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Utah County Level Drought Effect on Cattle Inventories 1981-2016

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UTAH COUNTY LEVEL DROUGHT EFFECT ON CATTLE INVENTORIES 1981-2016

by

Fred Openshaw

A thesis in the partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Applied Economics

Approved:

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UTAH STATE UNIVERSITY
Logan, Utah

2020

ABSTRACT

UTAH COUNTY LEVEL DROUGHT EFFECT ON CATTLE INVENTORIES 1981-2016

by

Fred Openshaw, Master of Science

Utah State University, 2020

Major Professor: Dr. Man-Keun Kim
Department: Applied Economics

The Utah cattle industry generates 20.6% of sales value for the agricultural sector. As well, this industry encompasses about 34.4% of Utah farms. Besides these figures, Utah cattle ranchers depend heavily upon both public and private lands for grazing as a primary source of feed for their herds. The soil moisture levels of pasturelands impacts the forage yield for a particular year. As a result, the primary purpose of this research is to determine if drought impacts Utah county cattle inventory numbers and what the magnitude of the impact is by analyzing data from 1981 to 2016. A secondary purpose of this research is also to estimate the potential economic impact drought has had on the Utah cattle industry. In looking at this effect, county-level PDSI data was collected and utilized in this study in a dynamic panel model. The results of this model showed that a moderate drought that would have an annual average PDSI index number between -2 and -2.99 was significant and would lead to cattle inventory numbers being decreased by 1,605 head of cattle at the county level. The research also showed that an unusually moist, very moist, and incredibly moist spell in the previous year in a particular county was also statistically significant and would decrease the following years county cattle inventory numbers by 752, 1,560, and 5,219 head of cattle respectively. Based off of the model it is estimated at the county level if in the previous year there was a moderate drought that the next year at the county level could reach $3.92 million. The economic impact at the Utah state level in the following year could reach $113.68 million. These values are according to the 2019 value per head of cattle that were reported by the United States Department of Agriculture (USDA).

(42 pages)

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Fred Openshaw

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INTRODUCTION

Utah Cattle Industry Background

In the state of Utah, the cattle calve sector has become a dominating sector since it has generated the most sales value and has either had the most or second to most amount of farms that have participated in this sector. Table 1 describes the market value statistics for Utah state over the period 1982-2017, from the census of agriculture that was collected by NASS on a five-year cycle . As shown in the third column, the Utah cattle and calve sector has either the most or second to most farms that participate in this industry in comparison to all farms that participate in Utah agriculture. Furthermore, the Utah cattle and calve sector has had the most sales value compared to any other agricultural sector. These statistics are consistent with Godfrey (2008), which suggests that the cattle sector has become the most dominant agricultural sector in Utah and an integrate part of the economy for rural communities in the state.

Table 1

Utah Cattle & Calve Industry Statistics 1982-2017

Census Year	Farms in the Industry	Total Farms[1]	% of Farms[2]	Industry Sales Value[3]	Total Sales Value[4]	% of Total Sales[5]
2017	6,333	18,409	34.4%	377,979	1,838,610	20.6%
2012	6,458	18,027	35.8%	364,214	1,816,147	20.1%
2007	6,257	16,700	37.5%	347,299	1,415,678	24.5%
2002	5,617	15,282	36.8%	371,418	1,142,567	33.3%
1997	7,598	14,181	53.6%	259,998	877,295	29.6%
1992	7,212	13,520	53.3%	269,610	725,159	37.2%
1987	7,520	14,066	53.5%	225,149	617,882	36.4%
1982	7,836	13,984	56.0%	184,445	555,428	33.2%

Source: USDA NASS Agricultural Census 1982-2017

1) All farms that are involved in Utah agriculture in a given census year. 2) This column was calculated by dividing farms in the industry by total farms all multiplied by 100. 3) This is total sales value that the Utah cattle and calve industry generated in ($1,000). 4) This is total sales value generated by Utah agriculture in ($1,000). 5) This column was calculated by dividing sales value in the industry by total sales value and multiplying by 100.

Additionally, figure 1 provides a graphical summary of how the cattle inventories numbers in Utah have increased and decreased over the past hundred years. Since 1935 Utah cattle inventories has been increasing from 411,000 to a maximum of 950,000 head of cattle in 1983. From 1983 to 2019, there have been cycles of cattle inventory decline and increase. The factors that contribute to these cycles in the Utah cattle industry are unknown; however, McGinty, Baldwin, and Banner (2009) stated that during that time, production cost have continued to increase. With production cost increasing during the 1983 to 2019 time period McGinty et al. (2009) mentioned that due to the cyclical nature in the Utah cattle industry, it could lessen the profitability. Due to the cyclical nature and that production costs have steadily increased, the hypothesis is that this has potentially caused the cycle of cattle inventory decline and increase over time. From 2003 till currently, cattle inventory has remained stable over the approximate range of 800,000 to 900,000 head of cattle. In addition it is hypothesized that climate factors have affected herd sizes in the past and possibly harmed this Utah agriculture sector.

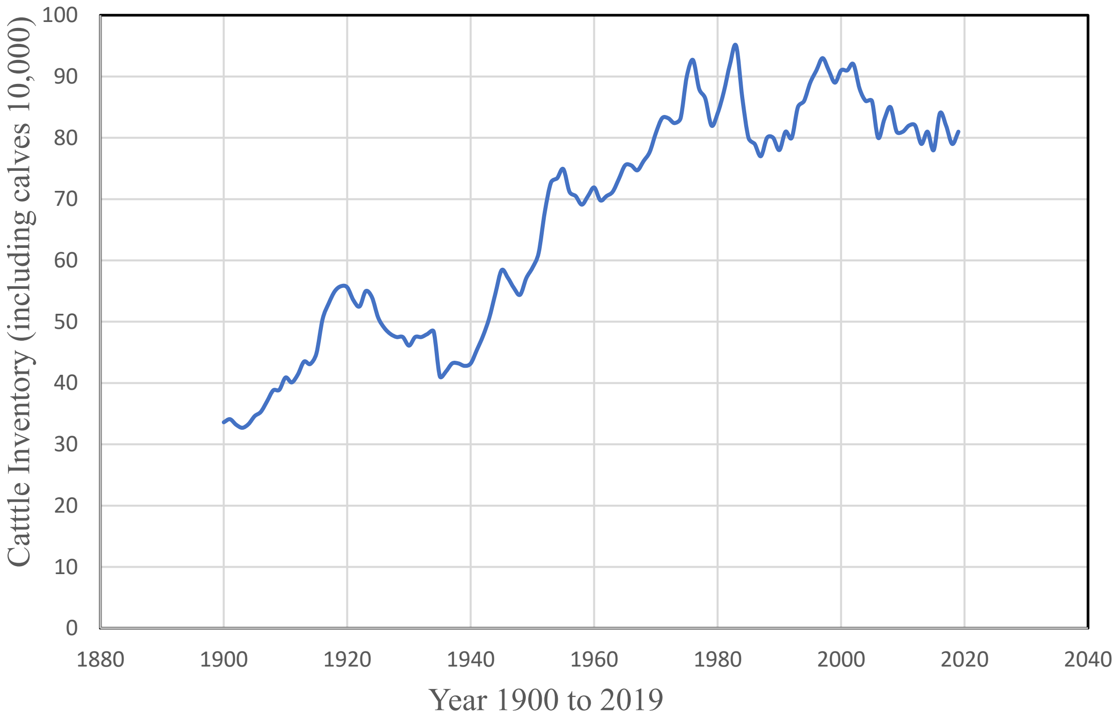

Figure 1
Utah Cattle Inventory 1900-2019
Source: USDA NASS 1900 to 2019

The availability of grazing land is another characteristic that shapes the Utah cattle and calves sector. Godfrey (2008) mentions that most Utah ranching operations depend upon grazing land, whether it is public or private, as a primary source of feed for herds. The Government Accountability Office (GAO) (2005) stated, having federal lands available to all livestock producers has increased the production of the whole livestock industry within the U.S. Within the state of Utah, private grazing land in 2017 totaled about 8.57 million acres according to the Utah state profile in 2017 (USDA, 2017). There are two federal government agencies that manage public land grazing in Utah state. The first agency is the Bureau of Land Management (BLM), and next is the National Forest Service. The BLM currently oversees about 2.2 million acres of public grazing land in Utah and offers 1410 grazing permits per year out to Utah livestock producers (BLM, 2020). These permits can provide around 1.3 million animal unit months (AUMs) in total (BLM,2020). The definition of AUMs is "the amount of forage needed to feed a 1,000 lb cow" Godfrey (2008). Now the public land managed by the National Forest Service; from 1986 to 2016, the number of grazing cattle has increased by 6,101 head of cattle. This increase also translates to an increase of 6,081 AUMs offered by the National Forest Service over that same period (USDA; 2017, 2007, 1997,1987). Since public and private grazing is imperative to the Utah cattle industry, any effect that lowers the yield of these pasture lands would result in a possible decrease in cattle herd size.

Utah Drought Background

Utah is known for being susceptible to drought. According to the National Integrated Drought Information System (NDIS) (2020), this agency states since 2000 a drought in Utah has lasted 288 weeks. Figure 2 demonstrates that from mid-2002 until 2006 and again in late 2012 to mid-2016, there was a period where the majority of Utah was in some degree of drought. Table 2 also provides information from 1981 to 2016 on what percentage of the 29 Utah counties were in different drought types. Some key takeaways from table 2 are that Garfield, Kane, Piute, Sanpete, and Sevier counties had 5.56% of the land area that experienced extreme drought from 1981 to 2016. Annually, for most of the counties, they either were in moderate drought or abnormally dry conditions during that same period.

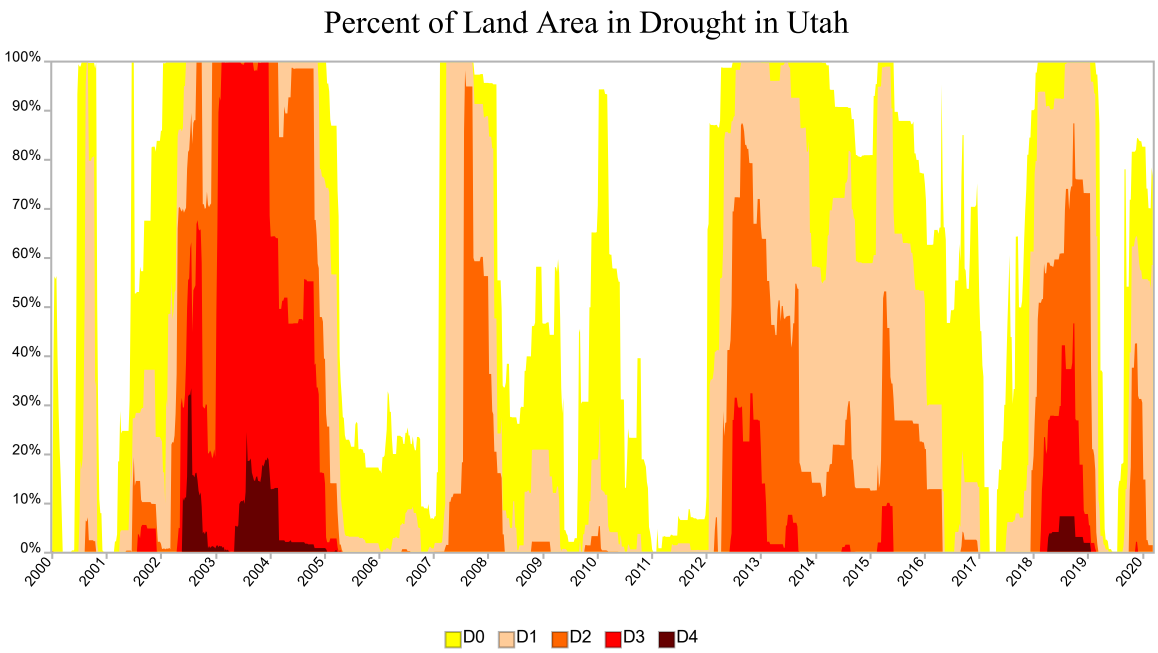

Figure 2

Percentage of Utah Area in Drought from 2000 through 2020

Source: NIDIS Drought in Utah, and United States Drought Monitor.
D0: Abnormally Dry causes exceptional pasture yield losses.
D1: Moderate Drought causes major pasture yield losses.
D2: Severe Drought causes pasture yield losses.
D3: Extreme Drought causes some pasture yield losses.
D4: Exceptional Drought causes slow growth of pastures.

Table 2

Percentage of Utah Counties in Different Drought Types 1981 to 2016

County	% Exceptional[1]	% Extreme[2]	% Severe[3]	% Moderate[4]	%Abnormally Dry[5]
Beaver	0.00	0.00	8.33	13.89	22.22
Box Elder	0.00	0.00	11.11	19.44	16.67
Cache	0.00	0.00	8.33	19.44	13.89
Carbon	0.00	0.00	8.33	11.11	13.89
Daggett	0.00	0.00	5.56	19.44	11.11
Davis	0.00	0.00	5.56	19.44	11.11
Duchesne	0.00	0.00	11.11	11.11	11.11
Emery	0.00	2.78	8.33	2.78	22.22
Garfield	0.00	5.56	2.78	5.56	19.44
Grand	0.00	2.78	11.11	2.78	19.44
Iron	0.00	0.00	8.33	13.89	19.44
Juab	0.00	0.00	8.33	13.89	22.22
Kane	0.00	5.56	5.56	2.78	19.44
Millard	0.00	0.00	8.33	16.67	19.44
Morgan	0.00	0.00	5.56	19.44	11.11
Piute	0.00	5.56	2.78	11.11	16.67
Rich	0.00	0.00	5.56	19.44	11.11
Salt Lake	0.00	0.00	11.11	22.22	11.11
San Juan	0.00	2.78	11.11	2.78	19.44
Sanpete	0.00	5.56	2.78	8.33	19.44
Sevier	0.00	5.56	2.78	11.11	16.67
Summit	0.00	0.00	5.56	19.44	11.11
Tooele	0.00	0.00	11.11	19.44	13.89
Uintah	0.00	2.78	11.11	8.33	19.44
Utah	0.00	0.00	5.56	22.22	16.67
Wasatch	0.00	0.00	5.56	19.44	11.11
Washington	0.00	2.78	8.33	11.11	19.44
Wayne	0.00	2.78	8.33	11.11	19.44
Weber	0.00	0.00	8.33	19.44	13.89

Sources: Centers for Disease Control and Prevention Palmer Drought Severity Index (PDSI), (1895-2016) and the United States Drought Monitor (USDM)

1) Exceptional Drought: PDSI range of [-5,-∞) and causes exceptional crop and pasture losses. 2) Extreme Drought: PDSI range of [-4,-4.99] and causes major crop and pasture losses. 3) Severe Drought: PDSI range of [-3,-3.99] and causes crop and pasture losses. 4) Moderate Drought: PDSI range of [-2,-2.99] and causes some crop and pasture losses. 5) Abnormally Dry: PDSI range of [-1,-1.99] and causes slow growth of crops and pastures.

Analogous to other states in the Intermountain West region, Utah is prone to droughts, and these drought years tend to reduce the profitability of cattle ranchers (McGinty et al., 2009). Consequently, investigating the relationship between drought and cattle herd sizes is vital in evaluating the impact of drought on cattle ranchers in this state.

Research Purpose

The main objectives for this research are, 1) discover the impact drought has had on Utah county cattle inventory numbers, 2) to quantify the impact of drought on Utah county cattle inventory numbers per year, and 3) to estimate the economic impact of cattle that are lost due to drought at the county and state level. The hypothesis is that since Utah is prone to droughts and pastureland grazing is utilized so heavily that drought will have a significant impact on cattle herd sizes in each county per year.

LITERATURE REVIEW

With the identification of the research objectives, an analysis of past work will provide further information on what previous work applies to this study. Drought classification is of importance to this study, and so research work that has defined different drought types is essential. As well, this review will look at previous research that has strived to quantify the impacts that drought has had on other agricultural sectors. Included in this review will be an analysis of past research that has investigated the economic impact that drought has had on the cattle industry and cattle inventory numbers within the U.S.

Wilhite and Glantz (1985) mentioned that throughout history, drought has been a regular part of the climate conditions for all areas in the U.S. The one area that drought has been more of a problem is in the western U.S (Wilhite & Glantz, 1985). Wilhite (1997) described drought as a "creeping phenomenon" in that it is a climactic event that is difficult to determine when it will end and how much the effect will be since it continually increases over the time frame of the drought. Freire-González, Decker, and Hall (2017) stated that drought in agriculture could have a lingering effect on the production of non-irrigated crops and pasture lands; this, in turn, can have lingering adverse effects on other industries as well. With that being the case, it is possible that having extended years that Utah counties are in drought conditions could result in a more massive effect on how much cattle herds sizes decrease. Besides that, a drought could result in the decimation of pasturelands in one year so that the number of cattle that can graze on non-irrigated pasture lands will be less in the following years.

Along with looking at drought and the effect it can have, Wilhite and Glantz (1985) mentioned that there are different drought classes, and one of these classes is called "agricultural drought" its symptoms is the shortage of water for crops and pasture lands. This type of drought usually is the first to occur (Wilhite,1997). Freire-González et al. (2017) they classified agriculture drought as being a part of the "green drought" category, which is the first to be affected at the start of drought conditions in an area.

Over the years there have been numerous studies done on analyzing the impact that drought has had on agriculture (Ding, Hayes, & Widhalm, 2011; Chowdhury, 2017; Dhoubhadel, Azzam, & Stockton, 2015; Belasco, 2013; Stockton & Wilson, 2007; Rucker, Burt, & LaFrance, 1984; Leister, Paarlberg, & Lee, 2015). There have also been reports done that analyze the economic impact that specific drought periods have had on certain regions in the U.S (Anderson, Welch, & Robinson, 2012; Watkins, 2012) and the nation as a whole (Henderson & Kauffman, 2012). Ding et al. (2011) mentioned that crops and pastures are directly affected by drought. Chowdhury (2017) research focused on the impact drought had on crops in North Dakota, South Dakota, and Minnesota. The one thing that is interesting about this study is that it utilizes PDSI numbers as an independent variable for capturing drought, which is the same variable this study will utilize as well. Henderson and Kauffman (2012) mentioned that from 2011 to 2012, pastures were affected by drought, and so ranchers had to reduce their cattle herd sizes because otherwise, they would have had to purchase feed from other costly sources.

Stockton and Wilson (2007); Leister et al. (2015) provided some insight as to what the fiscal effect of drought would be on cow-calf operations in the nation. With both of these studies even though the results do not provide information on how cattle inventory numbers would be decreased by drought. They do however provide some insight as to what the fiscal impacts of drought maybe for the U.S cattle industry. The following two paragraphs will mention what Stockton and Wilson (2007); Leister et al. (2015) utilized in factoring in drought and also what impact drought had on cow-calf operations.

Stockton and Wilson (2007), in their research, conducted a simulation of what cow-calf management practices would be best during a drought, and in their study, the drought index number utilized in the simulation was standard precipitation index (SPI). Stockton and Wilson (2007) simulated accumulated net worth as the way of determining which practices were best to utilize in drought conditions. From the simulation of 500 iterations, Stockton and Wilson (2007) noticed that March and June calving that relied on range forage and had an occurrence of a drought event resulted in the mean accumulated net worth change for calving operations would be an absolute value change of $100,145 and $156,993 respectively. In looking at the change in accumulated net worth for calving operations, having a drought occur severely decreased the net worth of operations that relied upon pasture lands for feed since the net worth would decrease by $156,993. With what Stockton and Wilson did in their study, even though the result looked at the effect drought would have on the net worth of a ranching operation, it does provide some insight in demonstrating that drought can potentially have an impact on these operations.

Leister et al. (2015) looked at the effects that the 2011-2012 drought had on the cattle industry, calculated the magnitude of this drought shock and the impact it would have on baseline moisture average. They then factored in that shock to modify the exogenous variables in the model (Leister et al., 2015). From that model, Leister et al. (2015) calculated the changes that would occur to the producer surplus of cattle ranchers. From their results, both 2011 and 2012, when the drought occurred, producer surplus saw negative changes in returns of 1,560.8 and 4,629 million dollars for all beef cattle ranchers in the U.S (Leister et al., 2015). What was unique from Leister et al. (2015) study was that even in 2013 were drought conditions were not impacting the country, the change in return of producer surplus for beef cattle producers was also negative at 4,769 million dollars. From those results, it could be probable that drought impacts not only the current year but also the upcoming year and potentially influences the behavior that cattle producers exhibit as they are making decisions on how many feeder cattle they will sell or hold back for breeding livestock in a given year.

Rucker et al. (1984) studied the drought impact on cattle inventories and was focused on the national level, and at Montana state level. Belasco (2013) looked at the national level, and how drought decreased cattle inventories. Dhoubhadel et al. (2015) focused on how drought would impact each part of the beef supply chain at the national level. Rucker et al. (1984), and Belasco, (2013) utilized hay crop production or yield as a way to account for drought and its effect on cattle inventory. Rucker et al. (1984) and Belasco (2013) described that hay production or yield would jointly symbolize what pasture yield was like during drought conditions.

Rucker et al. (1984) noted with their results that hay production in (tons) that accounted for drought was statistically significant in the models that they ran for total cattle herd size in both Montana, and the U.S. If hay production decreased by 10,000 tons then the next years cattle inventory numbers in Montana would be decreased by 2,710 head of cattle (Rucker et al., 1984). If the same decreased in the amount of hay produced occurred in the U.S. cattle inventory numbers, the following year would decrease by 781 head of cattle (Rucker et al., 1984). They also concluded that if hay production decreased by the same tonnage that in Montana, cattle inventory numbers in two years would increase by 2,440 head of cattle (Rucker et al., 1984). In the U.S, if hay production declined by the same tonnage, then cattle inventory would decrease by 918 head of cattle in two years (Rucker et al., 1984). From the results, hay production lagged by one and two years was statistically significant in those two models; however, the estimator for hay production lagged by two years in the Montana model had the opposite sign than predicted. This opposite sign would mean that if hay production decreased two years ago, total cattle herd size would increase in the current year. Rucker et al. (1984) stated that hay production lagged by one and two years was more statistically significant for the Montana total cattle herd model compared to the U.S total cattle herd model.

Dhoubhadel et al. (2015) looked at both the impact that drought had on grain crops and cattle industry in the U.S. In that study, one thing that is of interest is that they utilized both average rainfall and pasture yields as a way for accounting for drought. Dhubhadel et al. (2015) utilized an eleven year average of rainfall that occurred in the corn belt region to calculate a baseline average of how much annual rainfall occurs in the area. Based on the 2012 rainfall, Dhubhadel et al. (2015) found that there was a 32% deficit in rainfall from the baseline average in 2012. That 32% deficit in rainfall was taken into account in their model as a shock to the exogenous variables (Dhubhadel et al., 2015). They concluded that if in the U.S there was a drought were rainfall was decreased by 32%, average feeder cattle inventories would see a decrease of 10.4% at the farm level that is statistically significant at the 1% level (Dhubhadel et al., 2015).

Belasco (2013) has done the most recent research into measuring the effect that drought has had on cattle herd sizes over an extended period. The other thing that makes this research unique is that Belasco (2013) utilized a panel data model and the cross-sectional portion of the data set included all states within the U.S except for eleven states eliminated from the study due to cattle inventory being less than 100,000 head of cattle and the time portion was years from 1947 to 2012. Belasco (2013) transformed hay production variables into logarithm values. The results that Belasco (2013) concluded was that both hay production lagged by one and two years were statistically significant. The result would be that if hay production decreased by 1% in a specific state in both the previous year and two years ago, there would be a decrease in the current year cattle inventory for that state of .0683% and .0662%.

All of these previous studies have demonstrated that drought has influenced cattle herd sizes or cattle ranchers in some form. With that being the case, the reasons for this study is evident, since none of these studies have explicitly examined the effect of drought on Utah cattle inventory numbers on a county level. An equally unique aspect of this research is that the independent variable used to measure drought will be PDSI, which is different from other studies conducted which look at the drought effects on cattle inventories. Heim (2002) discussed that PDSI is easy to compare across years, and counties, and that this index is best for areas where rainfall is the primary source of soil moisture. Pastures in Utah rely on the soil moisture in order to grow the field crop that will turn into forage feed; that is why the PDSI index is utilized instead of any other drought indices in this study.

DATA

For this study, the dependent variable is total annual county cattle inventory numbers, including calves, collected from 1981 to 2016 from NASS. The drought variable utilized for this research is, monthly PDSI index numbers for each Utah county. The collection of the monthly PDSI index numbers from 1981 through 2016 came from the Center for Disease Control (CDC) database. From the monthly PDSI index numbers, the calculation of the annual average for each county occurred. The PDSI index number as was mentioned by National Center for Atmospheric Research [NCAR] (2019) can range from -10 (dry conditions) to 10 (wet conditions).

Besides those variables, this research utilizes three other variables as part of the model annual Utah hay prices, monthly feeder cattle futures prices in the U.S, and a binary variable for bovine spongiform encephalopathy (BSE) disease outbreak news reports that occurred in the U.S. Utah annual hay prices captures the effect feed input cost have on the cattle industry. Godfrey (2008) stated that besides pasture, forage hay is the other feed source utilized by the Utah cattle industry. Annual hay prices for Utah were retrieved starting in 1981 through 2016 from NASS. Hay prices are measured in dollars per ton.

Monthly future feeder cattle prices from 1981 through 2016 came from Quandl. The calculation of annual feeder cattle futures prices occurred from the monthly future feeder cattle prices. With the producer price index (PPI) retrieved from the Bureau of Labor Statistics, the conversion of nominal Utah annual hay and U.S future feeder cattle prices occurred. Feeder cattle futures prices in this study consider the demand that upstream members of the cattle industry supply chain have, and the pressure that this demand might have on cattle ranchers in selling more of their herd during a particular time. Feeder cattle futures prices are also measured in cents per pound.

The last variable in this model is a dummy variable that takes into account BSE news report that occurred from 2004 to 2007 in the U.S. Almas, Colette, and Amosson (2005); Hanrahan and Becker (2006) stated that in the U.S when the report came out starting in 2003 that BSE was in some beef cattle herds, there was a negative demand shock for beef in both the domestic and export markets. This negative demand shock would also affect cattle herd sizes during these years that this news report occurred. For this model, the hypothesis is that BSE will be significant and negatively affect cattle herd sizes. Almas et al. (2005); Hanrahan and Becker (2006) did mention that the demand shock that BSE caused to the beef industry mostly occurred from 2004 to 2007, and so the utilization of this period will occur. This dummy variable is encoded for 1 when the BSE news report occurred and 0 when it did not occur.

The sample includes 29 counties over 36 years (1044 observations in total). Table 3, reports summary statistics of all the non-binary variables, including cross-sectional summary statistics and time-series summary statistics. It is important to note that the price of hay is only available at the state level, and feeder cattle futures prices are only available at the national level. Due to the absence of county-level data, the cross-sectional standard deviations of these two variables are zero. In contrast to the price variables, cattle inventory and PDSI data have both cross-sectional and time-series summary statistics.

The PDSI index overall has a mean of about .04, which implies that soil moisture levels from 1981 to 2016 for all counties were in normal conditions on average across counties and years. Another observation from table 3 is that there is less variation from the mean PDSI index across counties than there is across years. In contrast, the time series summary statistics has a larger standard deviation than cross-sectional summary statistics. There is also a more extensive range of PDSI index numbers for the overall summary compared to other summary statistics mentioned in table 3. Table 3 shows that in Utah over the range of this study, the highest soil moisture level has been 7.63 that occurred in Davis county in 1983. Over that same range Washington county experienced a deficient PDSI level of -4.75.

Table 3

Overall Cross-Sectional and Time-Series Summary Statistics of Variables

Overall Summary Statistics of Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Cattle Inventory[1]	29214.56	22438.10	2500	110000
PDSI[2]	0.04	2.51	-4.75	7.63
Future Feeder Cattle Prices[3]	75.75	6.41	63.01	89.66
Hay Prices[4]	50.04	7.13	38.74	66

Cross-Sectional Summary Statistics of Variables

Variable	Standard Deviation	Minimum	Maximum
Cattle Inventory	22347.11	3669.44	92269.44
PDSI	0.20	-0.32	0.28

Time-Series Summary Statistics of Variables

Variable	Standard Deviation	Minimum	Maximum
Cattle Inventory	4780.61	9945.11	49511.78
PDSI	2.50	-4.39	7.39
Future Feeder Cattle Prices	6.41	63.01	89.66
Hay Prices	7.13	38.74	66

Sources: Cattle inventory and hay prices compiled from NASS, future feeder cattle prices compiled from Quandl, PDSI compiled from CDC, and calculated utilizing Stata.

1) Cattle Inventory: By head of cattle. 2) PDSI: It is a calculated index number from -10 to 10 (National Center for Atmospheric Research [NCAR], 2019). 3) Feeder Cattle Futures Prices: Cents per pound. 4) Hay prices: dollars per ton.

METHODOLOGY

For this research, the utilization of a panel data model will occur. Much like Belasco (2013), the objective of this research is to measure the impact drought has on cattle inventory in a particular group over a specified amount of years. At the start of the research, a panel model allowed the incorporation of the cross-sectional and time-series parts of the data set. One of the weaknesses of utilizing a panel model is that it lacks dynamic aspects that are present in the cattle industry. From preliminary results in utilizing a panel model, the calculated estimators demonstrated that the magnitude of the decrease in cattle inventories based on the explanatory variables would be higher than what intuitive reasoning would dictate. Jarvis (1974) summarized this reasoning that cattle breeding livestock is considered a capital good. The result is that cattle ranchers continuously have to hold back some of their female calves in order to have the breeding stock necessary to produce feeder cattle for the following years (Jarvis, 1974). By adding a dynamic variable to the panel model, it accounted for this principle to be fulfilled. This dynamic variable is a one year lag of the dependent variable in the model.

For this research, the dynamic variable would be cattle inventory lagged by one year in a particular county. The problem that occurs in simply adding this lagged dependent variable into a panel model is that the calculation of the other parameters will be wrong, as was stated by (Bond, 2002; Labra & Torrecillas, 2018). Bond (2002) also mentioned that even though the lagged dependent variable may not be a critical variable being analyzed in the model, it ensures that other explanatory variables have correct estimators. The utilization of these two equations will occur in this research.

1)

$$Y_{i,t} = \mu + \gamma * Y_{i,t-1} + \beta_x * X_{i,t} + \alpha_D * D_{i,t-1} + \beta_z * Z_t + \alpha_{bse} * bse_t + \varepsilon_{i,t}$$

2)

$$Y_{i,t} = \mu + \gamma * Y_{i,t-1} + \beta_x * X_{i,t} + \alpha_D * D_{i,t-1} + \beta_z * Z_{t-1} + \alpha_{bse} * bse_t + \varepsilon_{i,t}$$

In describing equation one and two i signifies the Utah counties [i=1,…,29], and t signifies the year [t=1982,…,2016]. $Y_{i,t}$ signifies cattle inventories, including calves in county i and year t. Then $Y_{i,t-1}$ on the right-hand side of the model, is a one year lag of cattle inventories, including calves in county i and year t-1. The variable that $X_{i,t}$ includes is the annual average PDSI numbers in county i and year t. $D_{i,t-1}$ includes six dummy variables for drought categories for what kind of moisture spell or drought spell occurred in county i in year t-1. The name of the dummy variable drought categories and the PDSI range that they cover are in table 4. Table 4 demonstrates that for the two equations, the base category utilized is a normal year, and then the rest of the variables are encoded as a one if in the previous year in county i the PDSI number was in a particular range. If it did not occur within that range, that dummy variable drought category for county i in year t-1 would then be zero.

Table 4

$PDSI_{i,t-1}$ Dummy Variable Drought Categories

Category Type	PDSI Range
Normal[1]	-1.9 to 1.9
Unusually Moist Spell	2 to 2.99
Moderately Moist Spell	3 to 3.99
Extremely Moist	4 and above
Moderate Drought	-2 to -2.99
Severe Drought	-3 to -3.99
Extreme Drought	-4 and less

Source: Compiled by Author

1) Base Category in Model

Z_t in equation 1 includes current national annual average future feeder cattle prices and annual hay prices in Utah for year t. Z_{t-1} in equation 2 includes a one-year lag of annual average future feeder cattle prices and annual hay prices in Utah. The variable bse_t is a dummy variable that takes into account the time frame that news reports of BSE occurred in the U.S.

During the research, there are some inherent limitations associated with models one and two. A limitation present in both of the models is that cattle inventory numbers at the county level include cattle owned by ranchers but also by dairies and any feedlots located in a specific Utah county. This limitation could mean that any reductions in county cattle inventory numbers may not be fully born by cattle ranchers and that other cattle operations may also bear the reduction that occurs due to drought. The reason that this limitation does exist is that the in Utah beef cattle inventory numbers at the county level were scares. By utilizing total cattle inventory numbers at the county level, a conclusion on how the drought has impacted cattle herd sizes at the county level could ensue. Another limitation of these models is that there are only annual total county cattle inventory numbers available from NASS. With only annual county cattle inventory numbers, it limits the ability to be able to look at potentially how county cattle inventory numbers potentially could decrease if a drought started, continued, or ended in the current or previous month in a particular year. This limitation can limit the ability to potentially examine if there is a particular month were county cattle inventory numbers are impacted more severely by drought. The last limitation with both of these models is that only monthly PDSI index numbers per county from 1981 until 2016 were retrievable. As a result, for this study, the PDSI index numbers past 2016 could not be analyzed in these two models.

Xtabond2 command, which was developed by Roodman in 2003, will be utilized in order to implement the dynamic panel model in Stata (Roodman, 2009). Roodman (2009) mentioned that xtabond2 utilizes generalized method of moments (GMM) in order to estimate the coefficients. A unique problem with this study is that the data set covers a more extended period, but a smaller amount of individual counties. Labra and Torrecillas (2018) mentioned that the rule is that dynamic panel models typically deal with a higher number of cross-sectional units and a lower number of periods. This study does not satisfy this rule and has more years compared to individual counties, and thus the calculation of more instrumental variables will result. Labra and Torrecillas (2018) describe that instrumental variables allow the inclusion of the lagged or difference dependent variable with other independent variables in the model. They also stated that there are two ways that the calculation of instrument variables occur first is difference instruments, and second is level instruments (Labra & Torrecillas, 2018). The utilization of first difference instruments will occur in this research. Labra and Torrecillas (2018) brought up that the number of instrumental variables generated for the lagged dependent variable depends on the number of time-periods. As a result, in this study, because there are more years covered than counties, this can lead to an exponential generation of instrument variables. With this problem, it can result in a higher probability that the model becomes over-identified (Labra & Torrecillas, 2018). Xtabond2 allows for the modification of the number of instrument variables that are calculated in order to prevent over-identification (Labra & Torrecillas, 2018; Roodman, 2009). As well the other reason for the utilization of xtabond2 in Stata is that both the autocorrelation tests and overidentification tests are performed automatically (Labra & Torrecillas, 2018).

EMPIRICAL RESULTS / ECONOMIC IMPACT

Empirical Results

As previously mentioned, the regression of the two models occurred through the statistical software developed by StataCorp. The results for these two models are in tables 5 and 6. Table 5 includes the results of the first model, which includes the current year estimated coefficients for hay prices and feeder cattle futures prices. While table 6 includes the results of the second model, which only has lagged hay prices and feeder cattle futures prices. Included in both of these tables are the test results for autocorrelation and over-identification. The first test to look at is for autocorrelation the Arellano-Bond AR1 and AR2 tests. P-values for AR1 and AR2 test are respectively .001, and .419 for the first model and .001 and .527 for the second model. With a 5% level of significance, or a p-value that is higher than .05 means no rejection of the null hypothesis of no autocorrelation. Both of these models, the error term is correlated in the first order but uncorrelated in the second-order. As a result, both models are correctly specified (Labra & Torrecillas, 2018).

Table 5

Model 1 Regression and Test Results

Variable	Coefficients	Corrected Standard Error	Level of Significance	95% Confidence Interval	
				Lower	Upper
Lagged Cattle	0.896	0.053	***	0.792	1
PDSI	41.278	109.141		-172.635	225.192
lwet1_d[1]	-834.049	481.900	*	-1778.560	110.458
lwet2_d[2]	-1943.678	1027.487	*	-3957.520	70.160
lwet3_d[3]	-5571.546	912.742	***	-7360.490	-3782.605
ldry1_d[4]	-1712.366	1019.577	*	-3710.700	285.967
ldry2_d[5]	-864.249	1314.102		-3439.840	1711.344
ldry3_d[6]	1423.752	5474.837		-9306.730	12154.240
Feeder Cattle Futures Prices	-27.879	19.979		-67.037	11.280
Hay Prices	15.155	20.173		-24.384	54.693
BSE	-912.108	471.802	*	-1836.820	12.607
Test Type		Result			
AR1[7]		0.001			
AR2[7]		0.419			
Sargan		0			
Hansen[7]		0.625			

*,**,*** indicates significance at the 10%, 5%, 1% levels.
Number of instrument variables utilized was 34.
1) Unusually Moist Spell. 2) Moderately Moist Spell. 3) Extremely Moist Spell. 4) Moderate Drought. 5) Severe Drought. 6) Extreme Drought. 7) Arellano-Bond autocorrelation tests. 8) Based on the Hansen test this model is robust but can be weakened by many instruments.

Table 6

Model 2 Regression and Test Results[1]

Variable	Coefficients	Corrected Standard Error	Level of Significance	95% Confidence Interval	
				Lower	Upper
Lagged Cattle	0.890	0.062	***	0.768	1.013
PDSI	80.377	86.212		-88.596	249.349
lwet1_d[2]	-752.791	432.125	*	-1599.741	94.158
lwet2_d[3]	-1560.129	931.264	*	-3385.374	265.115
lwet3_d[4]	-5219.599	759.864	***	-6708.906	-3730.292
ldry1_d[5]	-1604.912	950.913	*	-3468.667	258.843
ldry2_d[6]	-800.427	1511.255		-3762.431	2161.577
ldry3_d[7]	1745.163	8176.014		-14279.530	17769.860
Lagged Feeder Cattle Futures Prices	-1.814	26.659		-54.065	50.437
Lagged Hay Prices	-8.662	14.737		-37.547	20.223
BSE	-1117.243	551.284	**	-2197.739	-36.746

Test Type	Result
AR1[8]	0.001
AR2[8]	0.527
Sargan	0
Hansen[9]	0.564

*,**,*** indicates significance at the 10%, 5%, 1% levels.

Number of instrument variables utilized was 34.

1) The final model. 2) Unusually moist spell. 3) Moderately moist spell. 4) Extremely moist spell. 5) Moderate drought. 6) Severe drought. 7) Extreme drought. 8) Arellano-Bond autocorrelation test. 9) Based on the Hansen test this model is robust but can be weakened by many instruments.

The next test included in the tables is that for overidentification, which examination occurs using the Sargan and Hansen tests. These tests depend on whether the error term is homoscedastic or heteroskedastic. The null hypothesis of no overidentification is rejected utilizing the Sargan test for both models (p-value for model 1 = 0, and p-value for model 2 = 0), but it is not rejected by utilizing the Hansen test for both models (p-value for model 1 = .564, and p-value for model 2 = .625). Under the assumption that the error term is heteroskedastic, and the conclusion is that the overidentification issue is not present in both models. As well it can be concluded that both models are robust since there was no rejection of the null hypothesis in the Hansen test as long as there is not an excessive amount of instrument variables calculated. A struggle that was present with both models is that originally the number of instruments used by default was excessive, and so as a result, as shown in tables 5 and 6, the number of instruments utilized in these models has been reduced down to 34, to ensure that there is no overidentification issue.

In this study, it was unsure if feeder cattle futures prices and hay prices should be lagged or not. In analyzing the results, neither current nor lagged feeder cattle futures prices and hay prices are statistically significant. By recognizing those results, what truly elevates one model over the other is that the lagged future feeder cattle prices and hay prices both had negative coefficients. There are two reasons that this important and elevates model two over model one. The first intuitive reason is that since cattle inventory includes the head of cattle owned by cow-calf operations, dairies, and feedlots in a specific county, the lagged hay, and future feeder cattle prices show the correct signs. The reason is that as hay and feeder cattle futures prices increase in the previous year, ranchers sell more of their cattle to be profitable. With their decision to sell more cattle, it can result in them selling more of their breeding herd, and the outcome is that cattle inventory numbers in the next year will decrease by there being an increase in hay and feeder cattle prices from that previous year. With that concept, if current feeder cattle futures and hay prices increase and induce ranchers to sell more of their herd, including some of their current or potential breeding herd, that number is then potentially transferred to feedlots that are in the same county or state. This outcome means that at the county level, cattle inventory numbers should not change instantly, but rather over time. The final reason is that the impact of having higher feeder futures cattle and hay prices will impact future county cattle inventory numbers. The reason is due to the biological lag that occurs in cattle production. Since ranchers or cow-calf operations begin the beef supply chain if in a previous year they decreased their breeding cattle herds, the result will be that there will be additional years that these operations will need in order to be producing at the same level before the increase in prices occurred. In conclusion, the selection of model two resulted because of those reasons, and the results for that model are in table 6.

For this study, a robustness check of the final model occurred by eliminating one insignificant variable at a time from the final model. Key results analyzed during these tests was if variables became significant or insignificant and had changed in the sign of the coefficient. These insignificant variables that were dropped one in the five tests were PDSI, severe and extreme drought, lagged feeder cattle futures prices, and lagged hay prices. Table 7 includes the results of the five tests.

Table 7

Robustness Check of Final Model Parameters

Variable	Test 1[1]	Test 2[2]	Test 3[3]	Test 4[4]	Test 5[5]
Lagged Cattle	0.91	0.86	0.90	0.90	0.90
	(***)	(***)	(***)	(***)	(***)
PDSI	-	83.41	58.77	75.53	59.60
	-	-	-	-	-
lwet1_d[6]	-756.80	-619.09	-817.64	-802.82	-716.53
	(**)	-	(*)	(*)	-
lwet2_d[7]	-1727.30	-1559.03	-1704.21	-1538.70	-1846.98
	(**)	-	(*)	-	(**)
lwet3_d[8]	-4947.09	-5193.82	-5361.94	-5306.05	-5411.72
	(***)	(***)	(***)	(***)	(***)
ldry1_d[9]	-1963.85	-1879.45	-1986.47	-1640.80	-1784.56
	(***)	(***)	(*)	(*)	(*)
ldry2_d[10]	-768.03	-	-408.15	-742.22	-1008.08
	-	-	-	-	-
ldry3_d[11]	1353.08	-1187.78	-	2243.09	1812.71
	-	-	-	-	-
Lagged Feeder Cattle Prices	-2.60	-5.73	-2.49	-	-2.68
	-	-	-	-	-
Lagged Hay Prices	-6.43	-10.89	-11.46	-7.38	-
	-	-	-	-	-
BSE	-1135.55	-1166.24	-1225.91	-1223.72	-1043.35
	(*)	(**)	(**)	(**)	(*)

*,**,*** that are in parenthesis indicates significance at the 10%, 5%, 1% levels.
1) PDSI was dropped. 2) ldry2_d was dropped. 3) ldry3_d was dropped. 4) Lagged feeder cattle future prices was dropped. 5) Lagged hay prices was dropped. 6) Unusually moist spell. 7) Moderately moist spell. 8) Extremely moist spell. 9) Moderate drought. 10) Severe drought. 11) Extreme drought.

Table 7 demonstrates that the results of the tests of one and three show that by dropping both PDSI and extreme drought from the final model, all significant variables in the final model such as lagged cattle, unusually, moderately, extremely moist spells, moderate drought, and bse remained significant at the 10% level. The results of these two tests show that the other insignificant variables did not become significant upon dropping

PDSI and extreme drought one at a time. The signs of the significant variables did not change, as well, upon dropping these two variables separately. From these two test results, it is essential to note that insignificant variables from the final model did not become significant. The conclusion is that both PDSI and extreme drought are not crucial to the final model and that the estimated coefficients are robust in that regard.

The results for tests two, four, and five in table 7 demonstrate that eliminating severe drought, lagged feeder cattle futures, and hay prices resulted in some changes compared to the model in table 6. Test two results showed that by eliminating the severe drought variable, both unusually, and moderately moist spells became insignificant at a 10% level of significance. The parameters of the other significant variables from the final model did not switch signs nor became insignificant. Also, the other insignificant variables did not become significant as well from test two's results.

Results of tests four and five demonstrate that one of the significant variables from the final model became insignificant at a 10% level of significance, and those variables were unusually and moderately moist spells. In comparison to test two, the other significant variables from the final model remained significant, and they kept their same signs. The results of tests four and five demonstrate that the other insignificant variables in the final model did not become significant with eliminating either lagged feeder cattle futures prices or lagged hay prices. In conclusion, these five tests show that the significance of the parameters for the unusually moist spell and moderately moist spell, found in model 6, is not robust to the model specification.

In looking at the results as was expected, the lagged cattle inventory variable is highly significant. What this coefficient means is that from the previous year, 89% of cattle will be kept in a specific county. As for PDSI at the current year, it is not statistically significant from zero on effecting cattle inventories at the county level per year. After PDSI, the dummy variables that take into account the different moisture and drought levels from the previous year are listed as well in table 6 what the different variable names mean are fully described in the notes section of table 6. Out of all those dummy variables, moderate drought is significant at a 10% level of significance. Extremely moist condition was highly significant at a 1% level of significance. What is interesting is that both unusually moist and moderately moist spells were statistically significant at a 10% level of significance.

Along with those two variables being significant, it was interesting to notice was that if there was an unusual moist spell in the previous year that the sign was not as expected based on previous information. The expectation was that an unusually moist spell in the previous year would have a positive impact on county cattle inventory numbers. The reason that the sign is different than expected is that ranchers may not be able to utilize pasture lands as quickly when there is an unusually moist spell. Since normal conditions is the base category for this dummy variable drought category, any other type of conditions is less than optimal for ranchers, dairies, and feedlots in Utah and so if any climatic event occurs, then cattle inventories will be decreased in the following year.

In looking at this dummy variable category, the previous year's condition that seems to have the highest magnitude is if there was an extremely moist spell that occurred in a given county than the following year cattle inventory numbers in that county will be decreased by about 5,220 head of cattle in comparison to normal conditions in the previous year. The next variable that appears to be second in magnitude is if there were a moderate drought in the previous year, then cattle inventory in that particular county the decreased would be about 1,605 head of cattle in comparison to normal condition in the previous year. The last two variables that have less of an impact on cattle inventory numbers is if there was a very moist or unusually moist spell that occurred in the last year the result is that ranchers in that particular county will decrease cattle inventory numbers by 1,560 and 753 head of cattle respectively in comparison to there being a normal soil moisture level that occurred in the previous year.

Looking at the dummy variable for BSE first thing to note is that it is statistically significant at the 5% level. Also, the sign of the coefficient is as expected; and the result would be that from 2004 to 2007, cattle inventory numbers in all counties would decrease by about 1,117 head of cattle per year during that period.

Economic Impact of Drought

After looking at the results, the other objective of this research is to determine the economic impact that drought has had at the Utah cattle industry at the county and state levels. From the Utah Annual Bulletin 2019, the dollar value per head of cattle from 2015 to 2019 was retrieved (USDA, 2019). According to the report done by the USDA (2019) the value per head of cattle in Utah in 2019 was $1,130. At the county level in looking at the mean loss to cattle inventory numbers if there was a moderate drought in the previous year of 1,604 head of cattle see table 6. The mean estimated economic loss each county would incur ends up being $1.81 million. This estimated economic loss per county could also reach as high as $3.92 million.

In considering the estimated economic impact at the state level if all counties experience a moderate drought in the previous year the mean loss would be $52.59 million. It is possible that at the state level if all counties experienced a moderate drought in the previous year that the estimated economic impacted would result in a loss of $113.68 million.

CONCLUSION

In conclusion to this study, the results show that the previous year's drought category, if it was a moderate drought, will decrease the current year's county cattle inventory numbers. The results concluded that a negative impact would occur to county cattle inventory numbers if the previous year experienced an extreme, very moist, or unusually moist spell. Another thing to mention is that from this study, the estimated economic impact that drought has had on the Utah county level for the cattle industry could be as high as $3.92 million or $113.68 million at the state level.

Based on the results in Utah, helping to assist ranches or cow-calf operations at the county that are experiencing a moderate drought in the current year, can help prevent cattle inventory numbers from decreasing in the next year. It could allow those two operations the ability to pay for the added feed expense incurred and maintain more of their breeding herd to ensure that production does not decrease in the following year. The form of this assistance is unsure based on the limitations of this study. One recommendation from this study is potentially striving to collect monthly county cattle inventory numbers at the rancher or cow-calf operation level. The collection of this data can lead to a more in-depth understanding of how monthly drought can impact ranchers' cattle herd sizes. By looking into this study, assistance can be more accurately provided to cattle ranchers, so that minimization of supply shocks to the cattle industry occur in Utah. Additional studies which can occur in the future is a more current analysis of the impact that drought has had on cattle inventories in the western U.S and Utah. A more current analysis of how the drought in the most recent years has affected cattle herd sizes as well and also potentially breeding herd sizes at the Utah county level. Another study that could ensue as a result of this study is looking at the impact that drought has on sheep inventory numbers per county in Utah and the U.S. The reason is that drought would also impact sheep herds since they rely on the forage yield that pasture lands produce.

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