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Impact of Dairy Cows on Air Quality and Particulate Matter in the San Joaquin Valley

Daniel A. Bauerlein

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Impact of Dairy Cows on Air Quality and Particulate Matter in the San Joaquin Valley

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Impact of dairy cows on air quality and particulate matter in the San Joaquin Valley



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American Military University

EVSP 699 Environmental Policy and Management Capstone

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May 8, 2016

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Abstract:

The San Joaquin Valley (SJV) is the largest producer of dairy in California and the United States. The SJV consists of eight counties which held approximately 1.5 million dairy cows in 2014. The region continually fails to meet air quality standards for particulate matter under 2.5 micrometers ($PM_{2.5}$) set by the Environmental Protection Agency under the Clean Air Act. Previous studies have shown that the presence of dairy cows is a contributing factor increasing the amount of $PM_{2.5}$ in the air. This study investigates the relationship between the number of dairy cows, dairies, and cows per dairy with the number of days where $PM_{2.5}$ was the dominant pollutant ($PM_{2.5}$ days) and the concentration of $PM_{2.5}$ throughout the eight counties in the SJV. Using the Spearman's Rank Correlation Coefficient and the data collected from 2002-2014, the paired data sets were tested for association. Fresno, Kings, and Stanislaus Counties showed a strong, positive association between the number of cows and $PM_{2.5}$ days while Kern and Merced Counties showed a moderate, positive association. This suggests that in these counties as the number of dairy cows increased the number of $PM_{2.5}$ days also increased. This also suggests that more dairy cows within a county contribute to increased $PM_{2.5}$ in the air. Other associations observed in the results of this study were different throughout the counties suggesting that no obvious relationship exists. This study could be approved upon by collecting $PM_{2.5}$ data directly from dairy farms and strategic areas across the county rather than depending on centralized air monitoring sites.

Introduction:

If you have made the drive north from the Los Angeles Area through the Central Valley up to Sacramento on CA-99, you have most likely witnessed the large amount of cattle on a number of dairy farms. You may have even experienced for yourself the strong smell and heavy dust emanating from those farms. That is because California is the nation's leader in dairy production, producing 42.3 billion pounds of milk from over 1.7 million cows in 2014 (California Department of Food and Agriculture (CFDA), 2014). Of the 1.7 million dairy cows in California, approximately 1.5 million can be found on farms in the San Joaquin Valley (SJV) (CDFA, 2014). The SJV encompasses the southern half of the Central Valley stretching about 250 miles and consists of eight counties: Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, and Tulare (Ngo et al., 2010). The presence of so many dairy cows in this concentrated area makes the SJV an important area to research the environmental impacts of dairy farms. There are several environmental issues that are associated with large dairy operations which include: water-use, water quality degradation, greenhouse gas emissions, and local air pollution (Place & Mitloehner, 2010; Hoekstra, 2012; Environmental Protection Agency (EPA), 2016d). The US dairy industry contributes to climate change and poor air quality, while the SJV has the worst air quality in the nation in regards to particulate matter (PM) levels (Place & Mitloehner, 2010; Zhao et al., 2014). This study focuses on the relationship between PM and dairy farms in the SJV.

Environmental Issues- Water Use- Water Quality- Greenhouse Gas Emissions

Water use is one environmental issue that involves the meat and dairy industry. Many Californians are concerned with their water use and take steps to reduce their use.

There are many programs and websites developed by counties and water districts which sole purpose is to promote responsible water use and provides ways to reduce at home water use. However, 27% of the water footprint of humans can be attributed to the production of meat and dairy while the at home use of water only accounts for 4% (Hoekstra, 2012). The average Californian uses approximately 140 gallons of water per day for drinking, bathing, washing, and other daily activities (Fulton, Cooley, & Gleick, 2012). Much of the water used for agriculture is ultimately for feed grown for animal consumption (Hoekstra, 2012; Fulton, Cooley, & Gleick, 2012). The water use footprint concept refers to the amount of fresh water used throughout the production of a product (Hoekstra, 2012). In regards to meat and animal products, the process starts with the fresh water used to produce the feed for animals and ends when it reaches the consumer (Hoekstra, 2012). Growing the feed is the primary step that utilizes the most water (Hoekstra, 2012). The total water footprint from one animal can be calculated by adding the amount of water used to produce the feed consumed by the animal throughout its lifetime, the amount of water directly consumed by the animal, and the amount of water used to clean the stables (Hoekstra, 2012). 90% of California's water footprint is associated with agriculture while 47% is associated with meat and dairy products (Fulton, Cooley, & Gleick, 2012). In California in particular, where the state regularly suffers from drought conditions, water use and the ways to conserve water are important topics that frequently discussed.

The impact on water quality from nutrient pollution is the typical issue surrounding the US dairy industry (Place & Mitloehner, 2010). Nutrient pollution is caused by increases in nitrogen and phosphorus in waterways (EPA, 2016c). Phosphorus

and Nitrogen are important components of aquatic ecosystems (EPA, 2016c). They are responsible for algae and plant growth which are essential for habitat and food for fish and aquatic organisms (EPA, 2016c). However, too much of these nutrients can lead to pollution of the air and water (EPA, 2016c). Fertilizers and animal waste are the major contributors of nutrient pollution from agriculture (EPA, 2016d). The run-off of excess nutrients from agriculture pollutes the waterways (EPA, 2016d). Harmful algal blooms (HABs) are one example of the environmental impact of excess nutrients (EPA, 2016c). HABs can promote the growth of toxic diatoms which magnifies with each trophic level and remove oxygen from the water, negatively impacting aquatic life (EPA, 2016c). Nutrient pollution can result in ocean dead zones where aquatic organisms cannot survive due to the lack of oxygen in the water (EPA, 2016b). Nutrient pollution can also affect humans by contaminating drinking water (EPA, 2016c).

The 1972 Clean Water Act determined that concentrated animal feeding operations (CAFOs) were contributors to “point source” pollution and required National Pollutant Discharge Elimination System (NPDES) permits (Sneeringer & Hogle, 2008). The 1970 Porter-Colgone Water Quality Act was the initial state-wide regulation on water quality from dairies (Sneeringer & Hogle, 2008). The Act divided California into nine Regional Water Quality Control Boards which were responsible for regulating dairies in their region (Sneeringer & Hogle, 2008). In 1984, title 23 of the California Code of Regulations required dairy operations to manage the storage and application of manure (Sneeringer & Hogle, 2008). Title 27 replaced Title 23 in 1997 and established minimum standards for CAF discharge (Sneeringer & Hogle, 2008).

The interest in the U.S. cattle industry's role in contributing to greenhouse gas emissions and human caused climate change has been increasing over recent years (Place, Stackhouse, Wang, & Mitloehner, 2011). Dairy farms are a major contributor of greenhouse gas (GHG) emissions in California. There are three major GHGs that are emitted from dairy farms, Carbon Dioxide (CO₂), Methane (CH₄), and Nitrous Oxide (N₂O), and fall into two categories, enteric or manure-derived (Owen & Silver, 2015; Place, Stackhouse, Wang, & Mitloehner, 2011; Owen, Kebreab, & Silver, 2014). Enteric emissions are those that come directly from the digestive systems of the cows while manure-derived emissions come from the storage and application of cow waste. CO₂ is produced from the use of fossil fuels in equipment, transportation, and the generation of electricity (Place & Mitloehner, 2010). CH₄ and N₂O are GHGs that are primarily a result of manure storage practices (Place & Mitloehner, 2010; Place, Stackhouse, Wang, & Mitloehner, 2011; Owen, Kebreab, & Silver, 2014). Manure management from livestock accounts for 10% of GHGs from agriculture globally (Owen & Silver, 2015). 54% of CH₄ emitted from dairy farms comes from manure management methods such as liquid anaerobic lagoons, slurry tanks and settling ponds, and solid piles (Owen & Silver, 2015). Anaerobic lagoons, the primary means of manure management, have ten times the global warming potential as emissions from solid manure piles (Owen, Kebreab, & Silver, 2014).

Manure from farms is eventually used as fertilizer on agriculture fields where the primary greenhouse gas is nitrous oxide (N₂O) (Owen, Kebreab, & Silver, 2014). There have been little to no published field studies from California dairies as well as little data available in regards to GHGs (Owen, Kebreab, & Silver, 2014). The 100-year global

warming potential for CH₄ and N₂O are 21 and 310, respectively (Place, Stackhouse, Wang, & Mitloehner, 2011). For comparison, the 100-year global warming potential for CO₂ is 1, meaning that CH₄ and N₂O have the potential to contribute 20 to 300 times more to global warming. There is much variability in the different methods utilized in manure management which makes estimating measurements and modeling emissions difficult to conduct and compare adding difficult to regulating emissions (Owen & Silver, 2015).

GHGs have increased due to anthropogenic causes and have reached a level that is the highest in history (Intergovernmental Panel on Climate Change (IPCC), 2016). Climate is the long-term average weather that is partly affected by GHGs (Place & Mitloehner, 2010). GHGs trap long wave radiation causing warming of the lower atmosphere (Place & Mitloehner, 2010). The industrial revolution was the beginning of human influenced warming and increases in the concentration of GHGs in the atmosphere (Place & Mitloehner, 2010). Since that time, the temperature of the oceans and atmosphere has increased, the amount of snow and ice has decreased, and sea level has risen (IPCC, 2016). The current concentrations of CO₂, CH₄, and N₂O are at their highest levels in the last 800,000 years and are considered to be the primary gases responsible for climate change in the 20th century (IPCC, 2016). These changes are likely responsible for some of the extreme weather and climate events that have occurred recently (IPCC, 2016). Decreases in cold temperature extremes, increases in warm temperature extremes, increases in extreme sea level rise, and increases in the number of heavy precipitation events all impact humans' well-being and have been linked to human influences and GHGs (IPCC, 2016). California was the first state to regulate GHGs,

including GHGs from the agriculture sector, with Assembly Bill 32 (AB-32) also known as the California Global Warming Solutions Act of 2006 (Place & Mitloehner, 2010).

The California Global Warming Solutions Act of 2006 (AB-32) requires the reduction of GHG emissions in California (California Environmental Protection Agency (CalEPA), 2014). This program was the initial action taken by a state which addresses climate change in the long-term (CalEPA, 2014). The goal of AB-32 is to reduce GHG emission to 1990 levels by the year 2020 equaling a reduction of about 15% (CalEPA, 2014). AB-32 addresses seven major GHGs/ groups of GHGs which include: Carbon dioxide, Methane, Nitrous Oxide, Hydrofluorocarbons, Perfluorocarbons, Sulfur hexafluoride, and Nitrogen trifluoride (CalEPA, 2014). The first three listed occur at dairy farms.

Air Quality

The emissions from dairy farms may be contributing factors to air pollution and threats to human health (Zhao et al., 2014). Air pollution is primarily caused by anthropogenic activities with industrial facilities being a major contributor (Kampa & Castanas, 2008). The combustion of fossil fuels for use in energy and transportation is a primary cause of air pollution (Kampa & Castanas, 2008). Air pollutants can generally be categorized as gaseous pollutants such as Sulfur dioxide (SO₂), Oxides of Nitrogen (NO_x), Carbon monoxide (CO), Ozone (O₃), and volatile organic compounds (VOCs), persistent organic pollutants (dioxins), heavy metals (lead, mercury), or particulate matter (PM) (Kampa & Castanas, 2008). Air pollution can negatively affect human and animal respiratory health, ecosystem health, and visibility (Place & Mitloehner, 2010).

There are four general pathways for pollutants to enter the atmosphere from the

dairy industry (Place & Mitloehner, 2010). Emissions directly from the digestive system of the cows, emissions from the cropping systems, feed management practices, and cow waste management practices are the primary activities that contribute to air pollution from dairy farms (Place & Mitloehner, 2010). The three major pollutants that are a result of these processes and practices are particulate matter (PM), ammonia (NH₃), and volatile organic compounds (VOCs) (Place & Mitloehner, 2010). PM in the air occurs from dairy cattle movement in dry lot corrals, tillage and harvesting practices for feed production, and forming from interactions with ammonia (Place & Mitloehner, 2010). The presence of ammonia is a result of fresh manure, the storage of manure, and the application of manure as a fertilizer (Place & Mitloehner, 2010). Ammonia can have negative impacts on human and animal health while also degrading terrestrial and aquatic ecosystems (Rotz et al., 2014). Ammonia in the atmosphere also contributes to the formation of PM (Rotz et al., 2014). VOCs are a group of chemical compounds found on dairy farms that evaporate at room temperature and contribute to the formation of ozone (O₃) (Malkina, Kumar, Green, & Mitloehner, 2011). Diaries are considered to be one of the largest contributors of VOCs with silage piles being the dominant source (Malkina et al., 2011).

Poor air quality can have negative impacts on human and animal health (Place & Mitloehner, 2010; Kampa & Castanas, 2008). Inhalation, ingestion, and dermal contact are the routes of exposure from poor air quality which can result in nausea, difficulty breathing, skin irritation, cancer, birth defects, and immune system deficiency (Kampa & Castanas, 2008). Air pollution primarily affects the cardiovascular and respiratory systems but can also have negative impacts on the nervous system, urinary system, and

digestive system (Kampa & Castanas, 2008; Garcia et al., 2013). Workers on the farms and nearby residents are at the most risk from poor air quality and their well being has been of growing concern (Mitchell et al., 2014; Garcia et al., 2013). Studies have demonstrated a relationship between exposure to PM and acute and chronic health effects (Ngo et al., 2010). Dairy workers may be at increased risk do to the nature of their work and length of exposure to atmospheric PM (Ngo et al., 2010). Fine PM_{2.5} is capable of penetrating deep into the respiratory tract causing significant damage increasing mortality and illness (Ngo et al., 2010). Asthma is another consequence from exposure to particulate emissions (Ngo et al., 2010).

Particulate Matter (PM)

Particulate Matter (PM) consists of suspended particles in breathing air (Kampa & Castanas, 2008). PM is liquid or solid material like dust or smoke that gets suspended in the air (Ngo et al., 2010). PM can be present in various sizes and composition and originate from both natural and anthropogenic sources (Kampa & Castanas, 2008). Sources of PM include factories, power plants, refuse incinerators, motor vehicles, construction activities, fires, and natural windblown dust (Kampa & Castanas, 2008). PM can be particularly powerful pollutants due to their ability to absorb and transport many different types of pollutants (Kampa & Castanas, 2008). Dairies may also be a significant source of PM emission. Sources of emissions of PM from dairies include equipment use on farm and transportation, suspension in air from worker and livestock activity, the disturbance of dried manure, or gaseous emissions (Garcia et al., 2013; Ngo et al., 2010). Oxides of Nitrogen (NO_x) are also a significant precursor to PM_{2.5} (San Joaquin Unified Air Pollution Control District (SJVUAPCD), 2016). The different types of chemical

composition of PM_{2.5} include:

- o Organic carbon- emission from combustion sources
- o Elemental carbon- incomplete combustion of fuels
- o Geologic material- road and soil dust
- o Trace metals- combustion from engine and brake wear
- o Sea salt- Sodium Chloride in sea spray
- o Secondary organic aerosol- reactions of organic carbon
- o Ammonium nitrate -NH₄NO₃
- o Ammonium sulfate- (NH₄)₂SO₄
- o Combined water

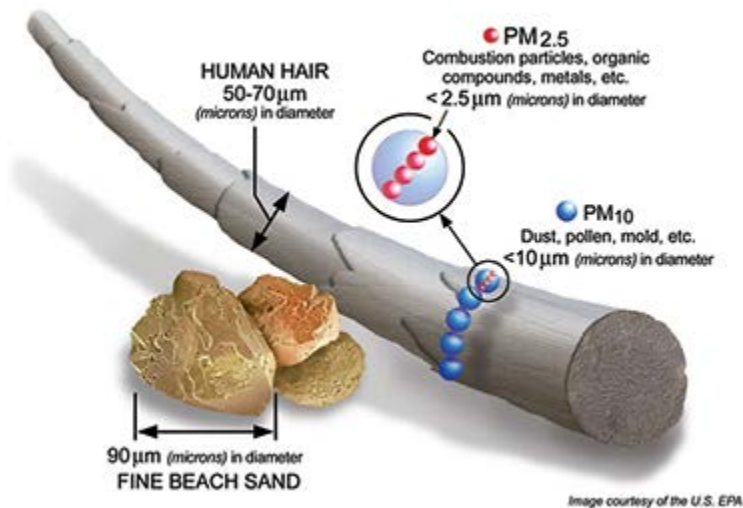


Figure 1. Various size comparisons for PM (SJVUAPCD, 2016).

Dairy Industry and the San Joaquin Valley

The cattle industry has different terms to define the types of cattle operations in

the state. Animal feeding operations (AFOs) are those operations that house cattle for at least a month and a half throughout the year (Sneeringer & Hogle, 2008). Confined animal feeding operations (CAFOs) are operations that house more than 300 cattle or if the operation is a significant polluter to waterways (Sneeringer & Hogle, 2008). In California, confined animal facilities (CAFs) are operations where animals are corralled or tethered (Sneeringer & Hogle, 2008). All three terms are used throughout the different policies that regulate the dairy industry. These terms are used interchangeably to refer to the large, industrial animal operations.

California's dairy industry is the largest throughout the U.S. and is a large contributor to the state's economy (Zhao et al., 2014; Owen & Silver, 2015; Garcia et al., 2013). The number of cows on dairy farms in California has increased 7% from 2002-2014 while the number of dairies has decreased by 31% (CDFA, 2014). This trend is evident at the dairies within the eight counties in the SJV. The counties in the SJV have reported increases in the number of cows and decreases in the number of dairies with the exception of Kern County which saw a significant increase in the number of cows (94%) as well as the number of dairies (24%) (CDFA, 2014). The number of cows per dairy also increased throughout the state (56%) as well as in the eight counties (CDFA, 2014). California has experienced a shift from small dairy farms to larger dairy operations defined as concentrated feeding operations (CAFOs) (Garcia et al., 2013).

Clean Air Act

In 1970, Congress passed the Clean Air Act (CAA) (EPA, 2007). That same year Congress also created the U.S. Environmental Protection Agency with one of the goals to enforce the CAA and clean up air pollution (EPA, 2007). Everyone has a role to play

under the CAA. The EPA's role is to set limits of pollutants for the entire nation. This includes limits on the sources of pollution and the amount of a pollutant in the air at any given time and place (EPA, 2007). The State's responsibilities include ensuring their air quality meets the limits set by the EPA (EPA, 2007). States accomplish this by monitoring air quality, conducting inspections and enforcing the CAA (EPA, 2007). The States are also responsible for developing State Implementation Plans outlining how they will reduce air pollution and achieve the standards set by the EPA (EPA, 2007). Public participation is also big factor when it comes to the development of plans (EPA, 2007). The public provides feedback to policy makers which assists in developing a comprehensive plan that supports the community. Up until 2006, the major focus of regulating the dairy industry was its contribution to water pollution. In 2006, the EPA began to focus on air pollution under the Clean Air Act where large livestock operations would begin to self monitor their emissions and that data would be used to regulate the facilities (Sneeringer & Hogle, 2008). The Clean Air Act also developed standards for GHGs and has allowed the EPA to take action to reduce GHG emissions (Environmental Protection Agency (EPA), 2016a). Implementation of the Clean Air Act to address GHGs include: regulatory initiatives such as the Clean Power Plan, the Final Greenhouse Gas Tailoring Rule, Landfill Air Pollution Standards, and the Greenhouse Gas Reporting Program (EPA, 2016a).

Attainment Status

Sections 108-109 of the Clean Air Act (CAA) outline the EPA's responsibility for setting national ambient air quality standards (NAAQS) (Esworthy, 2015). Standards are set for air pollutants that may endanger the public health or welfare and originates from

both mobile and stationary sources such as PM (Esworthy, 2015). The standards are reviewed every five years and are modified or maintained based on the latest scientific research (Esworthy, 2015). The EPA identified six criteria pollutants to be monitored: Particulate Matter, Ozone, NO₂, SO₂, CO, and PB (Esworthy, 2015). For PM, there are two types of standards in place, the 24-hour (short-term) and the annual (long-term) (Esworthy, 2015). PM is also classified into two categories. “Fine” PM with a diameter of 2.5 micrometers or less is categorized as PM_{2.5} while larger PM with a diameter of 10 micrometers or less is categorized as PM₁₀ (Esworthy, 2015).

At the end of 2012, the EPA published revisions to the NAAQS for PM (Esworthy, 2015). The annual standard was lowered from 15 micrograms per cubic meter to 12 micrograms per cubic meter while the 24-hour standard remained the same at 35 micrograms per cubic meter based on the three-year average of the 98th percentile of PM_{2.5} concentrations (Esworthy, 2015). Annual standard attainment requires that the three-year average of PM concentrations at each monitoring site does not exceed the maximum limit set by the EPA (Esworthy, 2015). The 24-hour (daily) standard attainment is based on the percentage of time that a monitoring station can exceed the set limit (Esworthy, 2015). An ex. 98th percentile standard means that a monitoring station can exceed the maximum limit concentration 2% of the days throughout the year (Esworthy, 2015).

An important part of the NAAQS process is identifying, or designating, geographical areas that are not reaching the air quality standards (Esworthy, 2015). These areas are designated as either attainment, non-attainment, or unclassifiable areas (Esworthy, 2015). Nonattainment areas are those that either violate or contribute to the violation of air quality standards (Esworthy, 2015). Unclassifiable areas are those where

the data was insufficient to determine compliance with the air quality standard (Esworthy, 2015). The NAAQS designation process is a cooperative process with state and tribal governments providing recommendations for designations to the EPA (Esworthy, 2015). The CAA requires the governor of each state to identify areas as either attainment or nonattainment to the EPA and recommend their designation based on their contribution to air quality (Esworthy, 2015). The EPA administrator is then responsible for making modifications to the state recommendation (i.e. changing the boundaries of the attainment/nonattainment areas) (Esworthy, 2015). Area designation is dependent upon the ability to measure and analyze air quality and a network of monitoring sites was implemented from 1999-2000 (Esworthy, 2015). There are several factors that should be considered by the state when determining attainment designations:

- o population density and urbanization
- o source location and vicinity of the population
- o current control on emissions
- o traffic and growth rates
- o meteorology
- o geography and topography
- o jurisdictional boundaries (city/county limits, air districts)

All eight counties in the SJV were recommended as non-attainment areas under the new 2013 PM_{2.5} annual standard (Esworthy, 2015). The eight counties also received non-attainment designations for 2006 and 1997 PM_{2.5} standards (Esworthy, 2015).

San Joaquin Valley Unified Air Pollution Control District

The responsibility for the management of air quality throughout the SJV falls on the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD). The overall goal of the SJVUAPCD is to reduce emissions that contribute to poor air quality in the SJV through collaboration with residents, business community, and local, state, and federal government agencies. The Mission of the district is,

“The San Joaquin Valley Air Pollution Control District is a public health agency whose mission is to improve the health and quality of life for all Valley residents through efficient, effective and entrepreneurial air quality management strategies. Our Core Values have been designed to ensure that our mission is accomplished through common sense.”

In 2015, the SJVAPCD developed a plan to address the 1997 PM_{2.5} National Ambient Air Quality Standard for the annual standard of 15 µg/m³ and the 24-hour standard of 65 µg/m³. This plan identified areas where Best Available Control Measures (BACM) and Most Stringent Measures (MSM) should be applied to reach attainment. The BACM refers to the maximum reduction of emissions based on the energy, economic and environmental impacts (SJVAPCD, 2016). The MSM refers to reduction measures that have been previously used in other state's implementation plans (SJVAPCD, 2016). One of the plan's major focuses is on reducing NO_x emissions but does not consider reducing VOC's and ammonia emission directly. The plan suggests that addressing VOC and ammonia emission would not result in a significant decrease in PM_{2.5} pollution (SJVAPCD, 2016).

Previous Studies

There have been several studies which identify dairy farms in the SJV as a source of PM_{2.5} concentrations. Chen, Watson, and Chow (2007) used various modeling methods (UNMIX and Positive Matrix Factorization (PMF)) to measure PM_{2.5} at 23 sites in the San Joaquin Valley (SJV). The study investigated air quality data taken from December 1999 to February 2001 in order to determine the sources contributing to PM_{2.5} during the high and low period (Chen et al., 2007). The study combined agriculture and dairy into one category and determined the percentage of PM_{2.5} contributions from agriculture-dairy (Chen et al., 2007). Agriculture-dairy was responsible for 2% and 5% from the UNMIX model during the winter and non-winter periods, respectively, and 2% and 4% from the PMF model (Chen et al., 2007). However, much of those percentages came from the single dairy site in the study where the NH₃ concentration was an order of magnitude higher than any other site (Chen et al., 2007). Chen et al. (2007) determines sources of PM_{2.5} from rural and urban areas but is not focused on dairies.

Sneeringer and Hogle (2008) explore the relationship between environmental regulations and the pollution “havens” that they can create. There are two major influences on dairy location in California: urban encroachment and environmental regulation (Sneeringer & Hogle, 2008). The authors look at environmental regulations from 1970 to 2007 to see how they have shaped the dairy landscape in California. They examine data from the Censuses of Agriculture to determine dairy locations and number of cows on dairy farms throughout the state. The authors study area is similar to the proposed study but it did not investigate the effect on PM emissions from large numbers of cattle concentrated in a confined area.

There have been several other studies that investigate the issue of poor air quality from dairy farms in California. There has been an established link with health impacts for workers on large California dairies (Mitchell et al., 2014; Garcia et al., 2013). These studies have not explored if the number of cows present on the dairies increased the amount of $PM_{2.5}$ and in turn increased the human health risk from poor air quality.

Research Questions

The purpose of this study is to investigate the relationship between the number of cows per county and the number of days where $PM_{2.5}$ was the dominant pollutant during the day throughout the year. This study also explores the relationship between the number of cows and the weighted annual mean for concentrations of $PM_{2.5}$ taken from monitoring sites across the SJV. This study attempts to determine if the number of cows per dairy has an influence on the number of $PM_{2.5}$ days and WAM for the eight counties in the SJV.

The eight counties that make up the SJV are Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, and Tulare. Trends in the number of cows, cow per dairy, and $PM_{2.5}$ days for these eight counties were compared to other counties throughout the state.

Hypotheses

- Increasing the number of cows on dairy farms throughout the county will result in an increase number of days where $PM_{2.5}$ is present.
- Increasing the number of cows per dairy farm will result in an increase number of days where $PM_{2.5}$ is present.
- Increasing the number of cows on dairy farms throughout the county will increase the weighted annual mean for the concentration of $PM_{2.5}$.

- Increasing the number of cows per dairy farm will result in an increase the weighted annual mean for the concentration of $PM_{2.5}$.

Methods

Data Collection

Five types of data were collected from 2002-2014 for comparison in this study: the number of cows throughout each county in the SJV, the number of dairies those cows were found on, the ratio of cows per dairy, the number of days throughout the year that $PM_{2.5}$ was the dominant pollutant present ($PM_{2.5}$), and the weighted annual mean concentration of $PM_{2.5}$ in each county. The number of cows, number of dairies, and cows per dairy data was collected from the California Department of Food and Agriculture's (CDFA) Dairy Statistics Annual (Table 1.). The California Dairy Statistic Annual is prepared every year by the Division of Marketing Services, Dairy Marketing Branch of the CDFA (CDFA, 2014). The annual is a collaborative effort between the CDFA and the USDA and is based on data that was previously published (CFDA, 2014).

Table 1. CDFA's Dairy Statistics Example for Fresno County.

Year	County	Cows	Dairies	Cows/Dairy
2014	Fresno	116,939	79	1480

Air quality data was collected from the Air Quality Index prepared by the USEPA (Table 2.). The Air Quality Index (AQI) is a single number representing a large amount of data used to report air quality data which have an impact on human health (Bishoi, Prakash, & Jain, 2009). The EPA AQI rates air quality from 0-500 with score of 100 being set at NAAQS (Bishoi, Prakash, & Jain, 2009). The Daily AQI calculation converts concentration values of the five criteria pollutants to numerical indexes (Bishoi, Prakash, & Jain, 2009). The five criteria pollutants are CO, NO₂, O₃, PM, and SO₂, with the NO₂

standard currently being re-evaluated (Bishoi, Prakash, & Jain, 2009). The overall AQI calculation identifies the max AQI among the pollutants at a site or station (Bishoi, Prakash, & Jain, 2009). The 0-500 scale is divided into 6 categories based on associated health, good, moderate, unhealthy for sensitive groups, unhealthy, very unhealthy, and hazardous (Bishoi, Prakash, & Jain, 2009). Table 2. provides an example of the AQI data collected from Fresno, Ca, in 2014.

Table 2. AQI Report Example for Fresno County

County	# Days with AQI	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy	AQI Maximum
Fresno County, CA	365	95	170	77	23	.	173
AQI 90th Percentile	AQI Median	# Days CO	# Days NO2	# Days O3	# Days SO2	# Days PM2.5	# Days PM10
129	71	.	1	213	.	147	4

The number of days with AQI refers to the days throughout the year that monitoring sites from a given county report measurements that contribute to an AQI value (EPA, 2016). The next five columns reflect the number of days throughout the year where the AQI value is Good (AQI score of 0-50), Moderate (51-100), Unhealthy for Sensitive Groups (101-150), Unhealthy (151-200), and Very Unhealthy (200+, and includes the Hazardous category) (EPA, 2016). The AQI maximum column represents the highest AQI value reported throughout the year (EPA, 2016). The AQI 90th Percentile refers to AQI values that were less than or equal to the 90th percentile value (EPA, 2016). The AQI Median column reports the median AQI value reported throughout the year (half of the values exceeded the median value and half were less) (EPA, 2016). The following columns represent the number of days which the calculated daily index value for that criteria pollutant was the main pollutant reported throughout the year (EPA, 2016). All of the data present in the table reflects the air quality for a given county,

however; the number of days PM_{2.5} will be analyzed in this study.

Air quality data was also collected the EPA’s Monitor Values Report. The report displays a summary of air pollution measurements throughout the year taken from individual monitoring sites within each county across the country (EPA, 2016). The measurements displayed are from a single monitor at a given site within the county (EPA, 2016). Table 3 displays an example of a Monitor Values Report for one monitor site in Fresno, Ca for 2014.

Table 3. EPA’s Monitor Values Report Example for Fresno County

County	City	CBSA	Address	Site ID	POC	Exc Events
Fresno	Fresno	Fresno, CA	3727 N First St, Fresno	60190011	1	None
Obs	First Max	Second Max	Third Max	Fourth Max	98th Percentile	weighted_arithmetic_meanC
345	94.6	82	76.4	75.1	69	15.1

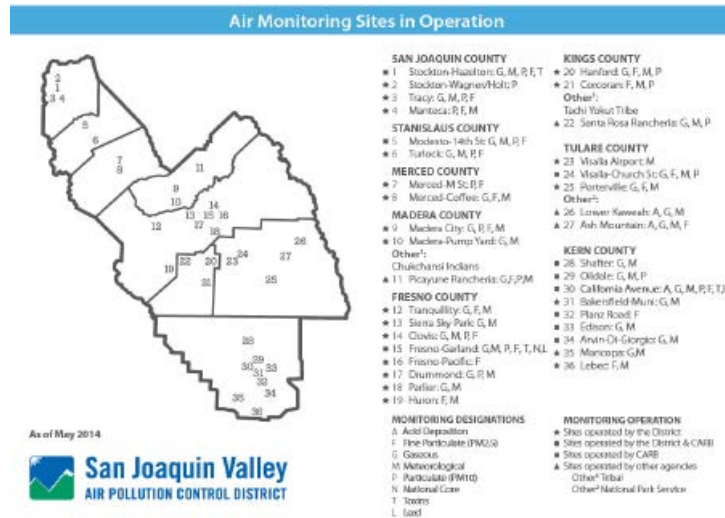
The site ID provided in the report corresponds to an air monitoring site within a county (EPA, 2016). Most counties have multiple monitoring sites and this ID allows them to be distinguished. The parameter occurrence code (POC) is used to identify multiple monitors at a single site (EPA, 2016). In some case there are up to three or four POCs at one monitoring site. Exceptional events (Exc Events) indicates whether any “flagged” data was included, excluded, or none in the report (EPA, 2016). “Flagged” data would include data influenced by exceptional events like high winds or wildfire) (EPA, 2016). The report also provides daily and annual values. The observations (Obs) column refers to the number of days throughout the year that measurement values were reported (EPA, 2016). The 1st Max, 2nd Max, 3rd Max, and 4th Max are the four highest 24-hour values reported throughout the year (EPA, 2016). The 98th percentile column refers to the days the 24-hour value is higher than 98 percent of the values throughout the year

(EPA, 2016). The Weighted Annual Mean (WAM) is the computed by AQS software and is the average of 24-hour values (EPA, 2016). All values are reported in micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) (EPA, 2016). For the purpose of this study, multiple WAMs from multiple monitoring sites and POCs are averaged to give a single value for $\text{PM}_{2.5}$ concentration for each county. Table 4 displays how the single annual average (14.5 $\mu\text{g}/\text{m}^3$) was calculated from the multiple POCs and monitoring sites for Fresno, CA, in 2014.

Table 4. Example of County Average of $\mu\text{g}/\text{m}^3$ Calculation

County	City	Address	Site ID	POC	WAM	County Average $\mu\text{g}/\text{m}^3$
Fresno	Fresno	3727 N First St, Fresno	60190011	1	15.1	14.5
Fresno	Fresno	3727 N First St, Fresno	60190011	2	14.3	
Fresno	Fresno	3727 N First St, Fresno	60190011	3	19.7	
Fresno	Fresno	3727 N First St, Fresno	60190011	4	16.4	
Fresno	Not in a City	32650 West Adams Avenue Tranquillity Ca 93668	60192009	3	7.6	
Fresno	Clovis	908 N Villa Ave, Clovis	60195001	1	14	
Fresno	Clovis	908 N Villa Ave, Clovis	60195001	3	15.2	
Fresno	Fresno	1716 Winery, Fresno Ca 93726	60195025	1	13.8	

Figure 2. Air Monitoring Sites throughout the SJV



Data Analysis

The data was analyzed using the Spearman's Rank Correlation Coefficient. The Spearman's Rank Correlation Coefficient is a non-parametric test for determining a linear relationship or association between two variables, or data sets (Gauthier, 2001). This technique ranks the data sets from lowest value to highest value and evaluates the relationship between the ranks rather than the raw data (Gauthier, 2001). For tied pairs, the average of the rank is calculated and used. Table 5. demonstrates how the data pairs are ranked, ties are resolved, and the Spearman's Rank Correlation Coefficient (r) is calculated.

Table 5. Example of Spearman's Rank Correlation Coefficient for Fresno County

Fresno Year	Number of Cows vs. Number of PM2.5 Days					
	Number of Cows	Rank	PM2.5 Days	Rank	<i>d</i>	<i>d</i> ²
2002	86115	1	122	1	0	0
2003	90345	2	128	2	0	0
2004	95577	3	134	3	0	0
2005	112600	5	137	4	1	1
2006	108945	4	157	7	-3	9
2007	120773	13	262	13	0	0
2008	120299	12	212	12	0	0
2009	115716	8	147	5.5	2.5	6.25
2010	118546	11	178	10	1	1
2011	117534	10	211	11	-1	1
2012	114204	6	160	8	-2	4
2013	114943	7	161	9	-2	4
2014	116939	9	147	5.5	3.5	12.25
					$\sum d^2$	38.5
					<i>n</i>	13
					<i>n</i> ³	2197
					<i>n</i> ³ - <i>n</i>	2184
					<i>r</i>	0.894

The number of cows within Fresno County from 2002 to 2014 were ranked from lowest to highest while the paired number of days PM_{2.5} was the dominant pollutant was also ranked from lowest to highest. In 2009 and 2014, there is the same number of days PM_{2.5}. These pairs were ranked as 5.5, rather than 5 or 6, and the next highest rank received a 7. The difference between the ranks for each paired set was then calculated and squared. *r* was then calculated using the Spearman's Rank Correlation Coefficient equation:

$$r = 1 - \frac{6 \sum d^2}{n^3 - n}$$

This test was used to calculate *r* values for all eight counties in the SJV comparing the

number of cows, the number of dairies, and the cows per dairy with the number of days PM_{2.5} was the dominant pollutant and the calculated average PM_{2.5} concentrations. The significance of the *r* values was determined using Table 6 taken from Zar, 1972.

Table 6. Critical Values of Spearman's Rank Correlation Coefficient

Critical Values of Spearman's Rank Correlation Coefficient (two-tailed)		
n	alpha=0.05	alpha=0.01
5	1.000	-
6	0.886	1.000
7	0.786	0.929
8	0.738	0.881
9	0.700	0.833
10	0.648	0.794
11	0.618	0.755
12	0.587	0.727
13	0.560	0.703
14	0.538	0.675
15	0.521	0.654
16	0.503	0.635
17	0.485	0.615
18	0.472	0.600
19	0.460	0.584
20	0.447	0.570

Results

Dairy Cows

The number of cows in Fresno County increased 35.8% from 86,115 in 2002 to 116,939 in 2014. At the same time, the number of dairies decreased 27.5% while the ratio of cows per dairy increased 87.3 %. The largest increase in number of cows occurred in 2005. The number of cows increased 17.8% adding 17,023 cows to the county. That same year the number of dairies increased 0.85 % and the ratio of cows per dairy increased 16.8% to 954.

Figure 3. Number of cows, dairies, and cows/dairy for Fresno County, 2002-2014

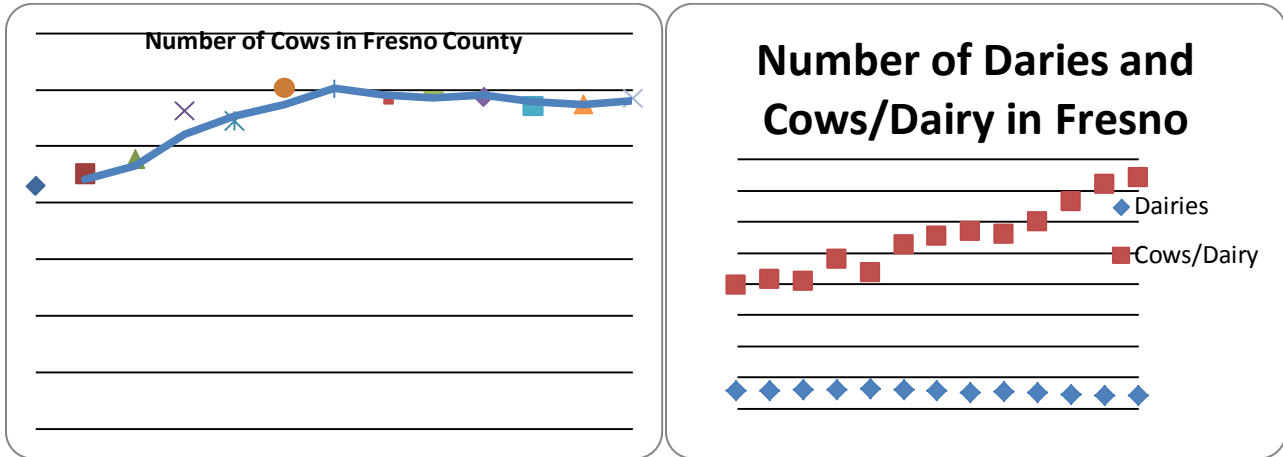


Table 7.1 Dairy Cow Data for Fresno County from 2002-2014

Fresno County							
Year	Cows	Dairies	Cows/Dairy	Year	Cows	Dairies	Cows/Dairy
2002	86,115	109	790	2009	115,716	102	1134
2003	90,345	109	829	2010	118,546	196	1118
2004	95,577	117	817	2011	117,534	98	1199
2005	112,600	118	954	2012	114,204	86	1328
2006	108,945	125	872	2013	114,943	80	1437
2007	120,773	115	1050	2014	116,939	79	1480
2008	120,299	109	1104				

The number of cows in Kern County increased 95.0% from 85,830 in 2002 to 167,309 in 2014, the largest increase throughout the SJV. During the same time frame, the number of dairies increased 24.4% while the ratio of cows per dairy increased 56.8 %. The largest increase in number of cows occurred in 2004, where the number of cows increased 23.0% adding 22,669 cows to the county. That same year the number of dairies increased 10.9% and the ratio of cows per dairy increased 10.9% to 2,375.

Figure 4. Number of cows, dairies, and cows/dairy for Kern County, 2002-2014

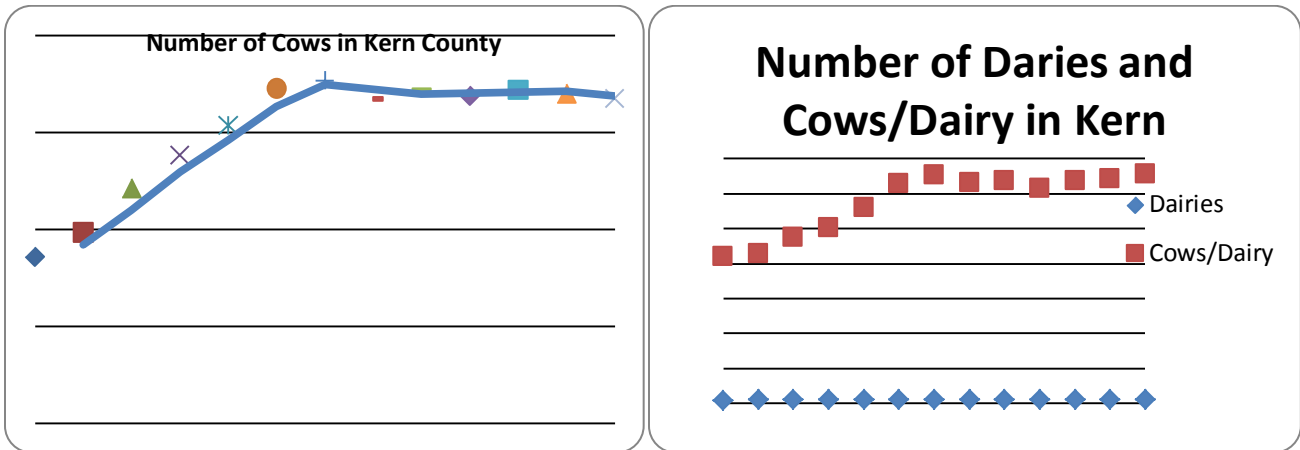


Table 7.2 Dairy Cow Data for Kern County from 2002-2014

Kern County							
Year	Cows	Dairies	Cows/Dairy	Year	Cows	Dairies	Cows/Dairy
2002	85,830	41	2,093	2009	167,309	53	3,157
2003	98,478	46	2,141	2010	171,674	54	3,179
2004	121,147	51	2,375	2011	168,794	55	3,069
2005	138,281	55	2,514	2012	171,931	54	3,184
2006	153,546	55	2,792	2013	169,938	53	3,206
2007	172,556	55	3,137	2014	167,347	51	3,281
2008	176,643	54	3,271				

The number of cows in Kings County increased 25.4% from 146,545 in 2002 to 183,775 in 2014. The number of dairies decreased 19.6 % while the ratio of cows per dairy increased 56.0 %. The largest increase in number of cows was observed in 2007. The number of cows increased 8.1% adding 13,373 cows to the county, the number of dairies increased 3.8%, and the ratio of cows per dairy increased 4.2% to 1076.

Figure 5. Number of cows, dairies, and cows/dairy for Kings County, 2002-2014

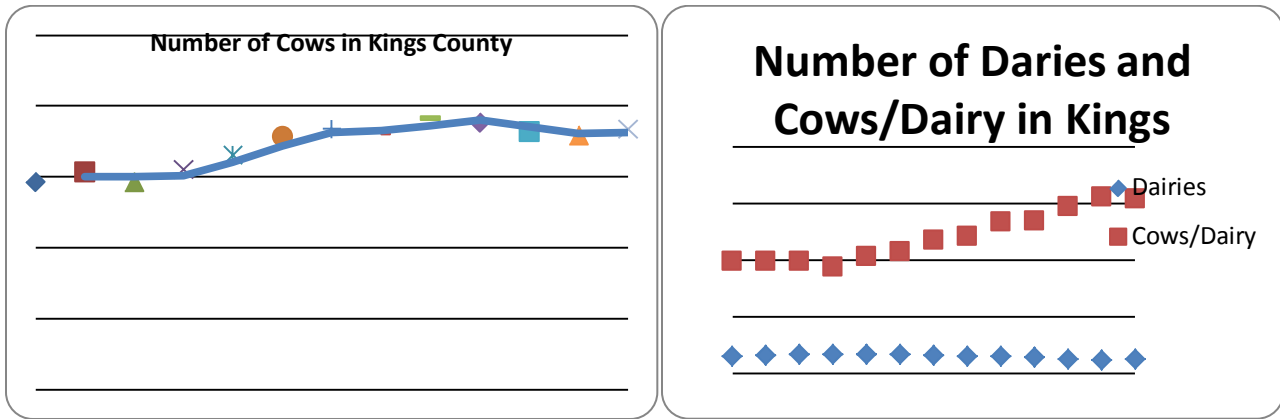


Table 7.3 Dairy Cow Data for Kings County from 2002-2014

Kings County							
Year	Cows	Dairies	Cows/Dairy	Year	Cows	Dairies	Cows/Dairy
2002	146,545	148	990	2009	181,243	150	1208
2003	153,475	155	990	2010	191,339	143	1338
2004	146,484	165	986	2011	188,416	140	1346
2005	155,238	165	941	2012	182,018	124	1468
2006	165,316	160	1033	2013	179,408	115	1560
2007	178,689	166	1076	2014	183,775	119	1544
2008	183,809	156	1178				

The number of cows in Madera County increased 57.2% from 49,899 in 2002 to 78,430 in 2014. At the same time, the number of dairies decreased 23.2% while the ratio of cows per dairy increased 104.7%. In 2003, the number of cows increased 14.4% adding 7,200 cows to the county. That same year the number of dairies remained the same at 56 and the ratio of cows per dairy increased 14.5% to 1020.

Figure 6. Number of cows, dairies, and cows/dairy for Madera County, 2002-2014

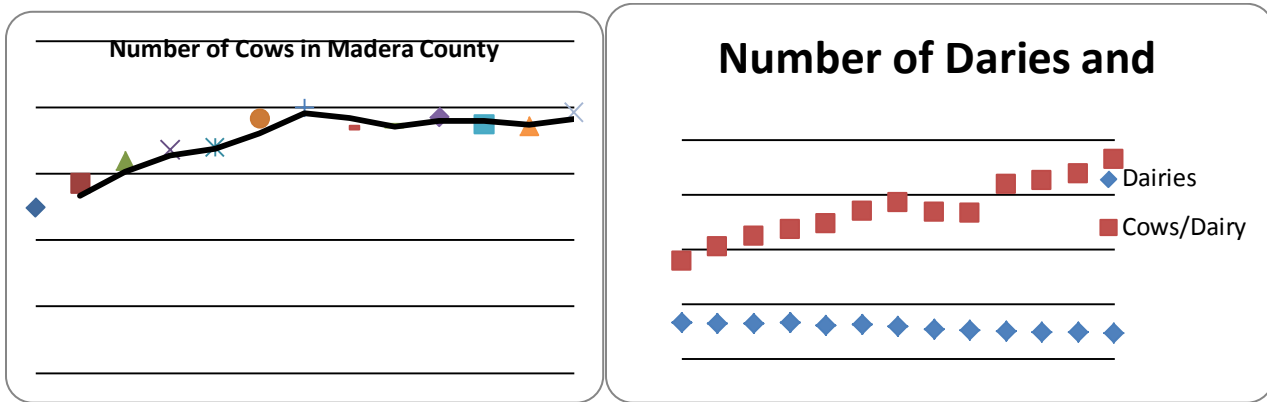


Table 7.4 Dairy Cow Data for Madera County from 2002-2014

Madera County							
Year	Cows	Dairies	Cows/Dairy	Year	Cows	Dairies	Cows/Dairy
2002	49,899	56	891	2009	73,747	55	1341
2003	57,099	56	1020	2010	74,411	56	1329
2004	63,934	57	1020	2011	77,110	49	1595
2005	67,173	57	1178	2012	74,929	46	1629
2006	67,900	55	1235	2013	74,384	44	1691
2007	76,640	57	1345	2014	78,430	43	1824
2008	79,810	56	1425				

The number of cows in Merced County increased 22.9% from 224,895 in 2002 to 276,359 in 2014. At the same time, the number of dairies decreased 31.1% while the ratio of cows per dairy increased 78.5%. The largest increase in number of cows occurred in 2007. The number of cows increased 7.9% adding 19,181 cows to the county. That same year the number of dairies increased 2.3% and the ratio of cows per dairy increased 5.5% to 843.

Figure 7. Number of cows, dairies, and cows/dairy for Merced County, 2002-2014

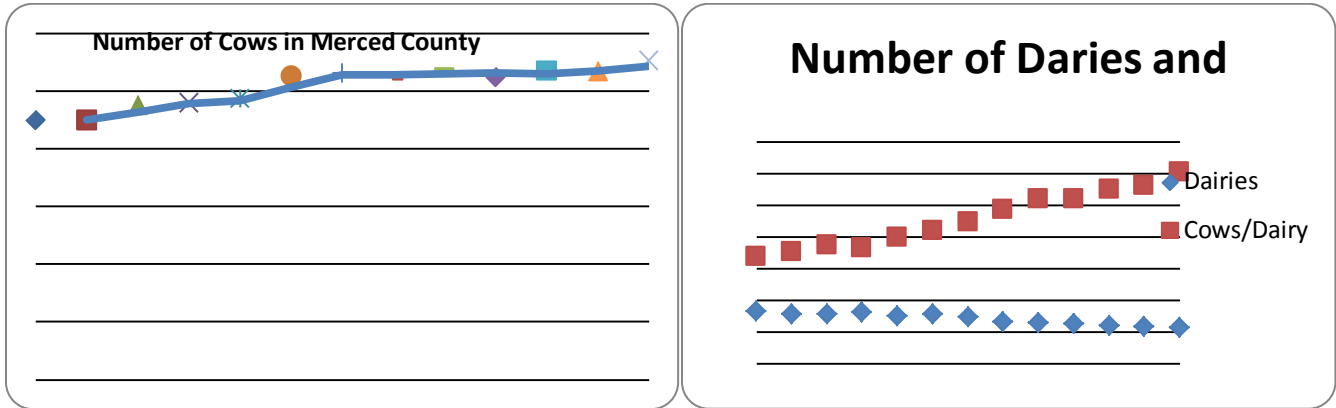


Table 7.5 Dairy Cow Data for Merced County from 2002-2014

Merced County							
Year	Cows	Dairies	Cows/Dairy	Year	Cows	Dairies	Cows/Dairy
2002	224,895	331	679	2009	261,529	268	976
2003	224,734	316	711	2010	268,312	258	1040
2004	237,865	317	750	2011	262,131	251	1044
2005	239,786	327	733	2012	267,728	243	1102
2006	243,762	305	799	2013	267,124	237	1127
2007	262,943	312	843	2014	276,359	228	1212
2008	265,660	297	894				

The number of cows in San Joaquin County increased 3.1% from 99,828 in 2002 to 102,934 in 2014. During the same time period, the number of dairies decreased 25.2% while the ratio of cows per dairy increased 37.8%. The largest increase in number of cows occurred in 2007. The number of cows increased 7.7% adding 7,981 cows to the county. That same year the number of dairies decreased 4.4% and the ratio of cows per dairy increased 12.6% to 857.

Figure 8. Number of cows, dairies, and cows/dairy for San Joaquin County, 2002-2014

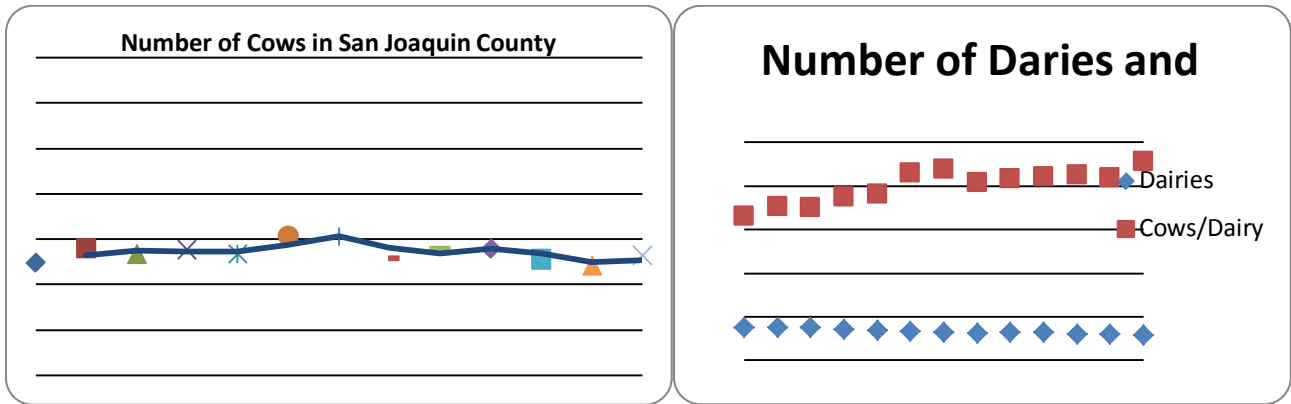


Table 7.6 Dairy Cow Data for San Joaquin County from 2002-2014

San Joaquin County							
Year	Cows	Dairies	Cows/Dairy	Year	Cows	Dairies	Cows/Dairy
2002	99,828	151	661	2009	101,444	125	812
2003	106,102	151	703	2010	105,810	127	833
2004	103,619	148	700	2011	106,012	126	841
2005	105,393	141	747	2012	101,236	119	851
2006	103,480	136	761	2013	98,495	118	835
2007	111,461	130	857	2014	102,934	113	911
2008	111,231	127	876				

The number of cows in Stanislaus County increased 9.3% from 164,558 in 2002 to 179,884 in 2014. The number of dairies decreased 33.0% while the ratio of cows per dairy increased 63.0%. The largest increase in number of cows occurred in 2003, where the number of cows increased 7.8% adding 12,874 cows to the county. That same year the number of dairies increased 1.3% and the ratio of cows per dairy increased 6.4% to 567.

Figure 9. Number of cows, dairies, and cows/dairy for Stanislaus County, 2002-2014



Table 7.7 Dairy Cow Data for Stanislaus County from 2002-2014

Stanislaus County							
Year	Cows	Dairies	Cows/Dairy	Year	Cows	Dairies	Cows/Dairy
2002	164,558	309	533	2009	180,020	259	695
2003	177,432	313	567	2010	184,161	248	743
2004	178,420	311	574	2011	180,416	232	778
2005	183,762	307	599	2012	187,061	216	866
2006	181,189	287	631	2013	183,901	210	876
2007	186,802	301	621	2014	179,884	207	869
2008	183,316	272	674				

The number of cows in Stanislaus County increased 14.0% from 164,558 in 2002 to 187,884 in 2014. At the same time, the number of dairies decreased 33.0% while the ratio of cows per dairy increased 27.4%. The largest increase in number of cows occurred in 2006. The number of cows increased 3.4% adding 15,499 cows to the county. That same year the number of dairies increased 2.1% and the ratio of cows per dairy increased 2.6% to 631.

Figure 10. Number of cows, dairies, and cows/dairy for Tulare County, 2002-2014

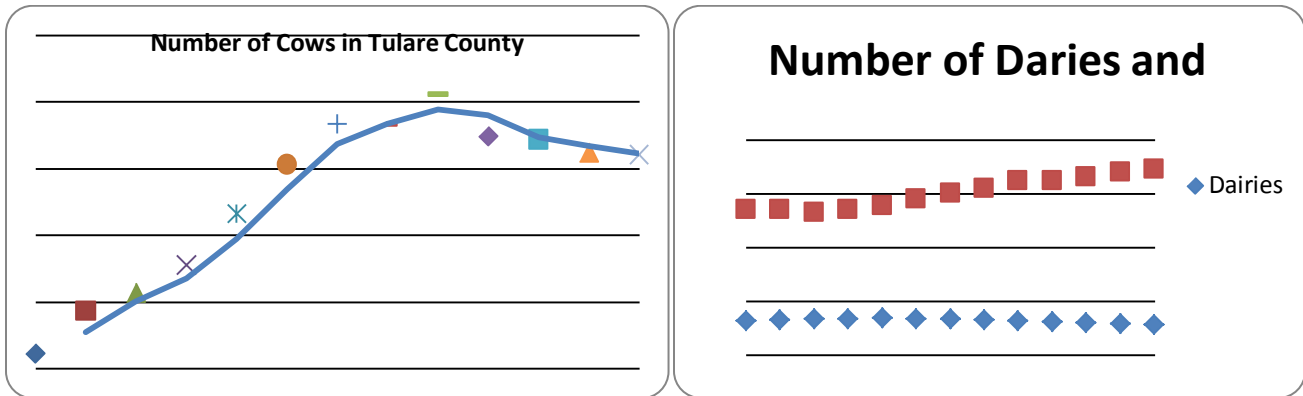


Table 7.8 Dairy Cow Data for Tulare County from 2002-2014

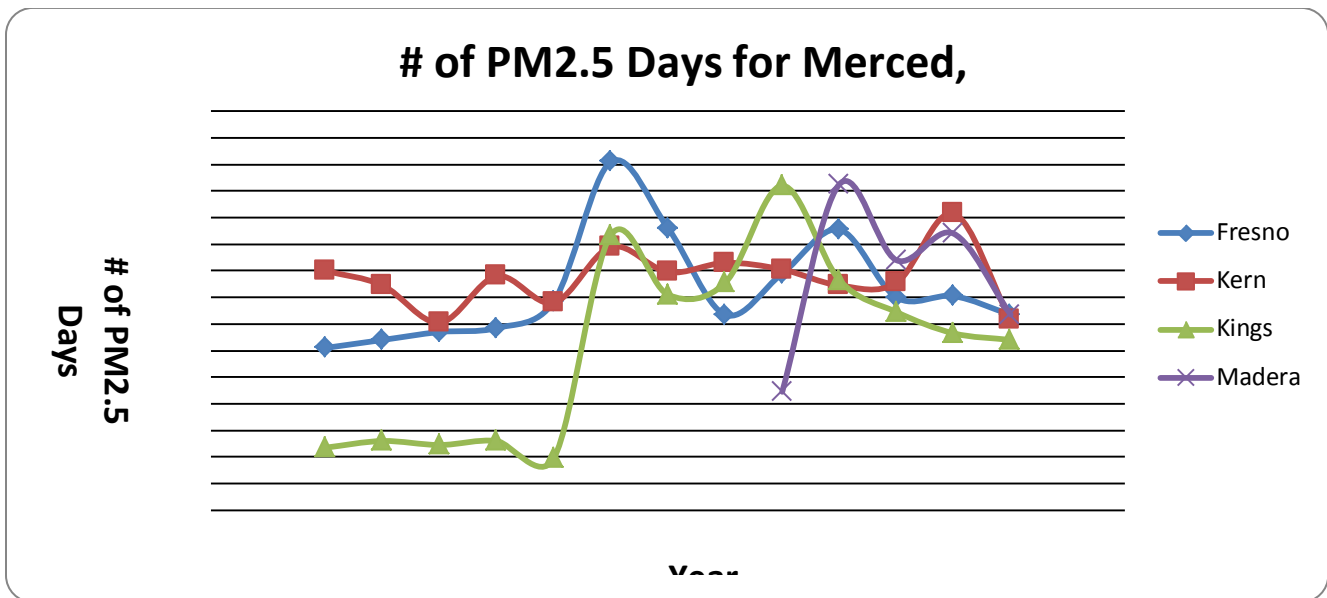
Tulare County							
Year	Cows	Dairies	Cows/Dairy	Year	Cows	Dairies	Cows/Dairy
2002	424,643	314	1,352	2009	493,292	319	1,546
2003	437,476	323	1,354	2010	502,395	311	1,615
2004	442,853	334	1,326	2011	489,740	307	1,615
2005	451,093	334	1,351	2012	488,821	296	1,651
2006	466,592	341	1,386	2013	484,845	285	1,701
2007	481,353	332	1,450	2014	484,258	281	1,723
2008	493,383	329	1,500				

Tulare County consistently had the most cows per year with over 400,000. Kern County saw the largest percent growth with 94%. Stanislaus had the largest decrease in dairies with 33%. All counties with the exception of Kern saw a decrease in number of dairies. All counties also had an increase in the ratio of cows per dairy. Madera County had the largest increase in the ratio of cows per dairy with 104.7%.

Air Quality Index (AQI) PM_{2.5} Days

Fresno County observed the most PM_{2.5} days in 2007 with 262 days with the lowest number in 2002 with 122. The average number of PM_{2.5} days was 166 for 2002 to 2014. The highest number of PM_{2.5} days observed in Kern County occurred in 2007 with 198 days. The fewest PM_{2.5} days occurred in 2004 with 141 days and the average number of PM_{2.5} days was 175. Kings County had the most PM_{2.5} days in 2010 with 244 days. The least amount of PM_{2.5} days occurred in 2006 with 39. The average number of PM_{2.5} days for Kings County was 124 days. Madera County's most PM_{2.5} days was 245 in 2011 and least PM_{2.5} days 89 in 2010. The average number of PM_{2.5} days was 175 days.

Figure 11. PM_{2.5} Days for Fresno, Kern, Kings, and Madera Counties



The highest number of PM_{2.5} days observed in Merced County occurred in 2011 with 208 days. The fewest PM_{2.5} days occurred in 2008 with 43 days and the average number of PM_{2.5} days was 93 days. San Joaquin County observed the most PM_{2.5} days in 2012 with 296 days with the lowest number in 2004 with 52 days. The average number

of PM_{2.5} days was 132 days. Stanislaus County's most PM_{2.5} days was 239 in 2007 and least PM_{2.5} days was 51 in 2004. The average number of PM_{2.5} days was 136. Tulare County had the most PM_{2.5} days in 2005 with 180 days. The least amount of PM_{2.5} days occurred in 2009 and the average number of PM_{2.5} days for Tulare County was 162.

Figure 12. PM_{2.5} Days for Merced, San Joaquin, Stanislaus, and Tulare Counties.

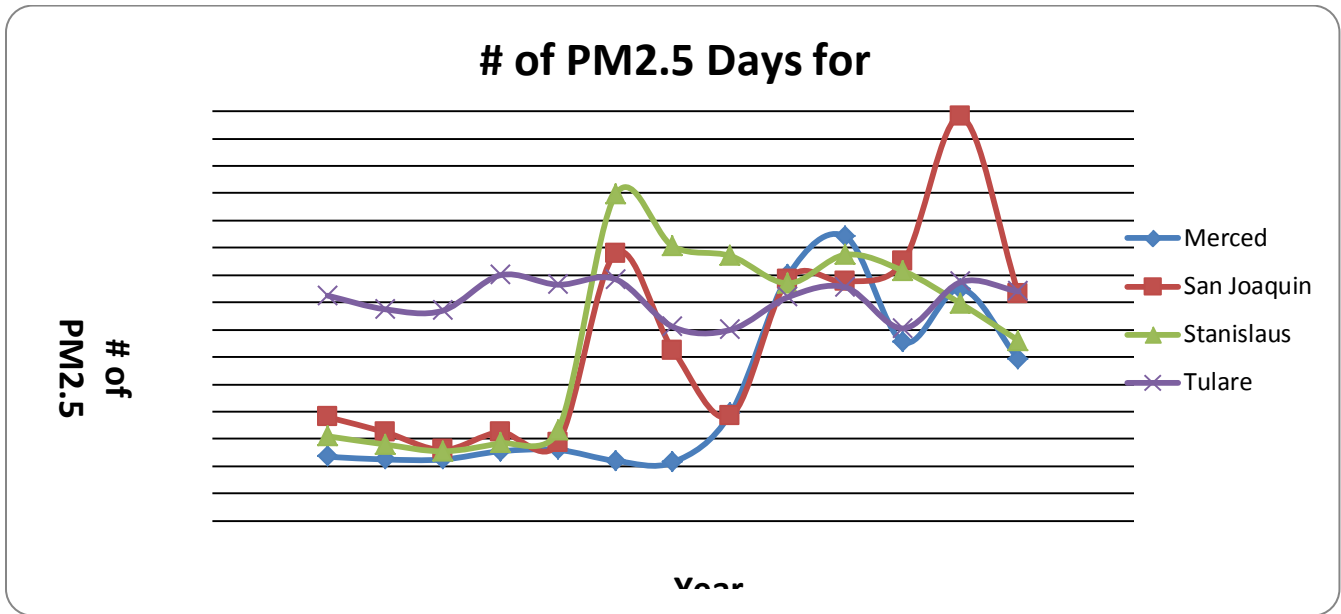


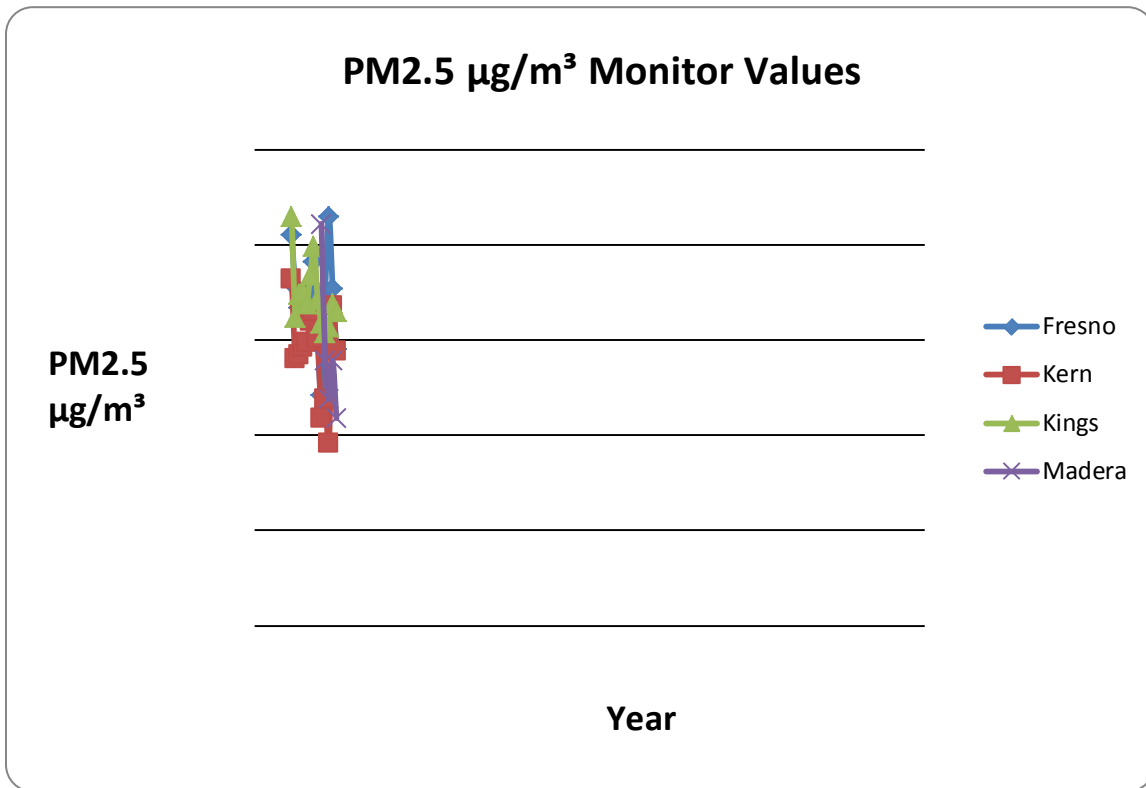
Table 8. Air Quality Index Reports for PM_{2.5} Days in the SJV

Air Quality Index (AQI) Reports 2002-2014 # of Days PM _{2.5}													
	Year												
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fresno	122	128	134	137	157	262	212	147	178	211	160	161	147
Kern	180	169	141	176	156	198	179	186	181	169	171	223	143
Kings	47	52	49	52	39	207	162	171	244	173	149	133	128
Madera	-	-	-	-	-	-	-	-	89	245	188	208	147
Merced	47	45	45	51	52	44	43	79	180	208	131	170	118
San Joaquin	76	65	52	65	57	196	125	77	177	175	190	296	166
Stanislaus	62	56	51	57	66	239	201	194	174	195	183	159	132
Tulare	165	155	154	180	173	177	142	140	164	171	141	175	168

Monitor Values Report PM_{2.5} µg/m³

The average weighted annual mean (WAM) concentration of PM_{2.5} for Fresno County from 2002 to 2014 was 17.2 µg/m³. The highest WAM for Fresno County occurred in 2011 with 21.5 µg/m³. The lowest WAM year happened in 2010 with 12.1 µg/m³. Kern County observed an average PM_{2.5} concentration of 14.4 µg/m³. In 2002, Kern County had a high WAM of 18.2 µg/m³ with a low of 9.6 µg/m³ in 2012. Kings County had an average of 17.3 µg/m³ from 2002 to 2014. The highest WAM came in 2002 with 21.5 µg/m³. The lowest WAM occurred in 15.7 µg/m³. Madera County averaged a WAM of 14.3 µg/m³. The highest WAM was observed in 2010 with 21.1 µg/m³ while the lowest WAM had a concentration of 10.9 µg/m³ in 2014.

Figure 13. PM2.5 Monitor Values for Fresno, Kern, Kings, and Madera Counties.



The average WAM of PM_{2.5} for Merced County was 14.5 µg/m³. the highest WAM for Merced County occurred in 18.7 µg/m³ in 2002. The lowest WAM happened in 2012 with 10.3 µg/m³. San Joaquin County observed an average PM_{2.5} concentration of 12.9 µg/m³. In 2002, San Joaquin County had a high WAM of 16.7 with a low of 10.9 µg/m³ in 2014. Stanislaus County had an average WAM 14.9 µg/m³ from 2002-2014. The highest WAM came in 2008 with a concentration of 23.2 µg/m³ while the lowest came in 2014 with 11.8 µg/m³.

Tulare County averaged a WAM of $18.0 \mu\text{g}/\text{m}^3$. The highest WAM occurred in 2002 with a concentration of $23.2 \mu\text{g}/\text{m}^3$. The lowest WAM for Tulare County occurred in 2010 with $13.6 \mu\text{g}/\text{m}^3$.

Figure 14. PM2.5 Monitor Values for Merced, San Joaquin, Stanislaus, and Tulare Counties.

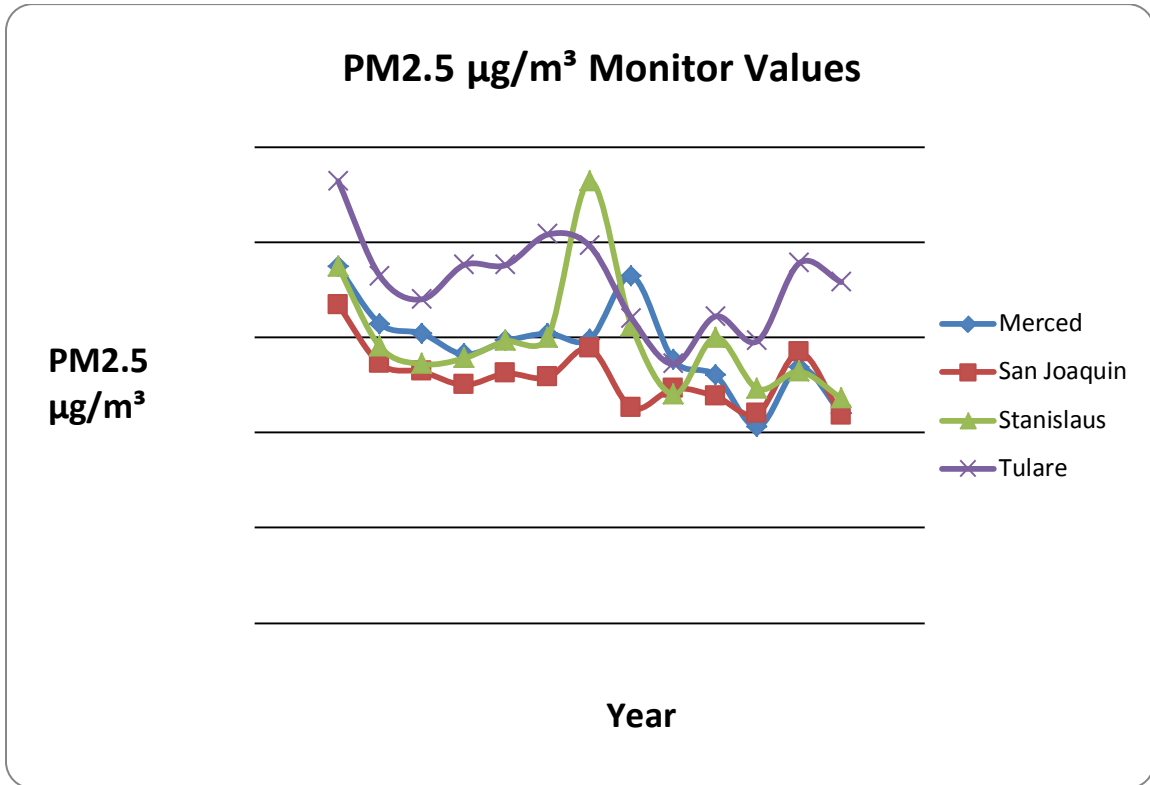


Table 9. Monitor Values Reports for PM_{2.5} Concentrations in the SJV

Monitor Values Reports 2002-2014 PM _{2.5} µg/m ³													
	Year												
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fresno	20.5	17.8	16.7	16.7	17.7	17.2	19.1	14.8	12.1	17.6	21.5	17.7	14.5
Kern	18.2	14.0	14.2	14.6	14.9	16.0	16.5	15.1	10.9	11.9	9.6	16.8	14.4
Kings	21.5	16.2	17.4	17.5	16.9	18.4	19.9	17.1	15.9	15.4	15.7	16.9	16.5
Madera	-	-	-	-	-	-	-	-	21.1	13.9	11.9	13.9	10.9
Merced	18.7	15.7	15.2	14.1	14.8	15.2	14.9	18.2	13.8	13.0	10.3	13.4	11.0
San Joaquin	16.7	13.6	13.2	12.5	13.1	12.9	14.4	11.3	12.3	11.9	11.0	14.2	10.9
Stanislaus	18.7	14.5	13.6	13.9	14.8	15.0	23.2	15.6	12.0	15.0	12.3	13.2	11.8
Tulare	23.2	18.2	17.0	18.8	18.8	20.4	19.8	16.0	13.6	16.1	14.8	18.9	17.9

Spearman’s Rank Correlation Coefficients (r) Values

Using Table X. (above), the significance of the Spearman’s Rank Correlation Coefficients (*r*) for the counties in the SJV was determined. Table X. displays the *r*-values for each county exploring the relationship between cows, dairies, and cows per dairy with PM_{2.5} days and the weighted annual mean (WAM). Each *r*-value will fall between $-1 < r < 1$, with *r*-values closer to 1 suggesting a positive, linear relationship and *r*-values closer to -1 suggesting a negative, linear relationship. An *r*-value of 0 would suggest that there is no association between the paired groups.

Table 10.1 Spearman’s Rank Correlation Coefficients (*r*) values for Fresno and Kern Counties

Spearman's Rank Correlation Coefficient (<i>r</i>) values		
Fresno County		
	PM2.5 Days	WAM
Cows	0.89	-0.35
Dairies	-0.08	-0.17
Cows/Dairy	0.51	-0.22

Spearman's Rank Correlation Coefficient (<i>r</i>) values		
Kern County		
	PM2.5 Days	WAM
Cows	0.41	-0.06
Dairies	0.13	-0.13
Cows/Dairy	0.23	-0.02

Fresno County resulted in an r -value of 0.89 when cows were tested with the number of PM_{2.5} days. With a sample size of $n=13$, an r -value of 0.89 suggests that there is a strong association between the amount of cows and number of PM_{2.5} days with 95% confidence. The number of cows per dairy and the number of PM_{2.5} days resulted in an r -value of 0.51. This value suggests that there is an association between cows per dairy and PM_{2.5} days with 90% confidence. Fresno County did not demonstrate any associations between cows and WAMs.

Kern County only showed a moderate association between cows and PM_{2.5} days with an r -value of 0.41. No other tests yielded any significant results that suggest an association between the data sets.

Table 10.2 Spearman's Rank Correlation Coefficients (r) values for Kings and Madera Counties

Spearman's Rank Correlation Coefficient (r) values		
Kings County		
	PM2.5 Days	WAM
Cows	0.77	-0.49
Dairies	-0.18	0.58
Cows/Dairy	0.52	-0.54

Spearman's Rank Correlation Coefficient (r) values		
Madera County		
	PM2.5 Days	WAM
Cows	0	-0.8
Dairies	-0.1	0.70
Cows/Dairy	0.1	-0.7

Kings County also resulted in a significant r -value of 0.77 for cows and PM_{2.5} days. An r -value of 0.77 suggests that there is a strong, positive association between the data sets with a 98% confidence. The number of cows per dairy and the number of PM_{2.5} days resulted in an r -value of 0.52. This value suggests that there is an association between cows per dairy and PM_{2.5} days with 90% confidence. Kings County also demonstrated a strong, positive association with the number of dairies and WAM with an r -value of 0.58 with 98% confidence. Kings County r -values suggest moderate,

negative associations between cows and WAM and cows per dairy and WAM with values of -0.49 and -0.54, respectively.

Madera County resulted in an *r-value* of 0.70 for the number of dairies and WAM suggesting a strong, positive association with a 95% confidence level. There was also a strong, negative relationship between the number of cows and WAM and the cows per dairy and WAM with -0.80 and -0.70, respectively. There was no significant association with PM_{2.5} days in Madera County.

Table 10.3 Spearman's Rank Correlation Coefficients (*r*) values for Merced and San Joaquin Counties

Spearman's Rank Correlation Coefficient (<i>r</i>) values			Spearman's Rank Correlation Coefficient (<i>r</i>) values		
Merced County			San Joaquin County		
	PM _{2.5} Days	WAM		PM _{2.5} Days	WAM
Cows	0.5	-0.74	Cows	-0.06	0.07
Dairies	-0.68	0.76	Dairies	-0.67	0.60
Cows/Dairy	0.67	-0.78	Cows/Dairy	0.69	-0.45

Merced County resulted in strong, positive associations between the number of dairies and WAM and the cows per dairy and PM_{2.5} days with *r-values* of 0.76 and 0.67, respectively. The confidence level for those associations was 95%. There was also a moderate, positive relationship between cows and PM_{2.5} days with an *r-value* of 0.50 and a 90% confidence. Merced County also resulted in a strong, negative association between cows and WAM, dairies and PM_{2.5} days, and cows per dairy and WAM with *r-values* of -0.74, -0.68, and -0.78, respectively. The confidence level for these values was 98%.

San Joaquin County resulted in strong, positive associations between dairies and WAM and cows/dairy and PM_{2.5} days with a 95% confidence and *r-values* of 0.60 and 0.69, respectively. San Joaquin County resulted in a strong, negative association between dairies and PM_{2.5} days with a 95% confidence and an *r-value* of -0.67. San Joaquin

County also had a moderate, negative association between cows per dairy and WAM with an *r-value* of -0.45.

Table 10.4 Spearman’s Rank Correlation Coefficients (*r*) values for Stanislaus and Tulare Counties

Spearman's Rank Correlation Coefficient (<i>r</i>) values			Spearman's Rank Correlation Coefficient (<i>r</i>) values		
Stanislaus County			Tulare County		
	PM2.5 Days	WAM		PM2.5 Days	WAM
Cows	0.57	-0.21	Cows	-0.31	-0.48
Dairies	-0.51	0.46	Dairies	0.15	0.31
Cows/Dairy	0.49	-0.51	Cows/Dairy	-0.08	-0.35

Stanislaus County resulted in a strong, positive association between cows and PM2.5 days with a 95% confidence and an *r-value* of 0.57. Stanislaus also had moderate, positive associations between dairies and WAM and cows per dairy and PM2.5 days with *r-values* of 0.46 and 0.49, respectively. Stanislaus resulted in moderate, negative associations between dairies and PM_{2.5} days and cows per dairy and WAM with *r-values* of -0.51 each.

Tulare County resulted in weak, negative associations between cows and PM_{2.5} days and cows per dairy and WAM with *r-values* of -0.31 and -0.35, respectfully. There was also a moderate, negative association between cows and WAM with an *r-value* of -0.48. Tulare County resulted in weak, positive relationship between dairies and WAM with an *r-value* of 0.31.

Discussion

The SJV has seen a significant increase of cows during the time frame of this study. All counties saw at least some increase of the number of cows from 2002-2014 and that number is expected to continue to rise (SJVAPCD, 2016). Kern County saw the largest increase in the number of cows, nearly doubling its total in the 13 years of the

study. Kern County was also the only county in the SJV that increased the number of dairies. All other counties had decreases in the number of dairies with most counties seeing reductions of 20-35%. These regional trends are consistent with the trends occurring throughout the state. From 2002-2014, California saw the number of cows increase by 7%, the number of dairies decrease by 32%, and the ratio of cows per dairy increase by 57% (CFDA, 2014). One possible explanation of this trend is that increased environmental regulations and population growth in urban areas like Riverside and San Bernardino County have created a need that the SJV has absorbed (Sneeringer & Hogle, 2008). The number of cows in Riverside County decreased by 59% from 2002-2014 while the number of cows in San Bernardino County decreased by 67% (CFDA, 2014). The number of dairies saw a similar trend with Riverside and San Bernardino Counties having decreases of 70% and 66%, respectively. Sneeringer & Hogle (2008) also point out that environmental regulations throughout the state may have influence “pollution safe havens” in the SJV. The SJV has seen a trend where more cows are present on fewer farms which decrease the options for manure application and management while increasing possible environmental impacts (Sneeringer & Hogle, 2008).

The AQI reports for the counties in the SJV generally show an improvement of air quality over the 13 years of the study. The SJV had a reduction in the number of unhealthy for sensitive groups, unhealthy, and very unhealthy days, with the exception of Kings and Madera which actually saw slight increases in those categories. The number of PM_{2.5} days for the eight counties either increased or remained steady during the study. However, it is important to remember that the number of PM_{2.5} days only references the number of days which PM_{2.5} was the most abundant pollutant that day. In most cases, the

days the $PM_{2.5}$ was not the most abundant pollutant, ozone was. It is also important to remember that ground-level ozone is another pollutant with concentration levels contributed to dairy farms.

The monitor values reports provided concentration levels of $PM_{2.5}$ that are useful in determining the success of control efforts to reach the standards set by the EPA. The previous annual standard for $PM_{2.5}$ was $15 \mu\text{g}/\text{m}^3$ and the current standard of $12 \mu\text{g}/\text{m}^3$ was set in 2012. Based on the average concentrations from monitoring sites for each county, Fresno, Kern, Kings, and Tulare Counties would not meet that $12 \mu\text{g}/\text{m}^3$ standard in 2014, while Kings and Tulare County would not meet the $15 \mu\text{g}/\text{m}^3$ standard. However, all counties have witnessed a reduction in annual concentrations from 2002-2012. For most counties, 2002 saw the highest concentrations of $PM_{2.5}$ and 2014 had the lowest. This could be a result of control efforts being successful in reducing the amount of $PM_{2.5}$ pollution throughout the SJV.

The AQI reports used by the EPA may not provide a detailed reflection of the air quality within a county. According to Bishoi, Prakash, and Jain (2009), the synergistic effects of multiple air pollutants are not considered in the reports. The reports determine the AQI by the concentration of individual pollutants but fail to express how the combination of pollutants may have an increased harmful effect on the public.

The data collected for air quality used in this study could be improved upon. This study relied on monitoring sites which were generally centrally located within a major city. There is also an issue of multiple POCs at the same site which record different concentrations for the same pollutant. In regards to this study, concentration observations from one POC could have skewed the results in one direction or other. The reports used

in this study do not accurately reflect the air quality for the entire county and may be different at localized spots. The data collected gave a general impression of the air quality in that given county.

For more accurate results, concentration levels should be observed throughout several sites in a county, and to improve upon this study, at different dairy farms. The important sites to monitor would be those that have residential areas in the proximity. Relating the pollution concentrations to the local population would allow for better understanding of the problem.

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