chapter summarizes some of the findings concluded to be applicable in this study and presents ways they can be implemented in the model.

3.1 Identifying Water Intensive Variables

Out of the variables presented in Table 3, it is known that "harvested land" is one of the most water intensive variables. Agriculture alone uses about 80% of California's developed water supply (Pacific Institute 2014). Since the initiation of water reductions from the California Water Resources Control Board, several agricultural regions within the state have been forced to depend on other water resources and others have left their cropland fallowed.

In addition to agriculture, several industries could potentially be affected by water shortages. In a study sponsored by the California Urban Water Agencies (Wade et al. 1991), various manufacturing industries within the state of California were surveyed to obtain a better understanding of industrial water usage and the effects drought played on their stability. Before beginning the survey process, the most water sensitive manufacturing industries were identified as candidates for the survey. The industry groups selected were based on 3-digit Standard Industry Classification (SIC) group codes listed in Table 4. SIC codes are used by the U.S government to identify the main business of various types of establishments. Groups 322, 331, and 341 were eliminated from the analysis as single responses were received from these groups.

Table 4: Manufacturing Plants Selected for CUWA Survey

SIC Code	Description of Plant	SIC Code	Description of Plant
201	Meat Products	322	Glass, Glassware
203	Preserved Fruits & Vegetables	327	Concrete, Gypsum, Plaster Prod.
205	Bakery Products	331	Blast Furnace & Steel Prod.
208	Beverages	341	Metal Cans. Shipping Containers
209	Misc. Foods & Kindred Prod.	344	Fabricated Structural Metal Prod.
265	Paperboard Containers and Boxes	357	Computer & Office Equip.
281	Industrial Inorganic Chemicals	366	Communication Equipment
283	Drugs	367	Electronic Comp. & Acc.
284	Soap, Cleaners & Toilet Goods	371	Motor Vehicles & Equip.
285	Paints & Allied Prod.	372	Aircraft & Parts
291	Petroleum Refining	376	Guided Missiles, Space Veh., Parts

The survey used a sample of 640 manufacturing plants located in various counties throughout the San Francisco and Southern California area including Alameda, Contra Costa, San Francisco, San Mateo, Santa Clara, Solano, Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura. These counties were selected because in 1987, they accounted for 85% of manufacturing output in the state and employed 88% of the labor associated with this output (Wade et al. 1991). The survey developed several questions that addressed possible future water shortage effects on manufacturing plant activity. Two different scenarios were developed; one assumed a 15% water shortage during the summer months (between April and November) and the other assumed a 30% water shortage during the entire year. Based on the survey results, there is an evident effect that water shortages have on industrial activities. Therefore, the industries listed in Table 4 were further investigated for use in this study. The remaining variables were not found to be significantly affected by water shortages.

3.2 Drought Effects on Manufacturing Industries

Very few studies have researched the way drought affects industrial output health. Part of the reason this area lacks research is that these sectors are often protected in various ways in order to prevent job losses that could eventually hurt the economy (Hanak et al. 2002). However, according to a study conducted in 2007 by the San Francisco Public Utilities Commission (SFPUC), water shortages can affect industrial operations.

The SFPUC analyzed the effects of water rationing on residential, commercial and industrial sectors and demonstrated the impacts this sets on employment under different water shortage scenarios. This study was carried out through an online survey distributed to approximately 1,000 commercial and industrial customers in the SFPUC and Bay Area Water Supply & Conservation Agency (BAWSCA) including the counties of San Francisco, Alameda, San Mateo, and Santa Clara. The survey questions were meant to serve as an indication of the ability and willingness of commercial and industrial users to reduce water consumption. Different water rationing options were analyzed using the survey responses. The percent change in output and employment were measured using sales and payroll as indicators of elasticity under 10%, 20%, and 30% water reductions and three different water rationing methods. Under the proportional rationing method, water shortages are distributed proportionally among all water agencies. While the other two methods aim at minimizing surplus loss by either recognizing the difference in price elasticity within its customers or allowing water trading among agencies. Results indicate that under the proportional rationing method a 10, 20, and 30 percent water reduction can lead to industrial employment losses of 1,323, 2,629, and 8,007 employees respectively within the industrial sectors with North American Industry Classification (NAICS) codes 31-33 as summarized in Table 5.

This estimate is only for the counties of Alameda, San Francisco, San Mateo, and Santa Clara. Therefore, this data was disaggregated to develop estimates for the FAZ level zones. In addition, it was found through the study from California Urban Water Agencies (CUWA) that manufacturing industries with NAICS codes 31-33 have varying sensitivities to water reductions. Therefore, employment losses per NAICS code from the CUWA study were used to proportionally distribute the employment loss effects from the SFPUC study into the NAICS 31-33 manufacturing industry types. More details on the disaggregation method can be found under Appendix B.

Table 5: Industrial and Commercial Sector Payroll and Job Losses (Berkham & Sunding 2007)

	Avg Payroll		**10% Drought Scenario**				**20% Drought Scenario**			
Sector & Model	**Total Payroll 2004 (thousands)**	**Avg Payroll per Employee (Thousands)**	**% Change in Industrial Consumption**	**Elasticity (0-15%)**	**Payroll Loss (thousands)**	**Equivalent Job Losses**	**% Change in Industrial Consumption**	**Elasticity (0-15%)**	**Payroll Loss (thousands)**	**Equivalent Job Losses**
	[I]	**[II]**	**[III]**	**[IV]**	**[V]= [I]x[III]x [IV]**	**[VI]= [V]/[II]**	**[VII]**	**[VIII]**	**[IX]= [I]x[VII]x[VIII]**	**[X]= [IX]/[II]**
Industrial										
Proportional Rationing	**$11,937,389**	**$72.59**	**7.8%**	**0.104**	**$96,052**	**1,323**	**15.4%**	**0.104**	**$190,868**	**2,629**
Efficiency Pricing	**$11,937,389**	**$72.59**	**9.2%**	**0.104**	**$113,381**	**1,562**	**18.2%**	**0.104**	**$225,444**	**3,106**
Regional Water Market	**$11,937,389**	**$72.59**	**10.2%**	**0.104**	**$125,875**	**1,734**	**18.9%**	**0.104**	**$234,304**	**3,228**
Commercial										
Proportional Rationing	**$87,552,091**	**$59.83**	**9.0%**	**0.009**	**$73,774**	**1,233**	**17.4%**	**0.009**	**$143,050**	**2,391**
Efficiency Pricing	**$87,552,091**	**$59.83**	**12.6%**	**0.009**	**$103,301**	**1,727**	**24.7%**	**0.009**	**$202,570**	**3,386**
Regional Water Market	**$87,552,091**	**$59.83**	**12.7%**	**0.009**	**$104,156**	**1,741**	**23.6%**	**0.009**	**$193,877**	**3,240**

Cont. Table 6: Industrial and Commercial Sector Payroll and Job Losses (Berkham & Sunding 2007)

	30% Drought Scenario				Payroll Loss %		
Cont. Sector & Model	**% Change in Industrial Consumption**	**Elasticity (0-15%)**	**Payroll Loss (thousands)**	**Equivalent Job Losses**	**10%**	**20%**	**30%**
	[XI]	**[XII]**	**[XIII]= 0.15x[I]x[VIII] +([XI]- 0.15x[I]x[XII]**	**[XIV]= [XIII]/[II]**	**[XV]= [V]/[I]**	**[XVI]= [IX]/[I]**	**[XVII]= [XIII]/[I]**
Industrial							
Proportional Rationing	**23.1%**	**0.411**	**$581,245**	**8,007**	**0.8%**	**1.6%**	**4.9%**
Efficiency Pricing	**27.3%**	**0.411**	**$786,369**	**10, 832**	**0.9%**	**1.9%**	**6.6%**
Regional Water Market	**27.7%**	**0.411**	**$808,677**	**11,140**	**1.1%**	**2.0%**	**6.8%**
Commercial							
Proportional Rationing	**25.9%**	**0.251**	**$2,512,614**	**41,996**	**0.1%**	**0.2%**	**2.9%**
Efficiency Pricing	**36.8%**	**0.251**	**$4,905,971**	**81,998**	**0.1%**	**0.2%**	**5.6%**
Regional Water Market	**34.6%**	**0.251**	**$4,427,035**	**73,993**	**0.1%**	**0.2%**	**5.1%**

Notes:

1) **The industrial sector is assumed to be NAICS codes 31-33**
2) **The commercial sector is assumed to be NAICS codes 42-81**
3) **Total payroll includes all payroll in the industrial and commercial NAICS codes for Alameda, San Francisco, San Mateo, and Santa Clara counties**
4) **To compensate for the fact that BAWSCA and SFPUC do not service the entire counties for which we have data, all of San Francisco and San Mateo County sales are included, while 50% of Alameda County and 80% of Santa Clara County sales are included.**
5) **Weighted-average industrial and commercial payroll elasticities were calculated using MHB payroll elasticities and 2004 County Business Patterns payroll data. The elasticities reported in the MHB study are for 0% to 15% and a 15% to 30% reduction in water supply.**

After the disaggregation procedure, it was determined that the employment reductions shown in Table 6 can be applied to the employment estimates for future years.

Table 7: Employment Reductions to Manufacturing Industries under Different Water Reductions

Employment Type (NAICS Code)	Total % Reduction for Each County under 10% water reduction	Total % Reduction for Each County under 20% water reduction	Total % Reduction for Each County under 30% water reduction
Food Manufacturing (311)	0.15 %	0.30 %	0.92 %
Beverage + Tobacco Product Manufacturing (312)	0.04 %	0.07 %	0.23 %
Paper Manufacturing (322)	0.04 %	0.09 %	0.27 %
Petroleum+ Coal Products Manufacturing (324)	0.00 %	0.00 %	0.01 %
Chemical Manufacturing (325)	0.10 %	0.21 %	0.63 %
Nonmetallic Mineral Prod Manufacturing (327)	0.01 %	0.02 %	0.06 %
Fabricated Metal Prod Manufacturing (332)	0.04 %	0.08 %	0.24 %
Computer + Electronic Prod Manufacturing (334)	0.28 %	0.56 %	1.69 %
Transportation Equipment Manufacturing (336)	0.14 %	0.27 %	0.82 %

Although droughts can have an effect on the number of people employed within an industrial manufacturing company, it is very unlikely that water reductions will have a severe effect on the number of establishments as policy makers can protect the commercial and industrial sectors by requiring higher water losses in the residential sector (Berkham and Sunding 2007). Therefore, it was assumed in this study that the number of industrial manufacturing establishments would remain unaffected.

3.3 Drought Effects on Agriculture

California agriculture has been among the most popularly discussed topics associated with the drought. Recent studies indicate that approximately 5% of California cropland was left fallowed by farmers in 2014 and this number is expected to increase for 2015 and the years to come (Hanak et al., 2015). In 2014, this resulted in total statewide economic costs around $2.2 billion for crop revenue loss, livestock and diary revenue loss, and extra groundwater pumping (Howitt et al., 2014). Several studies have been conducted related to the effect of climate change and water shortages on agriculture. However, most have either been too broad for use in this drought analysis or the focus has been on the economic effects of water shortages rather than direct fallowed crop estimates.

Among these studies is one by the USDA that analyzed the adaptation of U.S crops to climate change (Marshall et al. 2012). In this study, climate change models were used to predict changes in average temperatures and rainfall at a worldwide level. Four climate change scenarios were created for the year 2030 to predict crop growth changes per U.S region. Although this study demonstrates that climate change can potentially lead to changes in crops harvested, the study region is too broad to be able to apply it to the state of California. In addition, climate changes cannot be directly connected to water shortages.

In another study, Ding et al. (2010) conducted a literature review on the economic impacts of the drought. This analysis presents the idea that farmer losses cannot be equated with drought economic impacts because farmers can often rely on crop insurance. Therefore, it is concluded that agriculture economic losses cannot be used to predict direct crop acreage losses.

In 2005, the Department of Water Resources released the California Water Plan Update in which future food production and consumption in California was forecasted. The report reviews food production and consumption patterns in CA in recent years and forecast patterns for 2030. One of the main benefits of the model is that it predicts crop yield changes under several climate variations such as changes in temperature and precipitation, changes in CO2 fertilizer, and technology adaptations. In addition, crop yield changes are separated by California regions, which can increase estimation accuracy at more disaggregated levels. However, this study does not consider irrigation water supply or demand and does not consider changes in groundwater availability in the future.

Out of the current studies addressing changes in crop acreage due to the drought, the most applicable to this study is that from Howitt et al. (2015) from the UC Davis Center for Watershed Sciences. This study looks into the effects of the California drought on irrigated crop acreage for the years of 2015 to 2017 assuming 2015 surface water availability. Estimated changes in crop acreage are divided by regions in California and by crop type such as vegetables, orchards and vines, feed crops, grain, and other fields. Although the study does not take into consideration changes in groundwater availability, it is predicted that the impacts of drought in 2016 and 2017 will increase substantially under a future decrease in groundwater availability.

The crop acreage changes presented by the UC Davis Center for Watershed Sciences are the most relevant and up to date for a future analysis. The 2015-2017 crop changes summarized in Table 7 can be extrapolated for future years to create an estimate of 2020 irrigated crops fallowed. However, irrigated crops represent only a small portion of total crop acreage in the state of California. Therefore, estimates of total crops fallowed per year and county were obtained from the USDA's CropScape system (USDA NASS 2014). CropScape is an online query tool developed by the USDA to provide annual crop acreage data for various crops at the state, district, and county level. Crop acreage is estimated using geospatial visual analysis tools and provides estimates up to the year 2014; therefore, total crops fallowed for future years were estimated using USDA data. As a base for analysis, it is assumed that future total crops fallowed changes the same way as the irrigated crops fallowed presented in Table 7 from the UC Davis Center for Watershed Sciences. However, it is evident that non-irrigated crops are more likely to be affected by the drought as these crops are solely reliant on rainfall while irrigated crops have surface and groundwater resources. To demonstrate possible variations of total crops fallowed from the base assumption, a sensitivity analysis is applied. More information on the sensitivity analysis can be found in the following chapter.

In addition, since crop acreage estimates are aggregated into broad regions (Sacramento, San Joaquin, Tulare, Central Coast/ SoCal), the crop reductions of this report are disaggregated into the county level in order to be applied into the 97 FAZ's. The estimation and disaggregation procedure is summarized in Appendix B. Table 8 summarizes the resulting crop acreage reductions for Scenario 1 (no land use change) and Scenario 2 (California cropland reduction).

Table 8: Estimated Change in Irrigated Crop Acreage from Drought (thousands of Acres) (Howitt et al. 2015)

2015						
Region	**Vegetables**	**Orchards and Vines**	**Feed Crops**	**Other Field**	**Grain**	**Total**
Sacramento	-0.3	-4.4	-37.0	0.6	-138.1	-179.2
San Joaquin	0.1	-4.5	-38.2	-8.4	-21.4	-72.5
Tulare	-22.3	-27.3	-58.5	-901	-89.9	-288.0
Central Coast and So.Cal.	-1.2	0.2	2.0	-2.0	-1.4	-2.5
Total	-23.6	-36.0	-131.7	-99.9	-250.9	-542.1
2016						
Region	**Vegetables**	**Orchards and Vines**	**Feed Crops**	**Other Field**	**Grain**	**Total**
Sacramento	-0.4	-4.5	-37.4	0.5	-138.4	-180.2
San Joaquin	-0.1	-4.6	-38.9	-9.3	-21.6	-74.6
Tulare	-22.1	-27.3	-58.8	-89.9	-89.9	-288.1
Central Coast and So.Cal.	-1.2	0.2	2.0	-2.0	-1.4	-2.5
Total	-23.8	-36.2	-133.2	-100.8	-251.4	-545.4
2017						
Region	**Vegetables**	**Orchards and Vines**	**Feed Crops**	**Other Field**	**Grain**	**Total**
Sacramento	-0.5	-4.7	-38.0	0.4	-139.0	-181.8
San Joaquin	-0.3	-4.9	-39.8	-10.4	-21.7	-77.1
Tulare	-22.1	-27.3	-59.1	-90.0	-90.1	-288.5
Central Coast and So.Cal.	-1.3	0.2	2.1	-2.0	-1.5	-2.5
Total	-24.2	-36.6	-134.8	-102.1	-252.3	-549.9

Table 9: Percent Crop Reductions per County

COUNTY	Fallowed Acres (Thousands)	Scen. 1 (No land use change) % Acreage Reduction	Scen. 2 (CA Cropland decrease) % Acreage Reduction
Amador	203.87	2.87	3.28
Butte	70499.82	36.82	42.05
Calaveras	8.20	0.30	0.34
Colusa	86883.45	32.96	37.65
Contra Costa	4811.09	21.14	24.15
El Dorado	6.00	0.11	0.12
Fresno	247079.03	26.48	30.25
Glenn	51602.54	23.69	27.07
Imperial	92491.30	25.82	29.49
Kern	262756.65	36.05	41.17
Kings	215808.64	53.92	61.60
Los Angeles	8163.00	33.16	37.88
Madera	21538.00	8.54	9.75
Mariposa	20.70	7.60	8.68
Merced	63029.70	14.18	16.20
Monterey	30155.40	13.89	15.87
Placer	6152.33	29.36	33.54
Riverside	42132.40	26.99	30.84
Sacramento	23980.08	22.21	25.37
San Benito	11218.30	36.14	41.29
San Diego	836.00	1.30	1.49
San Joaquin	20814.07	4.91	5.61
San Luis Obispo	28834.10	28.68	32.76
Santa Barbara	9246.70	10.40	11.88
Santa Clara	4212.80	18.91	21.60
Shasta	3814.19	18.24	20.84
Solano	20336.87	17.72	20.25
Stanislaus	8202.89	2.80	3.19
Sutter	81265.66	35.30	40.32
Tehama	3640.39	6.31	7.21
Tulare	88476.50	16.57	18.93
Tuolumne	13.28	1.95	2.23
Ventura	906.50	0.98	1.12
Yolo	108941.25	44.26	50.56
Yuba	34167.94	57.36	65.52

CHAPTER 4: DROUGHT SCENARIOS

There have been some very different perspectives on the reason behind the current California drought. Some scientists claim that the drought will continue and will be heavily impacted by climate change effects. Others claim the drought to be temporary and expect El Niño to increase water availability in California during the next winter. Since rainfall intensity could vary significantly, both drought and non-drought effects are analyzed in this study.

Four different scenarios are developed using the crop reduction estimates from the previous chapter to analyze possible variations in model variables. Two of these scenarios address possible effects of a continued drought while the last two scenarios are base/ no drought scenarios for comparison. A sensitivity analysis is applied to each of the scenarios to show how variances in crop acreage reductions can affect results.

4.1 Scenario Descriptions

Scenario 1

One of the main characteristics of Scenario 1 is the assumption that the amount of cropland in the state of California remains the same as previous years. Scenario 1 takes the harvested acre reductions per county from Table 8 and applies these reductions to the original harvested acres estimated for 2020 as an input for the CSFFM model. These CSFFM harvested acre estimates assume no change in land use. In other words, the amount of land designated for growing crops remains the same up to the year 2020. In addition, employment reductions are applied assuming the effects of a worst case scenario (30% water shortage effects) on manufacturing industries. The drought effects on employment per NAICS code under a 30% water shortage are summarized in Table 6. For employment reductions, it is assumed that all manufacturing FAZ's within the state will have the same employment percentage loss.

Scenario 2

Scenario 2 is developed from Scenario 1. The same employment and harvested acre reductions are applied; however, there is a difference in the base 2020 harvested acres. Under scenario 2, a decrease in cropland within the state is assumed. Since 1984, approximately 1.4 million farm land acres in the state of California have been urbanized and these trends continue to increase (CA Department of Conservation, 2014). Just within the 10-year period of 2010 to 2020, there is an estimated loss of 12.3% of cropland. This estimate is based on the trend of cropland acre losses from each of the agricultural census reports since the year of 1997. The resulting fallowed acre percentage losses for 2020 are summarized in Table 8. The same estimation and disaggregation procedure as the Scenario 1 crops fallowed estimate is used.

Scenario 3

Under Scenario 3, it is assumed there is no drought and regular trends exist in crops harvested and employment. In addition, it assumes that there is no change in land use; therefore, there serves as a base for comparison with Scenario 1, which also assumes no land use change.

Scenario 4

Scenario 4 is also a no drought effects base scenario for comparison with Scenario 2. It assumes that there are no harvested acre and employment losses, but there is a decrease of cropland use of 12.3% in comparison to the amount of cropland there would be under no land use changes for the year 2020.

4.2 Truck Volume and VMT Scenario Results

The focus of the study results was on CSFFM truck classes 3(FHWA Classes 8,9, & 10) and 4 (FHWA Classes 11,12, & 13) which is equivalent to trucks pulling single trailers and tractors pulling multiple trailers, respectively. California is a major importer and exporter of goods both nation and worldwide; therefore, by focusing the study to these truck classes, any major changes that could have a large impact on the state are more evident. Results mainly indicate changes in long- haul trips from these type of trucks.

Figures 3 and 4 demonstrate daily trucks volumes for all four scenarios. The most impacted highways are the I-5, SR-99, I-10, I-15, I-40, and I-80. Figures 5 and 6 demonstrate the difference in truck volumes between each of the drought scenarios (Scenario 1 and Scenario 2) and the base, no drought scenarios (Scenario 3 and Scenario 4). The majority of the changes occur along the most impacted routes previously identified. For the most part, there is a decrease in daily truck volumes with values reaching slightly higher than 500 trucks per day. Higher impacts are evident along the I-5 and the SR-99 in the Central Valley Region. The Central Valley is the most affected as it is a major agricultural and food processing region in the state. In addition, there are major truck volumes decreases along the I-5, north of the Los Angeles area. This could be a representation of the loss of manufacturing employment as Los Angeles is a major manufacturing center in areas such as computer and electronic products, food products, transportation products , and much more. Significant variances are also evident near the state's sea ports. California is a major exporter of agricultural goods both nation and worldwide. Losses in agricultural products could lead to a decrease in exports at ports and a decrease in exports made along route I-10. Overall, it is evident that there is a larger effect under Scenario 2 (Drought and Cropland Use Decrease).

Figures 7 and 8 show the estimate of vehicle miles traveled (VMT) per FAZ region. FAZ's along the I-5 and FAZ's in the Inland Empire region have the highest VMT. This is due to the fact that the I-5 is a major connector between northern and southern California and other states. As for the Inland Empire region, it is a major freight supporter in the state with several intermodal rail yards and cargo-sorting cross-dock facilities. Figure 9 demonstrates the VMT percentage differences between the drought and no drought scenarios. Under both scenarios 1 and 2, there are high VMT changes in the Sacramento, Los Angeles, and Central Valley Regions. The most affected is Sacramento which lies along a major interstate highway leading to the east coast. This large difference in VMT could be a representation of the decrease in trucks using the I-5 and the I-80 to travel north or east. Most FAZ's in the outskirts of California have very minimal changes. This is especially true in the Central Sierra, Inland Empire, and San Diego Regions. However, results do indicate a slight increase in VMT for some of the northern FAZ's in Upstate California. This could be a result of higher inbound shipments from surrounding states to meet deficiencies.

Figure 3: Scenario 1 and Scenario 2 CA Daily Truck Volumes in 2020

Scenario 1 (Drought and No Cropland Use Change) | **Scenario 2 (Drought and Cropland Use Decrease)**

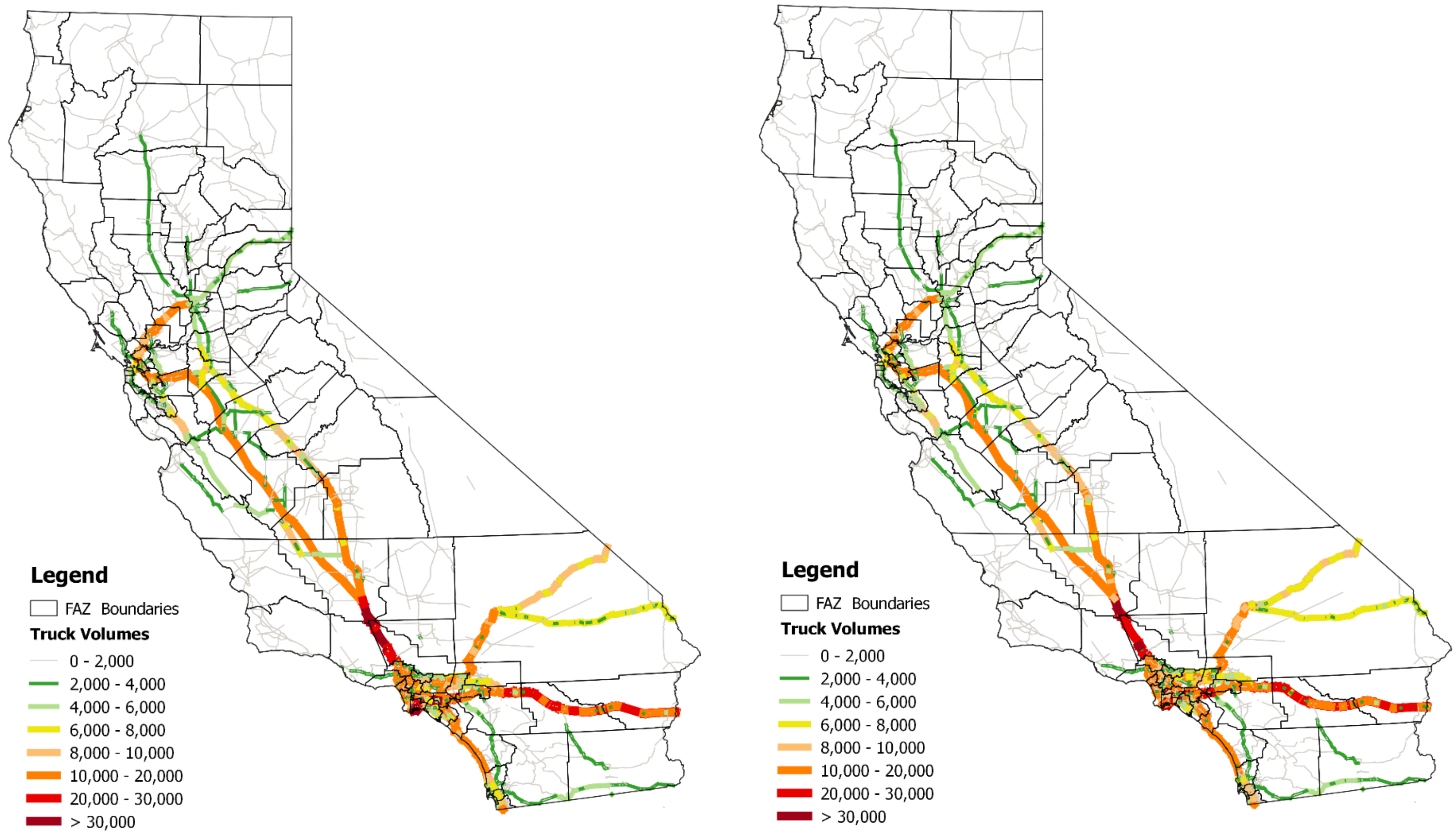
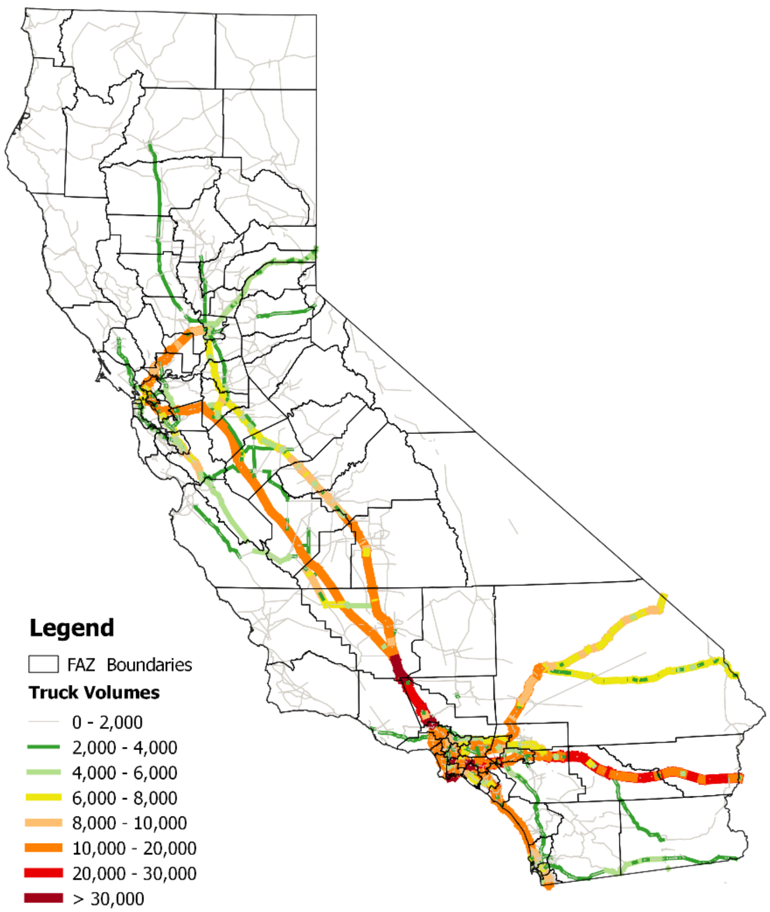


Figure 4: Scenario 3 and Scenario 4 CA Daily Truck Volumes in 2020

Scenario 3
(No Drought and No Cropland Use Change)



Scenario 4
(No Drought and Cropland Use Decrease)

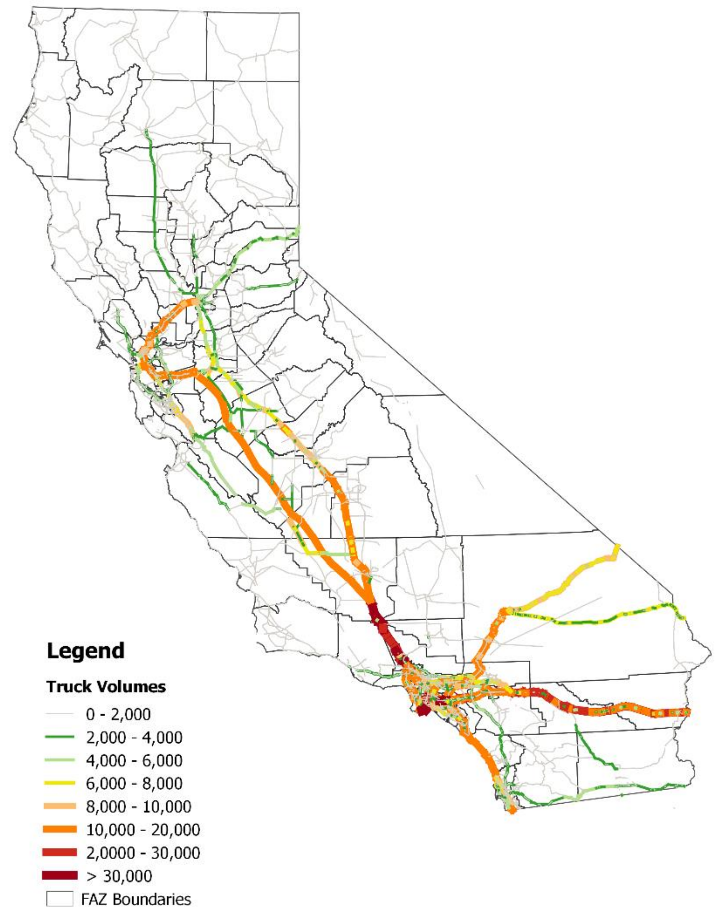


Figure 5: Difference in 2020 CA Truck Volumes Between Scenario 1 (Drought and No Cropland Use Change) and Scenario 3 (No Drought and No Cropland Use Change)

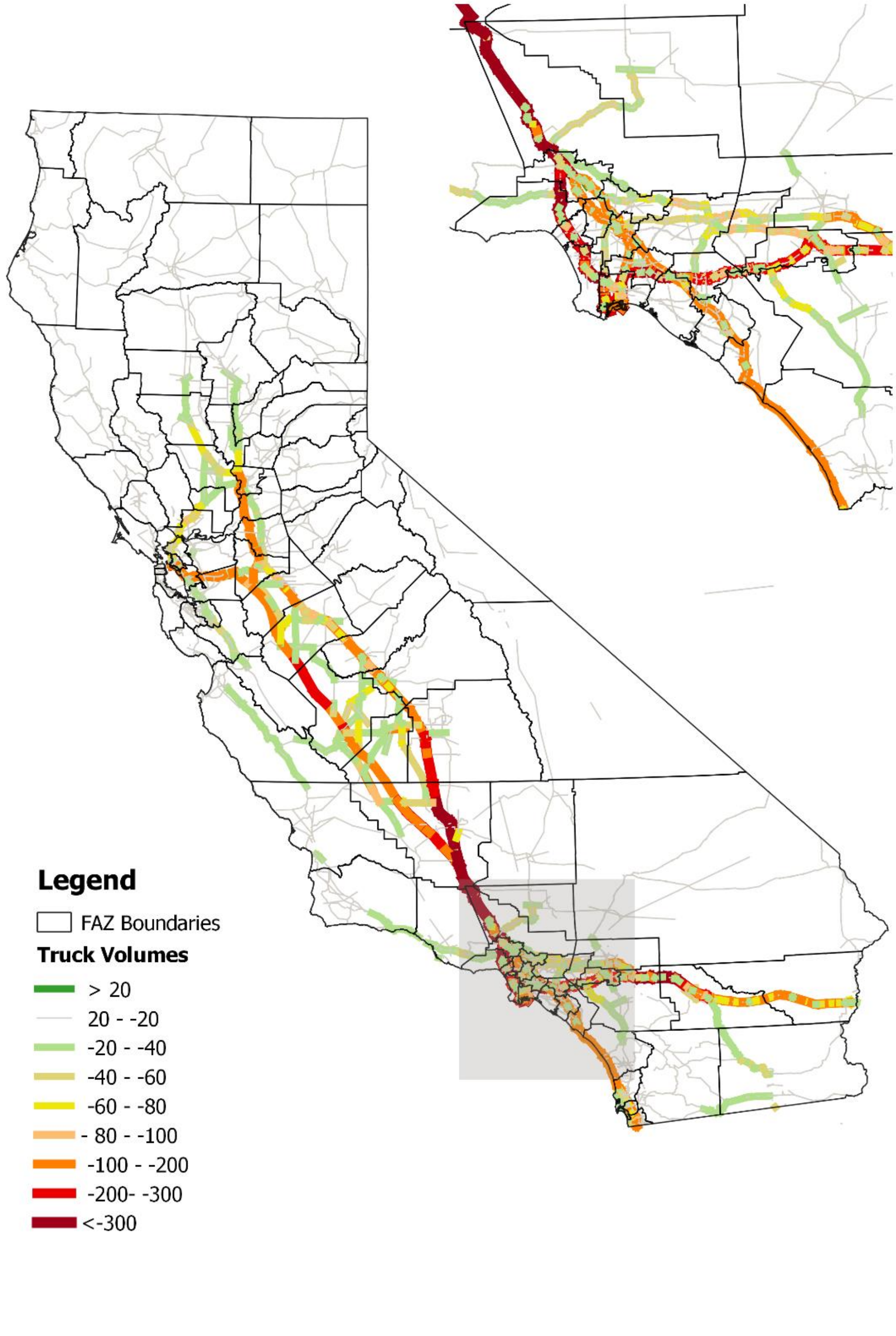


Figure 6: Difference in 2020 CA Truck Volumes Between Scenario 2 (Drought and Cropland Use Decrease) and Scenario 4 (No Drought and Cropland Use Decrease)

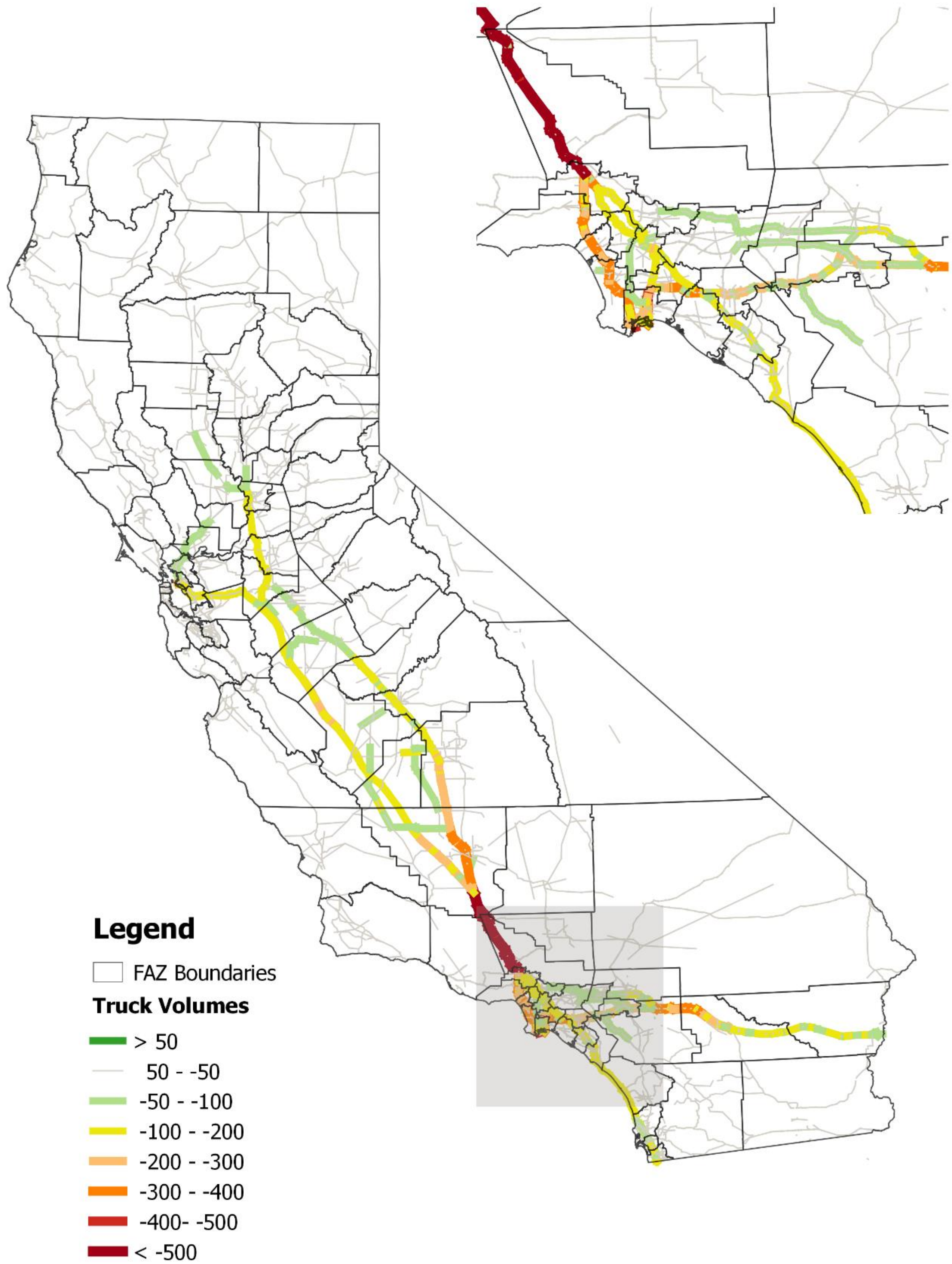
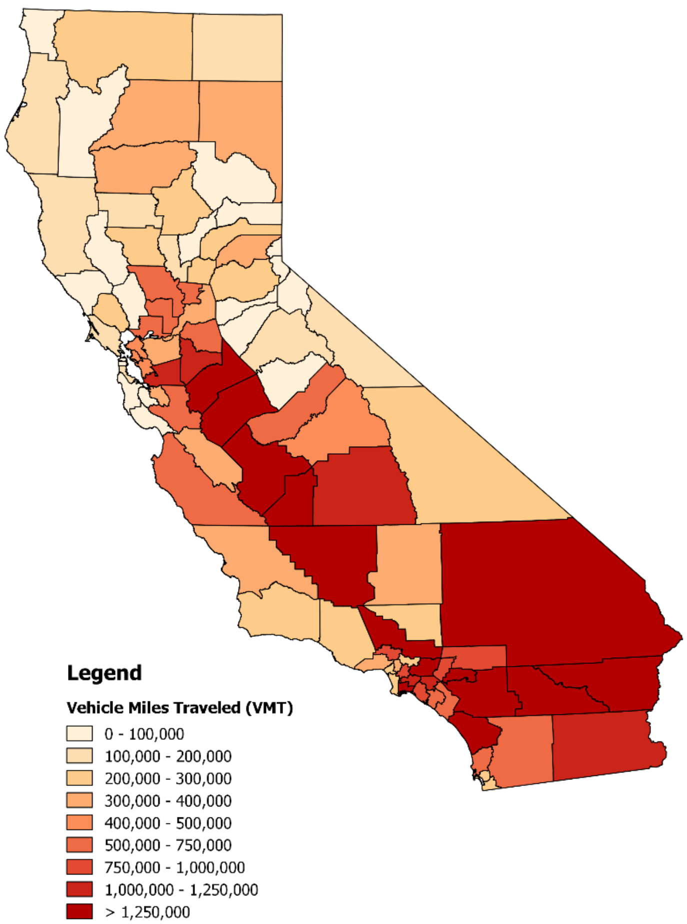


Figure 7: Scenario 1 and Scenario 2 CA Daily Truck VMT in 2020

Scenario 1
(Drought and No Cropland Use Change)



Scenario 2
(Drought and Cropland Use Decrease)

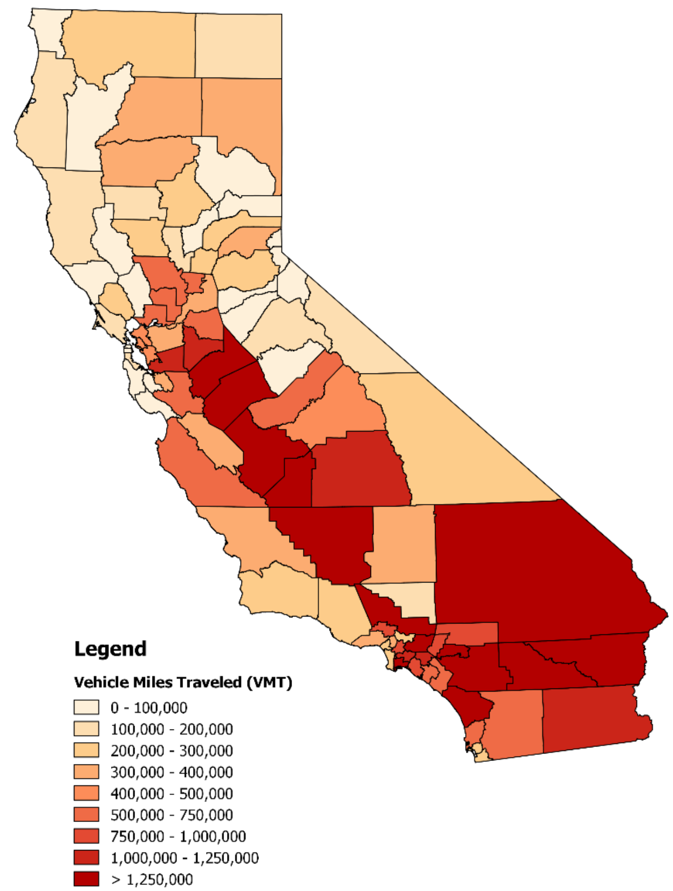
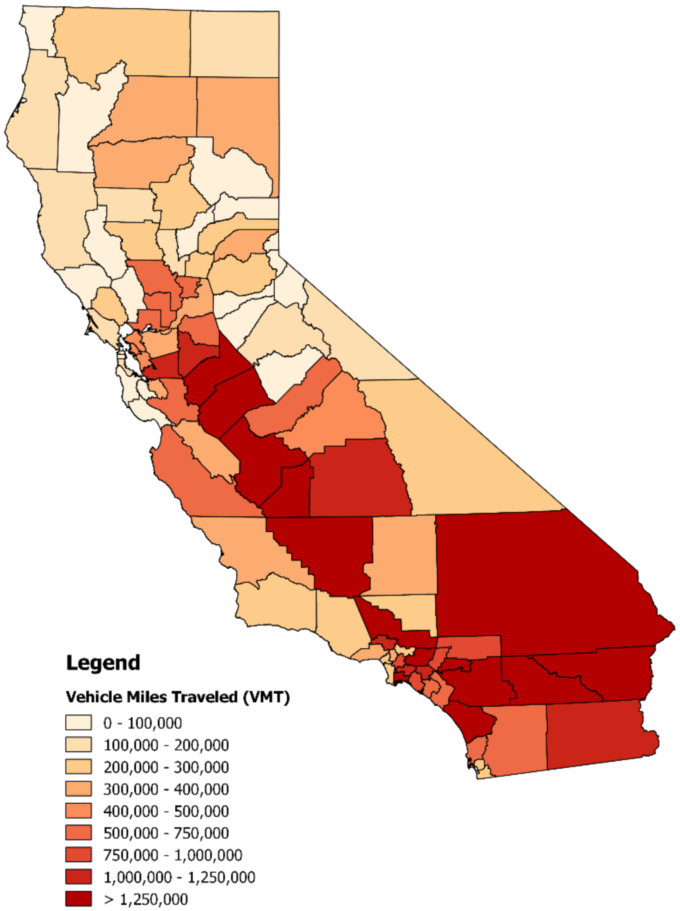


Figure 8: Scenario 3 and Scenario 4 CA Daily Truck VMT in 2020

Scenario 3
(No Drought and No Cropland Use Change)



Scenario 4
(No Drought and Cropland Use Decrease)

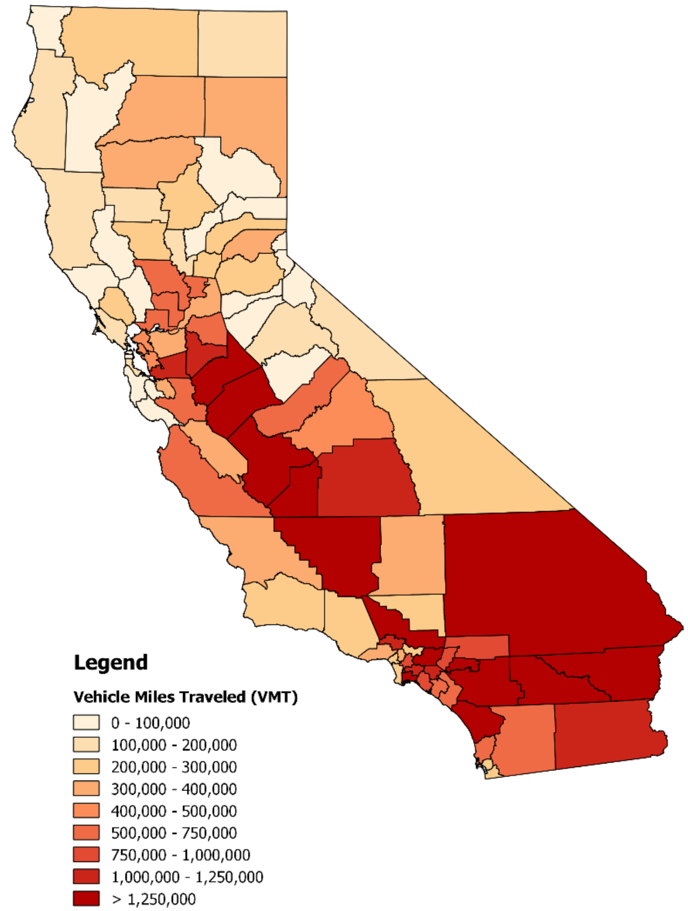
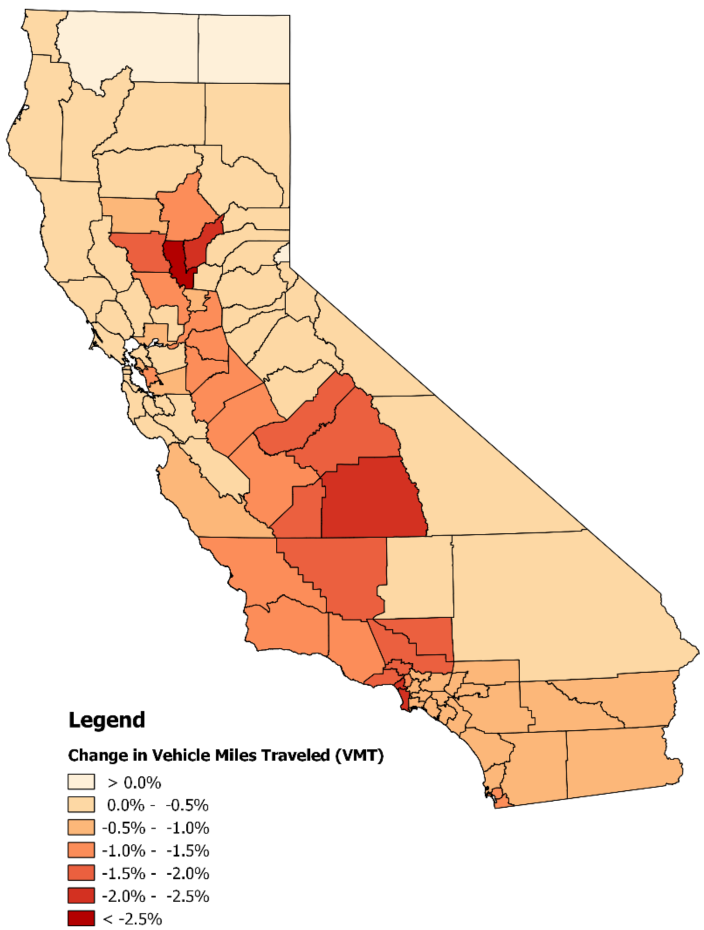
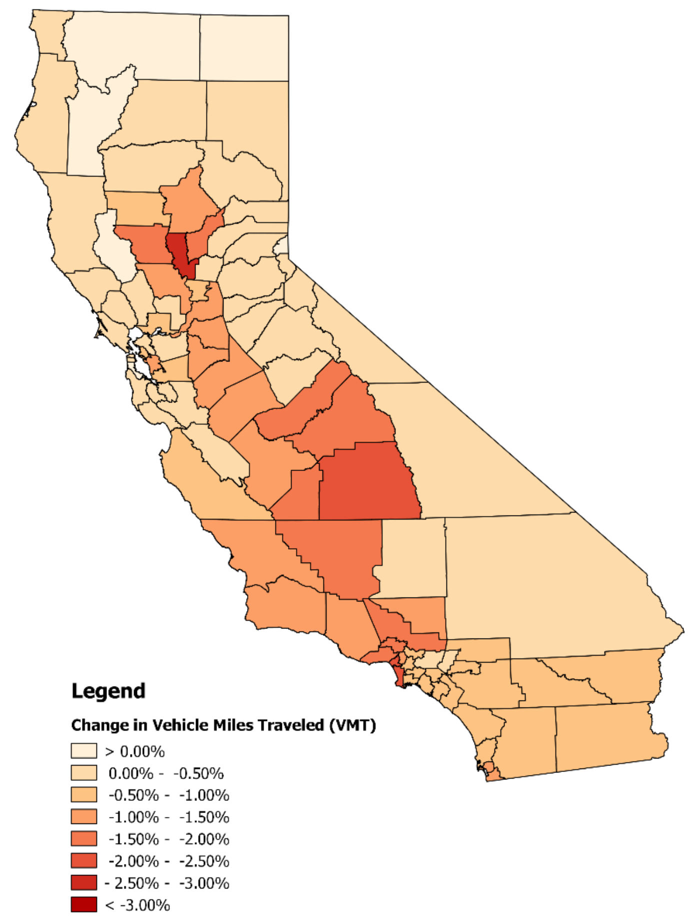


Figure 9: Percent Difference in 2020 CA Truck VMT

Difference Between Scenario 1 (Drought and No Cropland Use Change) and Scenario 3 (No Drought and No Cropland Use Change)



Difference Between Scenario 2 (Drought and Cropland Use Decrease) and Scenario 4 (No Drought and Cropland Use Decrease)



4.3 Truck Emissions Results

In addition to affecting freight movements in the state, the drought can have a resulting effect on truck emissions. Since the passage of the California Global Warming Solutions Act of 2006 (AB 32), emissions mitigation and monitoring have been a major state goal. This act requires that greenhouse gas emissions be limited in order to reach 1990 emission levels by the year 2020. Due to this demand, the Air Resources Board (ARB) developed CT-EMFAC in collaboration with Caltrans and the University of California, Davis. CT-EMFAC is an analysis tool that models on –road vehicle emissions for mobile source air toxins and carbon dioxide.

The California EMFAC emissions model is used to analyze the effects VMT changes have under each scenario for each of the California air basins. However, at such a large aggregated level, it is difficult to see differences in VMT per each scenario. Therefore, only the air basins with the largest VMT changes were modeled for emissions analysis. Air basins of San Joaquin and South Central Coast were found to have the largest VMT differences as shown in Table 10. Emission analyses were run for both of these regions.

Table 10: VMT per Air Basin

Air Basin	Scenario 1	Scenario 2	Scenario 3	Scenario 4	VMT % Diff Scen 1 and 3	VMT % Diff Scen 2 and 4
Great Basin Valleys	472511	471815	472522	471826	0.0%	0.0%
Lake County	68960	68827	68963	68824	0.0%	0.0%
Lake Tahoe	49631	49623	49633	49624	0.0%	0.0%
Mojave Desert	7969775	7958807	7992506	7980858	-0.3%	-0.3%
Mountain Counties	1326985	1325913	1327439	1326362	0.0%	0.0%

North Central Coast	959355	955330	965771	961736	-0.7%	-0.7%
North Coast	526528	525342	526719	525562	0.0%	0.0%
Northeast Plateau	788851	786993	788830	786969	0.0%	0.0%
Sacramento Valley	3906346	3888527	3940153	3922125	-0.9%	-0.9%
Salton Sea	4343664	4327079	4379479	4362864	-0.8%	-0.8%
San Diego	3313967	3300646	3340504	3327178	-0.8%	-0.8%
San Francisco Bay Area	5179853	5164276	5207757	5192453	-0.5%	-0.5%
San Joaquin Valley	17345033	17190638	17624449	17469201	-1.6%	-1.6%
South Central Coast	882134	875367	892652	885808	-1.2%	-1.2%
South Coast	18767081	18673779	18957290	18858699	-1.0%	-1.0%

The pollutants studied in the analysis include Total Organic Gas (TOG), Carbon Monoxide (CO), Oxides of Nitrogen (NOx), Carbon Dioxide (CO2), Particulate Matter with particle sizes of 10 micrometers or smaller in diameter (PM10), Particulate Matter with particle sizes of 2.5 micrometers or smaller in diameter (PM2.5). Total organic gas (TOG's) includes all reactive organic gases (ROG) and low reactivity organic compounds such as methane. Sources of TOG's include fuel burning, organic wastes and pesticides (SLO County APCD 2015). Carbon monoxide (CO) is a gas emitted by various combustion sources containing carbon such as gasoline and wood. Oxides of Nitrogen (NOx) are a group of highly reactive gases such as nitrogen dioxide (NO2) which contribute to ground level ozone. Sources include emissions from motor vehicles and power plants. Carbon dioxide (CO2) is one of the main greenhouse gases produced through daily human activities. The combustion of gasoline and diesel in transportation alone account for about 31% of total

U.S CO_2 emissions (EPA 2015). Particulate matter (PM10 and PM2.5) consist of different small particles ranging from 10 micrometers in diameter to less than 2.5 micrometers in diameter. These particles often result from dust, acids, metals, and organic chemicals (SLO County APCD 2015).

Table 11: 2020 Annual Emissions Comparison Associated with CSFFM Truck Classes 3 and 4 (Tons/day)

	Scenario 1		Scenario 2	
Pollutant (U.S tons)	**San Joaquin Valley**	**South Central Coast**	**San Joaquin Valley**	**South Central Coast**
TOG	4.02	0.138	3.982	0.136
CO	27.008	1.026	26.759	1.01
NOx	70.399	2.631	69.759	2.595
CO2	37942.872	1224.514	37597.97	1207.405
PM10	4.85	0.174	4.806	0.172
PM2.5	3.008	0.104	2.979	0.103
	Scenario 1 % Change from Scenario 3	**Scenario 2 % Change from Scenario 4**	**Scenario 1 % Change from Scenario 3**	**Scenario 2 % Change from Scenario 4**
Pollutant (U.S tons)	**San Joaquin Valley**	**South Central Coast**	**San Joaquin Valley**	**South Central Coast**
TOG	-1.5%	0.0%	-1.6%	-1.4%
CO	-1.5%	-0.4%	-1.6%	-1.6%
NOx	-1.5%	-0.5%	-1.6%	-1.4%
CO2	-1.5%	-0.5%	-1.6%	-1.4%
PM10	-1.5%	-0.6%	-1.5%	-1.1%
PM2.5	-1.5%	0.0%	-1.6%	-1.0%

Table 11 summarizes emissions changes for each of these pollutants in tons/day for CSFFM truck classes 3 and 4, which includes single trailer and multiple trailer trucks. The largest changes in emissions occur under Scenario 2 in the San Joaquin Valley Air Basin with decrease up to 1.6%. The San Joaquin Valley air basin consists of most of the prime agricultural counties in the state including Fresno, Kern, Kings, Merced, San Joaquin, Stanislaus, and Tulare. Therefore, this region demonstrates a greater difference in emissions changes between Scenarios 1 and 2 compared to the South Central Coast air basin, which has less agricultural acres. The decreases of emissions in these regions could also be a result of a decrease in manufacturing industry production as the San Joaquin Valley is home to several food processing and light manufacturing industries. One of the main differences between the emissions results under Scenario1 and Scenario 2 is the lack of an effect of crops harvested reduction on TOG and PM2.5 pollutants under Scenario 1 in the South Central Coast. This includes the counties of San Luis Obispo, Ventura, and Santa Barbara. Since fuel combustion is a source of TOG and PM2.5 pollutants, the lack of emission reductions for these pollutants could be an indication that this region has a higher thru traffic rate compared to regional traffic; therefore, the reductions in crops harvested under Scenario 1 was not large enough to result in a greater variation in emissions.

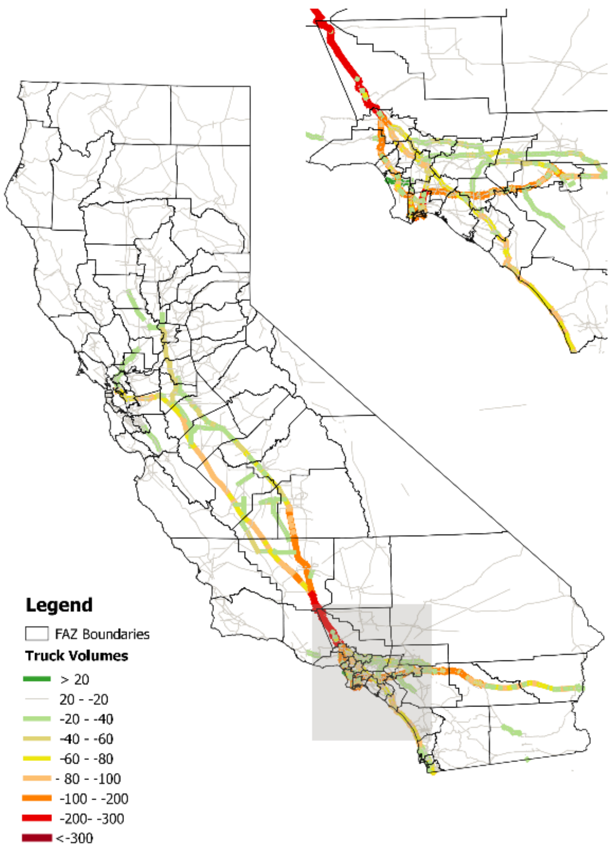
4.4 Sensitivity Analysis

A sensitivity analysis is conducted in order to get a better understanding of how larger and smaller changes to the model input data affects results. Employment changes remain the same under each of the sensitivity runs. The focus of the changes were on crops harvested as this has one of the largest effects on the model. Four different changes to crops harvested were analyzed by assuming that 10%, 20%, 30% and 40% of total crops harvested are left fallowed.

Under a 10% acres fallowed decrease, similar highways as the base drought scenario are affected, but at a reduced level. The region with the greatest effects remains to be the I-5, north of Los Angeles. Figures 10 through 13 demonstrate that this region receives the greatest changes in truck volumes in all sensitivity analysis scenarios. As expected, it gradually worsens as the total crops fallowed increases. It is evident that the increase in crops fallowed is part of the reason behind truck volume changes in this region as the difference initially increases from the I-5 to the SR-99 as you move from Figure 10 with 10% acres fallowed to Figure 13 with 40% acres fallowed. At the 40% acres fallowed level (Figure 13), the difference in truck volumes increases along the I-580 as it reaches the connection with the I-5 south. This could be an indication of less outbound good movements from the ports as the state has less to export. Figures 14 and 15 further support this idea as the change in VMT per FAZ also gradually increases moving from 10% acres fallowed to 40%. In addition, Figures 14 and 15 demonstrate that the San Diego region changes in VMT remain somewhat constant throughout most of its FAZ's, but this changes under the 40% acres fallowed Scenario 2 where differences in VMT are more evident along the southern portion of the I-5 leading to Mexico. This can again be due to a greater need for agricultural good movements into the state and less out.

Figure 10: Difference in CA Daily Truck Volumes for 2020: 10% Acres Fallowed

Difference Between Scenario 1 (Drought and No Cropland Use Change) and Scenario 3 (No Drought and No Cropland Use Change)



Difference Between Scenario 2 (Drought and Cropland Use Decrease) and Scenario 4 (No Drought and Cropland Use Decrease)

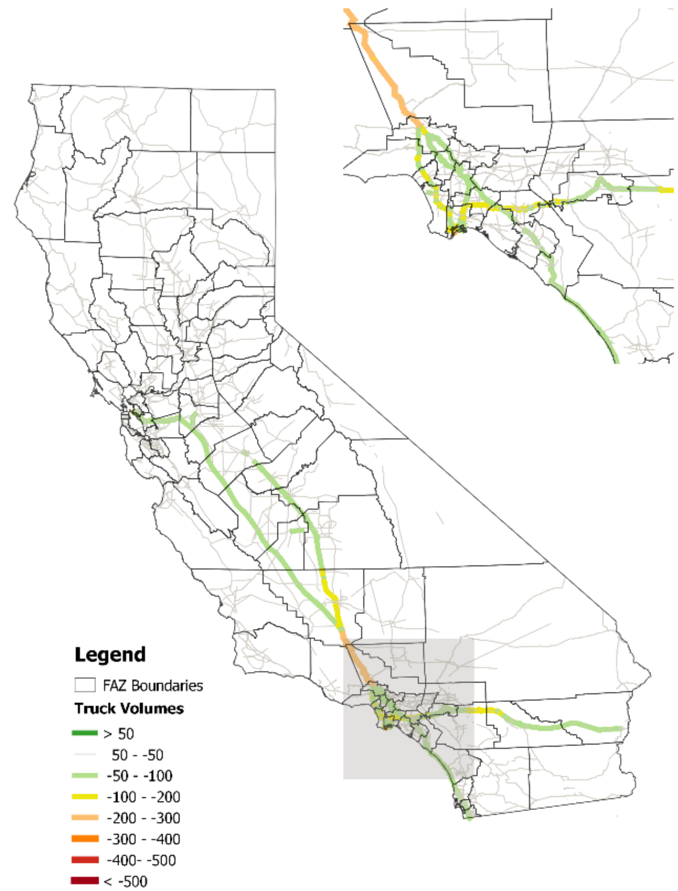
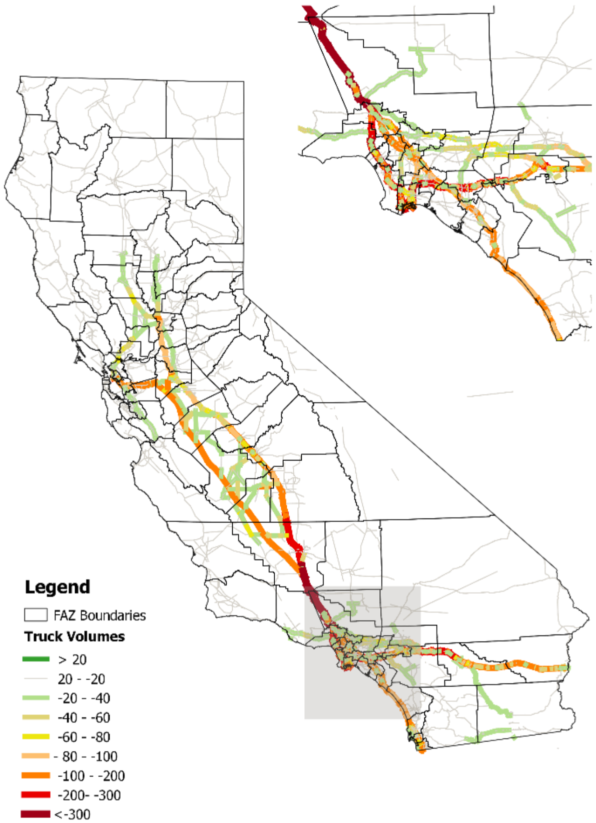


Figure 11: Difference in CA Daily Truck Volumes for 2020: 20% Acres Fallowed

Difference Between Scenario 1 (Drought and No Cropland Use Change) and Scenario 3 (No Drought and No Cropland Use Change)



Difference Between Scenario 2 (Drought and Cropland Use Decrease) and Scenario 4 (No Drought and Cropland Use Decrease)

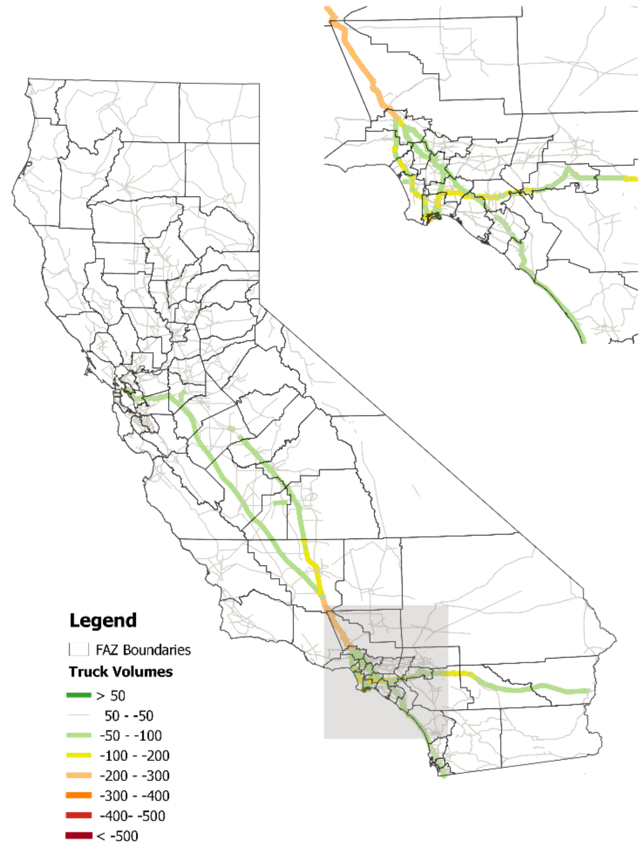
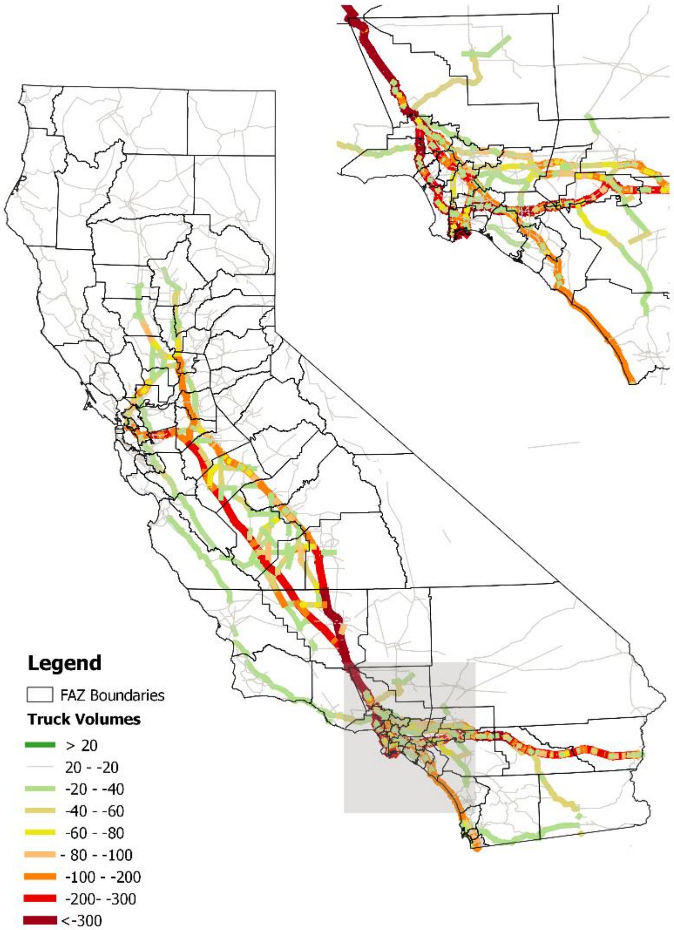


Figure 12: Difference in CA Daily Truck Volumes for 2020: 30% Acres Fallowed

Difference Between Scenario 1 (Drought and No Cropland Use Change) and Scenario 3 (No Drought and No Cropland Use Change)



Difference Between Scenario 2 (Drought and Cropland Use Decrease) and Scenario 4 (No Drought and Cropland Use Decrease)

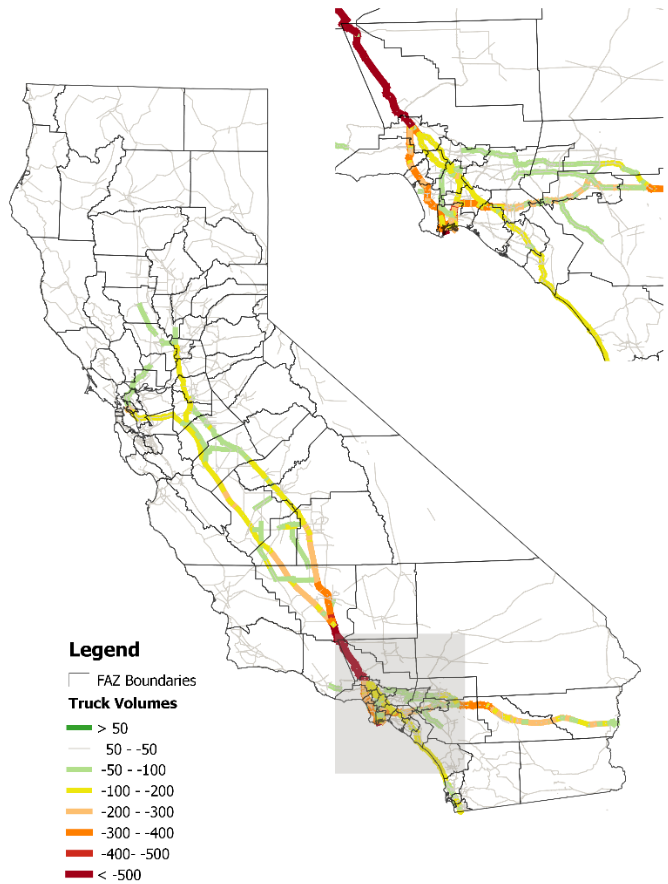
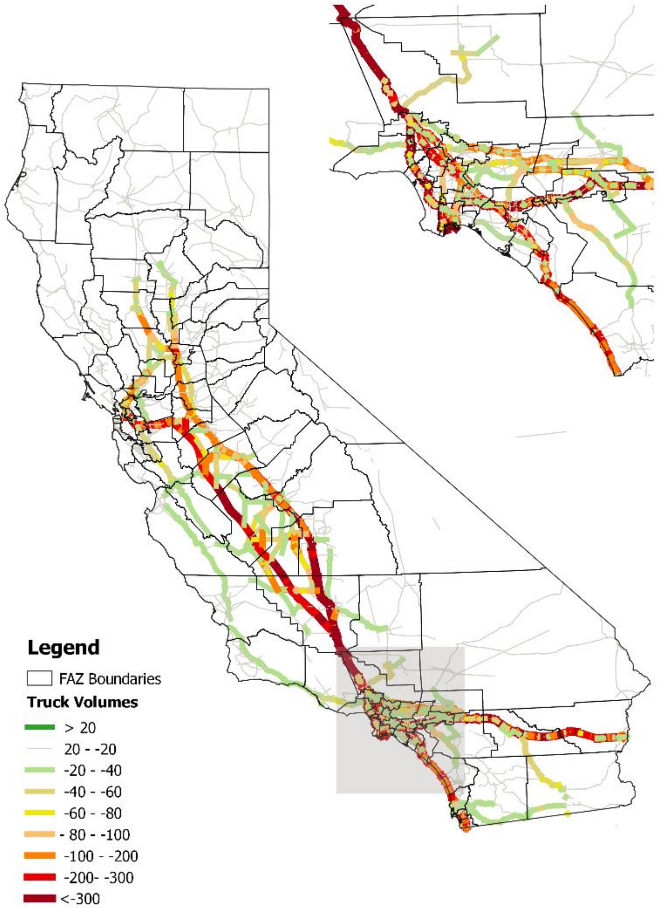


Figure 13: Difference in CA Daily Truck Volumes for 2020: 40% Acres Fallowed

Difference Between Scenario 1 (Drought and No Cropland Use Change) and Scenario 3 (No Drought and No Cropland Use Change)



Difference Between Scenario 2 (Drought and Cropland Use Decrease) and Scenario 4 (No Drought and Cropland Use Decrease)

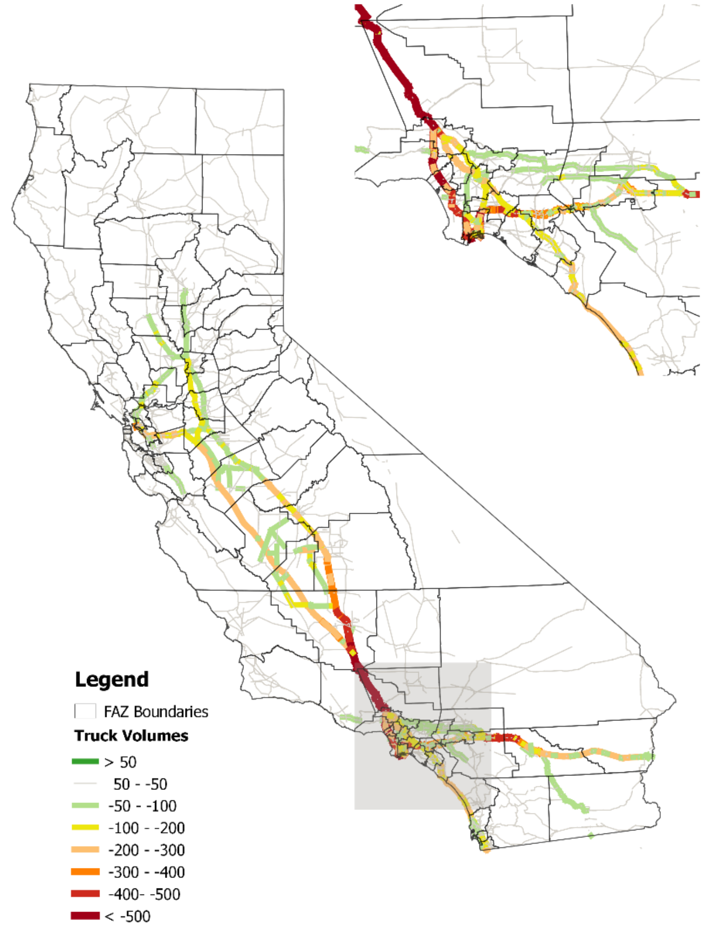
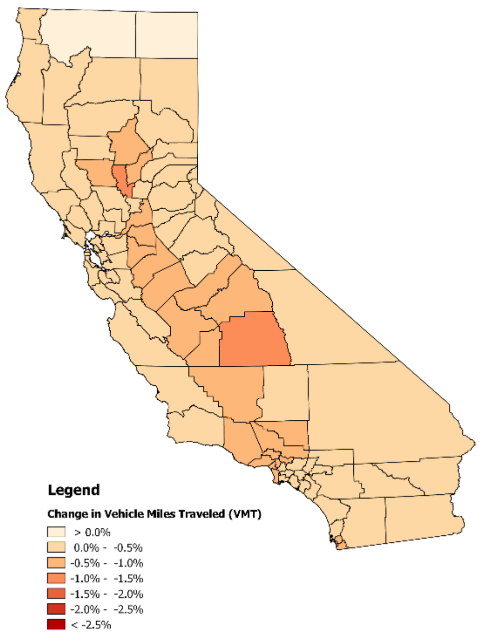
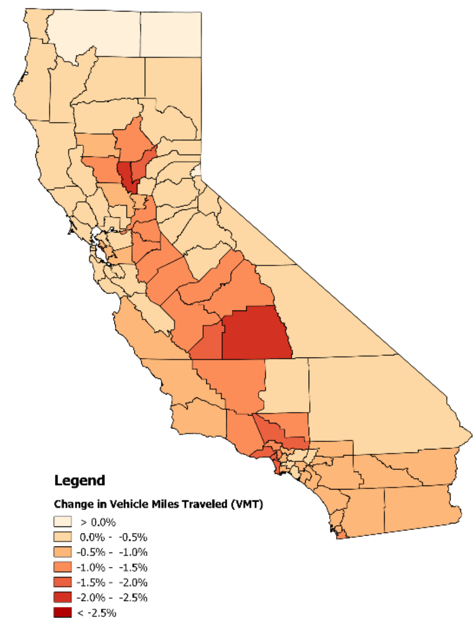


Figure 14: 2020 VMT Percent Difference Between Scenario 1 (Drought and No Cropland Use Change) and Scenario 3 (No Drought and No Cropland Use Change) Under Different Crop Reductions

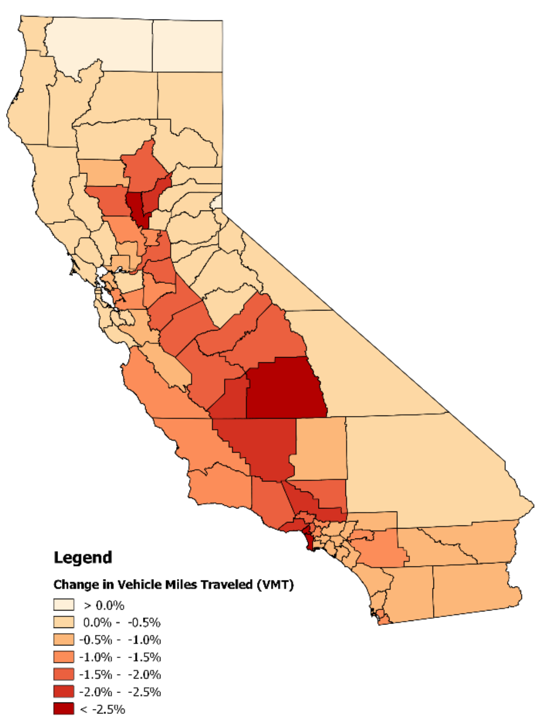
10% Acres Fallowed



20% Acres Fallowed



30% Acres Fallowed



40% Acres Fallowed

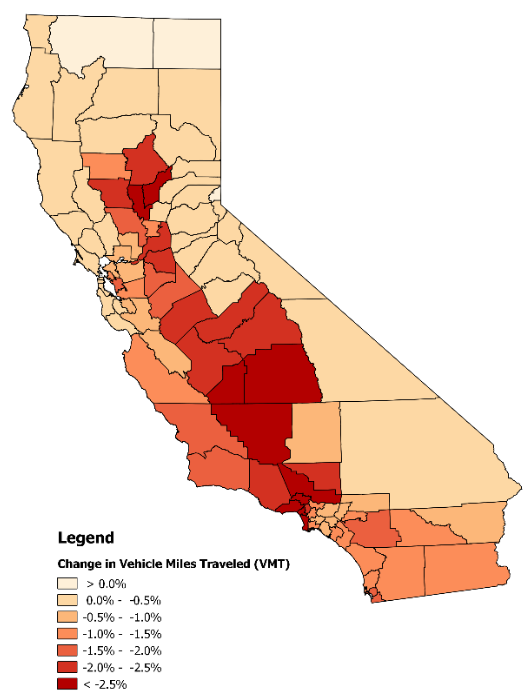
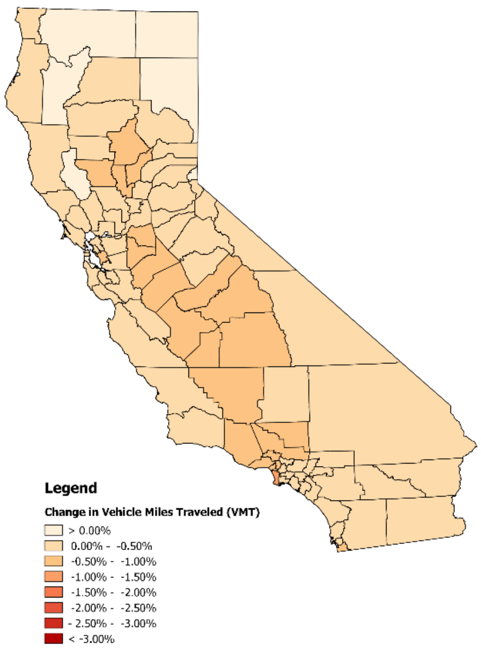
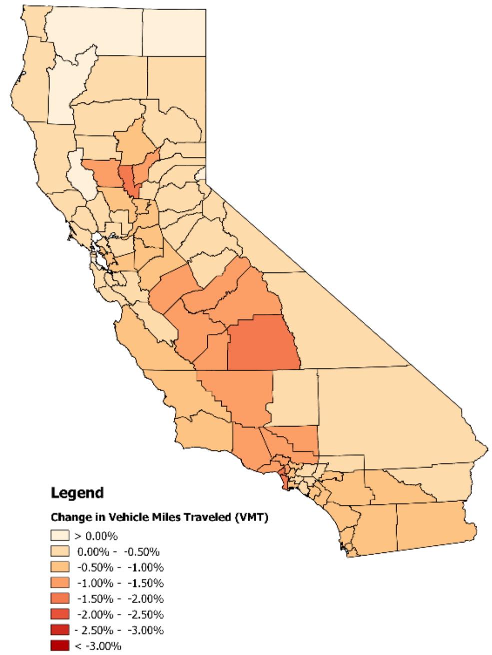


Figure 15: 2020 VMT Percent Difference Between Scenario 2 (Drought and Cropland Use Decrease) and Scenario 4 (No Drought and Cropland Use Decrease) Under Different Crop Reductions

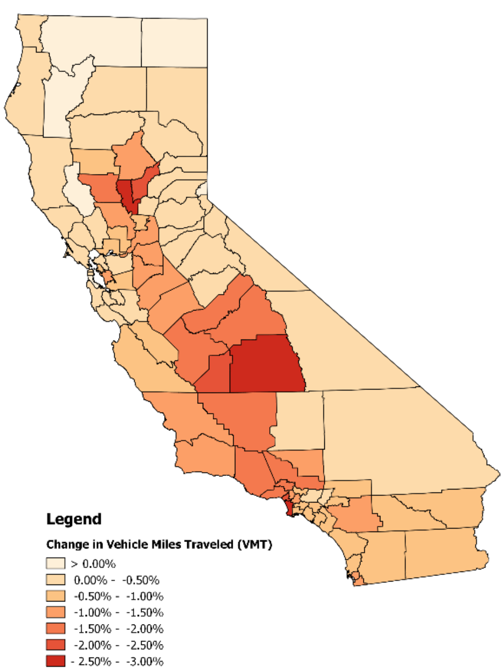
10% Acres Fallowed



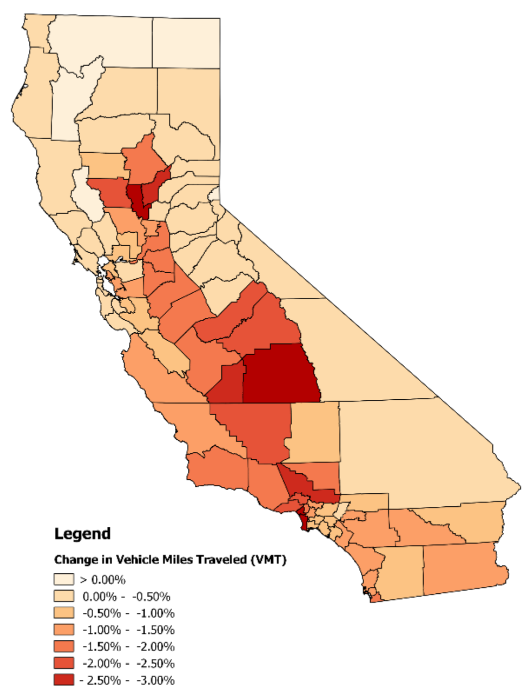
20% Acres Fallowed



30% Acres Fallowed



40% Acres Fallowed



4.4.1 Truck Emissions Sensitivity Analysis

Similarly to the base drought scenarios, the VMT per air basin was found in order to determine which areas are susceptible to emissions changes. Tables 11 and 12 summarize VMT changes per air basin for Scenario 1 and Scenario 2 sensitivity analysis. As before, the San Joaquin and South Central Coast air basins have the greatest VMT changes; therefore, emissions analysis were run for both of these regions.

Table 12: VMT per Air Basin for Scenario 1 Sensitivity Analysis

	Scenario 1 VMT				Scenario 1 VMT Percent Changes			
Air Basin	10%Crops Harvested Reduction (Scen 1.1)	20% Crops Harvested Reduction (Scen 1.2)	30% Crops Harvested Reduction (Scen 1.3)	40% Crops Harvested Reduction (Scen 1.4)	VMT % Diff Scen 1.1 and Scen 3	VMT % Diff Scen 1.2 and Scen 3	VMT % Diff Scen 1.3 and Scen 3	VMT % Diff Scen 1.4 and Scen 3
Great Basin Valleys	472513	472511	472513	472511	0.00%	0.00%	0.00%	0.00%
Lake County	68954	68960	68960	68960	0.01%	0.00%	-0.01%	-0.01%
Lake Tahoe	49630	49631	49631	49631	0.01%	0.00%	0.00%	0.00%
Mojave Desert	7982107	7973629	7965136	7957691	-0.13%	-0.24%	-0.34%	-0.44%
Mountain Counties	1327205	1327053	1326903	1326753	-0.02%	-0.03%	-0.04%	-0.05%
North Central Coast	962658	960353	958150	955961	-0.32%	-0.56%	-0.79%	-1.02%
North Coast	526543	526528	526527	526528	-0.03%	-0.04%	-0.04%	-0.04%

Northeast Plateau	788861	788855	788845	788835	0.00%	0.00%	0.00%	0.00%
Sacramento Valley	3925981	3912463	3899078	3886165	-0.36%	-0.70%	-1.04%	-1.37%
Salton Sea	4363410	4349818	4336243	4322761	-0.37%	-0.68%	-0.99%	-1.30%
San Diego	3325944	3318409	3308623	3298993	-0.44%	-0.66%	-0.95%	-1.24%
San Francisco Bay Area	5194093	5184125	5174739	5165542	-0.26%	-0.45%	-0.63%	-0.81%
San Joaquin Valley	17497361	17392097	17288497	17186284	-0.72%	-1.32%	-1.91%	-2.49%
South Central Coast	887800	883871	880035	876202	-0.54%	-0.98%	-1.41%	-1.84%
South Coast	18866710	18797928	18729949	18664330	-0.48%	-0.84%	-1.20%	-1.55%

Table 13: VMT per Air Basin for Scenario 2 Sensitivity Analysis

	Scenario 2 VMT				**Scenario 2 VMT Percent Changes**			
Air Basin	**10%Crops Harvested Reduction (Scen 2.1)**	**20%Crops Harvested Reduction (Scen 2.2)**	**30%Crops Harvested Reduction (Scen 2.3)**	**40%Crops Harvested Reduction (Scen 2.4)**	**VMT % Diff Scen 2.1 and Scen 4**	**VMT % Diff Scen 2.2 and Scen 4**	**VMT % Diff Scen 2.3 and Scen 4**	**VMT % Diff Scen 2.4 and Scen 4**
Great Basin Valleys	471815	471815	471815	471813	0.00%	0.00%	0.00%	0.00%
Lake County	68827	68827	68827	68827	0.00%	0.00%	0.00%	0.00%
Lake Tahoe	49623	49623	49623	49623	0.00%	0.00%	0.00%	0.00%
Mojave Desert	7971871	7964444	7957506	7951137	-0.11%	-0.21%	-0.29%	-0.37%

Mountain Counties	1326150	1326018	1325887	1325756	-0.02%	-0.03%	-0.04%	-0.05%
North Central Coast	958798	956869	954949	953066	-0.31%	-0.51%	-0.71%	-0.90%
North Coast	525342	525342	525342	525342	-0.04%	-0.04%	-0.04%	-0.04%
Northeast Plateau	787009	787000	786991	786983	0.01%	0.00%	0.00%	0.00%
Sacramento Valley	3909730	3897905	3886262	3875896	-0.32%	-0.62%	-0.91%	-1.18%
Salton Sea	4348454	4336581	4324734	4312970	-0.33%	-0.60%	-0.87%	-1.14%
San Diego	3316047	3307485	3298976	3290623	-0.33%	-0.59%	-0.85%	-1.10%
San Francisco Bay Area	5179076	5170839	5162667	5154870	-0.26%	-0.42%	-0.57%	-0.72%
San Joaquin Valley	17354176	17263283	17172885	17085720	-0.66%	-1.18%	-1.70%	-2.20%
South Central Coast	881396	878049	874692	871438	-0.50%	-0.88%	-1.25%	-1.62%
South Coast	18780400	18720863	18662380	18605998	-0.42%	-0.73%	-1.04%	-1.34%

Scenario 1 emissions sensitivity analysis demonstrate slightly constant changes in emissions per pollutant type, with a gradual increase from sensitivity Scenario 1.1 (10% crops fallowed) to Scenario 1.4 (40% crops fallowed). The San Joaquin Valley receives some of the greatest reductions in emissions compared to the South Central Coast. The South Central Coast has greater variances in tons of pollutant for each pollutant type, while the San Joaquin Valley has more constant changes for each. This could be an effect of location as the San Joaquin Valley is located between mountainous regions thus causing air flow restrictions. However, the South Central Coast has a greater opportunity for pollutants to travel to other regions depending on weather patterns. The pollutants with the largest reductions in the San Joaquin Valley include TOG and PM2.5 with reductions up to 2.4% under Scenario 1.4, while in the South Central Coast air basin, CO and TOG receive reductions up to 2.2% under Scenario 2.4 . Overall, the San Joaquin Valley air basin receives larger emissions reductions under Scenario 1 (drought and no cropland decrease) while the South Central Coast receives greater reductions under Scenario 2 (drought and cropland decrease). This indicates that changes in crops harvested have a larger effect in the San Joaquin Valley, while the South Central Coast is more affected by the changes in land use as this region has less cropland acres compared to the San Joaquin Valley air basin.

Table 14: Scenario 1 Sensitivity Analysis - San Joaquin Valley Emissions

	Scenario 1 San Joaquin Valley Emissions							
	Scenario 1.1		Scenario 1.2		Scenario 1.3		Scenario 1.4	
Pollutant (U.S tons)	Tons of Pollutant	Scenario 1.1 % Change from Scenario 3	Tons of Pollutant	Scenario 1.2 % Change from Scenario 3	Tons of Pollutant	Scenario 1.3 % Change from Scenario 3	Tons of Pollutant	Scenario 1.4 % Change from Scenario 3
TOG	4.052	-0.7%	4.028	-1.3%	4.005	-1.9%	3.983	-2.4%
CO	27.236	-0.7%	27.068	-1.3%	26.923	-1.8%	26.767	-2.4%
NOx	70.995	-0.7%	70.558	-1.3%	70.181	-1.8%	69.777	-2.4%
CO2	38263.898	-0.7%	38028.672	-1.3%	37825.773	-1.8%	37607.246	-2.4%
PM10	4.889	-0.7%	4.861	-1.3%	4.835	-1.8%	4.807	-2.4%

PM2.5	3.031	-0.7%	3.013	-1.3%	2.996	-1.9%	2.980	-2.4%

Table 15: Scenario 2 Sensitivity Analysis - San Joaquin Valley Emissions

	Scenario 2 San Joaquin Valley Emissions							
	Scenario 2.1		**Scenario 2.2**		**Scenario 2.3**		**Scenario 2.4**	
Pollutant (U.S tons)	**Tons of Pollutant**	**Scenario 2.1 % Change from Scenario 4**	**Tons of Pollutant**	**Scenario 2.2 % Change from Scenario 4**	**Tons of Pollutant**	**Scenario 2.3 % Change from Scenario 4**	**Tons of Pollutant**	**Scenario 2.4 % Change from Scenario 4**
TOG	4.020	-0.6%	4.000	-1.1%	3.978	-1.7%	3.960	-2.1%
CO	27.005	-0.7%	26.888	-1.1%	26.732	-1.7%	26.610	-2.1%
NOx	70.401	-0.7%	70.091	-1.1%	69.686	-1.7%	69.370	-2.1%
CO2	37944.301	-0.7%	37777.878	-1.1%	37558.506	-1.7%	37388.772	-2.1%
PM10	4.850	-0.6%	4.828	-1.1%	4.800	-1.7%	4.779	-2.1%
PM2.5	3.007	-0.7%	2.992	-1.2%	2.976	-1.7%	2.963	-2.1%

Table 16: Scenario 1 Sensitivity Analysis – South Central Coast Emissions

	Scenario 1 South Central Coast Emissions							
	Scenario 1.1		**Scenario 1.2**		**Scenario 1.2**		**Scenario 1.2**	
Pollutant (U.S tons)	**Tons of Pollutant**	**Scenario 1.1 % Change from Scenario 3**	**Tons of Pollutant**	**Scenario 1.2 % Change from Scenario 3**	**Tons of Pollutant**	**Scenario 1.3 % Change from Scenario 3**	**Tons of Pollutant**	**Scenario 1.4 % Change from Scenario 3**
TOG	0.138	0.0%	0.138	0.0%	0.137	-0.7%	0.136	-1.4%

CO	1.031	0.1%	1.026	-0.4%	1.017	-1.3%	1.010	-1.9%
NOx	2.645	0.0%	2.631	-0.5%	2.609	-1.4%	2.595	-1.9%
CO2	1231.204	0.0%	1224.673	-0.5%	1214.223	-1.4%	1207.561	-1.9%
PM10	0.175	0.0%	0.174	-0.6%	0.173	-1.1%	0.172	-1.7%
PM2.5	0.104	0.0%	0.104	0.0%	0.104	0.0%	0.103	-1.0%

Table 17: Scenario 2 Sensitivity Analysis – South Central Coast Emissions

Scenario 2 South Central Coast Emissions								
	Scenario 2.1		**Scenario 2.2**		**Scenario 2.3**		**Scenario 2.4**	
Pollutant (U.S tons)	**Tons of Pollutant**	**Scenario 2.1 % Change from Scenario 4**	**Tons of Pollutant**	**Scenario 2.2 % Change from Scenario 4**	**Tons of Pollutant**	**Scenario 2.3 % Change from Scenario 4**	**Tons of Pollutant**	**Scenario 2.4 % Change from Scenario 4**
TOG	0.137	-0.7%	0.137	-0.7%	0.136	-1.4%	0.135	-2.2%
CO	1.017	-0.9%	1.017	-0.9%	1.010	-1.6%	1.006	-1.9%
NOx	2.609	-0.8%	2.609	-0.8%	2.595	-1.4%	2.581	-1.9%
CO2	1214.223	-0.8%	1214.223	-0.8%	1207.561	-1.4%	1201.031	-1.9%
PM10	0.173	-0.6%	0.173	-0.6%	0.172	-1.1%	0.171	-1.7%
PM2.5	0.104	0.0%	0.104	0.0%	0.103	-1.0%	0.102	-1.9%

CHAPTER 5: CONCLUSION

Results indicate that the drought could potentially affect freight movements in the state to an extent. The most impacted regions include the highways along the Central Valley such as the I-5 and the SR-99 and the major interstate freeways leading to the eastern regions of the nation such as the I-10, I-40, I-15 and I-80. Tulare county was found to be the most affected by the drought with VMT percent changes reaching up to over 3%. A few FAZ's received truck volume and VMT increases instead of decreases. This is mainly for FAZ's in Northern California where inbound shipments could be increasing to meet state deficiencies under drought. The San Joaquin Valley and South Central Coast air basins were reviewed for the emissions analysis. Results indicate a slight difference in pollutant levels from the base scenarios with emissions reductions reaching up 2.4% in the San Joaquin Valley air basin. Scenario 2 (drought and cropland decrease) was found to have the largest effect on emissions reduction.

It should be kept in mind that these are estimated effects for the year 2020. Projecting effects for years further in the future would likely demonstrate higher differences, especially along the Central Valley where farmers are quickly running out of water. This could potentially lead to an increase in inbound shipments from sea ports and surrounding states.

However, there is additional work that can be applied to improve the estimation process carried out in this report. First, there is a need for more recent data on the effects of water shortages on manufacturing industries. Second, there is a need for recent and more accurate data on cropland acres per county. Lastly, more research is needed on crop growth factors per region. Eventually, these deficiencies could improve future state freight forecasts that are essential for mitigation of effects of natural disasters in the state's transportation system.

REFERENCES

Attavanich, McCarl, Fuller, Vedenov, Ahmedov (July 2011). The Effect of Climate Change on Transportation Flows and Inland Waterways Due to Climate-Induced Shifts in Crop Production Patterns. Department of Agricultural Economics, Texas A&M University. Retrieved from http://ageconsearch.umn.edu/bitstream/109241/2/AAEASelectedPaper_The%20Effect%20of%20Climate%20Change%20on%20Transportation%20Flows_13247.pdf

Berkham, M. and Sunding, D. (May 2007). Measures to Reduce the Economic Impacts of a Drought-Induced Water Shortage in the SF Bay Area. San Francisco Public Utilities Commission.

Burbank, Kuby, Oster, Posey, Russo, Rypinski (2015). Transportation*. U.S. Global Change Research Program*. Retrieved from http://nca2014.globalchange.gov/report/sectors/transportation

Caldwell, Quinn, Meunier, Suhrbier, Grenzeback (2002). Potential Impacts of Climate Change on Freight Transportation. Department of Transportation Center for Climate Change and Environmental Forecasting. Retrieved from http://acclimatise.uk.com/login/uploaded/resources/transport_freight.pdf

Christian-Smith, Heberger, Allen (August 2012). Urban Water Demand in California to 2100: Incorporating Climate Change. Pacific Institute. Retrieved from http://pacinst.org/publication/urban-water-demand-to-2100/

Ding, Hayes, Widhalm (2010). Measuring Economic Impacts of Drought: A Review and Discussion. Papers in Natural Resources. Retrieved from http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1198&context=natrespapers

Hanak, Lund, Thompson, Cutter, Gray, Houston, Howitt, Jessue, Libecap, Medellin-Azuara, Olmstead, Summer, Sudling, Thomas, Wilkinson. (May 2012). Water and the California Economy. Public Policy Institute of California. Retrieved from http://www.ppic.org/content/pubs/report/R_512EHR.pdf

Hanak, Mount, Chappelle, Lund, Medellin-Azuara, Moyle Seavy. (August 2015). What if California's Drought Continues. Public Policy Institute of California. Retrieved from http://www.ppic.org/main/publication_quick.asp?i=1160

Hoekstra, A and Chapagain, A. (October 2005). Water Footprints of Nations: Water Use by People as a Function of Their Consumption Pattern. Springer Science and Business Media. Retrieved from http://waterfootprint.org/media/downloads/Hoekstra_and_Chapagain_2006.pdf

Howitt, MacEwan, Medellin-Azuara, Lund, Sumner (August 2015). Economic Analysis of the 2015 Drought for California Agriculture. UC Davis Center for Watershed Sciences. Retrieved from https://watershed.ucdavis.edu/files/biblio/Final_Drought%20Report_08182015_Full_Report_WithAppendices.pdf

Howitt, Medellin-Azuara, MacEwan (August 2009). Estimating the Economic Impacts of Agricultural Yield Related Changes for California. *California Climate Change Center*. Retrieved from http://www.energy.ca.gov/2009publications/CEC-500-2009-042/CEC-500-2009-042-F.PDF

Howitt, Medellin-Azuara, MacEwan, Lund, Sumner (July 2014). Economic Analysis of the 2014 Drought for California Agriculture. UC Davis Center for Watershed Sciences. Retrieved from https://watershed.ucdavis.edu/files/biblio/ DroughtReport _23July2014_0.pdf

Krajick,K. and Lee, K. (March 2013). Climate Change Will Hit Transport Systems Hard, Says Government Panel. Earth Institute Columbia University. Retrieved from http://www.earthinstitute.columbia.edu/articles/view/2138

Larsen, Goldsmith, Smith, Wilson, Strzepek, Chinowsky, Saylor (August 2008). Estimating Future Costs for Alaska Public Infrastructure at Risk from Climate Change. *Global Environmental Change*. Retrieved from http://www.sciencedirect.com/science/article/pii/S0959378008000216

Malcolm, Marshall, Aillery, Heisey, Livingston, Day-Rubenstein (July 2012). Agricultural Adaptation to a Changing Climate: Economic and Environmental Implications Vary by U.S. Region. United States Department of Transportation. Retrieved from http://www.ers.usda.gov/media/848748/err136.pdf

Morikawa, Morrison, Gleick (May 2007). Corporate Reporting on Water: A Review of Eleven Global Industries. Pacific Institute. Retrieved from http://www.pacinst.org/wp- content/uploads/sites/21/2013/02/ corporate_ reporting_on_water3.pdf

Mount, J. and Cayan, D. (May 2015). A Dry Run for a Dry Future. Pacific Institute. Retrieved from http://www.ppic.org/main/blog_detail.asp?i=1781

Wade, Hewitt, Nussbaum (October 1991). Cost of Industrial Water Shortages. California Urban Water Agencies. Retrieved from http://www.cuwa.org/pubs/CostofIndustrialWaterShortages.pdf

Wilson, Smith, Haven, Mendelsohn (2003). Global Climate Change and California: Potential Implications for Ecosystems, Health, and the Economy. Electric Power Research Institute. Retrieved from http://www.energy.ca.gov/reports/500-03-058/2003-10-31_500-03-058CF.PDF

Yevdokimov, Y. (2008) Modeling Climate Change Impacts on Freight Transportation in Atlantic Canada. *Traffic and Transportation Studies (2008): pp. 310-319*. Retrieved from http://ascelibrary.org/doi/abs/10.1061/40995%28322%2929

(April 2014). California Farmland Conversion Report 2008-2010. California Department of Conservation Division of Land Resource Protection (DLRP). Retrieved from http://www.conservation.ca.gov/dlrp/fmmp/Documents/fmmp/pubs/2008-2010/fcr/FCR%200810%20complete.pdf

(2010). Census Bureau Economic Statistics Manufacturing Snapshot. U.S. Census Bureau Economic Statistics. Retrieved from http://www.census.gov/manufacturing/mfgstat/pdfs/CAManufacturing-snapshot.pdf

(2002). Federal Highway Administration: Freight Analysis Framework Overview. Publication FHWA, FHWA-OP-03-006. Retrieved from http://ops.fhwa.dot.gov/FREIGHT/freight_analysis/faf/index.htm

(July 2004). Freight Shipments by State of Origin. United States Department of Transportation. Retrieved from http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/state_transportation_statistics/state_transportation_statistics_2014/index.html/chapter3/table3-1

(2014). Freight Planning Fact Sheets-Index. California Department of Transportation. Retrieved from http://www.dot.ca.gov/hq/tpp/offices/ogm/fact_sheets_index.html

(2007). Freight Transportation National Policy and Strategies Can Help Improve Freight Mobility. United States Government Accountability Office. Retrieved from http://www.gao.gov/assets/280/270861.pdf

(June 2014). The Untapped Potential of California's Water Supply. Pacific Institute. Retrieved from http://pacinst.org/publication/ca-water-supply-solutions/#issuebriefs

(2007). United States Government Accountability Office: Freight Transportation National Policy and Strategies Can Help Improve Freight Mobility. Publication GAO, GAO-08-287

(2014). USDA National Agricultural Statistics Service Cropland Data Layer. 2014. Published crop- specific data layer [Online]. Retrieved from http://nassgeodata.gmu.edu/CropScape/. USDA-NASS, Washington, DC

(2015). Emissions Inventory. Air Pollution Control District San Luis Obispo County. Retrieved from http://www.slocleanair.org/air/emissions.php

APPENDIX A

Table A. 1: SCTG 2-Digit Codes

SCTG	Description	SCTG	Description
1	Live Animals and Fish	**22**	Fertilizers
2	Cereal Grains (including seed)	**23**	Chemical Products and Preparations, n.e.c.
3	Other Agricultural Products, except for Animal Feed	**24**	Plastics and Rubber
4	Animal Feed and Products of Animal Origin, not elsewhere classified (n.e.c.)	**25**	Logs and Other Wood in the Rough
5	Meat, Fish, and Seafood, and Their Preparations	**26**	Wood Products
6	Milled Grain Products and Preparations, and Bakery Products	**27**	Pulp, Newsprint, Paper, and Paperboard
7	Other Prepared Foodstuffs, and Fats and Oils	**28**	Paper or Paperboard Articles
8	Alcoholic Beverages	**29**	Printed Products
9	Tobacco Products	**30**	Textiles, Leather, and Articles of Textiles or Leather
10	Monumental or Building Stone	**31**	Non-Metallic Mineral Products
11	Natural Sands	**32**	Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes
12	Gravel and Crushed Stone	**33**	Articles of Base Metal
13	Non-Metallic Minerals, n.e.c.	**34**	Machinery
14	Metallic Ores and Concentrates	**35**	Electronic and Other Electrical Equipment and Components, and Office Equipment
15	Coal n.e.c.	**36**	Motorized and Other Vehicles (including parts)
16	Crude Petroleum Oil	**37**	Transportation Equipment, n.e.c.
17	Gasoline and Aviation Turbine Fuel	**38**	Precision Instruments and Apparatus
18	Fuel Oils	**39**	Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and illuminated Signs
19	Coal and Petroleum Products, n.e.c.	**40**	Miscellaneous Manufactured Products
20	Basic Chemicals	**41**	Waste and Scrap
21	Pharmaceutical Products	**43**	Mixed Freight

APPENDIX B
B.1 Disaggregation of Industrial Employment Data

Employment reductions data from the San Francisco Public Utilities Commission (SFPUC) was disaggregated to the same level as the water intensive manufacturing industries identified by the California Urban Water Agencies (CUWA) in Table B.2. The results from Table B.2 indicate a difference in the effects of water shortages on employment for various industry types. For the purposes of this analysis, the distribution of employee loss per industry type shown in Table B.1 is assumed to be the same for the losses in the SFPUC study. Therefore, employment losses from SFPUC are proportionally distributed to each NAICS code based on the proportions aggregated in Table B.2.

Table B. 1: SFPUC Industrial Employee Reductions for NAICS Codes 31-33

Industrial	Employee Reductions- 10% Drought Scenario	Employee Reductions- 20% Drought Scenario	Employee Reductions- 30% Drought Scenario
Proportional Rationing	1,323	2,629	8,007
Efficiency Pricing	1,562	3,106	10,832
Regional Water Market	1,734	3,228	11,140

Initially, the SIC (Standard Industrial Classification) codes from Table B.2 were matched with the NAICS (North American Industry Classification System) code system. Since the SIC code system is more disaggregate than the NAICS codes, most SIC codes fit within the NAICS code system directly into a single category as shown in Table B.2. The total employee reductions from each SIC category that fell within an NAICS category were summed to find the number of job losses per NAICS code. These values were then used to determine which NAICS manufacturing codes received the highest percent of job losses.

The percent of job losses per manufacturing industry was multiplied by the total job losses identified in Table B.2 from the SFPUC study to estimate how many jobs would be lost under the proportional rationing method per NAICS category. The total employee losses per category were divided by the total number of employees within NAICS codes 31-33 in 2004 to find employee percent reductions. Table B.4 summarizes the results under different water shortage scenarios. These employee reductions were assumed for all FAZ zones in this analysis.

Table B. 2: Direct Employment Reductions (Thousands) - 30% Water Supply Shortage by Region (Wade et al. 1991)

SIC CODE	Description of Plant	Total Employment 1989 (Thousands) (1)				Employment Reduction (Percentage) (2)			Employment Reduction (Thousands)		
		State Total	12 County Total	North Total	South Total	North % Loss	South % Loss	Weighted Average	North Total(3)	South Total(3)	12 County Total
201	Meat Products	20.4	9.2	2.3	6.9	6.4	6.4	6.4	0.15	0.44	0.59
203	Preserved Fruits & Vegetables	54.3	22.0	8.9	13.1	5.5	8.5	7.3	0.49	1.12	1.61
205	Bakery Products	20.5	17.5	5.5	12.0	17.0	17.0	17.0	0.94	2.04	2.98
208	Beverages	28.0	12.4	3.4	9.1	33.0	26.0	27.9	1.12	2.35	3.47
209	Misc. Food & Kindred Prod.	22.8	18.6	4.3	14.3	11.3	11.3	11.3	0.49	1.62	2.11
265	Paperboard Containers & Boxes	17.6	14.7	3.7	11.0	16.9	16.9	16.9	0.63	1.87	2.49
281	Industrial Inorganic Chemicals	8.0	7.2	2.6	4.6	1.4	1.4	1.4	0.04	0.06	0.10
283	Drugs	24.0	23.2	9.6	13.6	4.5	4.5	4.5	0.43	0.61	1.04
284	Soap, Cleansers & Toilet Goods	15.3	13.9	2.6	11.3	27.0	27.0	27.0	0.71	3.06	3.76
285	Paints & Allied Prod.	7.3	7.0	1.7	5.3	16.0	16.0	16.0	0.28	0.84	1.12
291	Petroleum Refining	11.6	9.9	4.6	5.3	0.0	0.1	0.1	0.00	0.01	0.01
327	Concrete, Gypsum, Plaster Prod.	21.5	16.1	3.4	12.7	3.3	3.3	3.3	0.11	0.42	0.53
344	Fabricated Metal Prod.	41.3	33.4	6.7	26.7	6.6	6.6	6.6	0.44	1.76	2.20
357	Computer & Office Equip.	99.3	91.7	60.6	31.1	12.6	2.4	9.1	7.63	0.75	8.38
366	Communication Equipment	150.2	143.5	27.5	116.0	0.0	0.1	0.1	0.00	0.12	0.12
367	Electronic Comp. & Acc.	148.1	137.3	78.4	58.9	6.9	3.3	5.4	5.41	1.94	7.35
371	Motor Vehicles & Equip.	33.1	28.2	4.9	23.3	0.0	0.0	0.0	0.00	0.00	0.00
372	Aircraft & Parts	169.9	165.5	1.8	163.8	3.5	3.5	3.5	0.06	5.73	5.79
376	Guided Missles, Space Vehicles, Parts	80.5	74.0	26.7	47.4	2.6	2.6	2.6	0.69	1.23	1.92
Total Respondent Industries		973.5	845.5	259.0	586.5			Industry Losses	19.60	25.98	45.58
Total State Manufacturing (EST)		2162.4	1874.1	468.8	1405.3			% Loss of Industries	7.6	4.4	5.4
Percent of State Manufacturing		45.0	45.1	55.3	41.7						

1) Source: EDD 1989
2) Spectrum Survey, Scenario III.11
3) Employment Reduction = % Employment Reduction multiplied by Employment

Spectrum Economics
9/9/91

Table B. 3: Matching Between SIC and NAICS Code Systems

SIC Code	SIC Code Name	Employment Loss per SIC Code (Thousands)	NAICS Code	NAICS Code Name	Employment Loss per NAICS Code (Thousands)	% of Job Loss Distribution
201	Meat Products	0.59	311	Food Manufacturing	8.65	18.98
203	Preserved Fruits & Vegetables	1.61				
205	Bakery Products	2.98				
209	Misc. Food & Kindred Products	3.47				
208	Beverages	2.11	312	Beverage & Tobacco Product Manufacturing	2.11	4.63
265	Paper Board Containers and Boxes	2.49	322	Paper Manufacturing	2.49	5.46
291	Petroleum Refining	0.10	324	Petroleum & Coal Products Manufacturing	0.1	0.22
281	Industrial Inorganic Chemicals	1.04	325	Chemical Manufacturing	5.93	13.01
283	Drugs	3.76				
284	Soap, Cleansers and Toilet Goods	1.12				
285	Paints +Allied Prod.	0.01				
327	Concrete, Gypsum, Plaster Prod.	0.53	327	Nonmetallic Mineral Product Manufacturing	0.53	1.16
344	Fabricated Metal Prod.	2.20	332	Fabricated Metal Product Manufacturing	2.2	4.83
357	Computer and Office Equip.	8.38	334		15.85	34.78

366	Communication Equipment	0.12		Computer & Electronic Products Manufacturing		
367	Electronic Computer and Accessory	7.35				
371	Motor Vehicles & Equipment	0.00	336	Transportation Equipment Manufacturing	7.71	16.92
372	Aircraft & Parts	5.79				
376	Guided Missiles, Space Vehicle, Parts	1.92				

Table B.4: Employment Reductions Applied to each Manufacturing Industry under Different Water Shortages

NAICS Code	NAICS Name	Total % Reduction for Each County under 10% water reduction	Total % Reduction for Each County under 20% water reduction	Total % Reduction for Each County under 30% water reduction
311	Food Manufacturing	0.15	0.30	0.92
312	Beverage+Tobacco Product Manufacturing	0.04	0.07	0.23
322	Paper Manufacturing	0.04	0.09	0.27
324	Petroleum+ Coal Products Manufacturing	0.00	0.00	0.01
325	Chemical Manufacturing	0.10	0.21	0.63
327	Nonmetallic Mineral Prod Manufacturing	0.01	0.02	0.06
332	Fabricated Metal Prod Manufacturing	0.04	0.08	0.24
334	Computer+Electronic Prod Manufacturing	0.28	0.56	1.69
336	Transportaion Equipment Manufacturing	0.14	0.27	0.82

B.2 Disaggregation of Agriculture Data

The estimated change in crop acreage from the UC Davis Center for Watershed Sciences was distributed to its corresponding counties per region based on the number of acres fallowed in 2014 per county. For each region, those counties with the greatest number of fallowed acres in 2014 received a higher percentage of the total acres fallowed for future years.

Acres fallowed between 2013 and 2014 in each county was found through estimates from the National Agricultural Statistics Service (NASS). Using these values, the proportion of fallowed acres per county was found for four California Agriculture Regions as summarized in Table B.5. These proportion estimates were then multiplied by the total acre reduction estimates per region (Table 7) for 2015, 2016, and 2017 to find acre reductions for all counties falling within the IMPLAN (Impact Analysis for Planning) regions listed in Table B.6. Note that only these counties are estimated to receive crop reductions as the counties within these regions represent most of the state's crop acreage. Acreage reduction estimates per county can be found in Table B.7.

Table B.5: Acres Fallowed in 2014 per County

Region	County	2014 Fallowed Acres	Proportion of Fallowed Acres
Sacramento River	Amador	47.8	0.0002
	Butte	28673.6	0.1495
	Calaveras	0	0.0000
	Colusa	48404.8	0.2523
	Contra Costa	1301.5	0.0068
	El Dorado	0	0.0000
	Glenn	23906.3	0.1246
	Placer	3939.3	0.0205
	Sacramento	3535.3	0.0184
	Shasta	1217.1	0.0063
	Solano	5445.8	0.0284

	Tehama	1346.4	0.0070
	Sutter	35236.7	0.1837
	Yolo	35425.7	0.1847
	Yuba	3347.2	0.0174
San Joaquin River	Madera	7516.8	0.1409
	Mariposa	0.6	0.0000
	Merced	33534.3	0.6285
	San Joaquin	9087.4	0.1703
	Stanislaus	3217	0.0603
	Tuolumne	0.2	0.0000
Tulare Lake Basin	Fresno	143619.1	0.5021
	Kings	64987.5	0.2272
	Tulare	24988.7	0.0874
	Kern	52417.8	0.1833
Central Coast & So Cal	Monterrey	10790.4	0.1341
	Santa Clara	1907.9	0.0237
	San Benito	4378.3	0.0544
	San Luis Obispo	9437.7	0.1173
	Ventura	26.7	0.0003
	Los Angeles	444.2	0.0055
	San Diego	308	0.0038
	Santa Barbara	1979.6	0.0246
	Imperial	34153.4	0.4246
	Riverside	17012.3	0.2115
		Sum	1.00

Table B.6: Counties Included by Region for the Economic Impact Analysis (Howitt et al. 2015)

IMPLAN Regions	**Counties**
Sacramento River	Amador, Butte, Calaveras, Colusa, Contra Costa, El Dorado, Glenn, Placer, Sacramento, Shasta, Solano, Tehama, Sutter, Yolo and Yuba
San Joaquin River	Madera, Mariposa, Merced, San Joaquin, Stanislaus, Tuolumne
Tulare Lake Basin	Fresno, Kings, Tulare, and Kern
Central Coast	Monterrey, Santa Clara, San Benito, San Luis Obispo
South Coast	Ventura, Los Angeles, San Diego, Santa Barbara
Inland Southern California	Imperial and Riverside

Table B. 7: Irrigated Acreage Reductions for 2015, 2016, 2017 per County

Region	County	2015 Thousands Acreage Reduction	2016 Thousands Acreage Reduction	2017 Thousands Acreage Reduction
Sacramento River	Amador	0.04	0.04	0.05
	Butte	26.79	26.94	27.17
	Calaveras	0.00	0.00	0.00
	Colusa	45.22	45.47	45.87
	Contra Costa	1.22	1.22	1.23
	El Dorado	0.00	0.00	0.00
	Glenn	22.33	22.46	22.66
	Placer	3.68	3.70	3.73
	Sacramento	3.30	3.32	3.35
	Shasta	1.14	1.14	1.15
	Solano	5.09	5.12	5.16
	Tehama	1.26	1.26	1.28
	Sutter	32.92	33.10	33.40
	Yolo	33.09	33.28	33.57
	Yuba	3.13	3.14	3.17
San Joaquin River	Madera	10.21	10.51	10.86
	Mariposa	0.00	0.00	0.00
	Merced	45.57	46.89	48.46
	San Joaquin	12.35	12.71	13.13
	Stanislaus	4.37	4.50	4.65
	Tuolumne	0.00	0.00	0.00
Tulare Lake Basin	Fresno	144.62	144.67	144.87
	Kings	65.44	65.46	65.55
	Tulare	25.16	25.17	25.21
	Kern	52.78	52.80	52.87
Central Coast & So Cal	Monterrey	0.34	0.34	0.34
	Santa Clara	0.06	0.06	0.06
	San Benito	0.14	0.14	0.14
	San Luis Obispo	0.29	0.29	0.29
	Ventura	0.00	0.00	0.00
	Los Angeles	0.01	0.01	0.01
	San Diego	0.01	0.01	0.01
	Santa Barbara	0.06	0.06	0.06
	Imperial	1.06	1.06	1.06
	Riverside	0.53	0.53	0.53

Since these estimates only reach the year of 2017, future irrigated crop reductions were estimated by finding a best fit line through the 2015 to 2017 crop reductions per county. A conservative approach was taken to estimate total crops fallowed by using the change in fallowed irrigated crop acreage in between years (Table B.7) to estimate the way total crops fallowed changes. In other words, it was assumed that total crops fallowed changes the same way as irrigated crops fallowed from Table B.7.

Estimates of total crops fallowed per year and county were obtained from the USDA's CropScape system. CropScape data from the year 2014 was used as a base to apply the estimated crop acreage changes in between years from Table B.7. Table B.8 summarizes the resulting crops fallowed for 2020 in thousands of acres per county. The percent acre reduction is a fraction of the total crops harvested assumed in the CSFFM model inputs for Scenario 3 (no land use change and no drought) and Scenario 4 (CA cropland decrease and no drought) .

Table B. 8: Percent Crop Reductions per County

COUNTY	Fallowed Acres (Thousands)	Scen. 1 (No land use change) % Acreage Reduction	Scen. 2 (CA Cropland decrease) % Acreage Reduction
Amador	203.87	2.87	3.28
Butte	70499.82	36.82	42.05
Calaveras	8.20	0.30	0.34
Colusa	86883.45	32.96	37.65
Contra Costa	4811.09	21.14	24.15
El Dorado	6.00	0.11	0.12
Fresno	247079.03	26.48	30.25
Glenn	51602.54	23.69	27.07
Imperial	92491.30	25.82	29.49
Kern	262756.65	36.05	41.17

Kings	215808.64	53.92	61.60
Los Angeles	8163.00	33.16	37.88
Madera	21538.00	8.54	9.75
Mariposa	20.70	7.60	8.68
Merced	63029.70	14.18	16.20
Monterey	30155.40	13.89	15.87
Placer	6152.33	29.36	33.54
Riverside	42132.40	26.99	30.84
Sacramento	23980.08	22.21	25.37
San Benito	11218.30	36.14	41.29
San Diego	836.00	1.30	1.49
San Joaquin	20814.07	4.91	5.61
San Luis Obispo	28834.10	28.68	32.76
Santa Barbara	9246.70	10.40	11.88
Santa Clara	4212.80	18.91	21.60
Shasta	3814.19	18.24	20.84
Solano	20336.87	17.72	20.25
Stanislaus	8202.89	2.80	3.19
Sutter	81265.66	35.30	40.32
Tehama	3640.39	6.31	7.21
Tulare	88476.50	16.57	18.93
Tuolumne	13.28	1.95	2.23
Ventura	906.50	0.98	1.12
Yolo	108941.25	44.26	50.56
Yuba	34167.94	57.36	65.52