Understanding Trends in the New Mexico Dairy Industry, and Accounting for Direct and Indirect Water Use in Dairy Production

by

Schuyler Smith

Committee

Dr. Robert Berrens

Dr. Bruce Thomson

Dr. Jingjing Wang

A Professional Project Submitted in Partial Fulfillment of the Requirements

for the Degree of

Master of Water Resources

Water Resources Program

The University of New Mexico

Albuquerque, New Mexico

July 2015

Committee Approval

The Masters of Water Resources Professional Project Proposal of Schuyler Smith

is approved by the committee:

______________________________________ ____________________

Chair Date

______________________________________ ____________________

______________________________________ ____________________

______________________________________ ____________________

Abstract

Water planning is important in all places, and particularly so in an arid state like New Mexico. How the water is used, and how much is thereby important. Often water use by the agricultural sector, is considered as an aggregated whole such as New Mexico First (2014). The objective of this research was to conduct an analysis of the growth and change of the New Mexico dairy industry, and water use to support this industry, that might better inform the future structure of state and regional water planning in New Mexico. The dairy industry has been a high growth industry in New Mexico since the 1990's (and then has leveled off more recently). The extent to which the New Mexico dairy industry exhibits a dual structure, an uneven distribution of farm sizes, with medium sized farms being less frequent, was examined. Recent changes to the national Farm Bill are also likely to impact the dairy sector. This industry has had concentration in the eastern part of New Mexico, and increasingly concentrated in terms of sales. The importance of dairy production in explaining the spatial variation in NM farm income was examined and demonstrated econometrically. A broad estimation of water use in the dairy production industry, including both direct use by dairies (32,361 acre-ft) and indirect use associated with production of animal feed (1,317,640 acre-ft), were developed following the approach of Guerrero et al (2012) in calculated based on dairy cow consumption.

Table of Contents

List of Tables

List of Figures

1. Introduction

Water plays an important role in the livelihoods of the people who live in arid environments. New Mexico is not an exception to this idea; the state has taken steps to address its water demand, relative to available water supply. However, the narrative of water use related to agriculture and in particular the dairy industry is an area that would benefit from greater depth of detail and analysis within water planning. Hydrological measures are such as precipitation and stream gage information are often included in New Mexico planning considerations, but economic and social measures are less frequently included. The construct of virtual water, or water as an embedded resource, can offer a different angle on the narrative of water planning. Virtual water was originally developed to describe the “water needed to produce agricultural commodities” (Allan, 2003, p. 5). The water that is embedded in agricultural goods moves from one area of New Mexico to another, from other states into New Mexico, as well as from New Mexico out into the larger US and international economy. The dairy industry is one area where the use of virtual water could be used, and is further illuminative in that the sudden growth of the industry has occurred since formal regional water planning began. There is a gap then between detailed acknowledgement in the planning process, and changes in and current characteristics of the dairy production industry. Including how those changes might relate or impact water use.

The objective of this research is to conduct an analysis of the growth and change of the New Mexico dairy industry, and estimate its embedded (both direct and indirect) water use for the full dairy herd including both the milk cows and the replacement herd in New Mexico. A large percentage of water diversions, both surface and groundwater, are used by the broad sector of agriculture in New Mexico. Within that broad sector, there is evidence of dynamic change, and what some sources have labeled a “dual structure.” Dual structure is where agriculture has a large numbers of small farms, a smaller and decreasing numbers of medium sized farms, and a large and increasing number of large farms. (Wolf & Sumner, 2001). Against that backdrop, there is the high-growth dairy production, processing and export industry. However, the primary focus will here will be on the dairy production industry.

After a detailed background discussion, the research approach has five primary tasks: (i) review trends in aggregate water diversions in NM and establish importance of understanding agriculture for understanding water use (ii) review trends and structure of the NM dairy industry, and show its spatial distribution and concentration of the industry (iii) explore variation in farm income by counties, and then test the hypothesis that dairy industry (with its known concentration and spatial distribution) is critical to understanding economic welfare of farms in NM using ordinary least squares regression approach (iv) calculate the total virtual water use, accounting for both direct and indirect water use, broadly needed to support the dairy industry in NM (v) conduct textual analysis of current state and selected regional water plans to examine current status of disaggregated planning for the dynamic dairy industry. Assuming a particular feed crop diet mix for an average high production dairy cow, necessary irrigated acreage requirements will be used to quantify the indirect water use via feed consumption in the dairy industry. Guerrero et al.'s (2012) method based on average feed consumption for the Southern Ogallala region's dairy herd (composed of 453,200 dairy cows including 127,200 which reside in eastern NM) will be applied to the whole of the New Mexico dairy herd utilizing data from the 2012 Census of Agriculture the United States Department of Agriculture (2014). The concentration of the dairy industry will be considered as part of the larger concept of the dual structure of agriculture. Information on the concentration of the dairy industry will come out of several Census of Agriculture reports. A selection of New Mexico regional water plans' economic sections were examined for references to planned and actual changes of the dairy industry within these water planning districts' boundaries.

There are a number of key results. One expected finding is that, despite some change across categories over the last several decades, agriculture remains by far the largest water diversion in New Mexico at 78.6 percent. In addition, the New Mexico dairy industry grew by 189 percent from 1992 to 2002 (United States Department of Agriculture, 1999, p. 31; United States Department of Agriculture, 2004, p. 20), and has since has somewhat leveled off with 318,878 dairy cows (United States Department of Agriculture, 2014, p. 21) and 8,149,000,000 lb of milk production in 2012 (United States Department of Agriculture – Economic Research Service, 2014). Ordinary least squares regression results at the county level support the hypothesis that dairy is a significant positive determinant of net cash farm income in NM (which is itself highly variable across counties. The New Mexico dairy production industry, with a food requirement of 776,618 total irrigated acres consumes roughly the more than the total irrigated acres for New Mexico in 2012. This current requirement of 776,618 irrigated acres (assuming a diet of 1.77 tons of alfalfa, 3.44 tons of corn grain, 16.79 tons of corn silage, and 0.84 tons of soybean for milk cows (Guerrero et al., 2012, p. 6)); calves for 0.78 tons of corn grain and 2.17 tons of hay assumed to be alfalfa, and heifers 0.15 tons of corn grain and

3.1 tons of hay assumed to be alfalfa from (Heinrichs and Swartz, n.d., p. 30)) would equate to 1,316,640 acre-feet of water annually given the irrigation requirements in Guerrero et al. (2012). Water planning at the state level does not include discussion or investigation of the dairy production industry. Water planning at the regional level may include or briefly discuss dairy, but not in any detailed way, with no detailed economic analysis of the industry, or even broad estimates of its water use, or import or export details.

2. Background

2.1. Water Planning in New Mexico: History and Litigation

Water has long been a contentious issue in New Mexico, with records of irrigation disputes dating to before 1851 (Rivera, 1998, p. 34). Given how important and scarce water is in a desert state, this is not surprising. One inter-state conflict over water that continues to impact water supply and use in New Mexico is the case of the City of El Paso vs S. E. Reynolds. In year, the City of El Paso sued New Mexico over policies preventing the export of groundwater to Texas (*City of El Paso v S, E. Reynolds*, 1983, p. 4). As the judge in this case found “the availability of water ... is crucial to the economic development of both the municipal and agricultural communities in southern New Mexico and El Paso” (*City of El Paso v S, E. Reynolds*, 1983, p. 4). One of the practices that came out of this case is increased water planning at the state level. This was encouraged by the ruling 1983, as the judge stated in the decision that “the state can and should carry on its policy of furthering the maximum beneficial use of the water supply” (*City of El Paso v S, E. Reynolds*, 1983, p. 12). In order to carry on its policy, which would mean the state had a history of water planning prior to this lawsuit if it is carrying on its policy; however, it formalized the idea of water planning in New Mexico. In the years since this ruling, this case has been cited as the impetus for water planning in New Mexico (Verhines, 2013); the prior history having been forgotten or disregarded. This is seen even in official state of New Mexico documents including those produced by the Office of the State Engineer. “The original impetus for regional water planning came in 1983, a federal court ruled that New Mexico's prohibition against out-of-state transfers of New Mexico's groundwater was unconstitutional” (Verhines, 2013, p. ii).

Water issues remain in New Mexico. Given that “even during periods of average water supply, demand in many parts of the State would exceed supply if all water rights and permits were fully exercised” (Office of the State Engineer & Interstate Stream Commission, 2003, p. 8), water remains important. Who and what uses the water in New Mexico is also important as agriculture, livestock, power, and industry accounted for 81.53% of the total water use for withdrawls (78.62%, 1.05%, 1.53%, and 0.33% respectively) in 2010 in New Mexico (Longworth et al., 2013, p. i-ii). Public water supply and self-supplied domestic water use accounted for only 9.08% of water withdrawls in New Mexico in 2010 (Longworth, Valdez, Magnuson, & Richard, 2013, p. i). Municipal water conservation has been an important concern as “many communities are changing their rate structures to tiered or block rates … in order to encourage water conservation” (Fort, 2013, p. 8-5). Given the scarcity of water in New Mexico and the percent of water used by the different economic sectors; the water use of the agriculture sector is important to economic planning for the state of New Mexico.

According to the New Mexico Office of the State Engineer, regional water planning was mandated by law in 1987 (Office of the State Engineer & Interstate Stream

Commission, n.d.-a). A water planning handbook and acceptance criteria for regional water plans were established in 1994 and 1999 respectively (Office of the State Engineer & Interstate Stream Commission, n.d.-a). The water planning handbook sets out information that must be included under legislative requirements. However, in the water demand section of the water planning handbook there is an sub-section on “economic growth and jobs” (Office of the State Engineer and Interstate Stream Commission, 1994) that can be included in the regional water plans, but it is not listed in the legislative requirements (Office of the State Engineer and Interstate Stream Commission, 1994). In 2003, the State Water plan was released (Office of the State Engineer & Interstate Stream Commission, 2003). In 2008, a review and proposed update of the State Water plan was conducted (Office of the State Engineer & Interstate Stream Commission, 2008). By the time the State Water plan update was published in 2008“regional water plans were accepted by the Interstate Stream Commission for 15 of 16 regions” (Office of the State Engineer & Interstate Stream Commission, 2008, p. 3). As of 2008, with the acceptance of the Taos Region plan (Office of the State Engineer & Interstate Stream Commission, n.d.-b) all 16 Regional Water plans had been completed and accepted by the Interstate Stream Commission.

In April of 2014, the New Mexico Interstate Stream Commission announced a “two-year regional and state water update process” (New Mexico Interstate Stream Commission & New Mexico Office of the State Engineer, 2014, p. 1). The New Mexico Interstate Stream Commission has laid out a schedule of public meetings for 2014-2015 across the state as part of the process (New Mexico Interstate Stream Commission, 2014, p. 1). The State Water Plan is anticipated to be updated by December 2015 (New Mexico

Interstate Stream Commission & New Mexico Office of the State Engineer, 2013, p. I).

Given the environmental and political realities in New Mexico water planning is very important to the state as first formally established in the ruling for the case of *City of El Paso v S, E. Reynolds* 1983. The mandate from *City of El Paso v S, E. Reynolds*, 1983 reflects the importance of planning, and the necessity of having plans in order to protect the state's water.

2.2. Economics Background and the Dual Structure of Agriculture

As a starting reference point, it is important to have some sense of the size of the NM economy. One of the measures of an economy is Gross Domestic Product, which is "the market value of final goods and services newly produced within a nation's borders during a fixed period of time" (Abel & Bernanke, 2001, p. 612). In 2010, the GDP of New Mexico was $83,798,000,000 in 2010 dollars (Bureau of Economic Analysis, 2014).

Agriculture in a desert state requires additional water from ground or surface water draws. According to the Office of the State Engineer in 1995, agriculture in New Mexico accounted for 75.38% of water withdrawals (Wilson & Lucero, 1997, p. 3). In 2000, agriculture accounted for 76.15% of water withdrawals (Wilson, Lucero, Romero, & Romero, 2003, p. 3). In 2010, agriculture had increased as a percentage of the total to 78.62% of water withdrawals (Longworth, Valdez, Magnuson, & Richard, 2013, p. i). According to the World Water Assessment Programme, "agriculture accounts for 70% of all water withdrawn by the agricultural, municipal and industrial … sectors" (World Water Assessment Programme, 2012, p. 46). New Mexico is therefore using a higher percentage of its water on agriculture then the world average.

In 1995, "agriculture (farms)" or IndCode 4, represented 1.31% of the New

Mexico GDP (Bureau of Economic Analysis, 2010). In 2010, "agriculture (crop and animal production)" or IndCode 4, was 1.63% of New Mexico GDP (Bureau of Economic Analysis, 2014). In 2012, New Mexico GDP was $89,188,000,000 in 2012 dollars (Bureau of Economic Analysis, 2014) while "the total value of the agricultural sector's production … $4.26 billion in 2012" (Diemer, Crawford, & Patrick, 2014, p. 1). Hurd and Coonrod "direct agricultural sector benefits … amounts to less than 0.8% of New Mexico's GDP, a slim slice of the economy that uses more than 80% of the water (Hurd & Coonrod, 2007, p. 80). New Mexico is using lots of water on agriculture for a relatively small economic return. Dairy is a significant slice of agricultural production in New Mexico.

Dual structure or bimodality in agriculture is an uneven distribution of farm sizes, with medium sized farms being less frequent. Wolf and Sumner (2001) describe bimodality in agriculture as a large numbers of small farms, a smaller and decreasing numbers of medium sized farms, and a large and increasing number of large farms. Lerman & Cimpoies (2006) described a small number of large farms, almost no medium sized farms, and a large number of small farms. For example, "in some commodity industries … farms have consolidated enough that most national production derives from fewer than 100 major producers" (Sumner, 2014, p. 163). In 2012 in New Mexico, 315 of the 24,271 operations are in the category of Operations with sales of $1,000,000 or more (United States Department of Agriculture, 2014, p 9).

Sumner (2014) is an article that summarizes "the economics of commercial agriculture in the United States, focusing on how growth in farm size and other changes in size distribution" (Sumner, 2014, p. 148). Sumner is not however consider all farms, as the article concentrated “on commercial farms—those that typically provide some positive net income and might engage in an operator on a full time basis” (Sumner, 2014, p. 148). One of the issues raised by Sumner (2014) is that different agricultural areas are measured in different ways, sales, acreage, and livestock numbers are all considered for certain agricultural products. There are results for each of those different measures. For sales, one key is the increase in farms with sales of $1 million (Sumner, 2014, p. 150), and that there is a shift in concentration away from small farms (Sumner, 2014, p. 150). The measure of concentration as a measure of grape acreage is highly concentrated (Sumner, 2014, p. 151). The number of livestock as a measure of concentration shows concentration for dairy farms and egg farms (Sumner, 2014, p. 151). Sumner (2014) also considers farm ownership, finding that “corporations produce about half of the value of crop output” (Sumner, 2014, p 152).

Another key point of Sumner (2014) is that “commercial farms have increase in size by every measure, both for US farming as a whole and across the full range of commodities” (Sumner, 2014, p. 153). Sumner (2014) then proceeds to give background information on the literature of farm and firm size which leads into his nine points about “how human capital and managerial capabilities affect the economics behind … farm size and growth” (Sumner, 2014, p. 155). These can be summarized as cost, technology, diversification, renting land, managerial capability, effect of nonfarm income, high level of managerial competence, and the government (Sumner, 2014, p 155, 156, 157). In addition, farms are utilizing technology for higher productivity (Sumner, 2014, p. 164); as well as, “subsidy programs seem to be relatively unimportant in the evolution of farming in the United States” (Sumner, 2014, p. 164).

Not only are the large farms more efficient, but they are more productive. Farms with a quarter million dollars in sales “made up only 12 percent of U.S. farms in 2007 but accounted for 84 percent of the value of U.S. production (Hoppe & Banker, 2010, p. iv). Broadly, within the agricultural sector in the US “production is shifting towards larger farms” (MacDonald et al. 2007, p. 1). This has clearly been the case for dairy production in the US. The number of larger dairy farms in the US are increasing, and the size of large dairy farms is also increasing. McDonald found that “during the 1990s, farms with 1,000-3,000 head were adding the most capacity, but capacity additions have since shifted to even larger farms, with 3,000-10,000 head” (MacDonald et al., 2007, p. iii). Within the dairy industry, economies of scale are a part of that shift as the “cost per hunderedweight of milk produced fall by nearly half as herd size increases from fewer than 50 head to 500 head” (MacDonald et al, 2007, p. iii). The question is whether this dual structure applies to New Mexico agriculture, and dairy production as a particular important part of that sector.

2.3. Virtual Water

The amount of water used in the production of any good is greater than just what water is directly consumed. Water is used in many ways that are transparent to the consumer or end user of a product; therefore, virtual water becomes a useful concept for water planning. This concept was originally developed to describe the “water needed to produce agricultural commodities” (Allan, 2003, p. 5), which is consistent with the basic objectives of this analysis. However, even early on it was recognized that “the concept could be expanded to include the water needed to produce non-agricultural commodities” (Allan, 2003, p. 5). "More recently, this concept has been applied to both agricultural water use and non-agricultural water use. 'Virtual water' has also been called 'embedded water' and is a similar concept as 'embedded energy'" (Chapagain, Hoekstra, Savenije, & Gautam, 2006, p. 188).

The concept of virtual water is over two decades old. Allen states that “the term 'virtual water' was coined at a seminar at SOAS in about 1993” (Allan, 2003, p 4). Allan offers some insight into why virtual water is currently the term of choice. “The term 'embedded water' was under-whelming in its impact. Virtual water, by contrast, had an immediate impact” (Allan, 2003, p. 4). Additionally, this concept can be used in a more aggregate sense, rather than as applied to one specific product. "Virtual water trade between nations and even continents could thus be used as an instrument to improve global water use efficiency and to achieve water security in water-poor regions of the world" (Hoekstra & Hung 2002, p. 10). Virtual water also allows for an understanding of how water is traded between countries in the form of both manufactured and agricultural products.

Some economic models consider the value of embodied water in cross state or even cross national transactions. Bouwmeester and Oosterhaven use an extended international input-output table (Bouwmeester & Oosterhaven, 2013, p. 308) to “develop a methodology that presents additive decomposition of the error resulting from the DTA [domestic technology assumption] assumption into its constituent elements” (Bouwmeester & Oosterhaven, 2013, p. 308). Bouwmeester and Oosterhaven “apply the methodology to embodied CO2 emissions and embodied water use” (Bouwmeester & Oosterhaven, 2013, p. 308). Wang, Huang, Yang and Yu describe state that their IO model “clearly quantifies intersectoral virtual water flows, representing both direct and indirect water inputs during production processes” (Wang, Huang, Yang, & Yu, 2013, p. 173). Aviso et al used the construct of water footprint in their economic model which they describe as “a multi-regional fuzzy input-output model … to optimize production and trade under consumption- or production-based water footprint constraints” (Aviso, Tan, Culaba, & Cruz Jr, 2011, p. 195).

As one recent NM example, according to Martin and Ruddell (2012, p. 1), using a embedded resource accounting framework, New Mexico is a net exporter of energy. Being an energy exporter is important for water planning as “electrical energy production accounts for the largest percentage of gross water withdrawals in the U.S.” (Martin & Ruddell, 2012, p. 1). “As population and industry continue to grow, resource demands increase and become more spatially concentrated around urban areas. This is particularly true of demands for electrical energy” (Martin & Ruddell, 2012, p. 1). Thus, while the rural areas have great need of water for agriculture; energy production has great need for (embedded) water for energy. Virtual water can be used in relation to energy as “embedded (or 'virtual') water accounting provides a method for the evaluation of proposed electrical energy production adaptations to water limitations” (Martin & Ruddell, 2012, p. 1). New Mexico is thereby also exporting water in the forms of energy to other regions.

Mubako (2011) creates both a water footprint, and an input output model of the virtual water in the United States for crop and livestock production. As part of his model, due to variability across the United States, Mubako “used at least one climatic station per state” (Mubako, 2011, p. 78) in estimating virtual water. Then, Mubako (2011) computes the import and export of virtual water for primary crops. New Mexico imports 1,212

Mm^3/yr (Mubako, 2011, p. 91), which is 982,584 acre-ft. However, for animal production New Mexico exports 3,020 Mm^3/yr (Mubako, 2011, p. 96), which is 2,448,353 acre-ft. The combination of imported and exported virtual water, is 1,809 Mm3/yr (Mubako, 2011, p. 101) or 1,466,580 acre-ft of exported virtual water from New Mexico to the rest of the United States. After calculating import and export of water for the lower 48 states, then Mubako (2011) focuses on an analysis of California and Illinois (Mubako, 2011, p. 120).

2.4. Water Footprints

Water footprints (WF) are an idea coming out of both the idea of an ecological footprint and virtual water. Hoekstra provides some thought into how he came up with the term. “Although the term 'water footprint' has obviously been chosen … in analogy to the ecological footprint and although the potential to bring the two concepts together in one analytical framework has been recognised [sic] from the beginning, the WF concept has other roots than the EF concept” (Hoekstra, 2009, p. 1964). However, Chapagain and Orr see ecological footprints as inadequate on their own “from a freshwater perspective, current EF models do not adequately capture freshwater use. An EF shows the area needed to sustain people's living; the WF indicates the annual water volume required to sustain a population” (Chapagain and Orr, 2009, p. 1221).

In addition to the ecological footprint research, the WF literature also drew its underpinnings from the idea of virtual water. Hoekstra and Hung specify that “the sum of domestic water use and net virtual water import can be seen as a kind of 'water footprint' of a country, on the analogy of the 'ecological footprint' of a nation” (Hoekstra and Hung, 2002, p. 7). The water footprint is an aggregation of many types of virtual water.

Additionally, one should consider both the domestic and total water footprints for a nation or region. Together these two water footprints can be used to create a measure of the country's control over its water sustainability. It is possible to compute this degree of control where "the water self-sufficiency – defined as the ratio of the internal to the total water footprint" (Hoekstra & Chapagain, 2007, p. 147). For example, this measure shows that the Netherlands is less dependent on foreign water for its agricultural products than Morocco is (Hoekstra & Chapagain, 2007, p. 147).

A water footprint for milk has been calculated in at least one place. A 200 ml glass of milk requires 100 liters of water (Hoekstra & Chapagain, 2011, "Water Use for Crop and Livestock Products," Table 2.2). In 2012, New Mexico produced 8,149,000,000 lb of milk (United States Department of Agriculture - Economic Research Service, 2014). According to the USDA, a gallon of milk is 8.6 lb (United States Department of Agriculture – Economic Research Service, 2015, "How ERS Calculates Farm Share for Individual Foods" paragraph 14). New Mexico thereby produced 947,558,138.5 gallons of milk, which converts to 3,586,897,743,503 ml. Thus, following the calculations of Hoekstra and Chapagain (2011), the total water footprint of the New Mexico milk production is 1,793,448,871,751.5 liters, which is 1,793,448,871.8 kiloliters, which is 1,453,972.7 acre-ft. Based on the methodology presented on the calculations in Hoekstra and Chapagain (2011) this is consumption. There is no mention of the grey water footprint being included in the calculations, where the "grey water footprint is the volume of polluted water that associates with the production of all goods" (Van Oel et al.,2009, p. 82). If consumption is estimated at 2.1 acre-ft per 3 acre-ft (Pease, 2008, p. 185), then for 2010 3,815,945 acre-ft is 2,671,161 acre-ft. The water footprint for milk in New Mexico is 54 percent of the estimated consumptive use for New Mexico.

2.5. Criticisms of Footprint Measures

Fiala's criticisms of the ecological footprint have some relevance both to water footprints and virtual water: "In the calculation of an ecological footprint, the technology level that is assumed for producing a given product is either a world average of technologies, called the global hectare, or more recently though the input/output literature, a calculated mixture based on trade data of imported and local technologies" (Fiala, 2008, p. 521). Virtual water calculations need to be aware of what technology and methods are being used in a particular region. In addition, "cross-country comparisons of the ecological footprint then rely on boundaries that are arbitrary, and thus potentially meaningless" (Fiala, 2008, p. 520). For smaller areas the boundaries can be equally arbitrary. In New Mexico, counties are not divided along watershed lines, meaning that examining at the county level would add a certain amount of arbitrariness to the results. In addition for dairy production, an issue would be the amount of water imported into the state in form of feedstuffs. Rather than try and rely on the water footprint measure, this research will examine New Mexico dairy production trends in more detail, and then try to calculate both direct and indirect water use associated with dairy production.

3. Research Methods

Given the background context in New Mexico, and the stated research objective, the research approach will include five primary research tasks, which will be conducted in the following logical sequence:

(i) review trends in aggregate water diversions in NM and establish importance of understanding agriculture for understanding water use

(ii) review trends and structure of the NM dairy industry, and show its spatial distribution and concentration of the industry

(iii) explore variation in farm income by counties, and then test hypothesis that dairy industry (with its known concentration and spatial distribution) is critical to understanding economic welfare of farms in NM using ordinary least squares regression approach

(iv) calculate the total virtual water use, accounting for both direct and indirect water use, broadly needed to support the dairy industry in NM

(v) conduct textual analysis of current state and selected regional water plans to examine current status of disaggregated planning for the dynamic dairy industry

Below, each of these primary tasks (i) – (v) is briefly reviewed in terms of both the methods and primary data sources that will be used.

3.1. Review Trends in Water Diversions in NM

In order to understand, current and historical water, the water use information from the New Mexico Office of the State Engineer's Water Use by Categories reports has been compiled. The Water Use by Category reports have been completed every five years. For this study, data from the years 1985 in B. Wilson (1986), 1990 in B.C. Wilson (1992), 1995 in B.C. Wilson & Lucero (1997), 2000 in B.C. Wilson, Lucero, Romero, & Romero (2003), 2005 in Longworth, Valdez, Magnuson, Albury, & Keller (2008) and 2010 in Longworth, Valdez, Magnuson, & Richard (2013) have been used. As some categories change over the different reports, categories were consolidated between years if necessary to maintain comparable data. Categories used include Public Water Supply & Self-Supplied Domestic; Irrigated Agriculture (surface water); Irrigated Agriculture (groundwater); Mining and Power (surface water); Mining and Power (ground water); Livestock, Commercial, and Industrial; and Evaporation from reservoirs with storage capacity greater than five thousand acre feet. These data were compiled into a spreadsheet.

3.2. Review Trends and Structure of the NM Dairy Industry

Information on the trends and structure of the New Mexico Dairy Industry was gathered from a variety of different sources. Data was taken from the USDA-NASS (2014) for long term historical information on milk cows in New Mexico. MacDonald et al (2007), and Hoppe & Banker (20120), Fort & Edwards (2009), and Guerrero et al. (2012), Cabrera et al. (2008) for information about changes to agriculture and dairy. Data from on employment trends in the dairy industry was taken from the U.S. Census Bureau (2013). Cheese Price supports information was from the United States Department of Agriculture (2010). Farm Bill was taken from information from Dillivan (2014), Newton & Kuethe (2014), and the *Agricultural Act of 2014*. Current economic conditions and the trend of the price of milk was taken from United States Department of Agriculture – Economic Research Service (n.d.) and the United States Department of Agriculture – National Agricultural Statistics Service (n.d.-j).

3.3. Explore Variation in Farm Income by Counties

The average net farm income of the different counties in New Mexico is highly variable. Given that the dairy industry is concentrated in a few areas of the state of New Mexico, and the idea of the dual structure of agriculture, it is possible that the concentration of the dairy industry may help to explain the variation in average net farm income.

In order to explain that dairy industry impact on average net farm income, an ordinary least squares (OLS) regression equations will be used, separately for 2007 and 2012. Other measures of agriculture production (average acres of pecans, average number of sheep, average number of other than dairy cattle, and average number of acres of wheat) were included as explanatory variables in some or all of these regression equations. Observations were included for all 33 New Mexico counties based on the data from the 2007 and 2012 Census of Agriculture in United States Department of Agriculture – National Agricultural Statistics Service (n.d.-g) United States Department of Agriculture – National Agricultural Statistics Service (n.d.-f), United States Department of Agriculture – National Agricultural Statistics Service (n.d.-a), United States Department of Agriculture – National Agricultural Statistics Service (n.d.-b) and United States Department of Agriculture – National Agricultural Statistics Service (n.d.-d). Values on the Census of Agriculture reports that were below the reporting threshold (values of 'D') were entered as zero.

3.4. Calculate the Total Virtual Water Use

The concept of embedded (virtual) water will be applied to the dairy industry in New Mexico. Direct water use was calculated using the 55 gpcpd from Guerrero et al. (2012), and the 65 and 100 gpcpd given in Longworth et al. (2013) where the conversion rate of gallons to acre-ft in Gleick (2006) was used. The amount of virtual water the dairy industry uses in terms of irrigated acres was calculated using the method described in Guerrero et al. (2012). In this method based on a diet of alfalfa, corn grain, corn silage, and soybeans, the dietary requirements for dairy cows in the Southern Ogallala region and yields for the Southern Ogallala region were used to create a total feed requirement. The amount of acreage required divided by the number of dairy cows in the Southern Ogallala region yields a requirement per dairy cow per crop. This number is then applied to the number of dairy cows in New Mexico. For the replacement herd, the number of calves and heifers were found by solving backwards for the cull rate using the equation in Goodling (2012) assuming that the New Mexico dairy herd is static and there are no imports or exports of calves and heifers. The feed requirements for calves and heifers were calculated using Heinrichs & Swartz (n.d.) assuming the grain is corn grain, and the hay provided is alfalfa. Calf starter was not included in the total as it was neither grain nor hay. The yield rates in Guerrero et al. (2012) were then applied to get the irrigated acres required for the replacement herd. In addition, Guerrero et al. (2012) was used to calculate the amount of virtual water of the milk and replacement herds. Guerrero et al. (2012) provides the consumptive irrigation requirements for the crops used, and these numbers were converted to acre-ft and applied to the number of irrigated acres required for the dairy herd and the replacement herd to get the indirect water use. The virtual water used was compared to the historical water use from the New Mexico Water use by Categories reports and the 2012 Census of Agriculture (United States Department of Agriculture, 2014).

3.5. Textual Analysis of Current State and Selected Regional Water Plans

Data used for document analysis were the state level planning documents the State Water Plan in Office of the State Engineer & Interstate Stream Commission (2003), State Water Plan Review and Update in the Office of the State Engineer & Interstate

Stream Commission (2008), the Working Towards Solutions in the New Mexico Interstate Stream Commission & New Mexico Office of the State Engineer (2013), and New Mexico First town hall in New Mexico First (2014). Regional water plans for inclusion in this research were determined based on the number of dairy cows in the region from 1997 through 2012 using the United States Department of Agriculture – National Statistics Service (n.d.-a). These water planning regions were: Lea County (Boivin, Mary EL, Peery, & Buller, 1999), Lower Pecos Valley (Pecos Valley Water Users Organization, 2001), Lower Rio Grande (Terracon et al., 2003), and the Northeast (Daniel B Stevens and Associates, Inc, 2007).

The selected water plans were examined for inclusion of economic or social factors in regards to the dairy industry. The regional water plans selected were the ones with the largest dairy cow populations in the state of New Mexico. These are the Lea County, Lower Pecos Valley, Lower Rio Grande, and the Northeast regional water plans. In particular, the plans were examined to see if any indication that they anticipated the growth that has happened with the dairy industry or have attempted to limit the dairy industry's growth.

4. Analysis & Results

Consistent with the approach outlined in the Methods section, the analysis and results will proceed logically through the five major Research Tasks set out there. The section begins with.

4.1. Trends in Aggregate Water Diversions in New Mexico

The information from Water Use by Categories reports has been complied into

Table 1. The compilation shows so the change in water withdrawls over time in New Mexico, and provides background information to put the calculations of virtual water into perspective. Table 1 shows water use by category for 1985 through 2010 (in increments of five years). This table shows an overall decline of water use in New Mexico from 4,158,600 acre-ft in 1985 to 3,815,945 in 2010. This represents a reduction of 8.24 percent. Public Water Supply & Self-Supplied Domestic is the water use category that had the largest increase (by acre-ft). It increased by 22.13 percent from 1985 to 2010. Livestock, Commercial, and Industrial had the largest increase by percent, with an increase of 64.59 percent from 65,200 acre-ft to 107,313 acre-ft. Given the population increase over these years, increases in these categories is not surprising. The category of Irrigated Agriculture with Surface Water is down by 11.61 percent from 1,848,500 acre-ft to 1,633,940 acre-ft, but Irrigated Agriculture with Ground Water is up by 4.02 percent over this time period from 1,313,400 acre-ft to 1,366,215 acre-ft. Both Surface and Ground water use for Mining and Power are down (by 13.94 percent and 53.55 percent respectively). Water loss due to evaporation from reservoirs is down by 38.08 percent from 423,500 acre-ft to 262,216 acre-ft. Clearly Agriculture is the still the largest share of water use in 2010 at 78.6 percent of withdrawls, and understanding how it is being used is crucial to water planning.

4.2. Trends and Structure of the NM Dairy Industry

4.2.1. Growth of the Dairy Industry in New Mexico

The location of the dairy industry is changing in the United States of America, “The location of milk production is shifting toward Western States such as California, Idaho, and New Mexico” (MacDonald et al, 2007, p. 1) Within that context, “large-scale family farms (annual sales of $250,000 or more), plus nonfamily farms, made up only12 percent of U.S. farms in 2007, but accounted for 84 percent of the value of U.S. production." (Hoppe & Banker, 2010, p. iv). Additionally, "during the 1990s, farms with 1,000-3,000 head were adding the most capacity, but capacity additions have since shifted to even larger farms, with 3,000-10,000 head" (MacDonald et al., 2007, p. iii).

In addition, some areas of the United States are actively recruiting dairy. For example, "states like Nebraska, Kansas, and Iowa are pitching themselves as a dairy heaven" (Gerlock, 2014, paragraph 1). Dairy recruiters are not new to 2014, in 2012 "representatives from Colorado, Idaho, Iowa, Kansas, New Mexico … have been filling gatherings such as the World Ag Expo in Tulare to encourage California dairy farmers to move to their respective states" (Angel, 2012, paragraph 2).

The NASS Survey data displayed in Figure 2 shows that the amount of dairy inventory in New Mexico has increased since water planning started in the 1980's. Specifically, there were 63,000 dairy cows in 1989, but 218,000 in 1999 a percentage change of 246 percent. In the 2000's, the numbers have moved around without a clear trend. Figure 1 shows that the number of milk cows in the 1970's represents a relative low between a modest high of 83,000 milk cows in WWII-era 1944 and 340,000 in 2006.

Clearly the dairy industry in New Mexico has relatively recently experienced a period of incredible growth. According to Fort, "the late 1990s were a period of rapid growth for New Mexico's dairy industry" (Fort & Edwards, 2009, p. 1). Much of the growth in the dairy industry in New Mexico occurred in the eastern counties. The eastern edge of New Mexico is in the Southern Ogallala Region, and from there generalizations can be made to the rest of New Mexico. In the Southern Ogallala Region, "cattle feedlots first appeared in the 1960s and grew steadily until inventories stabilized over the last decade" (Guerrero et al., 2012, p. 2). Using the historical survey information on milk cows, the number of milk cows went from 30,000 in 1974 to 340,000 in 2006 (USDA-NASS, 2014), which is a 1,033 percentage change.

4.2.2. Spatial Distribution of Dairy Production in NM by County

Figure 4 shows the dairy operations are concentrated in the eastern side of the state, primarily Chaves and Curry Counties. According to Figure 5, these two counties had the highest number of milk cows in New Mexico. In addition, four of the five counties in Figure 5 are in the eastern part of New Mexico. Table 7 has the distribution of dairy cows in New Mexico by county. The table has some figures that were obfuscated by the USDA. Table 7 shows that the mid level dairy counties are Eddy, Socorro, and Valencia Counties. Some dairy is located in the Middle Rio Grande, and some in the Lower Rio Grande, but most is in the Eastern part of the state with small amounts elsewhere. The counties of Curry, Lea, Socorro, and Valencia have all had an increase in the number of dairy cows for the period 1997 to 2012.

4.2.3. Importance of Dairy Production and Processing to the NM State Economy

Dairy has been important in New Mexico for some time. "In 2001, dairy farming became the most important agricultural industry in the state when it began generating more cash receipts than any other agricultural activity" (Cabrera et al., 2008, p. 2144).). In 2012, Crop sales in New Mexico were $616,938,000 and Livestock, poultry, and their products sales were $1,933,209,000 (United States Department of Agriculture, 2014, p. 7). Dairy sales are not available in 2012, however, milk sales are: $1,221,111,000 (United States Department of Agriculture, 2014, p. 21). Total taxable gross receipts

$50,407,300,096 (New Mexico Finance Authority, 2013), which would put milk sales at 2.4 percent of the total taxable gross receipts.

4.2.4. Dairy Employment Trends in NM

Since, 1997 dairy employment has been on the rise in New Mexico. On a local scale, dairies provide employment to their local areas as “a typical 3,000 head dairy requires 30 to 37 employees” (Guerrero et al., 2012, p 1). Figure 8 shows the estimated dairy industry employment numbers for New Mexico. The employment was estimated by calculating one half of the quarterly average stable employment of the 0112 NAICS Subsector (Animal Production) (U.S. Census Bureau, 2013). The estimated dairy employment went from 1,485 in 1997 to 2,392 in 2012 (U.S. Census Bureau, 2013), which is a percentage change of 61 percent. Dairy uses the equivalent of about 80% of the water in New Mexico; however, at the same time it is providing only 2,392 total jobs in New Mexico (U.S. Census Bureau, 2013). In 2012, the employment in New Mexico was 859,965 (Bureau of Business and Economic Research, 2015). Therefore, although the dairy industry is using 80% of the water, and providing 0.2 percent of the jobs in New Mexico.

4.2.5. Trends in Common Feed Production in NM and Region

The quantity of hay and haylage grown in New Mexico has been variable as is shown in Table 4. Certain counties within the state have shown an increase in the amount grown, but other areas of the state have shown a decrease. For instance, Valencia County went from 33,587 tons of hay and haylage in 2002 to 79,027 tons in 2012. Doña Ana County is another county showing an increase with 133,138 tons of hay and haylage in 2002, and 167,783 tons in 2012. Catron, San Miguel, and Santa Fe counties all show a decrease in the tons of hay and haylage from 2002 to 2012.The amount of corn acres harvested in New Mexico appears to be down in Table 5; however, that might be due to data problems. The reason being that New Mexico had 31,101 acres of corn (United States Department of Agriculture, 2014, p. 8) so it was either never harvested or the data was not released at the county level. In 2012, New Mexico had 209,110 irrigated acres of alfalfa, 78,140 irrigate acres of ‘corn for silage or greenchop,’ and no irrigated acres of soybeans (United States Department of Agriculture, 2014, p. 26). The feed production in New Mexico is important as the dairy industry has grown, is New Mexico bringing in feed from elsewhere.

4.2.6. Trends in Export of Dairy Products from NM

The export of dairy products from New Mexico would mean that the dairy industry is exporting the virtual water in those products. Figure 7 shows that Dairy product exports from New Mexico increased from $30.6 million in 2002 up to $146.8 million in 2008, and fell in 2009 (United States Department of Agriculture – Economic Research Service, 2013). From 2009 to 2013, the dollar amount of dairy products from New Mexico has been increasing from $87.2 million to $195.2 million (United States Department of Agriculture – Economic Research Service, 2013). Another important illustration of Figure 7 is that New Mexico is exporting over four times as much in dairy in 2013, than it did in the year 2000.

4.2.7. Federal Industry Support Status

There is a considerable history of federal price support for dairy products in the United States. Federal government purchase of products processed from dairy production, such as cheese, when prices drop to a certain level has the effect of propping up the demand for dairy production. During 2000 to 2009, price supports for cheese have been a significant component of supporting demand for the dairy industry in the US and New Mexico. These price supports were provided under the Dairy Product Price Support Program (United States Department of Agriculture, 2010, p. 1). Figure 6 shows that price supports have been used a number of times from 2000 through 2009 in New Mexico, but were not implemented for all years. Price supports for cheese were not implemented for New Mexico for 2000 and 2006. In 2009, nearly 35 million pounds of cheese were purchased by the Federal government from the New Mexico dairy industry, with a dollar value of $45,789,740 assuming it was all in 40 pound blocks (United States Department of Agriculture, 2010). However, going forward Federal support changes its format, but perhaps not its level of significance with the 2014 Farm Bill.

In the past, the United States federal government has passed a series of laws, primarily n the form of “Farm Bills” that have significantly impacted the dairy industry and its structure. For example, “historically U.S. federal dairy safety net support programs have been designed to provide milk price floors and counter-cyclical revenue” (Newton & Kuethe, 2014). A key impact was that “the MILC [Milk Income Loss Contract] program enacted with the Farm Security and Rural Investment Act of 2002, and as amended in 2008” (Newton & Kuethe, 2014). The reason was that it “provides countercyclical revenue support to dairy producers on up to 2.985 million pounds of milk per fiscal year (approximately 140 cows)” (Newton & Kuethe, 2014).

The average number of milk cows per dairy operation in New Mexico in 2012 was 777.8 (318, 878 dairy cows / 410 dairy farms) (United States Department of Agriculture, 2014, p. 21). In 2012 the average dairy producer in New Mexico was more than five times larger than the subsidy levels for the Milk Income Loss Contract, and most of the cows were in even larger operations. However, about 290 of these dairy farms were small producers averaging 10 or fewer cows. The other approximately 120 dairies were of a much larger scale, averaging approximately 2,730 milk producing cows (and having significant replacement herds).

The Agricultural Act of 2014, usually called the Farm Bill, will last until 2018 (*Agricultural Act of 2014*, 2014, p. 693). “The main feature of the new farm bill title is the Dairy Margin Protection Program” (National Milk Producers Federation, n.d.). The Margin Protection Program has the potential to significantly influence the dairy industry both across the United States and in New Mexico. “The main feature of dairy policy in the Agricultural Act of 2014 is the protection of producer margins” (Dillivan, 2014, paragraph 7). It is based on the cost of alfalfa, corn, and soybean meal (*Agricultural Act of 2014*, 2014, p. 688). With the Margin Protection Program, “should margins fall below a producer selected level, indemnity payments will be authorized based on actual milk production history and a coverage level participants elect” (Dillivan, 2014, paragraph 7). The coverage threshold range from $4.00 to $8.00 in fifty cent increments (*Agricultural Act of 2014*, 2014, p. 691), and the percentage of coverage of production history ranges from 25 to 90 percent (*Agricultural Act of 2014*, 2014, p. 691). A payment is made if “average actual dairy production margin for a consecutive 2-month period is less than the coverage level threshold selected” (*Agricultural Act of 2014*, 2014, p. 691). With high feed costs essentially insured at the federal level, the Farm Bill then has the potential to make the dairy industry relatively drought tolerant in providing insurance against high feed costs. This can be expected to be important support for New Mexico dairies. The other way that it effects New Mexico dairies is that it does not have a size limitation like the Milk Income Loss Contract. Reducing potential losses, or mitigating some of the risk, should allow any concentration of the dairy industry in the United States to pursue economies of scale in New Mexico and across the United States.

Clearly, the price of milk is also a consideration, affecting both profitability generally and also within the Farm Bill's Margin Protection program as described above. Figure 11 shows the general upward trend in nominal milk prices in US from 1980 until 2013 with an average price of $20.12 per hundredweight (United States Department of Agriculture - National Agricultural Statistics Service, n.d.-j). However when adjusted for inflation, real milk prices in the United States appear to be on a downward trend. In addition, the milk prices appear to be more volatile recently then they were in the 1980s and early 1990s. Downward pressure on milk prices, means that in order to keep in business dairy farmers would have needed to cut costs and potentially seek economies of scale in production, lowering their per unit costs, in order to stay in business. This is consistent with the increasing concentration in the dairy industry, both nationally and in New Mexico.

While the focus of this research is on dairy production, with the increasing concentration of dairy production, water quality is an issue that has been raised about dairy farms. Thus it is worth nothing that according to the United States Environmental Protection Agency, "the waste produced per day by one dairy cow is equal to that of 20-40 people" (US EPA, 2011). It is important to keep that in mind as "when improperly managed, animal waste can pose substantial risks to public health and ecological systems" (Wang, 2012, p. 5). According to Table 7, Chaves County in 2012 had 75,951 dairy cows, which would be having to account for 1,519,020 more people in terms of waste of disposal. Food & Water Watch says the 75,941 cows in Chaves County New Mexico have a human sewage equivalent of 16,800,000 people (Food & Water Watch, 2015), this is over 11 times as much as the United States Environmental Protection Agency based number. If the New Mexico dairy industry, is exhibiting a dual structure it will create large concentrations of waste as well.

4.2.11 Dual Structure of Farming

The dual structure of farming is seen in New Mexico. Table 10 shows that since 1987 the largest category of farms has become a larger proportion of the total farm sales in New Mexico. Table 10 illustrates that those operations with $1,000,000 or more in sales, the largest category, are only a small percentage of the total agricultural operations in New Mexico. In Table 10 for 2012, 1.3 percent of the farms were producing 75.76 percent of the sales. In contrast, Table 10 shows for 1987 0.97 percent of farms were producing only 47.29 percent of farm sales. Only a small number of the operations are doing most of the sales; thereby, demonstrating that the dual structure exists in agriculture in New Mexico. In addition, the change between 1987 and 2012 would suggest a greater concentration of agriculture in New Mexico. Significant economies of scale appear to be present in New Mexico agriculture.

The case can be made for the dual structure in the dairy industry. As show in Table 11: 75% of sales is generated by 116 dairy farms (317,650 dairy cows / 116 dairy farms), who average 2,739 cows, and 121 dairy farms with an average annual sales of $10,318,000. 50% of sales is generated 71 dairy farms (259,844 dairy cows / 71 dairy farms) for an average of 3,660 dairy cows, and 73 farms with $14,187,000 in average sales. 25% of sales is generated by 22 dairy farms (118,831 dairy cows / 22 dairy farms), who average 5,401 cows, and 23 dairy farms who average $20,857,000 in sales. 10% of sales generated by four dairy farms (40,800 dairy cows / 4 dairy farms) averaging 10,200 cows, and five dairy farms averaging $34,552,000 in sales. Table 11 shows that in 2012 14.6 percent of operations accounted for 25 percent of milk sales. In addition, Table 11 shows that the 23 operations generated $479,722,000 of milk sales. Table 10 shows that all agricultural sales in New Mexico was $2,550,147,000 for 2012. Thus, those 23 dairy operations are generating 18.8 percent of all of the agricultural sales in New Mexico. Table 11 also shows the top five dairy operations accounted for $172,761,000 in sales, which would be 6.8 percent of all agricultural sales in New Mexico. The approximately 20,000 small farms in New Mexico, with perhaps several thousand dollars of average annual sales stand in starkest contrast to the largest four dairy farms had 40,800 total milk cows, averaging just over 10,000 milk cows apiece and averaging $34,552,000 in annual sales. These large dairy farms also maintain large replacement herds. For the 318,878 milk producing cows in New Mexico in 2012, there were 206,395 cows in the replacement herd (United States Department of Agriculture, 2014, p. 21).

In addition, Figure 9 shows that from 1982 to 2007 as the number of dairy cows was increasing the number of dairy operations was decreasing in New Mexico. The industry was becoming more concentrated in larger dairy operations. Figure 10 further supports this point. As the number of dairy cows in New Mexico increased, so did the number of operations with more than 500 dairy cows. Thus, the evidence in New Mexico dairy production is fully consistent with the general pattern of evidence for increasing concentration in the dairy industry in the United States (MacDonald et al., 2007, p. iii).

4.5. Variation in Average Net Farm Income across NM

Given the high percentage (78.62% in 2010) total water withdrawls in New Mexico to the agricultural sector (Longworth, Valdez, Magnuson, & Richard, 2013, p. i), then it is argued that it is important for state and regional water planning to have a disaggregated understanding of the sector, including (and perhaps especially) in any dynamic subsector such as the dairy industry. One important available economic measure of the agricultural sector and farm welfare in NM is average net farm income. It is illustrative to look at the distribution or variation in this measure in order to better understand the structure of the agricultural sector in NM. This structure, and its spatial distribution across NM, can then be related to dairy production, to help better disaggregate and improve our understanding of this rapidly changing economic sector. Since, the full statistical distribution of average net farm income, and its geo-coded locations and production characteristics, is not publically available for NM, this illustrative analysis uses the county-level averages available (United States Department of Agriculture - National Agricultural Statistics Service. n.d.-g and United States Department of Agriculture - National Agricultural Statistics Service. n.d.-h), and focuses on the two most recent agricultural census years (2007 and 2012).

In year 2007 and year 2012, the average net farm income across the 33 NM counties was $15,285.03 (with a standard deviation of $30,756.07) and $16,722 (with a standard deviation of $26,456.24), respectively. In 2007, the high was $137,119 and the low was $-9,944, with 12 counties showing a negative value. In 2012, the high was $107,850 and the low was $-9,769, with 10 counties showing a negative value. This extreme variation helps to illustrate one facet of the dual farm structure in NM. It also shows that the statewide mean value of average net farm income is not a particularly useful measure for understanding NM agriculture. Given the focus of this analysis, it is natural then to try to better understand the role of dairy production in explaining the large observed variation in average net farm income in NM. As an initial observation, the high five NM dairy counties with 275,638 cows in 2012, had an average net farm income of $49,648. This is with the blending of large operation dairy farms with all other farms found in those counties, so it clearly understated the impact. This can be taken as one indicator of how different large dairy farms may be relative to the vast majority of USDA-defined farms in NM. To further explore the dual structure of NM agriculture, and the dairy industry's place in that structure, the following section use simple regression analyses to help understand the observed variation in average net farm income across the 33 counties.

This exploratory analysis begins with the general hypothesis that some measure of dairy production will be a key determinant of farm welfare in NM. Given our focus on the available (high variability) measure of average net farm income across the NM counties, and the clear spatial distinctions across diary production by counties, we use average net farm income as our dependent variable. We then want to control for other possible key explanatory production variables, which are not co-linear, and test for the possible effect of some commonly-available measure of dairy production on the dependent variable.

The ordinary least squares (OLS) regression approach (Pedace, 2013) is used to conduct the analysis, with the 33 counties in NM as the number of observations. A simple linear functional form is assumed, E.g., $Y = \beta_0 + \beta_1 X1 + \beta_2 X2 + \beta_3 X3 + \beta_4 X4 +$

$\beta_5 X5 + \varepsilon$, where Y is the dependent variable, the X's are the explanatory variables, the β's are coefficients to be estimated, and ε is a mean zero error term. The basic assumptions of OLS are: "The model is linear in parameters and has an additive error term; the values for the independent variables are derived from a random sample of the population and contain variation; no independent variable is a perfect linear function of any other independent variable(s); the model is correctly specified and the error term has a zero conditional mean; the error term has a constant variance; the values of the error term aren't correlated with each other" (Pedace, 2013, p. 94).

For this OLS regression analysis, the dependent variable is AVGNETFARMINC (average net farm income), with mean 16,722 and standard deviation 26,456.24 for 2012. Our explanatory variable of interest is AVGDAIRYCOW, which is defined as the number of milk cows divided by the number of farms in a county; its mean is 14.00 with standard deviation 33.27 in 2012. As the other explanatory variables, we also control for the effects of the following: AVGPECANACRES is the average number of acres bearing pecans county; AVGSHEEP is the average number of sheep including lambs in a county; AVGCATTLE is the average number of cattle and calves minus the number of milk cows in a county; and AVGWHEATACRES is the average number of acres of wheat harvested in a county. The full definitions for these variables and their descriptive statistics are provided in Table 2.

For each year of available county-level data, four different model specifications were investigated. They all include our variable of interest (AVGDAIRYCOWS) as an explanatory variable, but vary in terms of the other possible explanatory variables that are controlled for. Assuming a mean zero error term in each case, the four different model specifications are:

(1) $AVGNETFARMINC = \beta_0 + \beta_1 AVGPECANACRES + \beta_2 AVGDAIRYCOWS$

(2) $AVGNETFARMINC = \beta_0 + \beta_2 AVGDAIRYCOWS + \beta_3 AVGSHEEP + \beta_4 AVGCATTLE$

(3) $AVGNETFARMINC = \beta_0 + \beta_1 AVGPECAN\ ACRES + \beta_2 AVGDAIRYCOWS + \beta_3 AVGSHEEP + \beta_4 AVGCATTLE$

(4) $AVGNETFARMINC = \beta_0 + \beta_1 AVGPECAN\ ACRES + \beta_2 AVGDAIRYCOWS + \beta_3 AVGSHEEP + \beta_4 AVGCATTLE + \beta_5 AVGWHEATACRES$

We can now formally state our hypothesis, which will be examined separately for each model specification (Models 1-4), and for both years of data (2007 and 2012). Against the null of no effect, the alternative hypothesis is:

$H_A: \beta_2 > 0$

This hypothesis says that we expect that average dairy cows will be a significant positive determinant of average net cash farm income, at the county level, in NM. It is expected that this result will hold across all four model specifications (Models 1-4), for both the 2007 and 2012 data.

The results of the four OLS regressions, across model specification 1-4, are provided in Table 3 for 2007, and Table 4 for 2012. First, in terms or goodness of fit, for the 2007 data, the R^2 values in Table 3 show that each of the models explains over 80%

of the variation, with Models 3 and 4 explaining over 90% of the observed variation, in AVGNETFARMINC across NM counties. Overall across all four model specifications (1-4) for the 2007 data, the estimated coefficients for the variables AVGPECANACRES, AVGCATTLE, and AVGWHEATACRES were all positive and significant at the 0.01 level or better. For model 4 the significance levels were all $\alpha = 0.01$ level for AVGPECANACRES, AVGCATTLE, and AVGWHEATACRES. In 2007, with respect to the hypothesis on our variable of interest (AVGDAIRYCOW), the evidence across all four model specifications supports the alternative hypothesis at the $\alpha = 0.01$ level. But this is for a two-tailed test, for a one-tailed test the significance level would be even higher.

Results for the Models 1-4 using the 2012 data are shown in Table 4. In terms of goodness of fit overall, Model 1 had an R^2 of 0.43; however models 2, 3, and 4 all have an R^2 above 0.8. Overall for the 2012 models, AVGPECANACRES, and AVGCATTLE were positive and significant determinants of average net farm income across NM counties. For Model 4 the significance levels were at the 0.1 level for AVGPECANACRES and 0.001 level for AVGCATTLE. The estimated coefficient on AVGWHEATACRES was negative and not significant.

With respect to the hypothesis on our variable of interest (AVGDAIRYCOW), the evidence across all four model specifications supports the alternative hypothesis at the 0.10 level; however, this is for a two-tailed test, for a one-tailed test the significance level would be at the 0.05 level. The inference is that dairy cows are important in understanding net farm income in NM. As a side note, it is also clear that cattle and cows more generally were also important for farm income in 2012 (which was a drought year and perhaps heavily impacted by cattle sales).

In summary net farm income is highly variable across NM counties, and NM agriculture sector with its evidence of a dual farm structure. The geographic concentration of dairy production is consistent with high farm income counties, and it appears that a small number of dairy operations are driving this. The simple OLS econometric analysis at the county level shows that across all model specifications and both years (2007 and 2012), dairy cows are a significant positive determinant in understanding NM farm income. Having provided this illustrative analysis of the importance of dairy production in understanding the variability in New Mexico farm income, we turn to exploring the total amount of water use (both indirect and direct) in NM dairy production.

4.4. Virtual Water Used in Dairy Production and Processing

4.4.1. Water Directly Consumed in the Production of Dairy

There are several different possible calculations for the amount of water a dairy cow consumes. “Industry specialists estimate the average direct water use for each dairy cow in the Texas High Plains is 55 gallons per day” (Guerrero et al., 2012, p. 4). Longworth et al. use a calculation of “GPCD of 65” (Longworth et al., 2013, p. 32) for the state of New Mexico; however, “previous reports used a GPCD of 100 for dairy cattle” (Longworth et al., 2013, p. 32). Direct water used in the production of dairy includes only the amount of water “used for drinking and facility maintenance” (Guerrero, et al, 2012, p. 3). Using all three different numbers address’ Fiala’s criticism about different technology levels as “efforts have been made… reduce the amount of water use in facility sanitation” (Longworth et al., 2013, p 32). For New Mexico, using conversions for gallons into acre-ft (Gleick, 2006, p. 322), I calculate 0.06 acre-ft per cow per year of direct water usage using Guerrero's estimate of 55 gallons per cow per day. Using Longworth's estimate of 65 gallons per cow per day I calculate 0.07 acre-ft per cow per year, and 0.11 acre-ft per cow per year in direct water usage using Longworth's estimate of 100 gallons per cow per day. Table 9 presents the estimated annual direct water use for 2012, and New Mexico dairy cow of 318,878 (United States Department of Agriculture, 2014, p. 21) as 19,133 acre-ft, 22,321 acre-ft, and 35,077 acre-ft for 55gpcpd, 65 gpcpd, and 100 gpcpd respectively. For the replacement herd of 206,395 (United States Department of Agriculture, 2014, p. 21), 12,716 acre-ft, 15,023 acre-ft, and 23,113 acre-ft for 55gpcpd, 65 gpcpd, and 100 gpcpd respectively. The total then for the entire milk cow herd of 525,273 (United States Department of Agriculture, 2014, p. 21) of 32,361 acre-ft, 38,234 acre-ft, and 58,821 acre-ft for 55gpcpd, 65 gpcpd, and 100 gpcpd respectively.

4.4.2. Water Indirectly Consumed in the Production of Dairy

There are two different measures for indirect water usage. The first is irrigated acres, and the second is in acre-ft. The reason for calculating the indirect use is that in addition to the water directly consumed in the production of dairy, there is also water indirectly consumed. Indirect water consumed is the amount of water used to "grow forage and grain for feeding cattle" (Guerrero et al, 2012, p. 3). Guerrero et al. (2012), estimate the indirect use of land per cow is 2.078 irrigates acres (Guerrero et al., 2012, p. 5-6). This estimates the amount of irrigated acreage required to feed a dairy cow. The total irrigated acreage in New Mexico for 2010 was 872,664 (Longworth et al., 2013, p. ii). Based on that measure and ignoring any dietary composition assumption altogether, the irrigated acreage in New Mexico could theoretically support a population of 419,954 dairy cows if it were used exclusively for dairy cows which it is clearly not. **However,** the 2012 Census of Agriculture shows 680,318 irrigated acres in New Mexico (United States Department of Agriculture, 2014, p. 7) which would support a population of 327,391 dairy cows if used exclusively for dairy cows. In 2012 in New Mexico there were 318,878 dairy cows producing milk (United States Department of Agriculture, 2014, p. 21), and a total dairy cow herd of 525,273 (United States Department of Agriculture, 2014, p. 21). The total dairy cow herd requires 776,618 irrigated acres for feed production.

The indirect water use in acre-ft is show in Table 8. The numbers used to estimate the acre-ft are low. However, the New Mexico Office of the State Engineer does supply a Consumptive Irrigation Requirement for the entire state in the Water Use by Categories reports (Longworth et al., 2012). Therefore, the numbers in Guerrero et al. (2012) were used to calculate the indirect water use. The dairy cow herd of New Mexico requires an estimated 1,104,908 acre-ft of water to grow feed crops. The replacement herd requires an estimated 211,732 acre-ft of water to grow freed crops. In total, the indirect use for all of the dairy herd and replacement herd is 1,316,640 acre-ft.

4.5. Review of State and Select Regional Water Plans

Water plans were examined to see if they included information, and the level of detail of that information, about the dairy industry in New Mexico. References to dairy, dairy industry, or dairies were searched for in the published plans. Water planning documents for both the state level of New Mexico, and the several regional plans were examined. The regional plans were chosen if they were areas considered to have a high population of dairy cows.

4.5.1. State Water Planning

The State Water Plan (Office of the State Engineer & Interstate Stream Commission, 2003), the State Water Plan Review and Update (Office of the State Engineer & Interstate Stream Commission, 2008), and the Working Towards Solutions (New Mexico Interstate Stream Commission & New Mexico Office of the State Engineer, 2013) none of these documents make any mention of dairy production industry or dairies within their pages.

As another prominent example, outside the formal state planning process, New Mexico First recently held a series of town halls on water planning. Their document does not mention dairy or dairies (New Mexico First, 2014). Agriculture does get mention in a broad sweep such as "integrate public water supply and sanitation planning with the separate planning process for agriculture/ land use, transportation, and economic development" (New Mexico First, 2014, p. 6).

The lack of any water planning at the state level in New Mexico seems to be a large oversight. There was high growth in the dairy industry both before the State Water Plan was published, and after its publication. Even if for some reason it was missed in the original plan, other planning documents had the opportunity to pick up on the dairy industry and did not.

4.5.2. Lea County Regional Water Plan

The regional water plan for Lea County was "accepted by the Interstate Stream Commission in 1999" (Office of the State Engineer & Interstate Stream Commission, n.d.-d). The dairy industry is included within the plan. "Future water use predictions include an increase of 4,000 cows every five years" (Boivin, May El, Peery, & Buller, 1999, p. 7-22). Reality and their expectations have mixed results. Table 7 shows Dairy Cows by County and if 1997 is used as a base year, the data show that they under projected for 2002. The projected amount of 15,000 dairy cows in Lea County in 2002 is only about 60 percent of the actual number of dairy cows. The projections were close for 2007, 19,000 projected the dairy cows instead of 19,850 actual dairy cows. However, 2012 is under projected as there were 31,360 dairy cows instead of the projected 23,000 dairy cows.

4.5.3. Lower Pecos Valley Plan

The regional water plan for the Lower Pecos Valley was "accepted by the Interstate Stream Commission on August 23, 2001" (Office of the State Engineer & Interstate Stream Commission, n.d.-c). The Lower Pecos Valley includes most of Chaves, most of Eddy, and all of De Baca counties (New Mexico Interstate Stream Commission & New Mexico Office of the State Engineer, 2013, p. 51). In addition, parts of Lincoln, and Otero counties are included (New Mexico Interstate Stream Commission & New Mexico Office of the State Engineer, 2013, p. 51). Dairy is included in the regional water planning. "The future expansion of agriculture in the Pecos Valley depends on the dairy industry" (Pecos Valley Water Users Organization, 2001, p. 65). It was expected that "dairies will increase by 25 percent through 2035" (Pecos Valley Water Users Organization, 2001, p. 175). Using Table 7, the sum of all the counties in the region for 1997 is 88,508 dairy cows, and in 2002 103,195, a 16.6% percentage change. In 2012, according to Table 7 there were 87,502 dairy cows. Thereby, it would seem that region did receive some of the projected growth, but has since lost some of its dairy herds.

It is also important to note that most of the dairy cows in the Lower Pecos are in Curry County, and that Figure 5 shows that most of the growth in the dairy industry was before the water plan. The plan is from 2001 (Office of the State Engineer & Interstate Stream Commission, n.d.-c), the nearest census year is 2002, where there are 57,179 dairy cows in Curry county (United States Department of Agriculture – National Agricultural Statistics Service, n.d.-a). In 2012, there were 73,999 dairy cows in Curry county (United States Department of Agriculture – National Agricultural Statistics Service, n.d.-a). Thereby, roughly 77.3% of the growth occurred before the water plan was accepted.

4.5.4. Lower Rio Grande Water Plan

The Lower Rio Grande Water Plan was "accepted by the Interstate Stream Commission in 1999" (Office of the State Engineer & Interstate Stream Commission, n.d.-e). The concern with dairies in the Lower Rio Grande was water contamination. For example, "Ground water contamination sources in the Mesilla Valley include … dairies" (Terracon, John Shoemaker and Associates, Inc., Livingston Associates, LLC, Inc, Zia Engineering and Environmental, Inc, & Sites Southwest, 2003, p 9). In addition, "the large number of dairies within the Planning Region … are likely the main potential source of nitrate contamination" (Terracon et al., 2003, p. 105).

The plan also includes that "the market for corn is reasonably secure with the local dairies requiring silage" (Terracon et al., 2003, p. 179). However, there is no mention of past or future expansion of the dairy industry in the region. Table 7 shows that if 1997 is used as the base, the dairy cow population has increased; however, the dairy cow numbers appear to have peaked in 2007 and it will be at least until the next Census of Agriculture in 2017 before a trend can be discerned.

4.5.5. Northeast Water Plan

The Northeast Water Plan was “accepted by the Interstate Stream Commission in 2007” (Office of the State Engineer & Interstate Stream Commission, n.d.-a), this planning region “includes Union, Harding, Quay, Curry, and Roosevelt Counties” (Daniel B Stevens and Associates, Inc, 2007, p. ES-1). The dairy industry is included in the water plan in a number of ways. “In New Mexico, groundwater pollution is caused by a number of sources … dairies” (Daniel B Stevens and Associates, Inc, 2007, p. C-25). The established dairy industry in the region has led to an increasing number of value added businesses like the cheese plants” (Daniel B Stevens and Associates, Inc, 2007, p. E-13).

According to Table 7, Curry and Roosevelt Counties account for the majority of the cows in the region. Figure 5 shows that by 2007 when the water plan was approved, the growth of the dairy industry had already happened. While the number of cows in Curry County increased between 2007 and 2012, the number in Roosevelt County decreased resulting in 90 fewer cows for 2012 (United States Department of Agriculture – National Agricultural Statistics Service, n.d.-a).

The water plan has water use projections for 2000 to 2050 in increments of ten years (Daniel B Stevens and Associates, Inc, 2007, p. 6-35). For all of those years, “the low water use projection for livestock assumes no change in demand” (Daniel B Stevens and Associates, Inc, 2007, p. 6-34). In addition for livestock, “the high water use projection for Curry and Roosevelt Counties assumes a maximum increase of 10 percent between 2000 and 2010 , 5 percent between 2010 and 2020 and no further increase to

2050" (Daniel B Stevens and Associates, Inc, 2007, p. 6-34). Using Table 7, the percentage change from 2002 to 2012 in Curry and Roosevelt Counties was 8 percent.

Overall, the water plans investigated included the dairy industry and dairies minimally. No substantive discussions of the effects of large herds, or of the increasing concentration of herds was included in the planning. Meaningful economic analysis of the dairy industries' role in the transfer of water were for the most part not included.

5. Discussion & Conclusions

The objective of this research is to conduct an analysis of the growth and change of the New Mexico dairy industry, and its virtual water use, that might better inform the future structure of state and regional water planning in New Mexico. The following research tasks were done to in order to meet that objective: review trends in aggregate water diversions in NM and establish importance of understanding agriculture for understanding water use; review trends and structure of the NM dairy industry, and show its spatial distribution and concentration of the industry; explore variation in farm income by counties, and then test hypothesis that dairy industry (with its known concentration and spatial distribution) is critical to understanding economic welfare of farms in NM using ordinary least squares regression approach; calculate the total virtual water use, accounting for both direct and indirect water use, broadly needed to support the dairy industry in NM; and conduct textual analysis of current state and selected regional water plans to examine current status of disaggregated planning for the dynamic dairy industry.

The New Mexico dairy industry has shown high growth. In addition, it has shown a high level of concentration and the dual structure where a small number of firms control a large amount of the output. The total direct use of 55 gpcpd, 65 gpcpd, and 100 gpcpd results in 32,361 acre-ft, 38,234 acre-ft, and 58,821 acre-ft of water respectively. For the indirect water use, 1,316,640 acre-ft of water are consumed to grow the feed crops necessary for the dairy herd and the replacement herd in New Mexico. While this is a conservative number, it is in the right area when compared to similar calculations. The water footprint calculated earlier of 1,453,972.7 acre-ft (Hoekstra & Chapagain, 2011, “Water Use for Crop and Livestock Products,” Table 2.2), and Mubako (2011) calculated that New Mexico was importing 982,584 acre-ft of feed crops (Mubako, 2011, p. 91).

Another point is that, if devoted solely to the right feed crops, the irrigated acreage in New Mexico can support 327,391 milk cows. However, the dairy cows and replacement herd require an irrigated acreage of 776,618 acres which is more then was irrigated in New Mexico in 2012. Thus, New Mexico has to be importing feed in from other areas. New Mexico then has to be participating in regional trade via markets in the United States already. Which also means, that New Mexico is already adapting to drought and water constraints via the markets that are already in place. The implication for water scarcity being that markets can and will address the water scarcity issues already.

The dual structure of agriculture show in both New Mexico agriculture in general, and the dairy industry specifically, means that disaggregation of agriculture is important. The average level of agriculture or dairy is not indicative of what is actually going on, and can miss the important connections of ways they may already be adapting to water scarcity. It is also important to consider that dairy is not the only concentrated animal feed lots in New Mexico. There were 68 cattle feed lots, with 53,147 livestock in 2012 (United States Department of Agriculture, 2014, p. 39), which is down from 102 farms and 122,381 livestock in 2007 (United States Department of Agriculture, 2014, p. 38). Those cattle as well would need to have feed either brought in or purchased in-state with its on virtual water requirements. This disaggregation is not happening at the state level of water planning.

5. References

Abel, A. B., & Bernanke, B. S. (2001). *Macroeconomics* (Fourth Edition.). Boston: Addison Wesley Longman, Inc.

Agricultural Act of 2014, 128 U.S.C § 649 357 (2014). Retrieved from http://agriculture.house.gov/sites/republicans.agriculture.house.gov/files/pdf/legislation/Final_AgAct2014.pdf

Aldaya, Maite M, Pedro Marinez Santos,and M. Ramon Llamas.(2010) Water Resources Management. "Incorporating the Water Footprint and Virtual Water into Policy: Reflections from the Mancha Occidental Region, Spain." Volume 24, 2010, Pages 941-958.

Allan, J. A. (2003). Virtual water: – the water, food, trade nexus: Useful concept or misleading metaphor? *Water International*, *28*(1), 4–11.

Angel, N. (2012, June 5). Recruiters hope to take local dairy expertise out of state. Retrieved April 9, 2015, from http://www.turlockjournal.com/archives/15299/

Aviso, K. B., Tan, R. R., Culaba, A. B., & Cruz Jr, J. B. (2011). Fuzzy input-output model for optimizing eco-industrial supply chains under water footprint constraints. *Journal of Cleaner Production*, *19*, 187–196.

Boivin, D., May El, J., Peery, R., & Buller, G. (1999). Lea County Regional Water Plan. Lea County Water Users Association. Retrieved from http://www.ose.state.nm.us/Planning/RWP/region_16.php

Bouwmeester, M. C & Oosterhaven, J.. (2013). Specification and Aggregation Errors in Environmentally Extended Input-Output Models. *Environmental and Resource Economics*, *56*(3), 307–335.

Bureau of Business and Economic Research. (2015, January). New Mexico Statistics at a Glance. Bureau of Business and Economic Research. Retrieved from http://bber.unm.edu/econ/nm-sag.pdf

Bureau of Economic Analysis. (2010, November). U.S. Bureau of Economic Analysis (BEA) Gross domestic product (GDP) by state (millions of current dollars) 1963 - 1997. Retrieved April 20, 2015, from http://www.bea.gov/itable/iTable.cfm?ReqID=70&step=1#reqid=70&step=10&isuri=1&7003=200&7035=-1&7004=sic&7005=-1,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78&7006=35000&7036=-1&7001=1200&7002=1&7090=70&7007=1997,1996,1995,1994,1993,1992,1991,1990,1989,1988,1987,1986,1985,1984,1983,1982,1981,1980,1979,1978,1977,1976,1975,1974,1973,1972,1971,1970,1969,1968,1967,1966,1965,1964,1963&7093=levels

Bureau of Economic Analysis. (2014). U.S. Bureau of Economic Analysis (BEA) Gross domestic product (GDP by state (millions of current dollars) 1997 - 2013. Retrieved April 20, 2015, from http://www.bea.gov/itable/iTable.cfm?ReqID=70&step=1#reqid=70&step=10&isuri=1&7003=200&7035=-1&7004=naics&7005=-1,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90&7006=35000&7036=-1&7001=1200&7002=1&7090=70&7007=2013,2012,2011,2010,2009,2008,2007,2006,2005,2004,2003,2002,2001,2000,1999,1998,1997&7093=levels1&7001=1200&7002=1&7090=70&7007=2013,2012,2011,2010,2009,2008,2007,2006,2005,2004,2003,2002,2001,2000,1999,1998,1997&7093=levels

Cabrera, V. E., Hagevoort, R., Solis, D., Kirksey, R., & Diemer, J. A. (2008). Economic Impact of Milk Production in the State of New Mexico. *American Science Association*, 91(5), 2144-2150.

Chapagain, A. K., Hoekstra, A. Y., Savenije, H. H. G., & Gautam, R. (2006). The water footprint of cotton consumption: An Assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. *Ecological Economics*, *60*, 186–203.

Chapagain, A. K. and S. Orr. Journal of Environmental Management. “An improved water footprint methodology linking global consumption to local water resources: A case of Spanish tomatoes” Volume 90, 2009, Pages 1219-1228.

City of El Paso v S, E. Reynolds (United States District Court for the District of New Mexico January 17, 1983).

Daniel B Stevens and Associates, Inc. (2007, March). Northeast New Mexico Regional Water Plan Volume 1: Report, Appendix A. City of Tucumcari and Northeast New Mexico Regional Water Planning Steering Committee. Retrieved from http://www.ose.state.nm.us/Planning/RWP/region_01.php

Diemer, J., Crawford, T., & Patrick, M. (2014, December). Agriculture’s Contribution to New Mexico’s Economy. Cooperative Extension Service - College of Agricultural, Consumer and Environmental Sciences. Retrieved from http://aces.nmsu.edu/pubs/_circulars/CR675.pdf

Dillivan, K. (2014, April 1). Dairy Policy Changes in the 2014 Farm Bill | Agweb.com. Retrieved March 29, 2015, from http://www.agweb.com/article/dairy_policy_changes_in_the_2014_farm_bill_NAA_University_News_Release/

Fiala, Nathan. (2008). Measuring sustainability: Why the ecological footprint is bad economics and bad environmental science. *Ecological Economics*, 67, 519-525.

Food & Water Watch. (2015, May). Factory Farm Nation. Food & Water Watch. Retrieved from http://www.factoryfarmmap.org/wp-content/uploads/2015/05/FoodandWaterWatchFactoryFarmFinalReportNationMa y2015.pdf?utm_content=buffer1c401&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer

Fort, D. (2013). Water Matters! Utton Center. Retrieved from http://uttoncenter.unm.edu/pdfs/Water-Matters-2013/2013_water_matters.pdf

Fort, D., & Edwards, A. (2009, Summer). Dairies in New Mexico: The Environmental Implications of a New Industry. Natural Resources, Energy and Environmental Law Section Newsletter State Bar of New Mexico.

Gerlock, G. (2014, December 15). Midwest recruiting California dairies to pump up rural economy | Harvest Public Media. Retrieved April 9, 2015, from http://harvestpublicmedia.org/article/midwest-recruiting-california-dairies-pump-rural-economy

Gleick, P. H. (2006). *The World's Water 2006-2007*. Washington: Island Press.

Goodling, R. C. (2012, November 5). Herd Data Key to Managing Dairy Replacement Heifers — Dairy — Penn State Extension. Retrieved January 8, 2015, from http://extension.psu.edu/animals/dairy/news/2012/herd-data-key-to-managing-dairy-replacement-heifers

Guerrero, B., Amosson, S., & Jordan, E. (2012, September). The Impact of the Dairy Industry in the Southern Ogallala Region. Texas A&M AgriLife Extension System.

Heinrichs, A. J., & Swartz, L. A. (n.d.). Management of Dairy Heifers. Pennsylvania State University. Retrieved from http://extension.psu.edu/animals/dairy/nutrition/heifers/heifer-feeding-and-management/management-of-dairy-heifers

Hoekstra, A.Y. Ecological Economics. "Human appropriation of natural capital: A comparison of ecological footprint and water footprint analysis." Volume 68, 2009, Pages 1963-1974.

Hoekstra, A. Y., and Chapagain, A. K. (2011). "Globalization of Water: Sharing the Planet's Freshwater Resource." E-book. August 2011. Blackwell Publishing. Malden, MA.

Hoekstra A.Y., and Hung P.Q. (2002). "Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade" Value of Water Research Series No. 11, UNESCO-IHE. Available at http://www.unesco-ihe.org/content/download/2614/26914/file/Report11-Hoekstra-Hung.pdf.

Hoppe, R. A., & Banker, D. E. (2010, July). Structure and Finances of U.S. Farms 2010 edition. USDA. Retrieved from http://www.ers.usda.gov/media/184479/eib66_1_.pdf

Hurd, B. H., & Coonrod, J. (2007). Climate Change and its implications for New Mexico's Water Resources and Economic Opportunties. In *Beyond the Year of Water: Living within our Water Limitations* (pp. 59–91). Santa Fe, NM: New

Mexico Water Resources Research Institute. Retrieved from http://www.wrri.nmsu.edu/publish/watcon/proc52/coonrod.pdf

Lerman, Z., & Cimpoies, D. (2006). Duality of Farm Structure in Transition Agriculture: The Case of Moldova. Hebrew University of Jerusalem. Retrieved from http://ageconsearch.umn.edu/bitstream/7139/2/dp060010.pdf

Longworth, J. W., Valdez, J. M., Magnuson, M. L., Albury, E. S., & Keller, J. (2008, June). Water Use by Categories 2005. New Mexico Office of the State Engineer.

Longworth, J. W., Valdez, J. M., Magnuson, M. L., & Richard, K. (2013, October). Water Use by Categories 2010. New Mexico Office of the State Engineer. Retrieved from http://www.ose.state.nm.us/Conservation/PDF/NM%20Water%20Use%20by%20Categories%20Tech.%20Report%2054.pdf

Pecos Valley Water Users Organization. (2001, July). Lower Pecos Valley Regional Water Plan. Pecos Valley Water Users Organization. Retrieved from http://www.ose.state.nm.us/Planning/RWP/region_10.php

Martin, E. A., & Ruddell, B. (2012). Value intensity of water used for electrical energy generation in the Western U.S.; An application of embedded resource accounting (pp. 1–5). Presented at the 2012 IEEE International Symposium on Sustainable Systems & Technology, IEEE.

National Milk Producers Federation. (n.d.). Program Details | Margin Protection Program. Retrieved March 29, 2015, from http://futurefordairy.com/program-details

New Mexico Finance Authority. (2013). New Mexico Gross Receipts Data 60 Months January 2008 thru December 2012. Retrieved July 14, 2015, from https://my.nmfa.net/NMFAInternet/GetDoc.aspx?DocID=1419

New Mexico First. (2014). A Town Hall on Water Planning Development & Use. New Mexico First. Retrieved from http://nmfirst.org/LiteratureRetrieve.aspx?ID=207920

New Mexico Interstate Stream Commission. (2014, October 21). New Mexico Interstate Stream Commission Regional Water Planning Update Schedule 2014-2015-2016. Retrieved from http://www.ose.state.nm.us/Planning/Notices/ASB%20Ordered%20RWP%20Update%20Meeting%20Schedule%20Tracking%2010%2021%2014.pdf

New Mexico Interstate Stream Commission, & New Mexico Office of the State Engineer. (2013). Working Toward Solutions: Integrating Our Water and Our Economy State Water Plan 2013 Review. Retrieved from http://www.ose.state.nm.us/Planning/SWP/2013_NM_Water_Plan_ReviewWEB.PDF

Newton, J., & Kuethe, T. (2014, July 17). Mapping the Size of Dairy Safety Net Programs: Comparing MILC and the Margin Protection Program | farmdocdaily.

Retrieved March 29, 2015, from http://farmdocdaily.illinois.edu/2014/07/mapping-dairy-safe-net-mllc-margin-protection-program.html

Office of the State Engineer, & Interstate Stream Commission. (2003, December 23). New Mexico State Water Plan. Retrieved from http://www.ose.state.nm.us/water-info/NMWaterPlanning/2003StateWaterPlan.pdf

Office of the State Engineer, & Interstate Stream Commission. (2008, June). Review and Proposed Update New Mexico State Water Plan. Retrieved from http://www.ose.state.nm.us/Planning/SWP/SWP-Review&Update_6-26-08.pdf

Office of the State Engineer, & Interstate Stream Commission. *NM OSE/ISC State and Regional Water Planning*. (n.d.). Retrieved February 16, 2014, from http://www.ose.state.nm.us/Planning/regional_water_plans.php

Office of the State Engineer, & Interstate Stream Commission. *NM OSE/ISC State and Regional Water Planning Handbook*. (1994). Retrieved February 16, 2014, from http://www.ose.state.nm.us/Planning/RWP/rwp-handbook.php

Office of the State Engineer, & Interstate Stream Commission. (n.d.-a). *NM OSE/ISC State and Regional Water Planning Region 1 - Northeast New Mexico Regional Water Plan*. Retrieved January 13, 2015, from http://www.ose.state.nm.us/Planning/RWP/region_01.php

Office of the State Engineer, & Interstate Stream Commission. (n.d.-b). *NM OSE/ISC State and Regional Water Planning Region 7 - Taos*. Retrieved February 16, 2014, from http://www.ose.state.nm.us/Planning/RWP/region_07.php

Office of the State Engineer, & Interstate Stream Commission. (n.d.-c). *NM OSE/ISC State and Regional Water Planning Region 10 - Lower Pecos Valley*. Retrieved March 16, 2015, from http://www.ose.state.nm.us/Planning/RWP/region_10.php

Office of the State Engineer, & Interstate Stream Commission. (n.d-d.). *NM OSE/ISC State and Regional Water Planning Region 16 - Lea County*. Retrieved March 16, 2015, from http://www.ose.state.nm.us/Planning/RWP/region_16.php

Office of the State Engineer, & Interstate Stream Commission. (n.d.-e). *NM OSE/ISC State and Regional Water Planning - Region 11 - Lower Rio Grande Regional Water Plan.* Retrieved March 16, 2015, from http://www.ose.state.nm.us/Planning/RWP/region_11.php

Office of the State Engineer, & Interstate Stream Commission. (2003, December 23). New Mexico State Water Plan. Retrieved from http://www.ose.state.nm.us/water-info/NMWaterPlanning/2003StateWaterPlan.pdf

Office of the State Engineer, & Interstate Stream Commission. (2008, June). Review and Proposed Update New Mexico State Water Plan.

Pease, M. (2008). *Analysis of Constraints to Water Marketing and an Evaluation of Select ... - Google Books*. Southern Illinois University Carbondale. Retrieved from https://books.google.com/books?id=ofTNQ3h8iBAC&pg=PA185&lpg=PA185&dq=new+mexico+consumptive+use+2.1+acre&source=bl&ots=OJOB9VEs2l&sig=fYtJ0Ve387JrJutVpR7SEqez-0o&hl=en&sa=X&ved=0CB4Q6AEwAGoVChMI58_H2q7bxgIVRQ6SCh2VEgdJ#v=onepage&q=new%20mexico%20consumptive%20use%202.1%20acre&f=false

Pecos Valley Water Users Organization. (2001, July). Lower Pecos Valley Regional Water Plan. Pecos Valley Water Users Organization. Retrieved from http://www.ose.state.nm.us/Planning/RWP/region_10.php

Pedace, R. (2013). *Econometrics for Dummies*. Hoboken, NJ: John Wiley & Sons.

Rivera, J. A. (1998). *Acequia Culture: Water, Land & Community in the Southwest*. Albuquerque, NM: University of New Mexico Press.

Terracon, John Shoemaker and Associates, Inc., Livingston Associates, LLC, Inc, Zia Engineering and Environmental, Inc, & Sites Southwest. (2003, December). Lower Rio Grande Regional Water Plan. Lower Rio Grande Water Users Organization. Retrieved from http://www.ose.state.nm.us/Planning/RWP/region_11.php

Verhines, S. A. (2013, July 24). Presentation to the New Mexico Interim Water and Natural Resources Drought Subcommittee. New Mexico Office of the State Engineer.

U.S. Census Bureau. 2013. Quarterly Workforce Indicators Data. Longitudinal-Employer Household Dynamics Program. http://www.vrdc.cornell.edu/qwipu/

United States Department of Agriculture. (2004, June). 2002 Census of Agriculture - New Mexico State and County Data - Volume 1. Retrieved from http://www.agcensus.usda.gov/Publications/2002/Volume_1,_Chapter_2_County_Level/New_Mexico/NMVolume104

United States Department of Agriculture. (2009, December). 2007 Census Vol1, Chapter 2: County Level Data New Mexico. Retrieved from http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/New_Mexico/nmv1.pdf

United States Department of Agriculture. (2010). Fact Sheet Historical Data Dairy Product Price Support Program Updated through FY2010. USDA. Retrieved from http://www.fsa.usda.gov/Internet/FSA_File/dppsp_fact_sht_hist_data.pdf

United States Department of Agriculture. (2014, May). 2012 Census of Agriculture New Mexico State and County Data Volume 1 Geographic Area Series Part 31. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/New_Mexico/nmv1.pdf

United States Department of Agriculture - National Agricultural Statistics Service. (1989, July). 1987 Census of Agriculture Volume 1, Part 31, New Mexico. United States Department of Agriculture. Retrieved from http://usda.mannlib.cornell.edu/usda/AgCensusImages/1987/01/31/1987-01-31.pdf

United States Department of Agriculture - National Agricultural Statistics Service. (1999, March). 1997 Census of Agriculture. United States Department of Agriculture. Retrieved from http://www.agcensus.usda.gov/Publications/1997/Vol_1_National,_State_and_County_Tables/ac97anm.pdf

United States Department of Agriculture - Economic Research Service. (2014, May 1). Milk cows and production by State and region 2009-2013. Retrieved March 30, 2015, from http://www.ers.usda.gov/datafiles/Dairy_Data/milkcowsandprod_1_.xls

United States Department of Agriculture - Economic Research Service. (2015, May 25). USDA ERS - Price Spreads from Farm to Consumer: Documentation. Retrieved June 26, 2015, from http://www.ers.usda.gov/data-products/price-spreads-from-farm-to-consumer/documentation.aspx#.UyDxSfldV8E

USDA -NASS. (2014, December 11). USDA/NASS QuickStats Ad-hoc Query Tool - Census Crops Field Crops Hay & Haylage Hay & Haylage - Production, Measured in tons, dry basis Total County New Mexico 2012 2007 2002. Retrieved December 12, 2014, from http://quickstats.nass.usda.gov/results/A144473E-C79A-3512-AFCB-78A7DD151552

United States Department of Agriculture. (2014, May). 2012 Census of Agriculture New Mexico State and County Data Volume 1 Geographic Area Series Part 31. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/New_Mexico/nmv1.pdf

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-a). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Animals & Products, Livestock, Cattle, Inventory, Cattle cows milk inventory, Total, County, New Mexico, 2012 2007 2002 1997. Retrieved December 24, 2014, from http://quickstats.nass.usda.gov/results/08BE090D-DE22-3FC9-AE7D-9DFC17BBFF1F

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-b). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Animals & Products, Livestock, Cattle, Inventory, Cattle, Incl Calves - Inventory, Total, County, New Mexico, all counties, 2007. Retrieved February 2, 2015, from http://quickstats.nass.usda.gov/results/D918AAAF-CB6D-3A9F-B500-F0669E19B70D

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-c). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Animals & Products, Livestock, Sheep, Inventory, Sheep Incl Lambs - Inventory, Total, County, New Mexico, all counties, 2012. Retrieved January 6, 2015, from http://quickstats.nass.usda.gov/results/676249E6-B104-3D1C-B36D-4B7C054254AA

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-d). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Animals & Products, Livestock, Sheep, Sheep, incl lambs - Inventory, Total, County, New Mexico, all counties, 2007. Retrieved February 2, 2015, from http://quickstats.nass.usda.gov/results/547FDDAF-DECD-3B1A-878D-3645CEE0DC1D

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-e). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Crops, Field Crops, Wheat, Area Harvested, Wheat - Acres Harvested, Total, County, New Mexico, All counties, 2012, 2007, 2002, 1997, Annual. Retrieved January 19, 2015, from http://quickstats.nass.usda.gov/results/29ECD8C1-4F05-3EE4-842F-E6205174D767

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-f). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Crops, Fruit & Tree Nuts, Pecans, Pecans - Acres Bearing, Total, County, New Mexico, all the counties, 2012, 2007, 2002. Retrieved December 30, 2014, from http://quickstats.nass.usda.gov/results/00F40BEC-7C3C-3A00-961B-89AB99E2FE2D

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-g). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Economics, Income, Income, Net Cash Farm, Net Income, Income, Net Cash Farm, of Operations - Net INcome, Measured in $/ Operation, County, New Mexico, all counties, 2007. Retrieved February 1, 2015, from http://quickstats.nass.usda.gov/results/B121F73D-C9B0-3DE0-AF30-D318EB2D7A77

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-h). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Economics, Income, Income Net Cash Farm, Net Income, INCOME NET CASH FARM OF OPERATIONS - NET INCOME MEASURED IN $ / OPERATION, Total, County, New Mexico, All Counties, 2012. Retrieved February 13, 2015, from http://quickstats.nass.usda.gov/results/73ABE6C3-FCF9-3956-B465-843846CD4865

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-a). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Animals & Products, Livestock, Cattle, Inventory, Cattle cows milk inventory, Total, County, New Mexico, 2012 2007 2002 1997. Retrieved December 24, 2014, from http://quickstats.nass.usda.gov/results/08BE090D-DE22-3FC9-AE7D-9DFC17BBFF1F

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-b). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Animals & Products, Livestock, Cattle, Inventory, Cattle, Incl Calves - Inventory, Total, County, New Mexico, all counties, 2007. Retrieved February 2, 2015, from http://quickstats.nass.usda.gov/results/D918AAAF-CB6D-3A9F-B500-F0669E19B70D

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-c). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Animals & Products, Livestock, Sheep, Inventory, Sheep Incl Lambs - Inventory, Total, County, New Mexico, all counties, 2012. Retrieved January 6, 2015, from http://quickstats.nass.usda.gov/results/676249E6-B104-3D1C-B36D-4B7C054254AA

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-d). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Animals & Products, Livestock, Sheep, Sheep, incl lambs - Inventory, Total, County, New Mexico, all counties, 2007. Retrieved February 2, 2015, from http://quickstats.nass.usda.gov/results/547FDDAF-DECD-3B1A-878D-3645CEE0DC1D

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-e). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Crops, Field Crops, Corn, Corn, Grain - Acres Harvested, County, New Mexico, all counties, 2012, 2007, 2002, 1997. Retrieved January 22, 2015, from http://quickstats.nass.usda.gov/results/F7201922-E542-3FF6-88B4-27E8CE564B61

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-f). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Crops, Field Crops, Wheat, Area Harvested, Wheat - Acres Harvested, Total, County, New Mexico, All counties, 2012, 2007, 2002, 1997, Annual. Retrieved January 19, 2015, from http://quickstats.nass.usda.gov/results/29ECD8C1-4F05-3EE4-842F-E6205174D767

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-g). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Crops, Fruit & Tree Nuts, Pecans, Pecans - Acres Bearing, Total, County, New Mexico, all the counties, 2012, 2007, 2002. Retrieved December 30, 2014, from http://quickstats.nass.usda.gov/results/00F40BEC-7C3C-3A00-961B-89AB99E2FE2D

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-h). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Economics, Income, Income, Net Cash Farm, Net Income, Income, Net Cash Farm, of Operations - Net Income, Measured in $/ Operation, County, New Mexico, all counties, 2007. Retrieved February 1, 2015, from http://quickstats.nass.usda.gov/results/B121F73D-C9B0-3DE0-AF30-D318EB2D7A77

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-i). USDA/NASS QuickStats Ad-hoc Query Tool - Census, Economics, Income, Income Net Cash Farm, Net Income, INCOME NET CASH FARM OF

OPERATIONS - NET INCOME MEASURED IN $ / OPERATION, Total, County, New Mexico, All Counties, 2012. Retrieved February 13, 2015, from http://quickstats.nass.usda.gov/results/73ABE6C3-FCF9-3956-B465-843846CD4865

United States Department of Agriculture - National Agricultural Statistics Service. (n.d.-j). USDA/NASS QuickStats Ad-hoc Query Tool - Survey, Animals & Products, Dairy, Milk, Milk-Price Received, Measured in $ /CWT, Total, National, US Total, 1980 - 2015, Annual, Marketing Year. Retrieved March 20, 2015, from http://quickstats.nass.usda.gov/results/13EFD2F4-5793-3EAB-9176-323E35CEDE35

United States Department of Commerce - Bureau of the Census. (1984, July). 1982 Census of Agriculture, Volume 1, Part 31 New Mexico State and County Data. US Department of Commerce. Retrieved from http://usda.mannlib.cornell.edu/usda/AgCensusImages/1982/01/31/1982-01-31.pdf

United States Department of Commerce - Economics and Statistics Administration - Bureau of the Census. (1994). 1992 Census of Agriculture, Volume 1 Chapter 2 – New Mexico. United States Department of Commerce. Retrieved from http://www.agcensus.usda.gov/Publications/1992/Volume_1_Chapter_2_County_Tables/New_Mexico/index.asp

United States Department of Labor - Bureau of Labor Statistics. (n.d.). CPI Inflation Calculator. Retrieved June 25, 2015, from http://data.bls.gov/cgi-bin/cpicalc.pl

Van Oel, P. R., Mekonnen, M. M., & Guan, D. (2010). Assessing regional and global water footprints for the UK. *Ecological Economics*, *69*, 1140–1147.

Wang, J. (2012, June). *Policies for Controlling Groundwater Pollution from Concentrated Animal Feed Operations* (Doctoral Dissertation). University of California Riverside.

Wilson, B. (1986, November). Water Use in New Mexico in 1985. New Mexico State Engineer Office.

Wilson, B. C. (1992, July). Water Use by Categories in New Mexico Counties and River Basins, and Irrigated Acreage in 1990. New Mexico State Engineer Office.

Wilson, B. C., & Lucero, A. A. (1997, September). Water Use by Categories in New Mexico Counties and River Basins, and Irrigated Acreage in 1995. New Mexico State Engineer Office. http://www.ose.state.nm.us/PDF/Publications/Library/TechnicalReports/TechReport-049.PDF

Wolf, C., & Sumner, D. (2001). Are Farm Size Distributions Bimodal? Evidence from Kernel Density Estimates of Dairy Farm Size Distributions. *American Journal of Agricultural Economics*, *83*(1), 77–88.

World Water Assessment Programme. (2012). United Nations World Water Development Report 4. Volume 1: Managing Water under Uncertainty and Risk. UNESCO. Retrieved from http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/WWDR4%20

Volume%201-
Managing%20Water%20under%20Uncertainty%20and%20Risk.pdfhttp://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/WWDR4%20Volume%201-Managing%20Water%20under%20Uncertainty%20and%20Risk.pdf

6. Tables

Table 1. New Mexico Water use by Categories in acre-ft.

Category	1985	1990	1995	2000	2005	2010
Public Water Supply & Self-Supplied Domestic	283,600	332,611	378,774	366,943	355,922	346,362
Irrigated Agriculture (Surface Water)	1,848,500	1,839,325	1,921,796	1,846,357	1,730,927	1,633,940
Irrigated Agriculture (Ground Water)	1,313,400	1,537,102	1,431,842	1,376,597	1,344,587	1,366,215
Mining & Power (Surface Water)	67,700	47,597	52,743	53,465	53,084	58,279
Mining & Power (Ground Water)	89,600	97,791	78,705	77,561	70,747	41,619
Livestock, Commercial, & Industrial	65,200	50,458	63,874	80,503	115,838	107,313
Evaporation from reservoirs with storage capacity 5000+ acft	423,500	323,777	521,432	431,457	279,293	262,216
Total	4,158,600	4,228,661	4,449,167	4,233,891	3,950,398	3,815,945

Compiled from (B. Wilson, 1986), (B.C. Wilson, 1992), (Wilson & Lucero, 1997) (Wilson, Lucero, Romero, & Romero, 2003), (Longworth, Valdez, Magnuson, Albury, & Keller, 2008) (Longworth, Valdez, Magnuson, & Richard, 2013).

Table 2. Variable Definitions and Descriptive Statistics

Variable Name	Definition	2007	2012
AVGNETFARMINC	Average Net Farm Income for operations in dollars	15285.03	16722
		(30756.07)	(26456.24)
AVGPECANACRES	The number of acres bearing pecans divided by the number of farms	0.76	1.00
		(2.69)	(2.23)
AVGDAIRYCOW	The number of milk cows divided by the number of farms	13.1	14.00
		(31.27)	(33.27)
AVGSHEEP	The number of sheep including lambs divided by the number of farms	5.28	3.00
		(8.42)	(5.07)
AVGCATTLE	The number of cattle and calves minutes the number of milk cows all divided by the number of farms	75.77	64.00
		(71.59)	(56.17)
AVGWHEATACRES	The number of acres of wheat harvested divided by the number of farms.	12.73	4.00
		(37.91)	(10.67)

Notes: Observations are mean values, averaged across 33 NM counties take from (United States Department of Agriculture - National Agricultural Statistics Service, n.d.-h), (United States Department of Agriculture - National Agricultural Statistics Service, n.d.-i), (United States Department of Agriculture - National Agricultural Statistics Service, n.d.-g), (United States Department of Agriculture - National Agricultural Statistics Service, n.d.-a), (United States Department of Agriculture - National Agricultural Statistics Service, n.d.-d), (United States Department of Agriculture - National Agricultural Statistics Service, n.d.-c), (United States Department of Agriculture - National Agricultural Statistics Service, n.d.-a), (United States Department of Agriculture, 2014, p 225-229). Numbers in parentheses are standard deviations.

Table 3. Average Net Farm Income Regressions 2007, by NM Counties

	Model 1	Model 2	Model 3	Model 4
INTERCEPT	2545.32	226.27	-2369.2	-3557.43
	(2533.22)	(3371.61)	(3179.8)	(2313.16)
	1.00	**0.07**	**-0.74**	**-1.54**
AVGPECANACRES	1764.36		2053.2	2524.82
	(853.83)		(740.17)	(543.54)
	2.07**		**2.77*****	**4.65*****
AVGDAIRYCOW	870.34	856.43	821.89	667.6
	(73.32)	(75.52)	(69.20)	(58.39)
	11.87***	**11.34*****	**11.87*****	**11.43*****
AVGSHEEP		-437.64	-358.41	11.55
		(265.27)	(240.80)	(188.56)
		-1.65	**-1.49**	**0.06**
AVGCATTLE		81.18	95.33	65.63
		(31.80)	(29.11)	(21.85)
		2.55**	**3.27*****	**3.00*****
AVGWHEATACRES				247.27
				(48.08)
				5.14***
R squared	0.83	0.86	0.9	0.94
Observations	33	33	33	33
F-Stat	75.90***	58.73***	56.14***	91.01***

Notes: Observations used in the linear regression are farm averages at the NM county level taken from (United States Department of Agriculture – National Agriculture Statistics Service, n.d.-g), (United States Department of Agriculture – National Agricultural Statistics Service, n.d.-f), (United States Department of Agriculture – National Agricultural Statistics Service, n.d.-a), (United States Department of Agriculture – National Agricultural Statistics Service, n.d.-b), (United States Department of Agriculture – National Agricultural Statistics Service, n.d.-d)

Numbers in parentheses are standard errors.
Numbers in bold are t-statistics.
*, **, and *** represent significance at the 0.10, 0.05, and 0.001 levels, respectively.

Table 4. Average Net Farm Income Regressions 2012, by NM Counties

	Model 1	Model 2	Model 3	Model 4
INTERCEPT	8987.53	-7992.21	-9668.97	-9800.74
	(4082.24)	(3202.65)	(3200.62)	(3269.77)
	2.20**	**-2.65****	**-3.02****	**-3****
AVGPECANACRES	854.83		1538.98	1504.81
	(1630.09)		(822.13)	(839.98)
	0.52		**1.87***	**1.79***
AVGDAIRYCOW	521.76	137.82	127.96	144.52
	(109.24)	(74.26)	(71.44)	(84.92)
	4.77***	**1.86***	**1.79***	**1.70***
AVGSHEEP		-539.06	-458.64	-519.99
		(382.66)	(369.64)	(409.47)
		-1.41	**-1.24**	**-1.26**
AVGCATTLE		381.76	390.53	398.15
		(43.05)	(41.56)	(46.85)
		8.87***	**9.40*****	**8.50*****
AVGWHEATACRES				-105.52
				(281.04)
				-0.38
R squared	0.43	0.85	0.87	0.87
Observations	33	33	33	33
F-Stat	11.5***	55.83***	46.37***	37.08***

Notes: Observations used in the linear regression are farm averages at the NM county level taken from (United States Department of Agriculture – National Agriculture Statistics Service, n.d.-g), (United States Department of Agriculture – National Agricultural Statistics Service, n.d.-f), (United States Department of Agriculture – National Agricultural Statistics Service, n.d.-a), (United States Department of Agriculture, 2014, p 225-229), (United States Department of Agriculture – National Agricultural Statistics Service, n.d.-c)

Numbers in parentheses are standard errors.
Numbers in bold are t-statistics.
*, **, and *** represent significance at the 0.10, 0.05, and 0.001 levels, respectively.

Table 5. Tons of Hay and Haylage

County	2002	2007	2012
BERNALILLO	13,777	26,904	16,601
CATRON	7,663	2,644	1,050
CHAVES	199,184	205,158	165,346
CIBOLA	2,106	2,693	1,024
COLFAX	18,269	29,621	15,266
CURRY	100,473	97,139	106,573
DE BACA	26,271	29,117	31,436
DONA ANA	133,128	148,741	167,783
EDDY	179,146	224,496	130,522
GRANT	1,674	977	10,571
GUADALUPE	3,139	2,333	2,939
HARDING		3,482	
HIDALGO	6,545	30,986	39,930
LEA	81,781	57,901	89,031
LINCOLN		950	
LOS ALAMOS			
LUNA	13,677	24,918	40,977
MCKINLEY	1,655	5,059	2,001
MORA	9,985	16,288	6,327
OTERO	6,688	4,305	9,896
QUAY	25,640	27,236	12,141
RIO ARRIBA	16,181	34,150	34,373
ROOSEVELT	135,118	154,587	79,315
SAN JUAN	105,224	142,675	161,326
SAN MIGUEL	11,653	13,089	4,204
SANDOVAL	12,036	14,866	15,551
SANTA FE	26,421	16,285	11,218
SIERRA	14,784	14,752	42,337
SOCORRO	40,324	52,435	53,716
TAOS	6,596	23,608	30,987
TORRANCE	41,452	69,722	58,087
UNION	27,563	21,034	20,979
VALENCIA	33,587	66,922	79,027
Total Result	1,301,740	1,565,073	1,440,534

(United States Department of Agriculture – National Agricultural Statistics Service, n.d.-k).

Table 6. Corn Acres Harvested

County	1997	2002	2007	2012
BERNALILLO		17	4	
CHAVES				
CIBOLA	74		5	
CURRY	24,866	5,711	5,115	
DONA ANA	601			4
EDDY				
GRANT				
GUADALUPE				
HIDALGO	1,278	2,442		
LEA	364		801	960
LUNA	719			
MCKINLEY	32			
MORA			20	
QUAY	2,002			
RIO ARRIBA	64		28	130
ROOSEVELT	12,393	1,847	4,635	
SAN JUAN				
SAN MIGUEL	92		104	
SANDOVAL	768	421	21	17
SANTA FE			3	17
SIERRA				12
SOCORRO	351			390
TAOS	31			16
TORRANCE	5,612	456	430	
UNION	16,167	24,085	28,680	9,824
VALENCIA				
Total Result	65,414	34,979	39,846	11,370

(United States Department of Agriculture - National Agricultural Statistics Service, n.d.-

e)

Table 7. New Mexico Dairy Cows by County

County	1997	2002	2007	2012
BERNALILLO	6,560	2,920	2,809	
CATRON	10	4		19
CHAVES	67,124	85,288	85,067	75,951
CIBOLA	23	0	3	85
COLFAX	56	48	7	9
CURRY	23,859	57,179	63,883	73,999
DE BACA	47	8		
DONA ANA	38,109	44,714	52,751	43,395
EDDY	21,169	17,819	12,742	11,508
GRANT	16	20	3	11
GUADALUPE	27	10		
HARDING	10			
HIDALGO	19			5
LEA	11,254	24,940	19,850	31,360
LINCOLN	140	65		23
LUNA				
MCKINLEY			42	142
MORA	19	28	17	
OTERO	28	15	7	20
QUAY	180	12		27
RIO ARRIBA	47	11,254	5,390	176
ROOSEVELT	31,605	57,980	61,139	50,933
SAN JUAN	32	24,940		53
SAN MIGUEL	86	10	6	40
SANDOVAL			8	14
SANTA FE		9	22	35
SIERRA				
SOCORRO	5,474	9,537	8,730	10,987
TAOS	36		8	39
TORRANCE	33			
UNION	168	29	6	
VALENCIA	5,390	4,044	8,938	10,186
Total Result	211,521	340,873	321,428	309,017

(United States Department of Agriculture – National Agricultural Statistics Service, n.d.-a)

Table 8. Indirect Water Usage for Dairy Herd

Feed Crop	Irrigation (acre-ft)	Milk Cows (acre-ft)	Replacement Herd (acre-ft)	Total (acre-ft)
Alfalfa	2.00	205,388	197,769	403,156
Corn Grain	0.92	319,010	13,963	332,973
Corn Silage	0.83	330,543		330,543
Soybean	0.92	249,967		249,967
Total		1,104,908	211,732	1,316,640
Feed Crop		Milk Cows (irrigated acres)	Replacement Herd (irrigated acres	Total (irrigated acres)
Alfalfa		102,694	98,884	201,578
Corn Grain		174,006	15,233	189,238
Corn Silage		198,326		198,326
Soybean		187,476		187,476
Total		662,501	114,117	776,618

(Guerrero et al, 2012, p. 6), (United States Department of Agriculture, 2014, p. 26, 28)

Table 9. Direct Water Usage of NM Dairy Production

Direct water Use	GPCPD	Milk Cows Usage (acre-ft)	Replacement Herd Usage (acre-ft)	Total Usage (acre-ft)
Low	55	19,646	12,716	32,361
	65	23,211	15,023	38,234
High	100	35,709	23,113	58,821

(Guerrero et al, 2012, p. 4), (United States Department of Agriculture, 2014, p. 7), (Longworth, Valdez, Magnuson, & Richard, 2013, p. 32)

Table 10. Agricultural Concentration by Sales in New Mexico

	1987	1992	1997	2002	2007	2012
Number of Operations with sales of $1,000,000 or more	138	190	262	262	308	315
Total NM Operations	14,249	14,279	14,094	15,170	20,930	24,271
Percentage of Total NM Operations with sales of $1,000,000 or more	0.97%	1.33%	1.86%	1.73%	1.47%	1.30%
Sales from operations with $1,000,000 or more in sales (in $1,000's)	$501,305	$628,289	$1,037,861	$1,186,566	$1,593,258	$1,932,067
NM Sales (in $1,000’s)	$1,060,112	$1,258,883	$1,617,708	$1,700,030	$2,175,080	$2,550,147
Percentage of NM Sales from operations with $1,000,000 or more in sales	47.29%	49.91%	64.16%	69.80%	73.25%	75.76%

(United States Department of Agriculture, 2014, p 9), (United States Department of Agriculture, 2009, p. 9), (United States Department of Agriculture - National Agricultural Statistics Service, 1999, p. 12)

Table 11. Fewest Number of Dairy Farms Accounting for Total Sales Percentages in NM Dairy Industry.

	Farms			Sales ($1,000)		
Percent of Sales	2002	2007	2012*	2002	2007	2012*
10%	3	3	5	$53,940	$114,852	$172,761
25%	22	22	23	$230,906	$358,738	$479,722
50%	86	79	73	$588,168	$803,243	$1,035,662
75%	149	145	121	$726,067	$1,006,736	$1,248,463
Total	182	245	167			
	Farms			**Milk Cows**		
Percent of Sales	2002	2007	2012	2002	2007	2012
10%	3	3	4	24,500	27,696	40,800
25%	22	22	22	95,179	99,568	118,831
50%	86	78	71	245,398	248,395	259,844
75%	152	144	116	312,557	325,416	317,650
Total	377	272	410	315,130	326,400	318,878
	Farms			**Average Sales ($1,000)**		
Percent of Sales	2002	2007	2012*	2002	2007	2012*
10%	3	3	5	17,980	38,284	34,552
25%	22	22	23	10,495	16,306	20,857
50	86	79	73	6,839	10,168	14,187
75%	149	145	121	4,873	6,943	10,318
Total	182	245	167			
	Farms			**Average Number Milk Cows**		
Percent of Sales	2002	2007	2012	2002	2007	2012
10%	3	3	4	8,167	9,232	10,200
25%	22	22	22	4,326	4,526	5,401
50%	86	78	71	2,853	3,185	3,660
75%	152	144	116	2,056	2,260	2,738
Total	377	272	410	836	1,200	778

Notes: Sales are in $1,000.

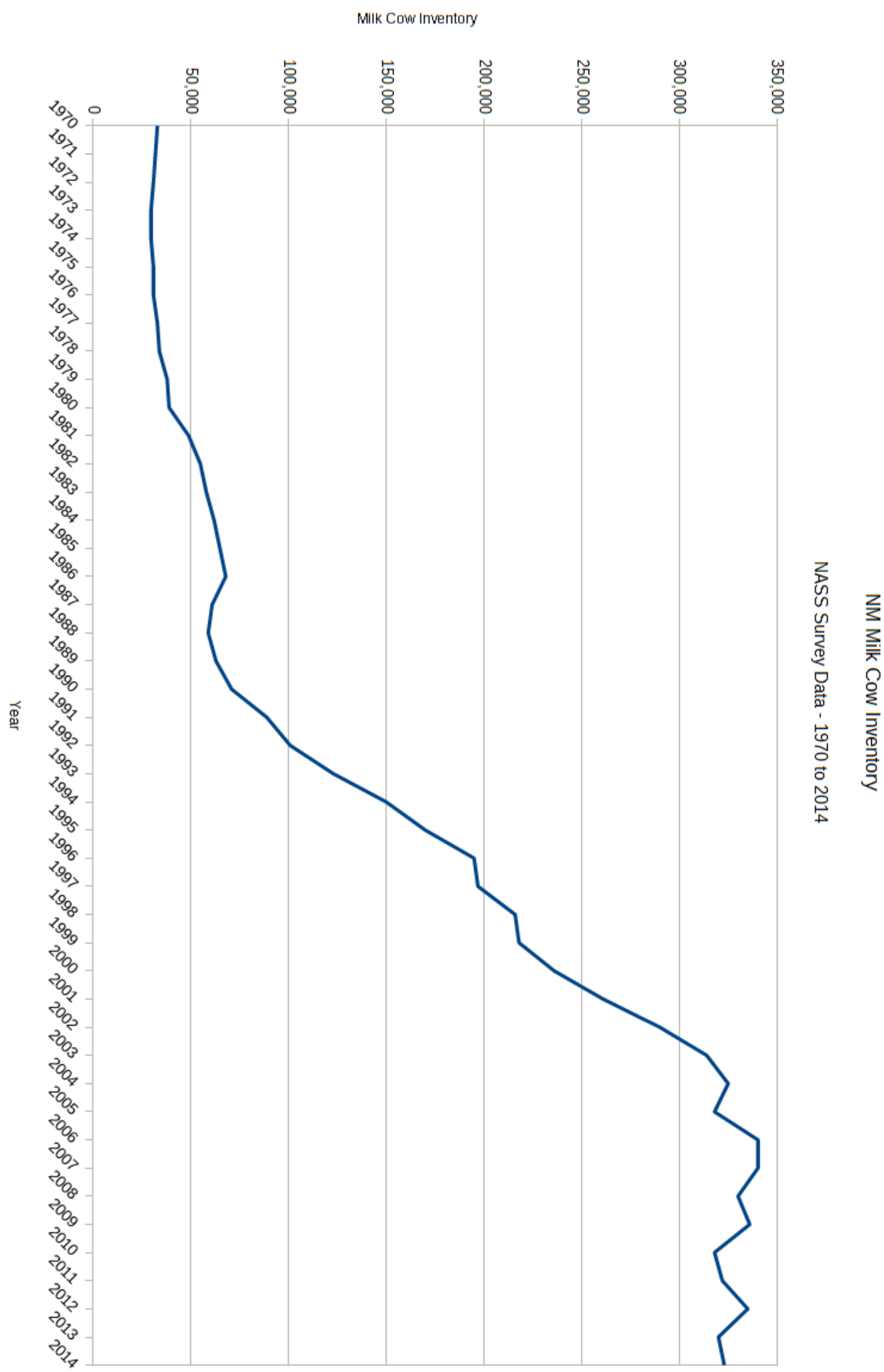
*" Milk from cows, value of sales. This is a new item for 2012. In 2007, milk from cows value of sales also included other dairy products from cows. Data are not comparable."

(United States Department of Agriculture, 2012, p. B-14)

(United States Department of Agriculture, 2014, p. 21, 36), (United States Department of Agriculture, 2009, p. 21, 35), (United States Department of Agriculture, 2004, p. 20, 33)

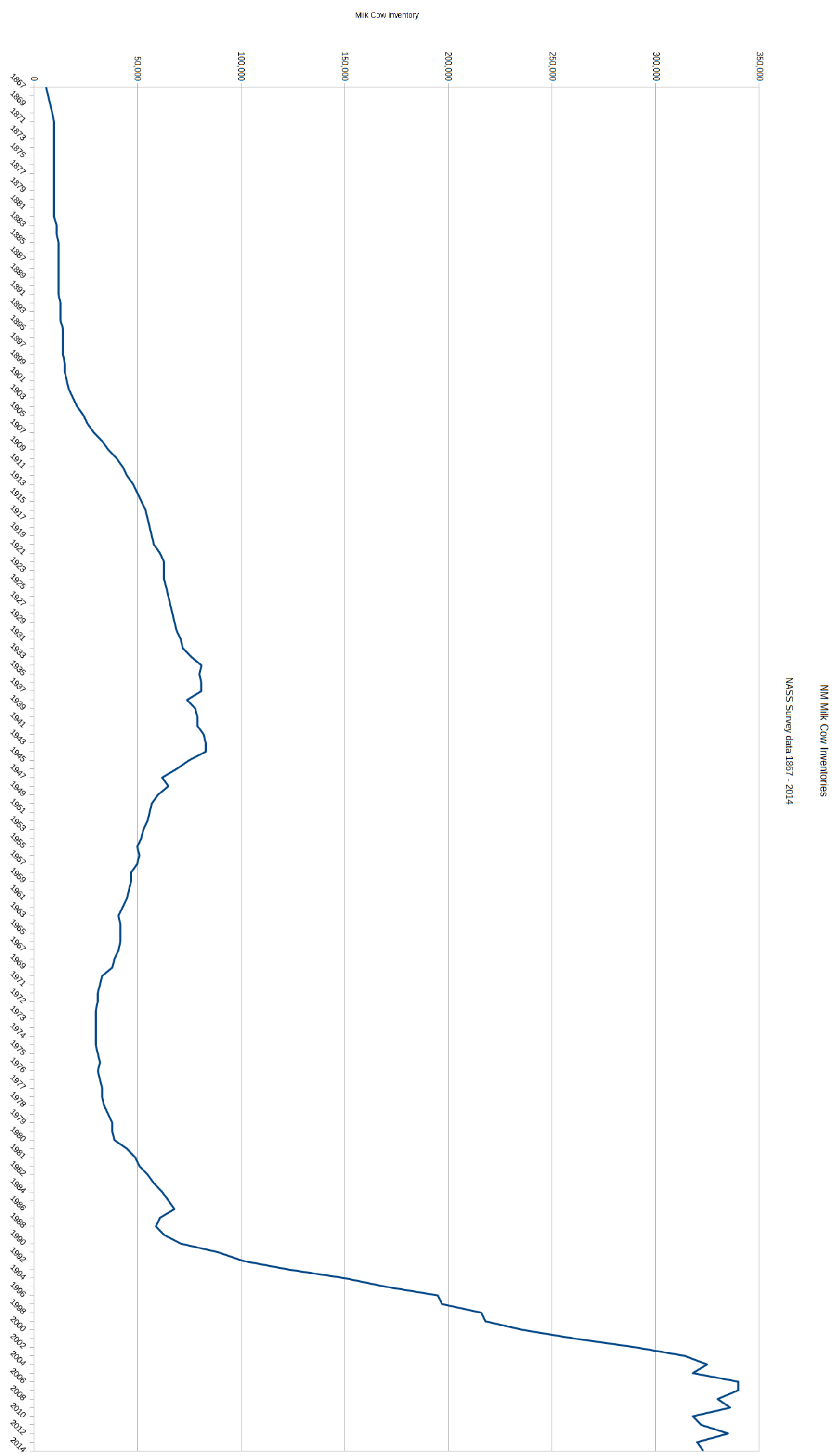
7. Figures

Figure 1. New Mexico Dairy cow inventory 1970-2014.



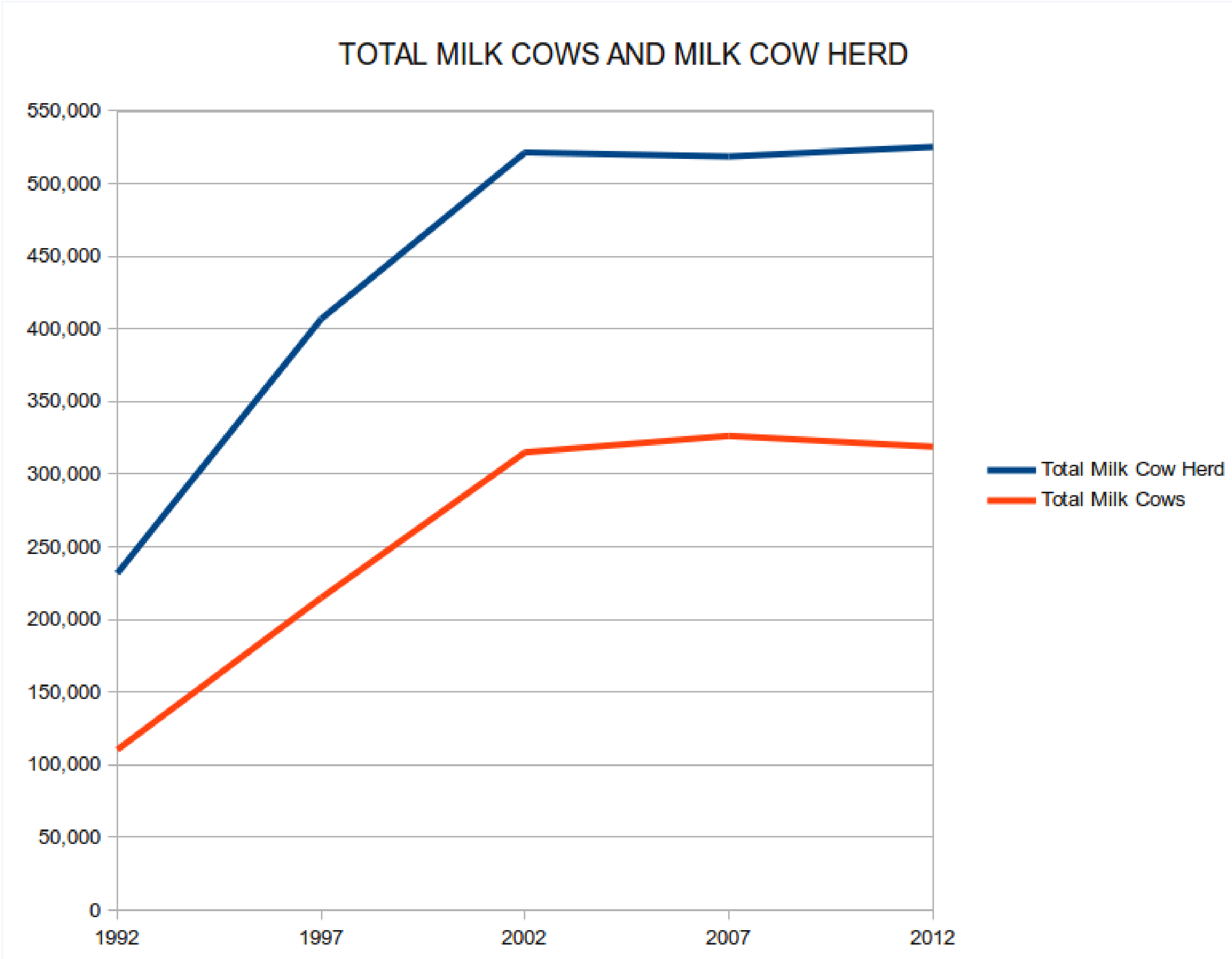
(USDA-NASS, 10/24/2014).

Figure 2. New Mexico Dairy Cow Inventory 1867 to 2014.



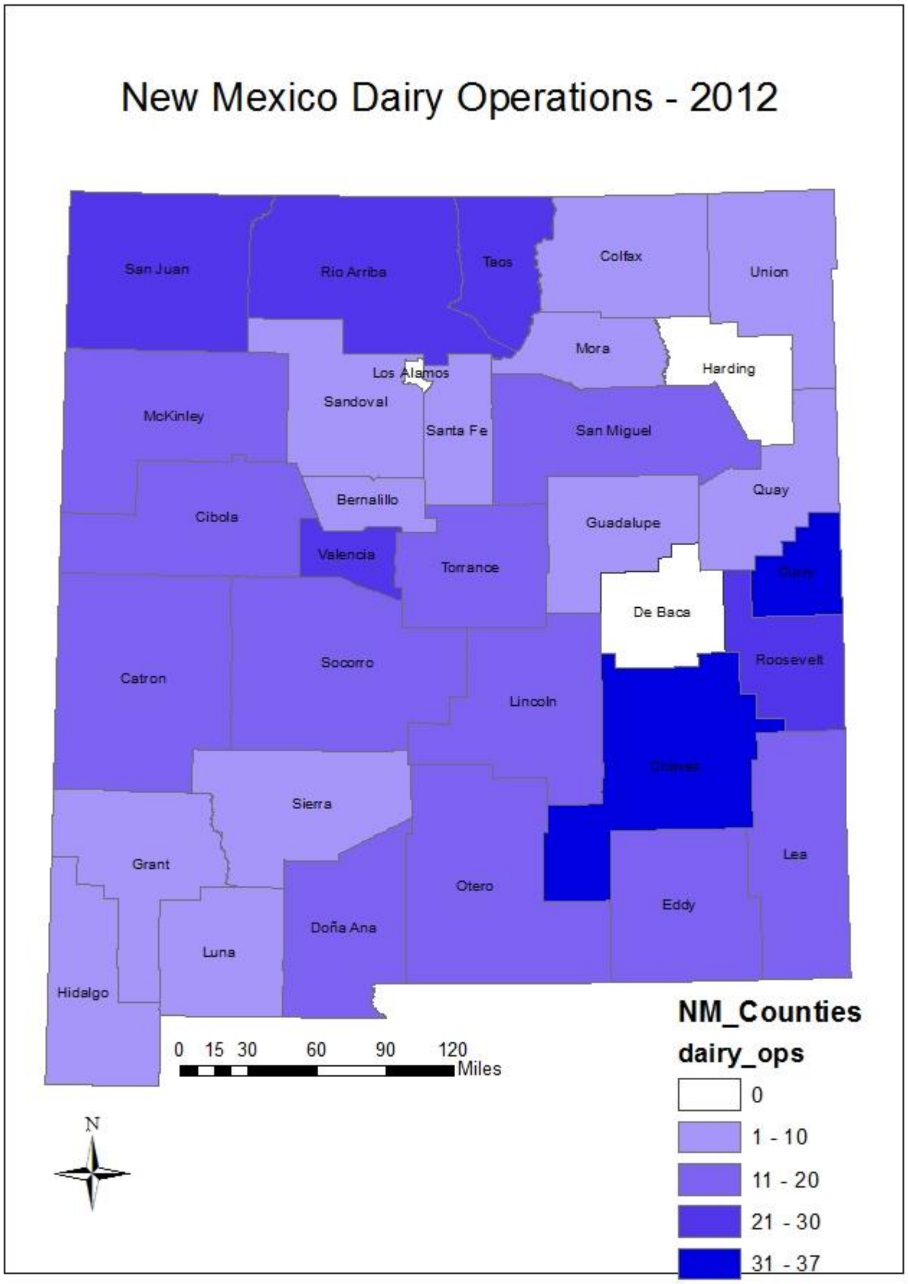
(USDA-NASS, 10/24/2014).

Figure 3. Milk Cow Totals and Milk Cow Herd Size



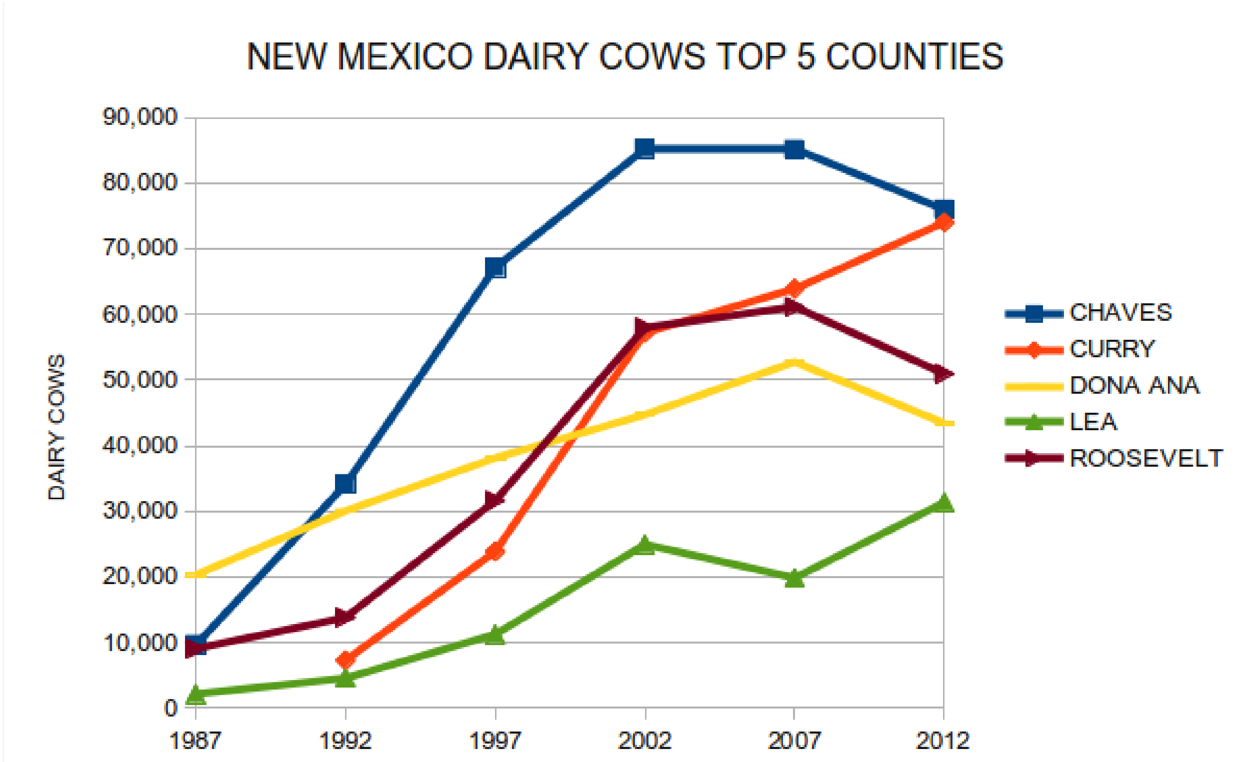
Data compiled from (United States Department of Commerce - Economics and Statistics Administration - Bureau of the Census, 1994, p. 31), (United States Department of Commerce - Economics and Statistics Administration - Bureau of the Census, 1994, p. 31), (United States Department of Agriculture- National Agricultural Statistics Service, 1999, p. 33), (United States Department of Agriculture, 2004, p. 20), (United States Department of Agriculture, 2009, p. 21), (United States Department of Agriculture, 2014, p. 21)

Figure 4. Spatial distribution of Milk Operations.



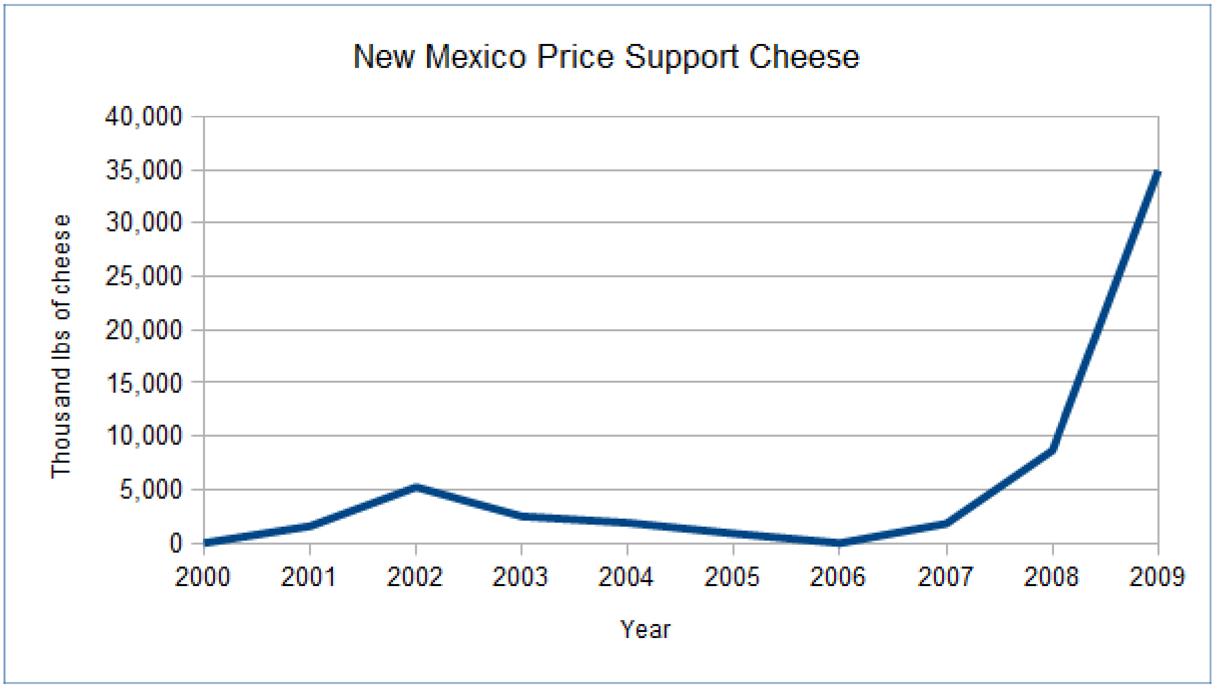
(United States Department of Agriculture, 2014, p. 285-289).

Figure 5. New Mexico Dairy Cows – Top Five Counties



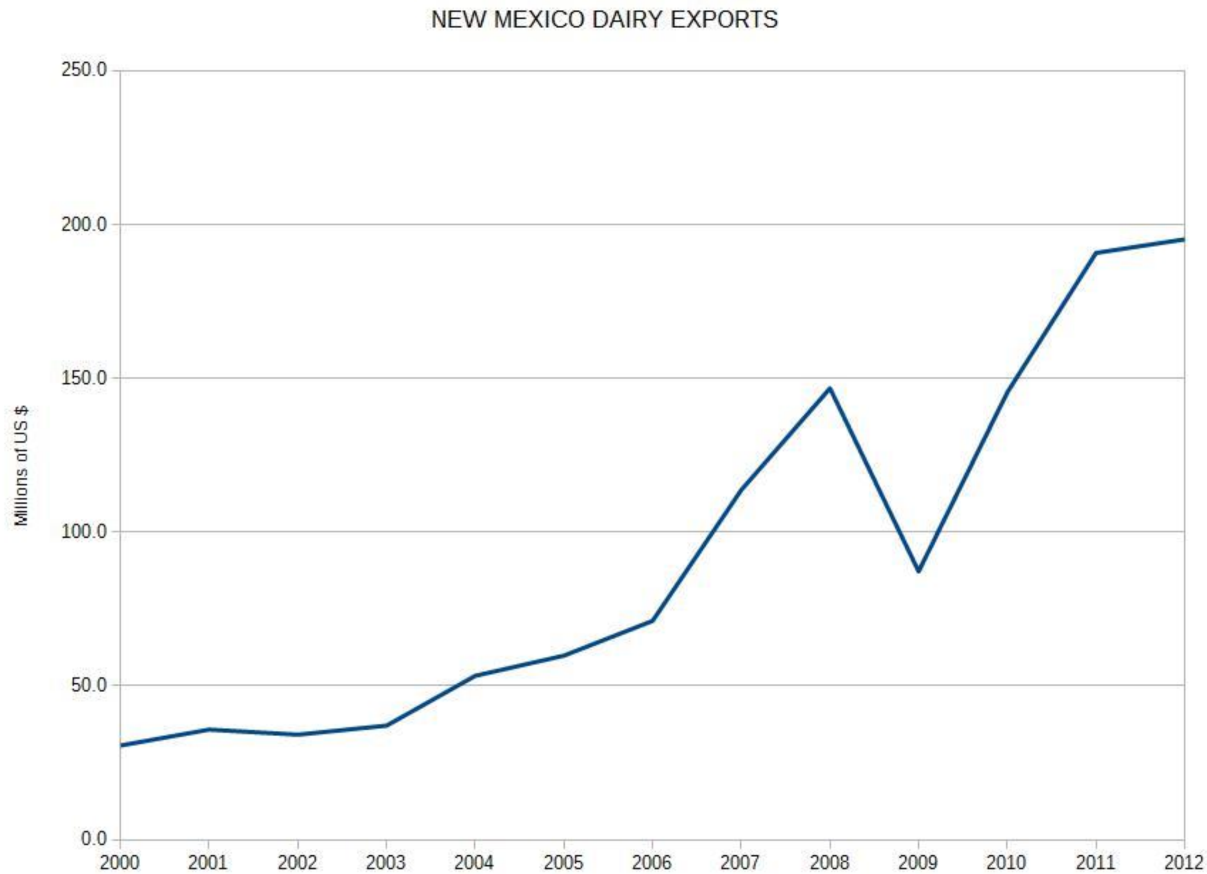
Compiled from (United States Department of Commerce - Economics and Statistics Administration - Bureau of the Census, 1994, p. 264), (United States Department of Agriculture – National Agricultural Statistics Service, n.d.-a)

Figure 6. New Mexico Price Support Cheese 2000-2009



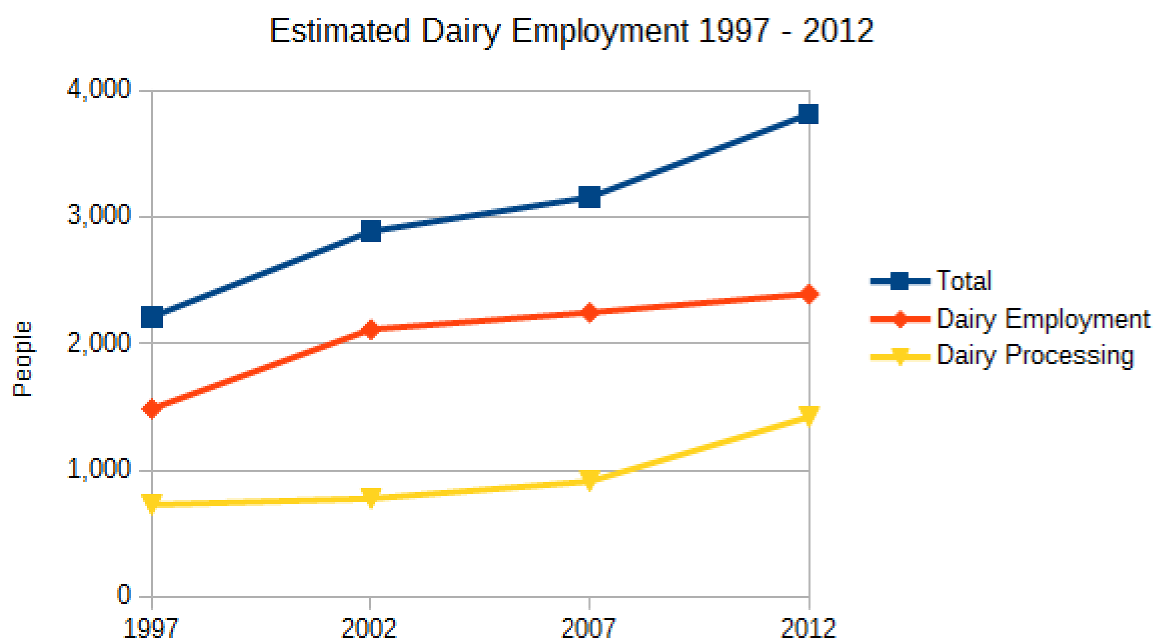
(United States Department of Agriculture, 2010, p. 12).

Figure 7. Value of New Mexico Dairy Exports 2000-2012



(United States Department of Agriculture – Economic Research Service, 2013).

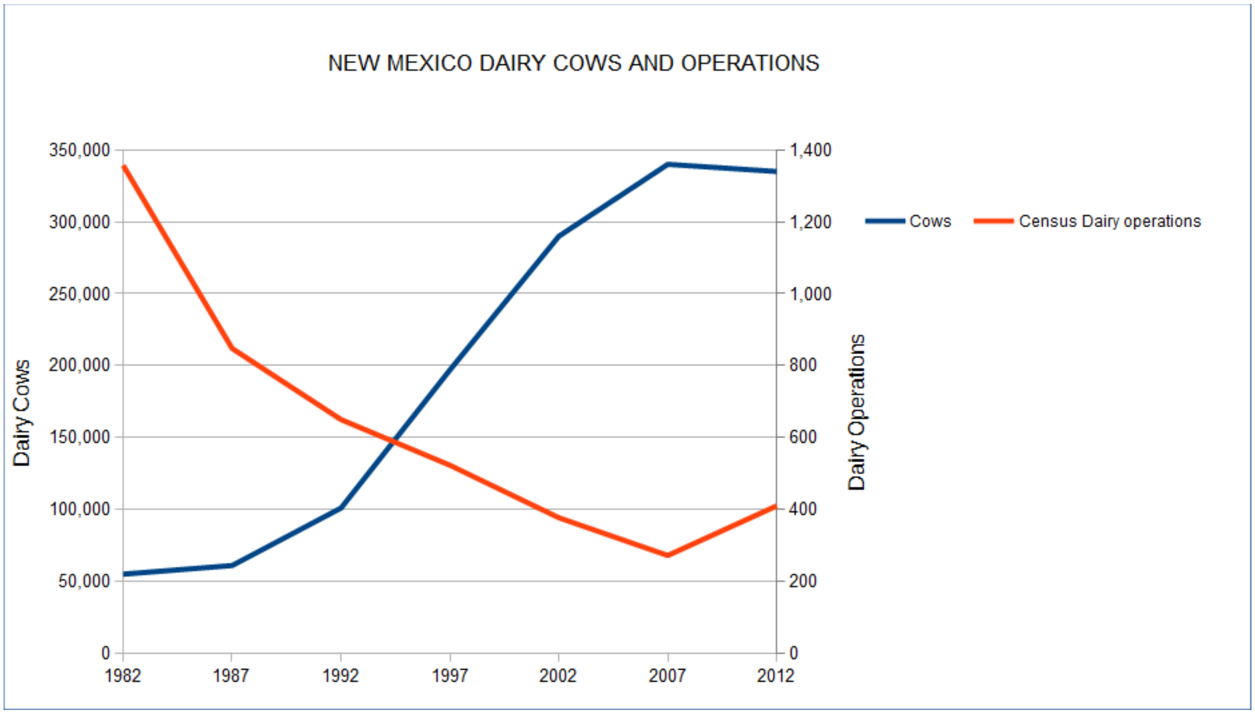
Figure 8. Estimated Dairy Industry Employment in New Mexico.



Note: The number was calculated based on one half of the quarterly average stable employment for the 0112 NAICS Subsector (Animal Production), which was added to the quarterly average of stable employment for the 3115 NAICS Industry (Dairy Product Manufacturing).

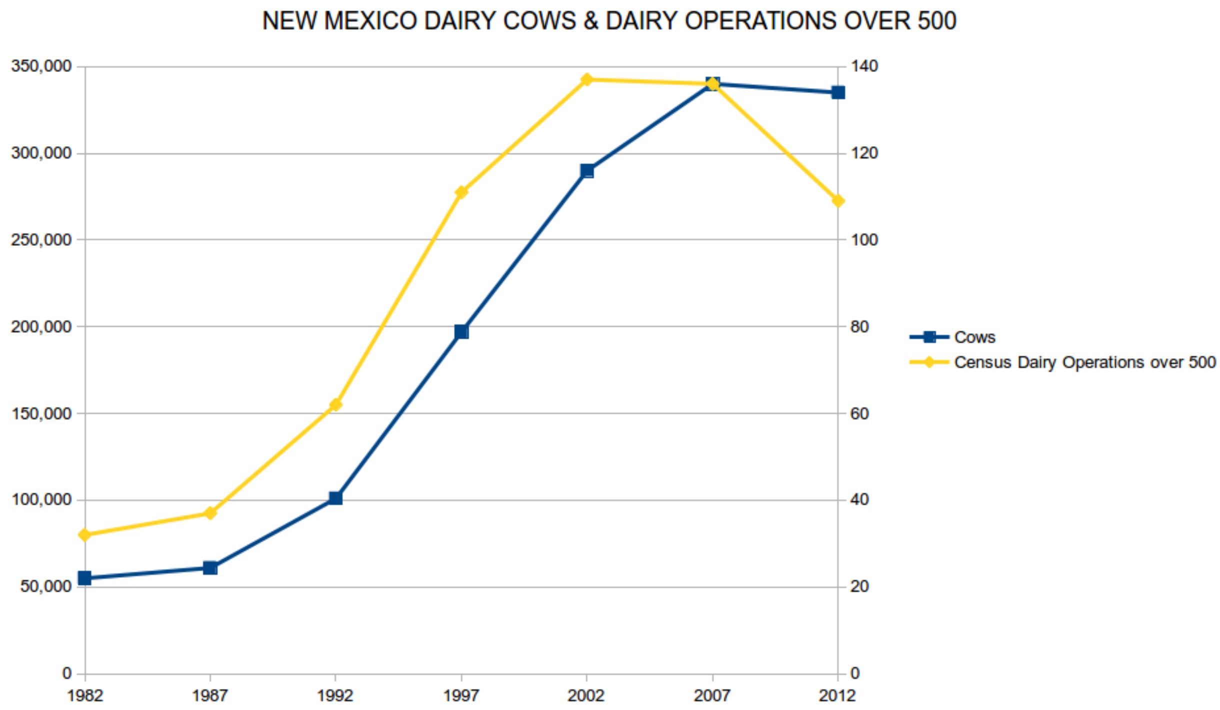
(U.S. Census Bureau, 2013)

Figure 9. Survey of Milk cows to Census dairy operations.



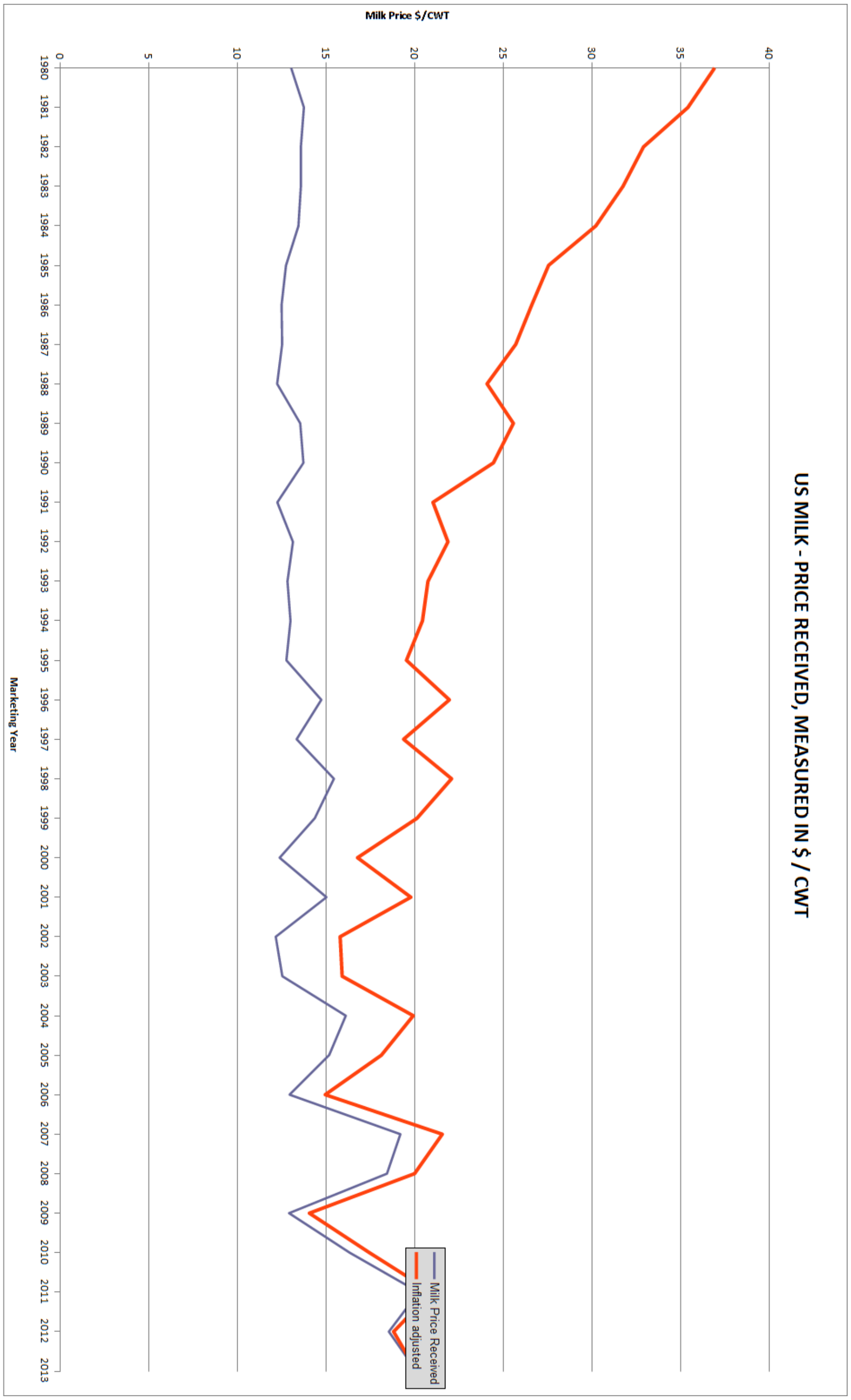
(USDA-NASS, 10/24/2014),
(United States Department of Agriculture, 2014, p. 7), (United States Department of Agriculture, 2009, p. 18), (United States Department of Agriculture - National Agricultural Statistics Service, 1999, p. 10), (United States Department of Agriculture - National Agricultural Statistics Service, 1989, p. 1)

Figure 10. Survey of New Mexico Dairy Cows to Census Operations over 500.



(USDA-NASS, 10/24/2014), (United States Department of Agriculture, 2014, p 21), (United States Department of Agriculture, 2009, p 21), (United States Department of Agriculture, 2004, p 20),(United States Department of Agriculture - National Agricultural Statistics Service, 1999, p 33), (United States Department of Commerce - Economics and Statistics Administration - Bureau of the Census, 1994, p 31), (United States Department of Agriculture - National Agricultural Statistics Service, 1989, p 30), (United States Department of Commerce - Bureau of the Census, 1984, p 15)

Figure 11. Dairy Price Received and Dairy Price Received Adjusted for Inflation.



Note: Inflation adjusted prices in 2013 dollars.

(United States Department of Agriculture - National Agricultural Statistics Service, n.d.-j),(United States Department of Labor - Bureau of Labor Statistics, n.d.)