8-2015

# Evaluating Agriculture Sustainability in Arizona

Anne M. Paz

## APUS Library Capstone Submission Form

This capstone has been approved for submission to and review and publication by the APUS Library.

| | | | |
|---|---|---|---|
| **Student Name** [Last, First, MI] * | Paz | Anne | M |
| **Course Number** [e.g. INTL699] * | EVSP699 | **Paper Date** [See Title pg.] | 06/2015 |
| **Professor Name** [Last, First] * | D'Andrea, Elizabeth | | |
| **Program Name** * See list | Environmental Policy and Management | | |
| **Keywords** [250 character max.] | agriculture, sustainability, Arizona | | |
| **Passed with Distinction** * Y or N | Y | | |
| **Security Sensitive Information** * Y or N | N | | |
| **IRB Review Required** * Y or N | N | If YES, include IRB documents in submission attachments. | |
| **Turnitin Check** * Y or N | Y | All capstone papers must be checked via Turnitin. | |

* Required

## Capstone Approval Document

The thesis/capstone for the master's degree submitted by the student listed (above) under this title *

Evaluating Agriculture Sustainability in Arizona

has been read by the undersigned. It is hereby recommended for acceptance by the faculty with credit to the amount of 3 semester hours.

| Program Representatives | Signatures | Date (mm/dd/yyyy) |
|---|---|---|
| Signed, 1st Reader * [capstone professor] | Dr. Elizabeth DAndrea — Digitally signed by Dr. Elizabeth DAndrea Date: 2015.06.14 21:31:26 -04'00' | 06/14/2015 |
| Signed, 2nd Reader (if required by program) | | |
| Recommendation accepted on behalf of the program director * | Digitally signed by CAPT Carol A. Pollio, Ph.D. DN: cn=CAPT Carol A. Pollio, Ph.D., o, ou=American Public University System, email=cpollio@apus.edu, c=US Date: 2015.06.27 20:04:42 -04'00' | 06/27/2015 |
| Approved by academic dean * | | |

* Required

EVALUATING AGRICULTURE SUSTAINABILITY IN ARIZONA

A Master Thesis

Submitted to the Faculty

of

American Public University

by

Anne Marie Paz

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

June 2015

American Public University

Charles Town, WV

DEDICATION

I dedicate this thesis to my loving husband. Without his unconditional love and support, the completion of this work would not have been possible.

## ACKNOWLEDGMENTS

I wish to thank the members of my committee for their unwavering support. Their guidance is most appreciated. Dr. Carol Pollio has been key to guiding me in a clear direction throughout this process.

I am greatly appreciative of the professors throughout my environmental policy and management program, as they have provided me the tools necessary to progress in a career of sustainability.

ABSTRACT OF THE THESIS

EVALUATING AGRICULTURE SUSTAINABILITY IN ARIZONA

by

Anne Marie Paz

American Public University System, June 21, 2015

Charles Town, West Virginia

Professor Carol Pollio, Thesis Professor

This research focuses on Arizona's top agriculture commodities in order to better understand the environmental impact of agriculture in Arizona compared to the rest of the United States. A single state agriculture analysis allows for a tailored approach to sustainable agriculture research. This type of approach is important, because each state has a unique agriculture climate with many different characteristics of production. The first phase of this research determines the top agriculture crop and livestock commodities in Arizona and compares them to the United States. An agriculture footprint is calculated using this information, which highlights the areas where Arizona has the largest impact within the United States. The production methods of the items with the largest agriculture footprint are then analyzed in order to determine the specific environmental impacts associated with producing these top

commodities. The final phase of the research will include an analysis of the production methods determined in the second phase of research with current information on sustainability. This will allow for a determination of Arizona's agriculture sustainability and where they could possibly improve in order to protect the environment.

TABLE OF CONTENTS

**Evaluating the Sustainability of Arizona's Agriculture**

Early United States agriculture consisted of subsistence farming, where families produced just enough resource to sustain life (Welling, 2012). This type of farming was heavily labor intensive, and the entire family held certain responsibilities on the farm. In the early 1900s, nearly 40% of the country's work force consisted of agriculture workers (Dimitri, 2005). Advancements in science and technology, however, significantly changed the makeup of the agriculture industry. Heavy machinery such as planters, cutters, huskers, cream separators, hay driers, and incubators, among many other technology advancements, lowered the labor intensity of agriculture practices, thereby reducing the number of workers required to produce output. Not only did it reduce the number of people required to work, but advancements in farming efficiency also increased total production output (Welling, 2012). The expansion and reliability of agriculture has allowed for the mass production of farm commodities like crops and livestock products, both of which the United States has become heavily reliant on as to feed its population and as economic exports.

The technological and efficiency advancements of farming practices has allowed for an overall increase in total farm output across the country (Alston, 2010). Farm output in the United States has risen at an average, consistent rate of 1.5% per year since the mid-1900s (ERS, 2014). This increase in output is reflected in commodity sales, which have increased nearly 300% to $400 billion in the past century (USDA, 2014). While farm commodity output has soared, the total number of farms producing commodities has remained relatively stable. The share of production, however, has drastically changed. Family farms, farms that are solely owned by the operator or the operator's family (Hoppe, 2014), account for 97% of total farms in the United States. The United States Department of Agriculture (USDA) characterizes these family farms as small, medium, or large. This characterization is based on the individual farm's aggregate annual income- large farms earn a total annual income of at least $350,000 or more, mid-sized farms earn an annual income between $350,000-$999,999, and large-scale farms earn one million dollars or more per year (Hoppe, 2014). Since the mid-1900s, the make up of these small, medium, and large farms has shifted. For example, as of 2011, small farms account for 90% of all family farms, but they only produce 26% of total farm output for the country. Mid and large-scale farms, on the contrary, account for only 8% of total family farms, but they produce over 60% of total farm output (Hoppe, 2014). This disproportional profile of United States farm output has significant implications for the environment.

The world's population has increased four fold in the past 150 years (McKibben, 2012). While the United States consists of less than 5% of the world's population, the country uses almost 35% of the world's natural resources (Pojman & Pojman, 2012). The country's larger population has become more dependent on agriculture, which has forced the agriculture industry to create more output. Creating more output, inevitably, has increased the demand of inputs, which includes the use of natural resources. For small farming businesses, the majority of farm operations in the United States, it is more cost advantageous to produce a single crop, thereby decreasing product variance per farm (Alston, 2010). Little product variance stresses soils and increases the number of pesticides, hormones, and antibiotics necessary to protect or further enhance the output (injecting hormones in livestock or spraying crops with insecticides, for example) (Wall & Smit, 2005). Small farms are not the only category of farms conducting operations that are harmful to the environment. Differing from small farms, large farming operations, those that consume the majority of agriculture profit in the United States, usually have the means to produce more than one commodity per farm. Unfortunately, the shear size of the operation requires much more water and energy input compared to their smaller farm counterparts (Wall & Smit, 2005). Regardless of size or source of environmental impact, both small and large farming operations utilize a significant amount of natural and artificial resources that heavily influence the environment.

Climate change is the overall warming of the planet due to anthropogenic activities (EPA, 2015). This warming occurs due to the greenhouse effect, which traps heat at the earth's surface. This blanket of air just above the earth's atmosphere that traps heat is created from greenhouse gases. Carbon dioxide accounts for over 55% of the greenhouse gas emission in the United States. Methane is the next largest greenhouse gas emission, accounting for 30% of emissions in 2012, and nitrous dioxide accounts for the remaining majority of emissions at 5% (EPA, 2015). In 2012, it was estimated that the agriculture industry was responsible for 10% of all greenhouse gas emissions in the United States (EPA, 2015). Among the agriculture emissions, nitrous dioxide accounts for 44% of all emissions with methane accounting for 36%. Carbon dioxide accounts for 20% (Wolfe, 2011). Compared to the United States, agriculture is responsible for one quarter of the methane emissions and nitrous oxide accounts for 70% (Wolfe, 2011), which significantly increase global climate change. The agriculture industry is a large contributor to the health of the environment. These environmental changes make it vital to understand individual agriculture systems in different regions of the country in order to mitigate and control the negative impacts and promote a more sustainable future for our food supply.

In 2004, Arizona ranked 11 out of the 48 contiguous states in agriculture growth rate with a 1.4 growth factor relative to average growth in the United States (ERS, 2014). Arizona's agriculture industry accounts for nearly $17.1 billion of the state's total annual income. Within the Arizona agriculture department, the dairy industry accounts for 20% of total farm receipts.

Cattle and calve operations account for 18% of the state's receipts. The rest of Arizona's agriculture income is comprised of fruits, vegetables, and other agriculture crops (University of Arizona, 2010). Being that the state is so heavily reliant on the food commodities of the agriculture industry, it is ever more important to understand the current sustainability of the state's agriculture systems. Currently, there are no direct comparisons on the sustainability of Arizona's conventional agriculture practices in regards to crops and animals. Therefore, this study will conduct a detailed analysis of the sustainability of Arizona's agriculture.

By examining the sustainability of Arizona's crop and animal agriculture, this study aims to expose areas the state could improve upon to ensure a productive and sustainable environment for future Arizona and national generations.

*Purpose Statement*

The main purpose of this study is to evaluate the sustainability of the agriculture food system in Arizona. This evaluation will focus on the specific crops and livestock products produced in the state and the various farming practices used to produce them over the entire production cycle. Researchers have conducted sustainability research in various locations across the country, but these projects fall short of a specific evaluation of sustainable agriculture. Most research in the field focuses on one specific aspect of the agriculture realm- either one crop or livestock product. Very few states have conducted actual evaluations of the sustainability of farming systems as a whole. For example, greenhouse gas emission levels of organic versus conventional farming systems have been analyzed in California (Venkat, 2012). Furthermore, there is a small pool of research that has studied the adaptation of different agriculture systems to the changing global climate (Burke & Emerick, 2012). Currently, there are no direct research studies on the sustainability of the agriculture food system in Arizona.

A large portion of research within the state of Arizona focuses on techniques for improving crop and livestock product yields. Other research centers on controlling pests and other insects that threaten yield production or specific hormones and antibiotics that fatten up the meat and increase milk production or protect animals from disease. The proposed study aims to directly analyze the processes and procedures used within agriculture in Arizona to determine the sustainability of current operations. The research will include an evaluation of a broad range of agriculture crops and livestock and the methods used in Arizona to produce these different commodities compared to the rest of the United States. The evaluation of the sustainability of the field will be compared to different sustainability studies in the United States to determine the sustainability of the state's agriculture food system to possibly improve practices.

## Method

### Research Questions

The proposed study will be conducted in two stages- data collection of agriculture outputs and practices and a mixed methods analysis of sustainability based on the data collected. This two-stage process will allow for an analysis of Arizona's environmental sustainability as compared to best practices and benchmarks for the rest of United States. Both stages of research will address the following central question: How sustainable is Arizona's agriculture system in regards to crop and livestock production? The study will also utilize several guiding questions that will focus the research to specifically answer the central question. These main guiding questions are:

1. What are the primary crop and livestock commodities produced in Arizona and the United States as a whole?

2. Of the primary crop and livestock products produced in Arizona and the United States as a whole, what is the individual market value for each product?
3. What methods are utilized to produce the various crop and livestock products in Arizona and the United States as a whole?
4. What are the land-use demands from Arizona's agriculture industry and how do these compare to the nation as a whole?
5. How much water does Arizona's agriculture system utilize? How does Arizona's water consumption compare to the nation as a whole?
6. How do the resource use characteristics of Arizona's agriculture industry compare to current sustainability reports for regions across the nation and the nation as a whole?

**Data Collection and Analysis**

The first stage of this research project will include a quantitative analysis of total crop and livestock output in Arizona and the United States. This will first include the collection of Arizona's total agriculture output as reported by the United States Department of Agriculture's (USDA) 2012 Census of Agriculture (USDA, 2014). Information extracted from the census is based on a USDA 5-year data collection cycle for the United States. Extracting total agriculture outputs for the state of Arizona allows for a determination of top crop and livestock production output for the state as a whole. Total market value, or cash receipts from sales, of output for the state of Arizona and the United States will be used instead of total commodity output. This is due to the varying degrees of agriculture input qualities and output measurements. For example, an analysis based on acreage of crops in total would be an unreliable measurement of top agriculture output, because different crops produce different yields over a different amount of acreage. Total amount of output is also considered an unreliable measure of top agriculture output for this study, because different crop and livestock outputs are measured in different units. Corn crop outputs, for example, are measured in bushels, while cotton outputs are measured in bales (EPA, 2012). Market value simplifies top output measurements, and it will stand as the top crop output.

It can also be assumed that the state produces more of the output that makes the most money, since it is the most profitable and contributes most to the state's economy. Therefore, top production outputs in terms of dollar amount sold will be used to focus the analysis of the sustainability of the most expansive and important practices for the state of Arizona (NASS, 2015). Similarly, it will also be assumed throughout this research that these outputs have the largest impact on the environment, since they are in the most demand and create the most profit for the state. Once total crop and livestock agriculture production in terms of market value is collected, the top three categories of both crop and livestock output will be used as the top Arizona production commodities for the study. Therefore, this study will utilize the top six agriculture commodities for Arizona- the top three crop outputs and the top three livestock outputs.

In order to determine the individual impact of all six top commodity outputs as they relate to Arizona's overall agriculture commodity, agriculture footprints will be calculated for each top commodity. This will allow the research to focus on the biggest potential influencers on the environment. Three commodity footprint calculations will be used for this phase of the research. The first commodity footprint calculation will relate Arizona's top crop commodities to the overall market value of all crop commodities sold in Arizona in 2012. This commodity footprint is calculated for each top crop commodity in Arizona using the following calculation,

$$footprint\,C = \frac{mvC}{mvTC}$$

where *footprintC* is the crop agriculture footprint of each of the three top crop commodities, *mvC* is the individual market value of top crop products sold, and *mvTC* is the total market value of all crop products sold in Arizona. The second commodity footprint calculation will relate Arizona's top livestock commodities to the overall market value of all livestock commodities sold in Arizona in 2012. This commodity footprint is calculated for each top livestock commodity in Arizona using the following calculation,

$$footprint\,L = \frac{mvL}{mvTL}$$

where *footprintL* is the livestock agriculture footprint for each of the three top crop commodities, *mvL* is the individual market value of top livestock products sold, and *mvTC* is the total market value of all livestock products sold in Arizona. Finally, the third commodity footprint calculation will relate all six top commodity outputs (both crop and livestock) to the combined market value of crop and livestock products sold in Arizona in 2012. This agriculture commodity footprint is calculated for all top commodities using the following calculation,

$$footprint\,AZ = \frac{mvI}{mvT}$$

where footprintAZ is the total agriculture footprint for each individual commodity output, mvI is the market value of an individual commodity output, and mvT is the total market value of all crop and livestock commodities sold in Arizona in 2012. An excel spreadsheet will be used to input the top Arizona commodities and their respective market values and to carry out the footprints calculations as detailed above. Once total and top Arizona commodity production is determined, top production for the United States, as a whole, will be extracted.

Next, the United States' agriculture output will be extracted via the same means as Arizona's output. Rather than determining the top crops and livestock products in the country, only information relating to the top outputs in Arizona will be obtained. Therefore, information on the top three commodity crop and livestock outputs for Arizona will be pulled for the United States as a whole. Obtaining information about United States commodity agriculture output that mirrors Arizona's top output will allow for a direct comparison of output relative to the country as a whole. This direct comparison will act as the foundation for the sustainability comparison of Arizona that will be conducted in part two of this research. Total United States expenditures will also be extracted from the USDA database (USDA, 2014).

The market value of the six top commodities in Arizona for the Untied States will be used to further calculate Arizona's agriculture footprint compared to the United States as a whole. This footprint will be calculated in the same way as the first three calculations, but it will be for total output for each commodity. Therefore, a percentage will be calculated based on Arizona's market value compared to the United States for the same commodity. The following calculation will be use,

$$USfootpr\text{int} = \frac{azmv}{usmv}$$

where *footprint* is Arizona's agriculture foot print for a specified commodity, *azmv* is the total market value of Arizona's specified commodity, and *usmv* is the market value of the United State's specified commodity. This calculation will be conducted for each top commodity for Arizona, resulting in six separate agriculture footprint results. After top agriculture information is extracted for the United States and Arizona and the outputs with the greatest impact in the United States are determined, production methods will be analyzed for these top commodities in order to better understand the sustainability of Arizona's agriculture in terms of how resources are utilized to produce these outputs.

Many different methods of production exist for the growth of different agriculture crop and livestock commodities. These varying methods also utilize land and water resources in very different ways. The ways in which land and water are used has a large impact on the overall health of the environment. This makes understanding the characteristics of resource use important for an overall assessment of a state's agricultural sustainability. Therefore, this research will focus on the water and land use characteristics for production of Arizona's top commodity outputs in relation to the state's overall use of the resources. The research will also focus on the water and land use characteristics for the United States as a whole to determine the state's overall impact compared to the rest of the country. For crop commodities, this research will focus on the amount of water utilized to grow individual crops. An analysis of the amount of land used for crops will also be considered, as well as a determination of tillage practices and insecticide use for top commodity crops. For livestock commodities, this research will focus on the amount of water used for the growth of pastureland from which animals feed. Consideration of how much water is used for animals to drink will also be analyzed. The amount of land used for livestock production will also be considered in relation to the rest of the land in Arizona.

According to the USDA, 80% of the water used in the United States is for agriculture, and this fraction of water used increases to 90% in western states (ERS, 2013). For crop production, this research will focus on the proportion of harvested cropland in Arizona that utilizes any form of irrigation. This information will be extracted from the USDA's 2012 Census of Agriculture as a benchmark for total water consumption for crop production. The research will then narrow the focus of consumption down to the top crop commodities for the state of Arizona that were found in the first phase of research. As in the first phase, the results for water consumption from top crop commodities will be directly compared to the state's overall consumption of water and the United States' total water consumption for commodity outputs. For livestock production, this research will focus on two uses of water- water used to irrigate pastureland and water used as drinking water for livestock. This information will also be extracted from the USDA's 2012 Census of Agriculture, and the research will focus on the top livestock commodities for the state of Arizona. Once information for water consumption in livestock production is extracted, it will also be compared to Arizona's total livestock water consumption and the United States' total water consumption. Land is the other resource that will be researched in order to determine the sustainability of Arizona's agriculture activities.

There were over 900 million acres of farmland in the United States in 2012, which accounted for about 45% of the total land area in the country (USDA, 2012). Utilization and distribution of land for agriculture practices has severe implications for the environment. The first focus will be on the utilization of land in Arizona. This will include an analysis of the amount of land used for agriculture compared to the rest of the state and the breakdown of farm size. Further analysis will reveal the type of farms within Arizona's agriculture (harvested farmland versus pastureland). This analysis will supply information on the actual activities on the land. For crop production, the amount of harvested land compared to total land will provide information on how much land is actually used. Further analysis will reveal the amount of land harvested that utilizes any form of tillage, which is a process that uses mechanical means of preparing cropland for planting (EPA, 2013). This information will be compared to the amount of cropland that uses no-till practices of crop production. This research will also analyze the amount of chemicals used to control insects, weeds, nematodes, and other diseases across Arizona's top crop outputs. For livestock production, this will include an analysis of the number of animals per pastureland compared to the rest of the United States. Once Arizona's production methods for resource utilization are analyzed, an estimation of Arizona's sustainability can be determined based on the overall agriculture profile of the United States. This research will conclude with recommendations for future research.

# Results

## Total Agriculture Output

### Arizona's Top Output Calculations.

In 2012, Arizona had just over 20,000 farms that accounted for over 26 million acres in land. Total cropland accounted for 8,144 farms and 1.1 million acres of land, but only 890,000 of those acres were actually harvested. Total pastureland, on the other hand, comprised 7,651 farms and accounted for a staggering 23 million acres of land. The majority of these commodity farms ranged between one and nine acres in size, and the average farm estimated at barely over 1,300 acres each. These small farms, however, contained the majority of market value of Arizona agriculture, each selling less than $2,500 in products for the year. While per farm value averages were relatively low in profit for the year, overall farm production value was $3.7 billion in commodities, making average sales per farm just under $200,000 each. Of total market value, farm crops consisted of just over $2 billion, while livestock, poultry, other animals, and their respective outputs represented nearly $1.7 billion (ERS, 2015).

According to the USDA's Census of Agriculture, top agriculture crop products in Arizona in terms of market value of products sold for the year of 2012 were cotton (to include cottonseed oil), wheat, and corn, respectively (Note: The category of vegetables, melons, potatoes, and sweet potatoes represented $764 billion of market value of products sold across 1,750 farms in Arizona. However, for the purposes of this study, this group of commodities will not be considered due to the lack of specific for each output). More than 800 farms in the state of Arizona grew one of these three top crops for cash profits, and they made up nearly 330,000 acres of total farmland in the state (USDA, 2012). Cotton accounted for over $220 million in cash receipts. Wheat and corn accounted for $95 million and $74 million in cash receipts, respectively (USDA, 2012). The overall market value of the three top agriculture crop products sold in Arizona and the respective number of farms for those outputs is summarized in **Table 1**. Market value dollar figures are rounded to the nearest whole million dollars.

**Table 1. Top Agriculture Crop Output in Terms of Market Value of Products Sold for the State of Arizona**

| Crop Commodity | Total # of farms | Market value (millions of dollars) |
|---|---|---|
| **Cotton** | 388 | $225 |
| **Wheat** | 225 | $95 |
| **Corn** | 196 | $74 |

USDA. (2012). Census of Agriculture: State Level Data- Arizona. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Arizona/azv1.pdf

Using this information of market value of crops sold in Arizona in 2012, an agriculture crop footprint is calculated using the following equation:

$$footprint\,C = \frac{mvC}{mvTC}$$

In 2012, Arizona's cotton industry had the single largest agriculture crop footprint, accounting for 11.25% of all crop outputs for the state. Wheat and corn had agriculture footprints of 4.75% and 3.75%, respectively, which collectively account for less than cotton's total impact combined.

The agriculture footprints for the three top crops in Arizona are summarized in **Table 2**. Agriculture footprints are rounded to the nearest quarter of a percentage.

**Table 2. Crop Footprint for Top Crop Commodities in Arizona Compared to Total Crop Outputs for the State**

| Crop Commodity | Market Value (millions of dollars) | Total AZ Crop Market Value (billions of dollars) | Total Crop Footprint |
|---|---|---|---|
| **Cotton** | $225 | $2 | 11.25% |
| **Wheat** | $95 | $2 | 4.75% |
| **Corn** | $74 | $2 | 3.75% |

USDA. (2012). Census of Agriculture: State Level Data- Arizona. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Arizona/azv1.pdf

The top livestock outputs in Arizona in terms of market value of products sold for the 2012 year were milk cows, beef cattle and calves, and horses (to include ponies, mules, burros, and donkeys). These livestock commodities were raised on 7,000 farms across Arizona and accounted for the majority of animal agriculture receipts for the state (USDA, 2012). Milk cows contributed nearly $763 million in cash receipts to Arizona's economy, while beef cattle and calves contributed over $700 million in cash receipts. The horse category contributed almost $32 million in cash receipts (USDA, 2012). The overall market value of the three top livestock products sold in Arizona and the respective number of farms for those outputs is summarized in **Table 3**. Market value dollar figures are rounded to the nearest whole million dollars.

**Table 3. Top Livestock Output in Terms of Market Value of Products Sold for the State of Arizona**

| Livestock Commodity | Total # of farms | Market value (millions of dollars) |
|---|---|---|
| **Milk Cows** | 104 | $763 |
| **Beef Cattle and Calves** | 3,364 | $700 |
| **Horse** | 1,954 | $32 |

USDA. (2012). Census of Agriculture: State Level Data- Arizona. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Arizona/azv1.pdf

Like agriculture crops, an agriculture footprint for livestock is calculated with the information of market value of livestock products sold in Arizona in 2012 and the following equation:

$$footpr\,\mathrm{int}\,L = \frac{mvL}{mvTL}$$

In 2012, Arizona's milk cow industry had the single largest livestock footprint with beef cattle and calves accounting for not much less. These two commodities accounted for over 85% of all livestock commodities sold in 2012 at 45% and 41.25%, respectively. Horse accounted for only a small fraction of all livestock products sold at only 2%. The agriculture footprints for the three top livestock commodities in Arizona are summarized in **Table 4**. Agriculture footprints are rounded to the nearest quarter of a percentage.

**Table 4. Livestock Footprint for Top Livestock Commodities in Arizona Compared to Total Livestock Outputs for the State**

| Livestock Commodity | Market Value (millions of dollars) | Total AZ Livestock Market Value (billions of dollars) | Total Livestock Footprint |
|---|---|---|---|
| **Milk Cows** | $763 | $1.7 | 45% |
| **Beef Cattle and Calves** | $700 | $1.7 | 41.25% |
| **Horse** | $32 | $1.7 | 2% |

USDA. (2012). Census of Agriculture: State Level Data- Arizona. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Arizona/azv1.pdf

Further exploitation of Arizona's top crop and livestock outputs shows the agriculture footprint of the top commodities compared to total agriculture market value of Arizona in 2012. These results show that two out of the three top livestock commodities account for nearly 40% of the agriculture footprint in Arizona. Milk cows and beef cattle and cows account for 20.5% and 19% of the market value of products sold, respectively. Cotton has the next largest agriculture footprint in Arizona compared to all agriculture products sold at 6%. Wheat, corn, and horse account for less than cotton's footprint combined. The total agriculture footprints for the top crop and livestock commodities in Arizona compared to the total market value of all commodities sold are summarized in **Table 5**. Agriculture footprints are rounded to the nearest quarter of a percentage.

**Table 5. Arizona's Total Agriculture Footprint for Top Commodities Compared to Total Agriculture Outputs for the State**

| Crop/Livestock Commodity | Market Value (millions of dollars) | Total AZ Market Value (billions of dollars) | Total Agriculture Footprint |
|---|---|---|---|
| **Cotton** | $225 | $3.7 | 6% |
| **Wheat** | $95 | $3.7 | 2.5% |
| **Corn** | $74 | $3.7 | 2% |
| **Milk Cows** | $763 | $3.7 | 20.5% |
| **Beef Cattle and Calves** | $700 | $3.7 | 19% |
| **Horse** | $32 | $3.7 | 1% |

USDA. (2012). Census of Agriculture: State Level Data- Arizona. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Arizona/azv1.pdf

**United States' Top Output Calculations.**

The total number of farms in the United States was just over 2.1 million in 2012. Those farms consisted of over 900 million acres of farmland (for crops) and pastureland (for livestock). The total market value of the United States farms in terms of market value of products sold was nearly $400 billion total, $212 billion of which came from crops and $182 billion from livestock, poultry, and their products (USDA, 2012). Like the state of Arizona, farms with a low market value made up the majority of the total market value of United States agriculture products sold in 2012. The majority of the farms in the United States, however, consisted of between 10 and 179 acres, which is a much different farm size profile than Arizona. Regardless of this difference, the average market value per farm in the United States in 2012 was just under $200,000 each, which is similar to Arizona's average output per farm for the same year (USDA, 2012). Naturally, Arizona's market value of top agriculture products sold was significantly less than the

United States'. The market value of agriculture crop and livestock products sold in the United States is summarized in **Table 6**. The same three top crop and livestock products as in Arizona were used as a direct comparison to the state. In this case, market value dollar figures are rounded to the nearest whole billion dollars. **Table 7** provides a direct comparison of the top outputs for Arizona and the United States.

**Table 6. Top Crop and Livestock Output in Terms of Market Value of Products Sold for the United States (referencing the top outputs for the state of Arizona)**

| Commodity | Total # of farms | Market value (billions of dollars) |
|---|---|---|
| **Cotton/Cottonseed** | 18,143 | $6 |
| **Wheat** | 147,022 | $13 |
| **Corn** | 361,744 | $67 |
| **Milk Cows** | 50,556 | $35 |
| **Cattle and Calves** | 742,978 | $76 |
| **Horse** | 114,255 | $1 |

USDA. (2012). Census of Agriculture. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

**Table 7. Comparison of Top Arizona Agriculture (Crop and Livestock) Output in terms of Market Value of Products Sold compared to the Same Outputs for the United States**

| Commodity | Arizona Market Value (millions of dollars) | United States Market Value (billions of dollars) |
|---|---|---|
| **Cotton/Cottonseed** | $225 | $6 |
| **Wheat** | $95 | $13 |
| **Corn** | $74 | $67 |
| **Milk Cows** | $763 | $36 |
| **Cattle and Calves** | $700 | $76 |

USDA. (2012). Census of Agriculture. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

Total market value of Arizona's agriculture products sold versus the United States' market value of agriculture products sold was determined as being one percent. Therefore, in relation to the rest of the United States, Arizona's total agriculture footprint is about 1% of the country's total footprint. An analysis of the agriculture footprint of specific agriculture outputs better serves to define Arizona's overall sustainability compared to the rest of the United States.

Commodity footprints are calculated by determining the percentage of output from Arizona compared to the United States for the top commodities found above using the following equation:

$$USfootprint = \frac{azmv}{usmv}$$

Arizona's footprint for all three top crop and top livestock commodities from 2012 was calculated, and it was determined that cotton, horse, milk cows, and beef cattle and calves have the largest agriculture footprint in the United States. Wheat and corn both have an agriculture footprint less than Arizona's overall agriculture footprint of 1%. Arizona's agriculture footprints in relation to total output in the United States are summarized in **Table 8**. Total agriculture footprint for each of top commodity is rounded to the nearest quarter of a percentage.

**Table 8. Arizona's Total Agriculture Footprint Compared to the United States**

| Commodity | Agriculture Footprint |
|---|---|
| **Cotton/Cottonseed** | 3.75% |
| **Wheat** | 0.75% |
| **Corn** | <0.25% |
| **Milk Cows** | 2% |
| **Beef Cattle and Calves** | 1% |
| **Horse** | 3.25% |

USDA. (2012). Census of Agriculture. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

## Agriculture Production Methods

### Water Use.

Production methods vary significantly across different commodity-producing farms in the United States. This is especially true for Arizona's top commodity outputs. As was discovered in the first phase of this research, cotton, milk cows, and beef cattle and cows have the largest potential impact on the state's environment, which makes understanding the production of these outputs important to the overall assessment of the state's agriculture sustainability. Therefore, further analysis of water and land use methods to produce these outputs will provide an understanding of the sustainability of these practices in Arizona compared to the rest of the country.

Arizona's cropland makes up a much smaller portion of farmland than that used for livestock and their outputs. In 2012, cropland consisted of only 1.1 million acres of total farmland. Of those 1.1 million acres, just under 900,000 were actually harvested and counted toward the state's total market value of products sold (USDA, 2012). Compared to farmland used for livestock, this only accounts for 4% of Arizona's total farmland. Almost 30% of all of Arizona's farms used some form of irrigation in 2012, which accounted for 880,613 acres of total land. Of the 900,000 harvested acres of Arizona cropland, 854,515 of them were actually irrigated. This equates to nearly 100% of all cropland harvested across 4,830 Arizonan farms that were irrigated in 2012 (USDA, 2012). Because cotton production has the largest agriculture crop footprint for Arizona, it is important to understand the water use characteristics of growing the commodity.

Cotton production in Arizona has the largest agriculture footprint in the United States, averaging about 14% of total cotton production in the country (USDA, 2012). Arizona's season for production of cotton lasts from around March or April timeframe until November or December, depending on the season and the characteristics of the land and temperatures in the state. Within this timeframe, the planting phase lasts approximately one month, and the growth stage lasts about five to six months. Additionally, the average harvesting period lasts approximately two months (USDA, 1997). For Arizona's dry climate, irrigation of cotton crops occurs in three distinct phases. The first phase occurs prior to cotton planting, followed by summer irrigation and a termination irrigation period before the crops are finally harvested. Summer irrigation accounts for the bulk of water consumed in Arizona's cotton industry, which is a result of the state's very hot and dry climate (NCC, 1992). Throughout a cotton production season, an average cotton farm requires approximately 326,000 gallons of water per acre of cotton (The Arizona Experience). Arizona's total output of cotton was 585,658 bales over 197,455 acres in 2012. Therefore, it can be estimated that Arizona utilized approximately 64 billion gallons of water for cotton production in that year. The United States, on the other hand, grew a total of 9.3 million acres of cotton in 2012 (USDA, 2012). This means the country utilized nearly 3 trillion gallons of water for all cotton crops in the same year. Therefore, Arizona's water usage for cotton crops was 2% of the total water usage in the country in 2012. Arizona's water consumption for cotton irrigation with a comparison to total water use for the same output in the United States in 2012 is summarized in **Table 9**.

Pastureland in Arizona accounted for 23 million acres of land across 8,344 farms in the state. Despite comprising the majority of land in the state, only 26,098 of these pastureland acres were irrigated in 2012, which accounted for only 1,308 farms total. Therefore, less than 1% of all pastureland in the state was irrigated in 2012 (USDA, 2012). For pastureland, irrigation systems generally provide water to the land at an average rate of three inches over a 12-hour period. On average, this accounts for nearly 40,000 gallons of water per acre for every watering period. Unlike irrigation water for cotton crops in the hot season, pastureland does not require water every day. In Arizona, the dry, hot season lasts for 6 months in the summer, and the lands are watered approximately every two weeks during this time (Casale, 2012). This is also referred to as the irrigation season, which varies in time each year. Therefore, in 2012, about

520,000 gallons of water were used to irrigate each acre of Arizona's pastureland. This equates to nearly 14 billion gallons of water for the 2012 year. The United States had 3,729,847 acres of irrigated pastureland in 2012. Therefore, according to a typical irrigation season, the country used approximately 1.9 trillion gallons of water to irrigate pastureland in 2012. **Table 9** summarizes Arizona's water consumption for pastureland irrigation with a comparison to total water use for the same output in the United States in 2012.

**Table 9. Arizona's Water Consumption for Cotton and Pastureland Irrigation with a Comparison to Total Water Use for the Same Output in the United States in 2012**

| **Commodity** | **Arizona Water Usage per Year (billion gallons)** | **United States Water Usage per Year (trillion gallons)** | **Percentage of United States Water Usage** |
|---|---|---|---|
| **Cotton Irrigation** | 64 | 3 | 2% |
| **Pastureland Irrigation** | 13.6 | 1.9 | <1% |

USDA. (2012). Census of Agriculture. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

Irrigation of pastureland is not the only use for water within livestock agriculture. Livestock also need to drink water, which accounts for a large portion of water consumption in the agriculture industry. In 2012, over 24 million acres of farmland were used for animal production in the United States. Pastureland accounted for 96% of the animal farmland, representing 23 million acres over 8,344 farms (USDA, 2012). Arizona's livestock industry included nearly 200,000 milk cows, which is the livestock commodity with the largest agriculture footprint in Arizona compared to the rest of the United States. Nearly four times the amount of beef cows resided on pastureland farms, accounting for 717,713 animals. Average milk cows and beef cattle and cows require an average of 15 gallons of water per day to survive (Casale, 2012). Considering the number of milk cows and beef cattle and cows in Arizona in 2012, the state required approximately 15 million gallons of water per day for livestock production outputs (milk cows and beef cattle and calves only). This accounted for nearly 5.5

billion gallons of water for the 2012 production year. For milk cows, this breaks down to 3 million gallons of water per day, or 1.1 billion gallons per year, and for beef cattle and calves, this breaks down to 12 million gallons per day, or 4.4 billion gallons of water per year. In 2012, the United States had a total of 80,742,342 beef cattle and cows and 9,252,272 milk cows. Therefore, the United States utilized nearly 1.3 million gallons of water per day. This equates to 51 billion gallons of water per year for milk cow production and 442 billion gallons of water per year for beef cattle and calves in 2012. Arizona's water consumption for milk cows and beef cattle and cows with a comparison of total water use for the same output in the United States in 2012 is summarized in **Table 10**.

**Table 10. Arizona's Water Consumption for Milk Cows and Beef Cattle and Calves with a Comparison of Total Water Use for the Same Output in the United States in 2012**

| Commodity | Water Usage per Day (millions of gallons) | Water Usage per Year (billions of gallons) | Percentage of US Water Usage for the Same Commodity |
|---|---|---|---|
| **Milk Cows** | 3 | 1.1 | 20% |
| **Beef Cattle and Calves** | 10.8 | 3.9 | <1% |

USDA. (2012). Census of Agriculture. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

**Land Use.**

It was determined that there were nearly one million livestock on 23 million acres of pastureland in Arizona during the 2012 agriculture year (USDA, 2012). The number of livestock feeding on Arizona's pastureland is an important piece to the overall analysis of Arizona's agriculture sustainability, because animal grazing can have a large impact on the environment due to soil erosion and other impacts. While land varies significantly across the country, it has been estimated that a mature cow (defined as a cow weighing at least 1,000 pounds) generally eats about 3,000 pounds of food from pastureland each day. It has also been estimated that one acre of pastureland can, on average, support about 1.5 mature cows (Casale, 2012). Therefore, using this general relationship, Arizona had the potential to support over 34 million livestock on its 23 million total acres of pastureland in 2012. Arizona had just less than one million total milk cows and beef cattle and calves in 2012. With the potential to hold 34 million livestock, this means that Arizona's pasturelands were occupied at 3% of the total milk cow and beef cattle and calve capacity, and the occupancy rate based on acreage was 5% (or 0.048 livestock per acre). Considering the vast amount of pastureland in the state, this is a relatively small amount of animals compared to the United States.

The United States had 428,112,127 acres of pastureland in 2012, which means the country could have theoretically supported up to 642,168,191 livestock animals at any one time. In that year, the United States had 29 million beef cattle and calves and 9.3 million milk cows, meaning the country had just over 38 million livestock on its 428 million acres of pastureland. With the capacity to hold over 600 million livestock, the livestock only occupied nearly 9% of the pastureland in 2012 (or 0.089 livestock per acre). The total land occupancy profile of pastureland in Arizona and the United States for milk cows and beef cattle and calves in 2012 is summarized in **Table 11**.

**Table 11. Total Land Occupancy Profile of Pastureland in Arizona and the United States for Milk Cows and Beef Cattle and Calves in 2012**

| Commodity | Pastureland (million acres) | Number of Livestock (million) | Total Livestock Capacity (million) | Percentage of Land Occupied |
|---|---|---|---|---|
| **Arizona Profile** | 23 | 1.1 | 34 | 5% |
| **United States Profile** | 428 | 38 | 624 | 9% |

USDA. (2012). Census of Agriculture. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

Pastureland is not the only type of farmland that is impacted by agriculture practices. While livestock have an impact on pastureland through grazing, humans have an impact on cropland through different methods of planting, cultivation, and the various forms of chemical control of cropland. In 2012, Arizona had 536,266 acres of cropland over 2,316 farms that used some form of tillage to prepare the land for seeding. Only 28,727 acres used no-till practices across 1,513 farms in the state. The United States had 182,347,775 acres of cropland that utilized tillage practices across 601,430 farms and 96,476,496 acres of cropland that utilized no-till practices over 278,290 farms. Tillage characteristics of cropland for the state of Arizona in 2012 are summarized in **Table 12**.

Arizona spent over $125 million on chemicals for pesticide and other controls in 2012 that were used across 3,407 farms. These chemicals were used to control insects, weeds, nematodes, and other disease across 1.5 million acres of cropland. The United States spent nearly $16.5 billion on chemicals to treat one million farms in 2012, and the chemicals were applied to 434,690,830 acres of land. Chemical forms of cropland use and control for Arizona and the Untied States are summarized in **Table 13**.

**Table 12. Tillage Characteristics for Arizona and the United States in 2012**

| | **Tilled Cropland Acres** | **No-till Cropland Acres** |
|---|---|---|
| **Arizona** | 536,266 | 28,727 |
| **United States** | 182,347,775 | 96,476,496 |

USDA. (2012). Census of Agriculture. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

**Table 13. Chemical Control Characteristics for Arizona and the Untied States in 2012**

| **Commodity** | **Number of Acres** |
|---|---|
| **Arizona Chemicals Applied** | 1,526,823 |
| **United States Chemicals Applied** | 434,690,830 |

USDA. (2012). Census of Agriculture. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

## Discussion

Over the past half century, Earth's climate has changed drastically. The most notable changes in climate have been seen with the increase of temperatures at the surface, which is ultimately caused by an increase in the greenhouse effect. These changes have been due in part by natural variations of Earth's rotation, tilt, and other environmental and spatial variances. Just in the last 15 years, however, it was determined that the unprecedented changes in the temperatures of the earth are largely due to human influences, which are increasing the greenhouse effect (NASA, 2015). The greenhouse effect, which is necessary to sustain life on earth, has been increased by the increase of greenhouse gas being emitted into the atmosphere. These greenhouse gases are a result of the burning of fossil fuels, the excretion of methane from farm animals, and many other factors. Therefore, scientists and activists alike have spent as much time determining ways to mitigate global climate change. One way to do this is through sustainability plans and improvement.

Many definitions of sustainability exist, so, naturally, many ideas of environmental sustainability also exist. It has been discussed in recent research that the difference in the concepts of environmental sustainability is a direct result of the complexities of the issue. There are many different working parts within agriculture, so when it comes to defining the term, many definitions exist and different actions are taken depending on the idea of the term (Beachy, 2010). Most of the current definitions or concepts of environmental sustainability, however, do focus on the importance of protecting the environment today for the benefit and preservation of future generations. The EPA defines sustainability as the ideal that "creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations," (EPA). This broad definition of sustainability is easily translated into agriculture terms, and it has been generally accepted that many different methods of sustainability in agriculture exist that all involve a set of practices aimed toward a common environmental goal. Some of these methods include the exploitation and implementation of alternative energies to reduce reliance on carbon-intensive energies, control of pesticide and chemical use to product the world's water supply, and ecosystem preservation and restoration for the prosperity of organisms, among many other actions. In order to understand any one side of the issue, the discussion must focus down to a since facet.

Agriculture sustainability has been clearly defined for over two decades, and each variation of the definition involves the EPA's main focus on preservation of the planet for future generations. The Agriculture Act of 2014 uses the words "sustainable" or "sustainability" only nine times, and each time it is used, the term refers to the enhancement, improvement, or push towards current sustainable actions (GPO, 2014). The enhancement of sustainably referred to in the 2014 Act refers to the definition introduced in the 1990 Agriculture Act that states that sustainability should, "make the most efficient use of nonrenewable resources, enhance quality of life for farmers and society as a whole, and enhance the environmental quality and the natural resource base upon which agriculture economy depends," (Beachy, 2010). Therefore, agriculture sustainability, like other working definitions of sustainability in other fields of concern, focuses on the preservation and best practice utilization of today's resources while focusing on the needs and perseverance of future generations. Due to the expansiveness of agriculture, this can mean very different things to the different sectors of the agriculture industry.

When discussing agriculture sustainability, it has been generally accepted that measuring sustainability is a complicated venture. This is proven in recent research involving a wide variety of scientific and social methods aimed at quantifying sustainability of the agriculture industry. Current research uses the common conception that agriculture sustainability is composed of three distinct categories that function independently. These three classifications of understanding are the economic, environmental, and social aspects of agriculture. While these areas of measure exist independently, a working understanding of their interactions with and within one another is necessary in order to provide a reliable analysis of the sustainability of agriculture for a certain region or area (Hayati, 2010). Therefore, a singular understanding of each category must first happen before a clear analysis of sustainability within agriculture can be pursued. There is also another realm of sustainability research that must be considered for agriculture.

While it is important to understand the categories of sustainable agriculture independently and dependently among the three, it is also important to consider the scope of impact agriculture activities have on each category of understanding. Recent research has shown that a good understanding of agriculture sustainability must consider the spatial impact of agriculture to include the local, regional, and national levels (Hayati, 2010). This first includes an understanding of the local agriculture practices of a certain place of concern. This first level of understanding is the most important, because agriculture practices are extremely location-dependent. Being location-dependent simply means that different regions grow and raise different agriculture commodities based on the characteristics of the location. Therefore, it can be agreed upon that not all locations are agriculturally equal. Once the local characteristics of a certain place are understood, the information can then be used on a larger scope to understand sustainability relations in the terms of concern. In an attempt to understand and measure the sustainability of Arizona's agriculture system, this research focused on one piece of the agriculture realm across all scopes of understanding.

This research focused on the environmental category of agriculture sustainability in an attempt to evaluate the sustainability of Arizona's agriculture system. In order to analyze the environmental category of the state's agriculture system, a regional understanding of agriculture had to be analyzed. Top agriculture commodities were determined based on the 2012 Census of Agriculture, which takes local data across Arizona and presents it regionally (regionally, in this case, was the state of Arizona as a whole). Analysis showed that the top commodities for the state included cotton, wheat, corn, milk cows, beef cattle and cows, and horse, to include species within the horse family. It was further determined that cotton had the largest agriculture crop footprint for the region at 11% of total crop share, and milk cows and beef cattle and cows had the largest livestock footprint with 45% and 41% total livestock share for the state, respectively. By combining the crop and livestock groups, it was determined that milk cows, beef cattle and calves, and cotton were the top three commodities in Arizona in 2012, with 21%, 19%, and 6% impact, respectively. Therefore, it can be determined that livestock had a larger agriculture impact in Arizona than crops. This understanding of Arizona's crop and livestock commodities allowed for determination of the agriculture footprint on a national level.

Understanding Arizona's role in agriculture compared to the rest of the United States is important, because national policies affect agriculture at the state level. Issues at the national level affect how many livestock or crops are produced and sold and how that process is allowed to work (Hayati, 2010). To compare Arizona's role in agriculture at the national level, top crop commodity outputs were compared with the output for the same commodities in the United States. On a national level, it is obvious that the United States produces more collective output than Arizona does for any given item. It was determined, however, that cotton, Arizona's top crop commodity output, has the state's largest agriculture footprint on a national level, responsible for nearly 4% of the crop in the nation. Milk cows and beef cattle and calves, on the other hand, only accounted for a 2% and 1% agriculture footprint, respectively. The agriculture footprint calculations for cotton, milk cows, and beef cattle and calves show that Arizona had a commodity agriculture footprint as large as or larger than the state's total agriculture footprint for the three commodity outputs in 2012. Therefore, it was determined from the agriculture footprint in relation to the market size in the country that cotton, milk cows, and beef cattle and calves production have the largest potential environmental impact in the state of Arizona, even though milk cattle and calves have a larger footprint at the local level in Arizona. This is due to the agriculture characteristics of the region in that cotton is only mostly grown in the western part of the country, and livestock are raised and produced all over the country. This understanding of Arizona's agriculture production on a national level allowed for further analysis of the production methods of those three categories.

According to some scientists, an ecological footprint is an estimate of how much load humans impose on the ecosphere in terms of land and water resources used to sustain the population (Rees). Knowing the agriculture footprints of Arizona's top agriculture commodities on a national level allows for an understanding of this footprint. The environmental piece of the agriculture sustainability puzzle focuses on many different parameters to understand environmental sustainability in agriculture. In most research today, these parameters include, but are not limited to, the use of pesticides, herbicides, and fungicides, the physical inputs and efficient use of inputs in an agriculture system, crop diversification and rotation, tillage and soil erosion, energy demands and use, pest management, and improved water and land use (Rees). This research focused on the water and land use in Arizona on both a local and a national scale in relation to the largest outputs in the state. These outputs with the biggest potential environmental impact were found to be from cotton, milk cow, and beef cattle and cow production. From the environmental category of measuring sustainability, water use, land use, and chemical application characteristics were studied to further expand the understanding of Arizona's agriculture impact on the environment.

Analysis showed that 536,266 acres of Arizona's harvested cropland utilized tillage in 2012, and only 28,727 used no-till practices. Additionally, the state grew a total of 197,455 acres of cotton for the year. While there is no firm data available on the exact number of cotton acres utilizing no-till operations in 2012, a 2010 study showed that nearly 15.2% of cotton produced in the United States utilized no-till operations in 2003 across 12.8 million acres of cotton farms. Of the main cotton-producing states in the United States, Arizona rounded out the bottom of states utilizing no-till for that year at only 3.7%. Further analysis shows that in 2007, total no-till practices accounted for 20.7% of cotton crops in the United States, an increase of 5.5% over the four-year period. This increase was mostly seen in the mid-western and central states, also referred to as the "Cotton Belt", where the average increase of no-till practices increased an average of over 25% per state. Unfortunately, Arizona did not have an increase of no-till operations significant enough to make the comparison study for the 2007 year. Interestingly, California, the number one cotton producer in the United States, utilized zero no-till operations for both years, further verifying the lack of no-till operations in western states where the temperatures are warmer and more dry (Horowitz, Ebel, & Ueda, 2010). Since Arizona's no-till operations were too small to report in 2007, it can be assumed that the state, on average, utilizes no-till operations on about 4% of total cotton crops. Therefore, it is estimated that only about 8,000 acres of cotton used no-till operations in 2012, which accounts for nearly 28% of the total land that used no-till practices. Therefore, to better understand the environmental impact of cotton production in Arizona, it is necessary to focus on the impacts of tillage, since the majority of cotton produced in the state uses tillage of some sort.

Many different methods of tillage exist, and each method poses different stresses on the environment across the different regions of use. For cotton production, tillage is an important step before cottonseeds can be planted. This is because the main goal of tillage is to bury old crop in an effort to prevent disease, insects, and weeds. Burying the remnants of the old crop ensures the protection of new crops during the growth phase. Old cotton crops, however, are very tough, which means it takes several tills before the ground is ready for cottonseeds to be planted (Albers, 2015). Therefore, on average, cotton tillage is more extensive than tillage for other crops in that one field will generally need to be tilled two to three times for one season. Therefore, this means that Arizona's cotton farms are more susceptible to the negative environmental effects of tillage than the United States is as a whole. Several negative affects exists in regards to cotton tillage.

One of the biggest impacts associated with tillage in agriculture is soil erosion. Disk in fall tillage, just one of the many methods of tillage used on cotton crops, mixes the land up to bring the residue from under the surface of the ground into the top layer of the soil. This allows for the material that has been sitting under the soil to come in contact with the air in order to decompose at a faster rate than if it were to stay underneath the ground. This method, however, reduces the amount of residue on the surface of the soil, which makes the land more susceptible to being blown away from the wind. This is just one, common example in which soil is eroded over time from tillage (Albers, 2015). When soil erodes in this way, secondary negative effects also occur. One such secondary effect is the pollution of the natural water sources of an area. Soil erosion is the process of soil being removed from wind or water. As was shown in the example of disk in fall tillage, the wind blows soil away as a direct result of tillage. When soil is removed, however, it has to go somewhere. A lot of times, soil is blown into rivers, lakes, and other bodies of water. Once this happens, the body of water becomes contaminated, which, depending on the water system, makes it unusable for the end-user of the water product (Uri, 1999). Water is a very precious resource need for sustainment of life, and the treatment of water is very costly and invasive. Therefore, it is very important to try and avoid contamination of water from tillage use in agriculture. Another negative environment affect of agriculture tillage is the increase in energy use. For cotton tillage, large machines are needed to till a field. Since cotton field usually requires more than one till per season, the category of concern uses more energy than other farming practices. Increased energy consumption is directly related to increases in greenhouse gas emissions and cost (Albers, 2015). Therefore, considering the negative impacts associated with cotton tillage, Arizona could greatly benefit from no-till and conservation tillage practices for cotton production.

No-till or conservation tillage in agriculture are alternative processes of tillage that are both used in cotton production across the country. In a no-till process, cotton is planted in a field where no tilling has occurred. In this case, the crop is planted into the old cotton crops or a cover crop (if cover crops were used). Conservation tillage, on the other hand, is a process where 30% of the residue soil is required to remain after tillage, which requires less invasive tillage to reach the same goal (Burmester, 2013). There are several advantages to no-till or conservation tillage operations across cotton fields. One advantage includes the savings of energy from not having to use heavy equipment across a field the amount of times needed for cotton production (Meijer). This, of course, helps reducing greenhouse gas emissions associated with cotton production. No-till and conservation tillage also leaves more soil on the surface of the land, which makes the fields less susceptible to soil erosion. This, in turn, reduces the possibility of water pollution (Albers, 2015). It has also been determined that the use of no-till or conservation tillage in agriculture does not affect the yield of cotton, making it a very viable option for Arizona (Burmester, 2013). However, there are some disadvantages utilizing no-till or conservation tillage for cotton production. One of the main disadvantages to no-till or conservation tillage is the need to use additional pest and weed control on fields. With conventional tillage on cotton fields, the process naturally acts to reduce these impacts (Mejier). Therefore, there is a possibility that cotton production would require the use of more chemicals, which Arizona already uses for current cotton production.

Several threats are posed on cotton crops throughout a normal production season, especially in a hot climate like Arizona. Some of these risks include weeds and pests that can destroy an entire field of cotton crops. Within cotton production, cotton aphid is the most common pest. This pest, however, is most commonly managed by the introduction of other insects onto the fields. These insects include beetles, wasps, and certain types of fly categories that eat the bad pests before they become a bigger problem for the cotton crops (IPM Center, 1999). Other threats to cotton crops include beet armyworms, lygus bug, sweetpotato whitefly, saltmarsh caterpillar, and other mites, worms, bugs, and beetles. Pests are not the only threat to cotton, however. Cotton crops can become susceptible to disease ranging from fungi to southwestern rust to root rot. They are also susceptible to weeds and other grass species, which affect the cotton crops by competing for water and other nutrients form a field (IPM Center, 1999). Regardless of the threat, they all have a common aspect, which includes the use of chemicals to control the threat and protect cotton yields. Chemicals are also used in order to enhance the cotton production cycle. Furthermore, it has been estimated that the use of insecticides on cotton crops accounts for nearly 50% of total insecticide use in the United States (Ellsworth, 2006). Also, defoliants, desiccants, boll openers, boll conditioners, boll defoliants, and defoliation enhancers are all chemicals that are applied to the cotton crop to further enhance cotton production (Wang, Norton, & Loper, 2014). Arizona uses these chemicals to both control pesticides and other threats and to enhance the cotton production cycle.

In 2012, Arizona applied some form of chemical to over 1.5 million acres of cropland, and all nearly 200,000 acres of cotton cropland received chemical application of some quantity. These chemicals ranged from acephate and chlorpyifos across the majority of cotton acres to naled and neem oil over a very small percentage of acres (IPM Center, 1999). The application of pest management, disease prevention, and/or harvest enhancement chemicals varies depending on the reason. For cotton production, common chemical application strategies include conventional sprayers, aerial application, and chemigation. The use of chemical sprayers is the most popular form of chemical application to cotton crops. In order to control cotton aphid in the most plausible way, for example, the region of infection is spot sprayed with a chemical (EPA, 2012). Unfortunately, the use of chemicals in agriculture has negative effects on the environment and human populations.

There are several disadvantages to using chemicals in agriculture. Like tillage operations, the use of chemicals on cotton crops can significantly threaten the water supply of a region. In the same way soil is eroded, chemicals that are applied to a cotton field can run off via wind or water and end up in a nearby water source. Additionally, these chemicals can leech into the ground water supply through the field it is applied (Environmental Justice Foundation, 2007). Further harm can occur to farm workers who are applying chemicals to the cotton crops. Farmers can come into direct contact with chemicals unintentionally through the improper handling of the chemical or via indirect inhalation. The use of chemicals on agriculture fields can also harm organisms other than humans. When a pesticide or an insecticide is applied to a cotton crop, for example, the intent is to either kill a pest (insects, weeds, etc) and/or a disease. Therefore, the chemical is lethal to the organism intending to receive the chemical. However, there is no way to protect other organisms, those that do not threaten the cotton crops, from any chemical applied to a field. Therefore, ecosystems are unintentionally harmed through the use of chemicals in cotton production (PAANA). Since all cotton crops receive some form of chemical to treat or enhance the crop, it is important to understand the alternative methods of control that do not utilize chemicals in order to safeguard the environment.

There are several methods utilized in the United States today that control the use of chemical in agriculture. One such method includes the use of crop rotation, which is a process of rotating the crops that are grown in a field from season to season. This process changes the characteristics of a field, so pests and other diseases don't go rampant on one field. Biological pesticides are also utilized in the cotton industry. This form of pest control targets specific pests, which means other organisms will generally be safe from application (EPA, 2012). One of the most common ways to control pests on cotton crops is through the exploitation of beneficial organisms across cotton fields. Most of the time, this is accomplished through the application of a food supplement that attracts the good organisms. By attracting the good organisms, the ration of good insects versus pests is high, which allows the good organisms to rid the bad ones (Mensah, Vodouhe, Sanfillippo, Assogba, & Monday, 2012). This form of pest management and decreased chemical use is common throughout organic cotton farms across the country and the world. Arizona's cotton agriculture could greatly benefit from the reduced use of chemicals. There is also another area that Arizona could improve upon in regards to environmental impacts, which includes a reduction in water consumption for both cotton crops and animal commodity production.

The agriculture industry in the United States utilizes lakes, rivers, reservoirs, and wells to irrigate the 900 million acres of farmland across its 2 million farms. It is estimated that the water extracted from these freshwater systems for agriculture accounts for 60% of the total fresh water used in the United States (Perlman, 2015). Unfortunately, the world's fresh water supply is scares. The majority of earth's water is salt water, and the fresh water on the planet is locked in ice near the poles. This creates problems within the agriculture industry for the hot, dry regions of the world, as they require more water to irrigate farmland (Chapagain, Hoekstra, Savenije, & gautam, 2006). For the United States, this includes the majority of the western states to include Arizona.

Arizona requires a significant amount of water to irrigate its farmland. In 2005, the state withdrew 4% of the total water withdrew in the country, totaling about 5 billion gallons of water per day or 1.8 trillion gallons of water per year (Perlman, 2015). The majority of the water withdrawn in Arizona is used toward the production of the state's top crop commodity outputs. In 2012, cotton, the crop with the largest environmental footprint for the state, required approximately 64 billion gallons of water across all 18,000 cotton farms. This equates to about 2% of the total water usage for cotton in the United States, as 6.5% of the total water used in the country goes towards cotton irrigation. This is a significant amount of water, especially considering the total available amount of water in the world. The majority of the irrigation for cotton production in Arizona and the United States is through furrow irrigation (Chapagain, Hoekstra, Savenije, & gautam, 2006). Unfortunately, this is not the most sustainable method of irrigation.

Furrow irrigation is the most popular form of cotton irrigation around the world. This form of irrigation is essentially the process of pouring an given amount of water onto the ground of crops and letting it soak into the ground. This type of irrigation is environmentally inefficient, and it is estimated that about 50% of the water applied in this way never gets to the crop. This is due to the process of evaporation, which is especially common in the dry and hot regions where cotton is produced like Arizona. Less wasteful forms of irrigation include drip irrigation and spray irrigation. Drip irrigation is a form of irrigation that lays pipes along rows of crops that sit at the root of the crop. This allows for the water to inject directly into the root, which greatly reduces evaporation. Spray irrigation, on the other hand, utilizes a sprinkler-type system that pivots at a central point to spray a large area of cropland. These types of sprinkler systems can also be hung over the crops to cut back on evaporation and displacement of the water from the wind. It is estimated that spray irrigation reduces waste by nearly 60% (Perlman, 2015). These two alternative forms of irrigation are best for fruit and vegetable crops because of the way the roots lay. Therefore, the best way for cotton irrigation is the most inefficient. Arizona, however, could greatly benefit from methods of sustainability to ensure less water is wasted that do not require drip or spray irrigation.

Arizona could still utilize the same furrow method of irrigation for the cotton crops without having to institute drip or spray irrigation. These methods include more efficient field and water planning. In furrow irrigation for cotton, water is poured directly onto the land that cotton is planted. If the land is not level, this water will run off and increase the amount of waste, thereby increasing the amount of water needed to effectively irrigate the cotton crops. Therefore, properly leveling of cotton fields after tillage will reduce this waste. Likewise, the proper timing of cotton irrigation can greatly reduce the amount of water needed for the crops. This includes establishing appropriate water intervals of flooding the fields based on time of day and the current environmental conditions (whether it is a dry season or relatively more moist due to current rain trends). This will reduce evaporation and water runoff on cotton fields. Implementing this form of irrigation planning will also increase the amount of water runoff that can be collected to be reused into the irrigation system. Capturing the water that runs off the fields can be accomplished via man-made ponds. These sustainability methods for Arizona require proper pre-planning, but the implementation will cut back on the total water needed, thereby increasing the state's sustainability.

Like crop commodities, livestock agriculture requires a significant amount of water in order to raise the animals and produce the respective commodity outputs. In 2005, it was estimated that the United States withdrew nearly 2.1 trillion gallons of water for livestock production, the majority of which came from surface water sources like ponds and lakes. While this is a significant amount of water, it accounts for about 1% of all water withdrawn in the country for all agriculture practices (Perlman, 2015). Given the amount of livestock raised and produced in the country as a whole, Arizona was only responsible for a very small percentage of water used for the total livestock agriculture industry in 2012.

Arizona only had a total of 1.1 million beef cattle and cows and milk cows in 2012, while the United State's had over 38 million of the same livestock. Therefore, Arizona required about 5 billion gallons of water for these livestock, which was only about 1% of the total water consumed by all beef cattle and calves and milk cows in the United States for the same year. This small footprint within the country is due to the state's smaller livestock numbers, as the majority of livestock are produced in the Middle West and central/southern plains regions and not Arizona or other dry climate regions. However small this footprint for Arizona, this water is still obtained from the 1% of total freshwater on the planet. Therefore, understanding the impact of water consumption in the livestock industry and possibly more sustainable methods can greatly benefit the state's agriculture industry.

There are several best practices for agriculture livestock water consumption in which Arizona could benefit. Like cotton crop irrigation, these methods include diligent previous planning by farmers. One of the most important aspects of water sustainability in livestock production is controlling the amount of water provided to the livestock. For free-range beef cattle and cows and dairy cows, this includes processes like properly fencing standing water sources and preventing cattle and cows from access to water that flows. Many livestock farms utilize ponds and other open water source like wells and springs for animals to drink. Unlimited access to these resources can significantly harm the water quality and deplete the resource. Therefore, to eliminate these risks, fences should be built around the water source and built-in tanks should be implemented that control the water fed to beef cattle and calves and milk cows. This ensures that the livestock get a healthy, steady intake of water and do not contaminate the water source with feces or urine (Ward & McKague). The consideration of water conservation for livestock will greatly increase the sustainability of Arizona livestock commodity output.

**Research Limitations**

No good research goes without limitations. This research used the Agriculture Census of 2012 to collect and analyze detailed information about farms and farm practices in Arizona and the rest of the country. This option was chosen for this research, because it is a single source of information. The information contained in the census is a compilation of information provided by farmers and ranchers across the United States. The requested information is sent out as a questionnaire to registered farms across the country. Individual farm owners answer specific questions pertaining to farming operations and send in responses, which are compiled and organized to create the census document used for this research. Despite the USDA's strong effort to ensure 100% participation through programs, media, and organizations (USDA, 2014), some farms across the country may not have completed a census or sent in a completed census. This poses an obvious problem in that not all farms and farm activities are represented in the data. Therefore, the agriculture footprints presented in this research could be off. Other limitations exist from using the Agriculture Census of 2012.

Another possible issue with using the census as the sole data source for this research is the human factor in providing information on the questionnaire. There is no way to know with absolute certainty that information individual farmers provided was indeed accurate. Several factors could contribute to information being skewed. For example, a farmer may not have had records for all information being asked about, so they could have taken a "best guess" to answer a certain question. While these two issues pose possible limitations, however, the control for this research was the census, since it was the only source of official agriculture information in one place. Therefore, the limitation is consistent throughout the research for information obtained throughout Arizona and the United States. Reliability of data is not the only limitation presented in this research.

Very limited data exists for the majority of information in the second phase of the research, so extrapolation was used to contribute to the sustainability analysis and determine specific impacts. These limitations included specific water usage profiles for irrigated cotton crops and pastureland (separately) and specific water usage for animal consumption. It was reliably assumed based on the 2012 census data that all cotton crops in Arizona are irrigated. The amount of irrigation, however, is not certain based on research. This is due to a limited amount of data available for specific cotton sites, which is important, because irrigation of crops is site-dependent. Therefore, this research uses is a best estimate based on available information for generalized cotton crops. Another limitation exists with the composition of pastureland in Arizona and the amount water used on this type of land. The available data allows for a general estimate of pastureland irrigation, but no data was available specifically detailing pastureland irrigation for 2012. Similarly, information detailing animal water consumption was also unavailable. Therefore, like cotton cropland and pastureland irrigation, an estimate was used based on general animal water consumption profiles. All estimates were utilized in the same way for both Arizona and the United States evaluations. Limited data also existed for land use specific analyses.

This research focused on land use practices for the top commodities in Arizona. Unfortunately, information for specific animal use on pastureland was not available. Just because land is designated as pastureland does not necessarily mean it was impacted by animal use. Therefore, a limitation exists on detailing the actual impact of milk cows and beef cattle and cows on the land. Specific tillage and pesticide practices for cotton production were also not available for this research. This specifically applies to cotton crop production, of which very little detailed information was available. Therefore, it is not certain whether all cotton corps use tillage or apply pesticides, although it can be scholarly assumed based on literature on cotton production. Even if it is assumed that Arizona's cotton production utilizes tillage, implications are not certain or even understood. Therefore, just because the state uses tillage for all cotton production does not make them unsustainable. The same can be said for pesticide use on cotton crops. While it is inferred through detailed research on available literature that all cotton crops use pesticides, information on the specific types of pesticides and amounts used is not available. Therefore, this research used a broad extrapolation that does not necessarily detail exact information for Arizona's cotton industry. These limitations present many recommendations for future research on the sustainability of agriculture in Arizona.

**Recommendations for Future Research**

This research attempted to analyze Arizona's agriculture sustainability through an analysis of the state's main agriculture commodities and the characteristics of land and water use for each of those top outputs. The basis of discussion for this research used the ideal that agriculture sustainability can be categorized into the economic, social, and environmental aspects on a local, regional, and national scale. Instead of focusing on all categories, this research focused on the environmental aspect by detailing the land and water use practices involved in production at the local, regional, and national levels. While this research narrowed the analysis down to only the environmental aspects, it still proved a difficult job. This was evident in the lack of reliable information on specific land and water use practices for the state. Therefore, it is recommended that future research either focus on the sustainability analysis of one commodity or limiting the scope of analysis to one level rather than incorporating them all.

Focusing agriculture sustainability research to one commodity rather than multiple commodities could significantly improve this research plan. The current research conducted in this paper first determined the top three crop and livestock commodities. The results were further narrowed based on the total percentage of commodity produced based on the rest of the commodities in Arizona. This provides a useful understanding of the agriculture industry in Arizona and allows for a direct comparison to the United States. It also makes the research rather hard to focus, because the realm is more collective than independent. Only focusing on one commodity would allow for more attention to on one commodity, which would provide a means for better understanding sustainability of the commodity in relation to itself. If the cotton crop was chosen, for example, more attention could be given to the different types of cotton grown in the state and how the agriculture practices differ among these species. Limiting the number of commodities analyzed is not the only recommendation for future sustainability research.

Limiting the scope of analysis to one level rather than incorporating them all in one research project will narrow the focus to more specific information on commodities. This research focused on a regional level analysis, the region being the state of Arizona. Once information was obtained on Arizona, it was compared to the United States as a whole on a national level. While this is a useful analysis to understand the frame of a state's agriculture practices, it does not allow for much focus and understanding on any one level of scope. For example, this research compares Arizona's information to the United States as a whole, but all regions of the country do not produce the same commodities. This is due to the environmental differences that exist between locations, since all places cannot physically produce the same commodities. To narrow the scope, future research could relate top commodities to the states that produce the same commodity, thereby eliminating "noise" from the rest of the country. Narrowing the commodity number or scope is not the only method that could prove more successful in future research.

Limiting the number of commodities analyzed or the scope of research considered would be more beneficial with field research. Therefore, another recommendation for future sustainability research would be to conduct field research to get accurate, reliable data on specific information. This type of research would require spending one or two seasons analyzing practices for given products in a location or region. One of the limitations to the research conducted in this paper was the potentially unreliable data obtained from the USDA's agriculture census. If field research was conducted across Arizona instead of using a census, the limitation of relying on old, possibly incomplete data could be eliminated. Another major limitations to this project was the lack of specific irrigation, water use, and land use practices for cotton crops and milk cows and beef cattle and cows. Each of these commodities requires different practices that vary significantly between farms, especially if different farmers are present across the farms. Conducting research in the field could eliminate this limitation by providing actual information on the practices as observed. Field research could be conducted at the local level on one farm in Arizona or across multiple farms of common production on a regional level. Whichever the case, however, it is recommended that the field research focus on one commodity rather than a variety of top commodities as was done in this research. Time and monetary constraints make the implementation of these recommendations hard to implement in on online setting. It is the author's hopes that these recommendations be implemented in future agriculture sustainability research.

## Conclusion

The purpose of this study was to evaluate the sustainability of Arizona's agriculture food system through an evaluation of crop and livestock production and production practices throughout the state compared to the rest of the United States. In order to make this sustainability determination, a detailed analysis of the EPA's 2012 Agriculture Census was conducted to calculate an environmental footprint for each top commodity in Arizona. Environmental footprint calculations showed that cotton, milk cows, and beef cattle and calves have the largest environmental footprint in Arizona in relation to market value of products sold than any other agriculture commodity in the state. Further analysis showed that, among these three top commodities, cotton has the largest agriculture footprint in terms of market value of products sold in relation to the rest of the United States at about 4%. Even though the environmental footprint for cotton in Arizona proved to be relatively small in relation to the rest of the United States, it is an important impact, because production is still more for states that don’t even produce cotton. Therefore, further analysis of production practices proved to be important for the top commodities in Arizona.

Production practices for different crops and livestock vary significantly across the country, because climate and environmental characteristics dictate what can be grown or raised in different locations. It was discovered that Arizona, along with other cotton producing states in the west, use virtually zero no-till operations for cotton production. Therefore, the state’s cotton farms are more susceptible to soil erosion. At the same time, however, using tillage operations limits the amount of pesticides required compared to a strictly no-till operation. Water consumption as also found to be a heavy impact on the state’s environment in terms of the rest of the United States. Cotton production requires a significant amount of water, especially during the hottest part of the season. Therefore, the state could greatly benefit from additional water conservation practices for the production of cotton and raising livestock for milk or beef. The information determined throughout the research proved to present more areas of study.

Arizona’s agriculture industry could greatly benefit from further research on specific aspects of the state’s agriculture commodities. Future study should focus on one commodity across a specific region, which would narrow the scope to avoid outside influence of information. Since cotton has the largest footprint for the state, a study conducted throughout a cotton season or two on tillage practices, chemical use, and water use would fulfill the void of information that is lacking on the commodity for the state. Regardless of the commodity chosen, specific commodities should be analyzed separately in order to get the most reliable information on the sustainability of Arizona's agriculture as a whole.

References

Albers, D.W., Reinbott, D.L. (2015). Cotton Tillage and Planting Guidelines. Retrieved from http://extension.missouri.edu/p/G4270.

Alston, J.M., Anderson, M.A., James, J.S., Pardey, P.G. (2010). A Brief History of U.S. Agriculture. Retrieved from http://faculty.apec.umn.edu/ppardey/documents/9781441906571-c1.pdf.

Baroni, L., Cenci,., Tettamanti, M., & Berati, M. (2007). Evaluating the environmental impact of various dietary patterns combined with different food production systems. European Journal of Clinical Nutrition. 61(2). 279-286. doi: 10.1038/sj.ejcn.1602522

Beachy, R.N. (2010). Science and Sustainability: The Emerging Consensus. *Bioscience*, 60(6), 406-407, doi: 10.1525/bio.2010.60.6.2.

Burke, M., Emerick, K. (September 11, 2012). Adaptation to Climate Change: Evidence from US Agriculture. University of California at Berkley, Department of Agriculture and Resource Economics.

Burmester, C.H. (March 20, 2013). Cotton Tillage and Seedbed Preparation. Retrieved from http://www.extension.org/pages/65673/cotton-tillage-and-seedbed-preparation#.VUVJ49NViko.

Casale, Rich. (2012). Pasture Managmenet. Retrieved from http://www.livestockandland.org/PDF/Pasture%20Management.pdf.

Chapagain, A.K., Hoekstra, A.Y., Savenije, H.H.G., Gautam, R. (March 9, 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. Retrieved from http://waterfootprint.org/media/downloads/Chapagain_et_al_2006_cotton.pdf

Coffin, T. (2012). The world food supply: The damage done by cattle-raising. In L.P. Pojman & P. Pojman (Eds.), *Environmental ethics: Readings in theory and application* (6th ed., pp. 360-364). Boston, MA: Wadsworth, Inc. (Reprinted from *The Washington Spectator*, 19(2) (January 15, 1993)).

Dimitri, C., Effland, A., Conklin, N. (June 2005). The 20th Century Transformation of U.S. Agriculture and Farm Policy. Retrieved from http://www.ilovefarmers.org/downloads/The20thCenturyTransformationofU.S.AgricultureandFarmPolicy.pdf.

Duda, B.M., Rusu, T., Bogdan, I., Pop,A., Moraru, P.I., Giurgiu, R.M., & Coste, C.L. (2014). Considerations regarding the opportunity of conservative agriculture in the context of global warming. Research Journal of Agriculture Science, 46(1), 210-217.

Ellsworth, P. (2006). Cotton IPM: A decade of reduced insecticide use in Arizona. Retrieved from http://ag.arizona.edu/impacts/2006/1_5.html.

Environmental Justice Foundation. (2007). The Deadly Chemicals in Cotton. Retrieved from http://freesetglobal.com/uploads/images/tees/resources/the_deadly_chemicals_in_cotton.pdf.

EPA. (April 15, 2015). Global Climate Change. Retrieved from http://www.epa.gov/climatestudents/basics/today/index.html.

EPA. (October 23, 2012). Crop Production. Retrieved April 8, 2015 from http://www.epa.gov/agriculture/ag101/printcrop.html.

EPA. (April 12, 2013). Soil Preparation. Retrieved from http://www.epa.gov/agriculture/ag101/cropsoil.html.

EPA. (April 9, 2015). Sources of Greenhouse Gas Emissions. Retrieved from http://www.epa.gov/climatechange/ghgemissions/sources/agriculture.html.

EPA. (n.d.). Sustainability. Retrieved from http://www.epa.gov/sustainability/basicinfo.htm.

ERS. (October 31, 2014). Agriculture Productivity in the U.S. USDA. Retrieved from http://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us/findings,-documentation,-and-methods.aspx.

ERS. (June 7, 2013). How Important is Irrigation in US Agriculture? Retrieved from http://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/background.aspx.

ERS. (June 7, 2013). Irrigation and Water Use. Retrieved from http://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use.aspx.

Gadberry, S. (n.d.). Water for Beef Cattle. University of Arkansas, Division of Agriculture. Retrieved from http://www.uaex.edu/publications/pdf/fsa-3021.pdf.

GPO. (February 7, 2014). An Act. Retrieved from http://agriculture.house.gov/sites/republicans.agriculture.house.gov/files/pdf/legislation/Final_AgAct2014.pdf.

Hayati, D., et al. (2010). Measuring Agriculture Sustainability. *Biodiversity, Biofuels, Agroforestry and Conservation Agriculture*, doi 10.1007/978-90-481-9513-8_2.

Hoppe, R.A. (December 2014). Structure and Finances of U.S. Farms: Family Farm Report, 2014 Edition. Retrieved from http://www.ers.usda.gov/media/1728096/eib-132.pdf.

Horowitz, J., Ebel, R., Ueda, K. (November 2010). "No-Till" Farming is a Growing Practice. Retrieved from http://www.ers.usda.gov/media/135329/eib70.pdf.

IPM Center. (August 1999). Crop Profile for Cotton in Arizona. USDA. Retrieved from http://www.ipmcenters.org/cropprofiles/docs/AZcotton.pdf.

Kerna, A., Frisvold, G. (October 2014). Agriculture in Arizona's Economy: An Economic Contribution Analysis. Retrieved from http://www.azfb.org/f/71db4e85-0dd1-41e5-82a6-da8d8da6eb84/az-ag-contribution-analysis-2014.

Kreuger, W. (November 2002). Environmental Impacts of Livestock on U.S. Grazign Lands. Council for Agriculture Science and Technology. Retrieved from http://oregonstate.edu/dept/range/sites/default/files/l_Impacts_of_Livestock_on_U_S__Grazing_Lands.pdf.

McKibben, B. (2012). A special moment in history: The challenge of overpopulation and overconsumption. In L.P. Pojman & P. Pojman (Eds.), *Environmental ethics: Readings in theory and application*, (6th ed., pp. 260-271). Boston, MA: Wadsworth, Inc. (Reprinted from *The Atlantic Monthly,* (May 1998).

Meijer, A.D., Edmisten, K.L. (n.d.). Cotton Production with Conservation Tillage. Retrieved from http://content.ces.ncsu.edu/cotton-production-with-conservation-tillage.pdf.

Mensah, R., Vodouhe, D., Sanfillippo, D., Assogba, G., & Monday, P. (2012). Increasing organic cotton production in Benin West Africa with a supplementary food spray product to manage pests and beneficial insects. International Journal Of Pest Management,58(1), 53-64. doi:10.1080/09670874.2011.645905

Merriam-Webster. (2015). Pastureland. Retrieved from http://www.merriam-webster.com/dictionary/pastureland.

NASA. (April 14, 2015). Climate change: How do we know? Retrieved from http://climate.nasa.gov/evidence/.

NASS. (March 15, 2015). 2014 State Agriculture Overview. Retrieved from http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=ARIZONA.

NCC. (August 1992). Cotton Irrigation Scheduling. Cotton Physiology Today. Vol 3(8). Retrieved from https://www.cotton.org/tech/physiology/cpt/plantphysiology/upload/CPT-Aug92-REPOP.pdf.

PAANA. (n.d.). Environmental Impacts. Retrieved from http://www.panna.org/issues/persistent-poisons/environmental-impacts.

Pishgar-Komleh, S., Sefeedpari, P., & Ghahderijani, M. (2012). Exploring energy consumption and CO2 emission of cotton production in Iran. Journal Of Renewable & Sustainable Energy, 4(3), 033115-033115-14. doi:10.1063/1.4727906

Perlman, H. (Mar 14, 2014). Irrigation water use. USGS. Retrieved from https://water.usgs.gov/edu/wuir.html.

Perlman, H. (March 17, 2015). Livestock water use. USGS. Retrieved from https://water.usgs.gov/edu/wulv.html.

Pojman, L., & Pojman, P. (2012). Environmental ethics: Readings in theory and application (6th ed.). Boston: Jones and Barlett.

Rees, W.E. (n.d.). The Eco-Footprint of Agriculture: A Far-from (Thermodynamic) Equilibrium Interpretation. Retrieved from http://nabc.cals.cornell.edu/Publications/Reports/nabc_16/16_3_2_Rees.pdf.

The Arizona Experience. (n.d.). Cotton Today. Retrieved from http://arizonaexperience.org/land/cotton-today.

University of Arizona. (January 13, 2010). A Look at Arizona Agriculture. Retrieved from http://www.agclassroom.org/kids/stats/arizona.pdf.

University of Arizona. (2012). Value of Industries Supported by College of Agriculture and Life Sciences Programs. Retrieved http://cals.arizona.edu/dean/career-economy/valuesofindustries.pdf.

Uri, N.D. (1999). The impact of public policy on conservation tillage use in U.S. agriculture. International Journal of Environmental Studies, 56(4), 547.

USDA. (2012). Census of Agriculture. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

USDA. (2012). Census of Agriculture: State Level Data- Arizona. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Arizona/azv1.pdf

USDA. (August 2014). Farm Production Expenditures. Retrieved from http://usda.mannlib.cornell.edu/usda/current/FarmProdEx/FarmProdEx-08-01-2014.pdf.

USDA. (February 2014). U.S. Farms and Farmers. 2012 Census of Agriculture. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Preliminary_Report/Highlights.pdf.

USDA. (December 1997). Usual Planting and Harvesting Dates for U.S. Field Crops. Retreived from http://swat.tamu.edu/media/90113/crops-typicalplanting-harvestingdates-by-states.pdf.

Venkat, K. (2012). Comparison of Twelve Organic and Conventional Farming Systems: A Life Cycle Greenhouse Gas Emissions Perspective. Journal of Sustainable Agriculture, 36(6), 620-649. doi: 10.1080/10440046.2012.672378

Wall, E., & Smit, B. (2005). Climate Change Adaptation in Light of Sustainable Agriculture. Journal Of Sustainable Agriculture, 27(1), 113-123. doi:10.1300/J064v27n01-07

Wang, G., Norton, R., & Loper, S. (January 2014). Choosing Harvest Aid Chemicals for Arizona Cotton. Retrieved from http://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1556.pdf.

Ward, D. & McKague, K. (May 2007). Water Requirements for Livestock. Ministry of Agriculture. Retrieved from http://www.omafra.gov.on.ca/english/engineer/facts/07-023.pdf.

Welling, G.M. (2012). Revolution in Agriculture. Retrieved from http://www.let.rug.nl/usa/outlines/history-1994/growth-and-transformation/revolution-in-agriculture.php.

Wolfe, D. (November 2011). Farm Energy, Carbon, and Greenhouse Gases. Cornell University College of Agriculture and Life Science. Retrieved from http://www.nrcc.cornell.edu/climate_change/climate_farmenergy.pdf.