Trimming the fat of beef production: the transportation of ranching

by

Scott Anthony Hazelton

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF REGIONAL AND COMMUNITY PLANNING

Department of Regional and Community Planning

College of Architecture Planning and Design

KANSAS STATE UNIVERSITY

Manhattan, Kansas

2020

Approved by:

Major Professor

Dr. Gregory Newmark

Copyright

Abstract

Transportation is a crucial portion of an agricultural producer's daily activities. Agricultural products require many miles to produce, both from direct producers and from outside contractors. This research thesis analyzes the daily travel of a ranch using GPS trackers installed into the ranch's vehicles. The most significant finding is the high percentage of idling, over 29.9 percent of engine use. The ranch used over 4,700 gallons of fuel at idle resulting in over $10,000 in fuel wastes and 52.8 tons of carbon dioxide emitted. Metrics were developed for further evaluation and regional comparisons of ranch work. The metrics show the cow to miles ratio, acre to miles ratio and the stocking ratio to miles per acre. These metrics were created to show the efficiency of the ranch's travel on a yearly basis and for comparison between different ranches. Recommendations were given to the rancher to limit their idling, such as habitual and technological changes, and reduce their vehicle-miles traveled and travel time by chaining trips, diversifying their fleet and changing routing decisions to save miles and drive time. This study provides a base for further study into the daily transportation of agriculture, a base data set has been created and more data is needed to compare ranches to one another.

Keywords: Sustainable Agriculture, Transportation

Table of Contents

List of Figures

List of Tables

List of Equations

Acknowledgements

I would like to thank my advisor, Dr. Greg Newmark, for his support throughout the learning process of this thesis. Furthermore, I would like to thank Dr. Robert Weaber, Animal Science, Dr. Shawn Hutchinson, Geography, and Dr. Tim Keane, Landscape Architecture, for serving as my supervisory committee and all their assistance in forming this thesis. I would also like to thank the Mannix Brothers Ranch in Helmville, Montana for their initial support in this project. I would also like to thank the Dwight David Eisenhower Transportation Fellowship for their support on my project. Finally I would like to thank the Mushrush Red Angus Ranch as they served as the study ranch for my thesis.

Preface

The responsibility of feeding projected population growth falls to the agricultural industry. The beef industry must become more efficient if beef is to a play a significant role in feeding the future. The transportation associated with the production stage of the beef industry has not been studied on a ranch by ranch basis. The constraints of the industry will undoubtedly provide optimization hurdles, but it is possible that incremental changes could have far reaching effects. This project hopes to alleviate costs to the producers of the beef industry and provide them metrics to analyze their own travel patterns.

Agriculture products are grown on farms and ranches then shipped to processing plants to be converted into useful products. This study focused on the production stage. The production stage of agriculture incorporates the processes of raising the living products, either crops or livestock, to the age of harvest. The study found inefficiency in the transportation network of beef production. A case study methodology was used on a red angus stock ranch in the Flint Hills of Kansas. The study ranch raises red angus cattle for sale to other producers and for slaughter. The ranch produces no cash crops and all of the farming activities are used to support cattle production. Using a GPS service, the researcher was able to gather data on the vehicular travel of the ranch and accurately draw the ranch's transportation network. This study gave the ranchers the ability to assess where their time and resources are going.

This study provides a significant benefit to the beef industry. Analyzing the vehicle-miles traveled, travel time, routing decisions, and the idling time of the ranch could lead to more efficient practices. The study has made note of the ranch's carbon emissions from idling. This study made recommendations to the rancher to improve their efficiency.

Chapter 1 - Introduction

The human population is expected to reach 9 billion people by 2050 translating into a need to produce 70% more food than is currently generated (Dickinson & Stanton, 2011). Meat production will need to increase by over 200 million tons and grain production will need to increase by over 500 million tons to meet the projected population's needs (Dickinson & Stanton, 2011). This study worked to optimize the beef industry by reducing the vehicle-miles traveled, altering routing decisions, reducing idle time of ranch equipment and limiting the carbon emissions of the ranch.

This study analyzed the transportation of a red angus ranch in the Flint Hills region of Kansas. This ranch is primarily a stock production ranch. This means that the ranch raises male and female cattle to be sold as seed stock to other ranchers. These ranchers then will use the cattle for beef production. Data collection for the study began on June 1st of 2019 and continued until December 31st of 2019. This allowed for multiple seasonal activities to be captured for comparison. The study tracked 9 vehicles. The vehicles range in size from small quads, or four wheeled all-terrain vehicles, to tractors.

Data was compiled using GPS trackers on ranch vehicles. This dataset is used to address the inefficiencies in the ranch's travel. It is understood, by the researcher, that there are limitations in place that affect the ranch's ability to operate at perfect optimization. Therefore it will be necessary to work with the study ranch to provide recommendations that are implementable for the ranch.

Metrics were developed from the ranch's travel data. These metrics were developed to show the ranch's efficiency in terms of their travel. Metrics were based on ranch assets, number of livestock and acres, and total aggregated statistics, idling time. These metrics will be used to track the ranch's efficiency over the years to look for improvements. Additional studies will need to be completed but metrics were developed so that ranches could be compare even given differences in products and region.

Studying a ranch in this manner creates the opportunity for new ways to optimize ranch travel. Ranch travel has not been studied on a day-to-day, fine-grain level. The study was completed in the hope of opening a new avenue of research. Previously unstudied, daily transportation of production stage agriculture, could present some unique savings to ranchers. On ranches it is rare that someone has the additional time or resources to take an in-depth study of their transportation. While this study focuses on a single ranch attempting to address issues in their transportation network the potential impacts of this study are nationwide. The hope of the researcher that through this research thesis it can be shown that there is merit to studying the transportation of a ranch in this manner.

Chapter 2 - **Literature Review**

The agriculture industry produces everything from the food we eat to the clothes we wear. Agriculture has a traditional model of large monoculture fields worked by heavy powerful machines. An increase in food production of such magnitude is inherently problematic; political, environmental, logistical, and equality are issues associated with this growth. The burden of producing this food falls to the agriculture industry (United Nations, 2001).While research has not been done extensively into the production transportation of the agriculture industry a literature review was conducted.

Agriculture's Dependence on Transportation Networks

Regionally and locally, transportation is one of the most important factors in the agriculture production network. Products must processed before reaching final consumers (United States Department of Agriculture, 2019). "Supply chain planning (SCP) is comprised, at the highest level, of three main decision-making functional processes: production planning, inventory control and physical distribution" (Ahumada & Villalobos, 2009). Agriculture product processing is a long process with high levels of vehicle-miles traveled (VMT) starting with inefficient large machinery all the way down to personal vehicles. The retail value of agriculture products transported was estimated to be 1,200 billion US dollars (James et al., 2006). The distribution stage has been studied in detail while the transportation of the agriculture producers has been largely ignored (Duewer, 1984; Hsueh & Chang, 2010; Jeyamkondan et al., 2000).

Growing agriculture products is a highly intensive land use that requires large tracts of land to be efficient (MacDonald et al., 2013). This stipulation of the agriculture industry means that farms are rarely located near any major city centers.

Transportation on the day to day production of a farm also increases the costs, both economically and environmentally, of the food industry (Sands & Westcott, 2011). The current, and most efficient, model of farming requires the use of heavy machinery. These machines are rarely efficient and consume large amounts of fossil fuels, typically diesel fuel. The relationship of the farmer's cost of production to end product pricing is what influences the price of these products (Sands & Westcott, 2011). Healthy options, such as fresh fruits and vegetables are associated with higher levels of care and more intensive transportation requirements. This requires more intensive refrigeration regulations and farming practices (H. Johnson & Breakiron, 1956). These products are grown in specific climates that are not near large scale distribution centers. This lengthens the distribution network for producers and these costs are carried down to final consumers.

Current Transportation Research in Agriculture

Current research in the United States on the transportation of agriculture was born from the 2008 Farm Bill. This caused the Department of Agriculture and Department of Transportation to create the Study of Rural Transportation Issues document (*Rural Transportation Issues Executive Summary*, 2008)This study was important because it began to look at transportation in the agriculture industry. The study looked at the distributional transportation of agriculture. The transportation of producing these products was not studied. The research initiatives that came from this study focused on either animal safety, transporting the animals to slaughterhouses, and delivery of perishable items while maintaining the quality of product (Akkerman, Farahani, & Grunow, 2010; Farahani, Grunow, & Günther, 2012; Huertas, Gil, & Piaggio, 2010). There has been research into electronically tracking the quality of perishable agricultural products as they travel from producers to consumers (Tsang et al., 2018). This body of research does not account for the production stage.

Beef Cattle Emissions

Emissions from beef production comes in two forms, emissions from the cattle themselves, in the form of belching, and the tailpipe emissions of the vehicles used to raise livestock (Thoma et al., 2013). The natural emissions from cattle have been detailed in many studies (K. Johnson et al., 1994; Steinfeld et al., 2006; Thoma et al., 2013). These numbers have been studied to an extent as reactions to the book "Livestock's Long Shadow" which made the claim that globally the agriculture industry produces 18% of all greenhouse gases (Steinfeld et al., 2006). Livestock's Long Shadow uses a life cycle assessment for livestock production but does not use the same comprehensive methodology on other industries, such as the transportation industry. (Pitesky et al., 2009). The study was skewed as commercial agriculture was the only industry that was studied using a true life cycle assessment methodology. In Livestock's Long Shadow it is stated that transportation emissions from the livestock industry are difficult to account for due to the high level of variance in management practices in the livestock sector (Steinfeld et al., 2006). It is certain that emissions from livestock production do contribute to greenhouse gas emissions, however its impact was overstated in Livestock's Long Shadow. This was shown because of the difference in data techniques between the different industries. Transportation was not studied in a life cycle assessment as the agriculture industry (Pitesky et al., 2009).

The agriculture industry in the United States of America is working for higher efficiency (Beauchemin & McGinn, 2005, 2006; K. Johnson et al., 1994; McGinn et al., 2004). Emissions of the agriculture industry have been categorized multiple times and currently the EPA states that the agriculture industry produces 9% of the United States' greenhouse gases (US EPA, 2015). This is at odds with the "Livestock's Long Shadow" number of 18%. Livestock production accounts for 43.9% of the agriculture sector's greenhouse gas emissions (*Greenhouse Gas Inventory Data Explorer | US EPA*, 2018).

Emissions from the meat industry traditionally are measured from the natural outputs of the livestock. This range of study includes dietary alterations and best practices for ways to compost manure (Beauchemin & McGinn, 2005, 2006; McGinn et al., 2004). While an important portion of the lifecycle analysis of the meat industry, it leaves an incomplete picture.

There has been research into farming practices to limit the greenhouse gases of crop production (T.O West & Marland, 2002). The efforts to lower emissions in meat production focus on improving the diet and digestibility of feed, improving animal health and husbandry, manure management and utilizing precision agriculture practices (Naveed et al., 2016). These recommendations do not take into account the transportation.

Precision livestock farming is a management technique that is aimed at making producers more efficient with a higher quality product. While precision livestock farming has many options they all focus on the animal science aspects of a ranch (Berckmans, 2014; Laca, 2009). The animal science section of precision livestock farming covers animal health and wellness.

This approach is logical as the primary product of the industry is an animal. There are many factors that are worthy of study that make up the beef industry. Cattle produce methane through their digestive system, and this leads to the cattle industry being labeled as a high polluter (Beauchemin & McGinn, 2005, 2006, 2006; Stackhouse-Lawson et al., 2012; Tristram O West & Marland, 2002).

Precision Livestock Farming

Analytical systems play an ever increasing role in how industries are managed. Precision Livestock Farming, is becoming an ever more practiced system to increase producer yields. "The main purpose of precision livestock farming is to enhance farm profitability, efficiency and sustainability by improving on-farm acquisition, management and utilization of data that can be used for improving the nutritional, environmental and other management aspects of various livestock species" (Desrochers & Lusk, 2015). The European Union has invested into a program called the European Union Precision Livestock Farming (Berckmans, 2014). This is a largely animal welfare based initiative to optimize agriculture. Precision livestock farming practices focus on feed management, pen sizing, movement and monitoring of animals in innovative ways however they do not address the transportation of producers (Van Hertem et al., 2017).

Precision livestock farming has not taken off as quickly in the United States as precision agriculture. There are limitations to the acceptance of precision livestock farming from producers. There is not a set methodology to evaluate precision livestock farming treatments, it is a costly system for producers and simply a lack of awareness of these practices (Banhazi et al., 2012).

Transportation as a Focus in Agriculture

The transportation focus of the agriculture industry is about the safe handling and delivery of products. When looking at transportation in regard to the beef industry producers discuss safe handling of animals and ensuring that the products they are delivering are as high a quality as possible. This process works to obtain the transportation model of efficiency, reduction of VMT and reducing travel time. This study only pertains to consumer products (Akkerman et al., 2010; Farahani et al., 2012). These studies incorporate the important factors of the perishable nature of food products. The research even extends to loading and unloading methods for cattle (*Cattle Transport Guidelines for Meat Packers, Feedlots, and Ranches*, 2008). This shows that there is research interest in food production and distribution network.

Carbon Emissions in Agriculture Transportation

Research has been done into the "foodprint" of agriculture and additional life cycle assessments of carbon emissions for food production. The idea of a foodprint is the carbon footprint of receiving food products from producers. This is an important piece of the overall agriculture system however this simply looks at delivering end products to consumers (Johansson, 2005). Research has looked into the foodprint even in situational food distribution aspects such as large events and tourism (Gössling et al., 2011). Foodprints look at the lump sum of carbon emissions from packaging and delivering a food product, but does not take a fine grain approach, nor do they offer any form of efficiency solutions to producers.

Life cycle assessments have been used extensively to find the cost of our food on the environment (Steinfeld et al., 2006; Stoessel et al., 2012). Life cycle assessments quantify and study almost all aspects of a system, taking into account for agriculture such inputs as: land use, fuel consumption, energy needed in producing fertilizers, water use and other factors as they apply to different agricultural systems (Stoessel et al., 2012). While it is good to quantify this, a life cycle assessment looks at fuel consumption as a lump sum. For example, the farm or ranch used x number of gallons of fuel and it produced this amount of carbon dioxide. The lump sum understanding of carbon and food is important information and in some cases the data is being passed along to consumers (Mugnier et al., 2010). However, the life cycle assessments are not designed to look at the daily travel or offer any suggestions on how to minimize the fuel consumption of a farm.

Some studies have gone in depth on worker outputs in physical labor on farms, but they disregard vehicular usage (Dada & Abiola, 2010). Studies have covered the total energy usage and environmental cost of different sectors of the agriculture industry to try and show which products are the least intrusive (Eshel et al., 2014).

Much of the literature surrounding transportation in agriculture is looking at lump sums and the issues that are inherent with such heavy resource dependent industries. This is a good way to define the problems that are found in agriculture but it must be researched further to find solutions to these problems. The lack of research, to solve the transportation issues of the agriculture industry is what led to this study. Transportation of end products are an important piece of the agriculture transportation puzzle, but excluding the production stage leaves an incomplete picture. This study looks to fill in the puzzle providing a more complete picture of producer travel while addressing ways to optimize the producer's travel.

Chapter 3 - **Ranch Background**

The study ranch is located in the Flint Hills of Kansas. Figure 1 shows the ranch's location and the different types of travel by ranchers.

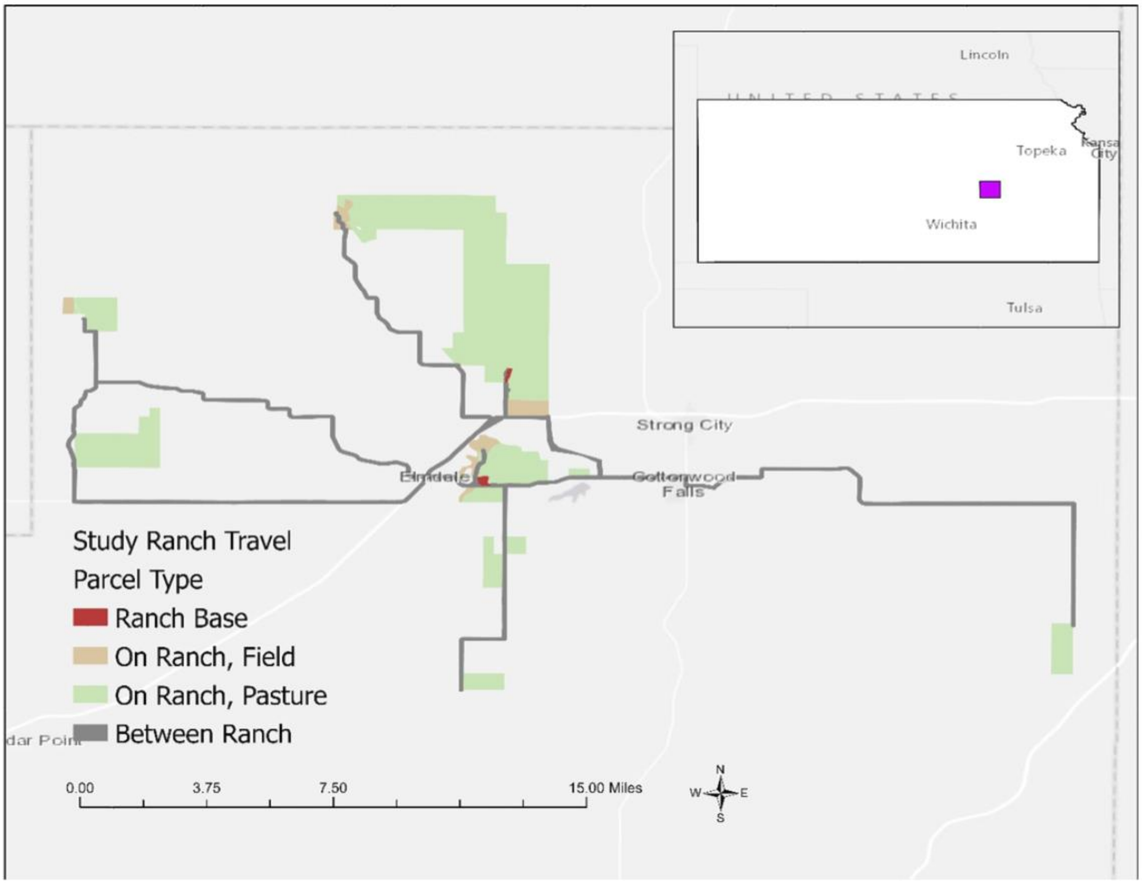

Figure 1-Ranch Location and Map

Cattle grow from a calf into either a bull or heifer. A heifer is a female cow that has not given birth. After a heifer has carried her first calf a heifer becomes a cow. Bulls are male cattle. Steers are neutered male cattle. The study ranch is primarily a stock ranch. They have two main locations, or ranch bases. The ranch bases are approximately 6 miles apart from one another. The ranch raises cattle for reproductive purposes. The cattle are then sold to other ranches. The cattle industry raises different breeds of cattle to produce different products. For example, different breeds are grown for producing milk than are grown to produce beef. Red angus cattle are grown for beef production.

The study ranch has rangeland, or large grassland pastures, and a feed yard, a confined area where the feeding of the cattle can be regulated.

The study ranch relies on heavy machinery to move the feed for the cattle. The cattle are fed various combinations of hay (cut grass), grains, silage (fermented sorghum), and allowed to graze rangeland depending upon the season.

Figure 2-Feedlot

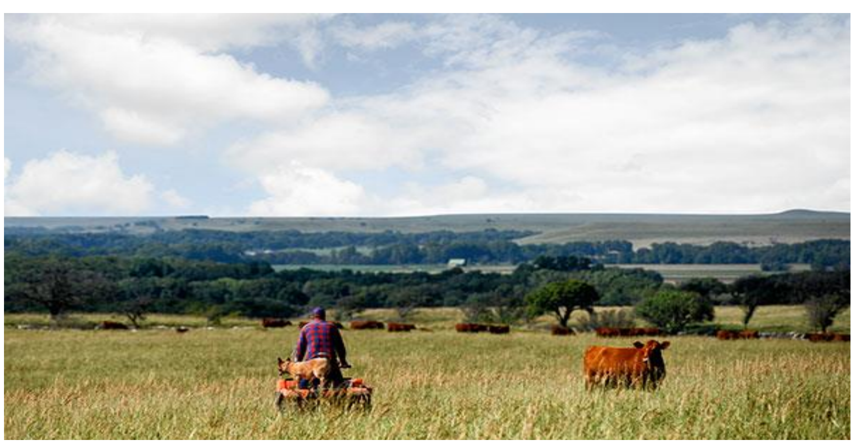

Figure 3-Pastureland

During winter months when rangeland is not viable as a food source the cattle are fed manually. This requires moving of large quantities of different feed types by the machinery.

Figure 4-Winter Feeding

The cattle industry reacts to changes in the seasons similar to all agriculture industries. The study ranch maintains two herds, one that is bred to calve in the spring and the other that is bred to calve in the fall. Herd calving is carefully managed by the ranch to attempt to aggregate their calving periods, a set time when cattle give birth to the ranch’s next calf crop. Herd impregnation is done through the use of artificial insemination to manage when the cattle are bred and to which sire. The ranch does this to always maintain a supply of older calves. The older calves will bring a better return at their yearly sale or the calves can be sold early to satisfy a need for cash. The study ranch weans, separating the 7-8-month-old calves from their mothers, during the fall. The fall calving season takes place from the end of August until the first half of October.

While cattle are raised throughout the year, the supporting activities vary greatly due to the season. Spring and summer seasons are used to produce hay and grains that are fed the cattle throughout the year. Haying is the cutting of various grasses that are dried and rolled into large bales. The bales are then stored and fed to the cattle throughout the winter when grasses are no longer available on the rangeland. Winter and fall, when rangeland is less productive, is a heavier feeding time for the ranchers. There are many other support activities that fluctuation throughout the season, but these are the major changes in day to day activities. The data collection period for the study was from June 1st, 2019 until December 31st, 2019 therefore the study covered these different activities.

The study focused on the vehicle travel of the ranch. The ranch utilizes several different vehicles for different activities. These vehicles range in size from diesel tractors to gasoline fueled quads, or four wheelers. The vehicle classifications are based on the vehicles primary use or body style, respectively. The classification system does have overlap in vehicle use. Due to the versatile use of the tractor and pickup classification it was determined to separate these vehicles by body type instead of function.

All of these vehicles perform specific functions on a ranch. The Tractor classification are used for haying, and farming activities that are used. The John Deere Loader is used by the ranch to load the Peterbilt feed truck to feed the cattle in the feed yard. These vehicles are the Feeding Classification. The Pickup classification is used for general transportation of ranchers and other materials. The Pickup category does most of the traditional highway transportation and is the most heavily used vehicle class. The tractor classification, one a John Deere 6140M the other a John Deere 6340M, are used for general field work and moving of heavy materials, such as round bales, during the appropriate seasons. The Tractor classification is used for other functions, such as a drive engine for a Power Take Off, or PTO, implement. In Figure 5 a local rancher is using his tractor at idle to run an auger using a PTO.

Figure 5-Using the a tractor to power an auger

The tractors are used when the power requirements to complete a job exceed other vehicle's ability. The utility classification made up of two Honda Quads, a Polaris Ranger and a New Holland Skid Steer, is used for light work. These vehicles are used for herding cattle, checking fence, moving medium-sized loads and used to check the herd during calving seasons. They are also used for intermediate transportation on the ranch. Trackers were installed on the vehicles shown in Table 1:

Table 1-Vehicle Information

Class	Type	Year	Fuel Type	Miles per gallon	Gallons per hour
Feeding	John Deere Loader	1988	Diesel		N/A
	Peterbilt Feed Truck	2011	Diesel	est. 3.5	
Tractor	John Deere 6340M Tractor	2015	Diesel		14.3
	John Deere 6140M Tractor	2015	Diesel		14.3
Pickup	Ram 3500	2010	Diesel	14	
	Ford F350	2006	Diesel	14	
Utility	New Holland Skid Steer	2012-2014	Diesel		approx. 2.5
	Honda Quad	2016	Gas	33	
	Honda Quad (Orange)	2016	Gas	33	
	Polaris Viking	2016	Gas	approx. 20	
	Honda Quad	2018	Gas	33	

("2017 Honda ATV Horsepower / Torque / MPG Comparison Review | Power-to-Weight Ratio Performance Numbers," 2016; *New Holland Series Specifications*, n.d.; *Skid Steer Fuel Mileage in General Board*, 2005; *UTV Fuel Economy - ATVConnection.Com ATV Enthusiast Community*, n.d.; University of Nebraska Tractor Test Labratory, 2013)

Chapter 4 - **Methodology**

Data Collection

Global Positioning System, GPS, trackers were installed by taking apart the ignition wires of each vehicle. The trackers were Linxup Asset 3G Cellular Trackers. To prevent this study from interfering with day to day operations of the ranch the trackers were wired to prevent depleting the vehicle's battery. The trackers use the 3G cellular data network to report a GPS location. The trackers report at the frequency listed in Table 2.

Table 2-Reporting Frequency

Vehicle Motion	Reporting Frequency
On and in motion	Once a minute
On but not in motion	10 minutes
Off	Once an hour

The trackers record a 5 decimal point GPS location which translates to an area of 1.1 square meters accuracy. The data is collected and stored by the GPS company and then sent to the researcher for analysis in monthly downloads. The dataset includes the location of the trackers, speed when moving, trip duration, and stop time. Trip duration includes the entire time from first ignition until the engine is shut off again. Stop time includes the length of time the vehicle is not in motion, either idling or off. The GPS points are used to analyze the ranch's travel by converting the points into lines, drawing the ranch's travel network. The Stop data are used to analyze the idling of the ranch vehicles. Outside vendors are a crucial part of ranching operations. Outside vendor data was either secured through discussions with the rancher or contacting the vendor themselves. Code used for cleaning and organizing of the data is found in Appendix B.

Factors not considered

Due to time constraints and availability of data some factors were not considered. Some outside vendors were not tracked. The study ranch uses several local farmers (local defined as within 100 miles of the study ranch) for some of their hay and, depending on the vendor, these miles were unable to be added to the system. Feed and Seed deliveries were not added to the study due to the burden it would place upon the rancher. It was not clear to the researcher at the start of the study that this data would be difficult to compile.

Chapter 5 - **Data Collection**

Data was received from the GPS company in monthly comma separated values (CSV) tables. Data was collected from June 1st until December 31st 2019. The data came in “Position”, “Stops” and “Trips” format. The Positions data records the GPS location for each vehicle based on the GPS device’s serial number. The Stops data shows where a vehicle is not moving. The Trips dataset includes the vehicles first ignition GPS location and then the GPS location of when the vehicle is shut off and the duration in milliseconds and length in miles of the trip. This data was then cleaned in R Studio. R Studio is a computer programming software that is used for statistical analysis and creating graphics, converting the devices unique id to a meaningful name. The naming and device ID table can be found in Appendix A as Table 23. From there, depending on the data type and analysis run, the data were either read back into R Studio or ArcPro.

The Positions data set contains a device id, the latitude and longitude, speed and direction of travel. The Positions dataset contained the velocity in miles per hour. The data were used to draw the lines that were used to calculate the mileage.

The Stops dataset contained the same device id and a latitude and longitude point for each stop. An event was considered a stop if the vehicle did not move outside of the 1.1 square meter area at for 3 minutes. This dataset also included a Stop_Type field and this was populated with either “Idle”, “Null” or “Off” and a duration of the stop in minutes. This dataset was used for the idling analysis and provided the most amount of insight into the efficiency issues on the ranch.

Trips data were used to calculate the driving time of the ranch. This data set came with a mileage field, start latitude and start longitude, end latitude and longitude and duration in milliseconds. The milliseconds was converted into minutes for ease of understanding.

From here the positions and trips data were aggregated by the vehicle class and the travel type, (On, Off, or Between Ranch) along with the land use (Field or Pasture). The seasonal information was added. Both the total of the two factors and the median was calculated. The median was used over other measures of central tendency due to the highly skewed data. Therefore, outputs would have the schema shown in Table 3:

Table 3-Table Schema

Vehicle Class	Travel Type	Trip Count	Sum of Miles	Median
Pickup	On Ranch, Pasture	###	###	###
Pickup	On Ranch, Cropland	###	###	###
Pickup	Off Ranch	###	###	###
Pickup	Between Ranch	###	###	###

This allowed for analysis regarding where the rancher's time and miles were spent. This aggregation was done in R Studio and written to CSVs that could be easily converted into tables.

Outside Vendors

Ranches require resources and services outside of what is available on their ranch. A ranch requires fuel deliveries, seed and feed deliveries, veterinarian visits, chemical applications, and various other contractors to be operational. These needs are not universal to all ranches. Some ranchers or farmers apply their own chemicals. Some ranchers have a veterinarian in the family. Also some ranchers grow all of their own feed. All of these factors limit the need for outside vendors and it changes from agricultural operation to agricultural operation.

Veterinary Travel

The veterinarian mileage data was received from the veterinarian. The veterinarian charges mileage by a range for example if the veterinarian must travel up to 20 miles it is charged at a certain rate but if the veterinarian must travel 21-30 miles it is a different rate. The study ranch was charged for 10 visits during the study period. However, a discount is applied if the veterinarian is nearer to the ranch on another visit. To estimate the mileage the veterinarian traveled during the study period the physical address of the ranch and the veterinarian were used. The veterinarian's office is 25.5 miles from the ranch. The total mileage was multiplied by the discount that was applied to the veterinarian to give the ranch its mileage cost. For example, many of the calls were in the second range and 7 of the 9 calls were at a 50% discount and therefore 12.75 miles was the "charge" to the ranch. This discount was only applied to travel to the ranch the entire 25.5-mile range was added for return travel. Total veterinarian miles shown in Table 4.

Table 4-Veternarian Mileage

Range (miles)	Number of Trips	Discount Applied	Estimated Mileage
0-20	1	5%	19
21-30	7	50%	89.3
21-30	2	5%	48.5
Return Travel	10	0%	255
Total	10		411.8

Fuel Deliveries

Fuel delivery comes from a local vendor and their physical location is 7.5 miles from the study ranch. The rancher received 6 fuel deliveries during the study period. Therefore to get the mileage cost of fuel deliveries the distance was multiplied by the trip count to get the 90 miles that were added for fuel deliveries.

Hay Deliveries

Hay is an important feed for cattle. The study ranch imports much of its hay from local vendors. According to rancher estimates the ranch brings in, on average, half of the hay that is fed in a year. This year the rancher received approximately 500 bales from outside vendors. This was about a third of total hay due to a successful hay year on the ranch. The rancher stated that the amount of hay brought in fluctuates from year to year. The hay is delivered from approximately 120 miles away. The ranch received 5 loads from this vendor totaling approximately 1200 additional miles.

Feed Deliveries

Feed brought to the ranch has a long storage time. This will misconstrue some outside vendor numbers. The day the feed arrives it brings a large transportation cost to the ranch but since this feed can be spread over a long period the transportation cost decreases over time. This is the same question that applies to hay deliveries. The goal is to reduce total miles but it must first be decided how miles should be allocated. The amount of feed delivered on a yearly basis fluctuates with every ranch. Due to the variability of feed deliveries there would have been an undue burden on the rancher to acquire this information for the research and therefore these numbers were excluded.

Outside vendors are a crucial part of a ranch's operations. They differ for every ranch and agricultural style. For the study ranch the type and amount of deliveries to the ranch can be seen in the Table 5.

Table 5-Outside Vendors

Vendor Type	Trip Count	Vendor Distance	Mileage
Veterinarian	10	25.5	411.8
Fuel	6	7.5	90
Seed	N/A		N/A
Hay	5	120	1200
Feed	N/A		N/A
Chemical	2	5.5	22
Total	23		1723.8

As we begin to look at all of the additional miles that happen outside of a single ranch it becomes clear that ranches and farms are complex transportation centers and should be studied as such. To progress this research, it would be beneficial to identify all outside vendors. This also brings up the possibility of studying an agriculture-based vendor as an avenue to optimize the agricultural system.

Due to the incomplete outside vendor dataset and the need for estimates there are no resolutions for optimization. This could be resolved by having a longer study that can identify all outside vendors and meeting with these vendors to discuss and research ways to limit the need for excess trips. For example the ranch could purchase fuel tanks that hold the same number of gallons that the fuel delivery truck can to limit the need for fuel trips. This research was not completed for this study, but could hold value in the future.

Issues with Data

There were multiple issues with the dataset that needed to be addressed. Using regional knowledge of the local roadways and an understanding of ranching practices the researcher was able to resolve these issues. The issues presented by the data and how they were remedied are presented in the following paragraphs.

10-minute collection data vs. 1-minute collection

There were several issues when converting the GPS points to lines. It was originally found that two of the trackers had not been given the proper software update. The outdated software caused the trackers to collect data every 10 minutes when in motion and every hour while at rest. This was discovered after attempting to use the GPS points to draw the routes in GIS. When drawing the routes using the 10 minute data it caused the software to cut the corners of routes, altering the mileage data, as shown in Figure 6.

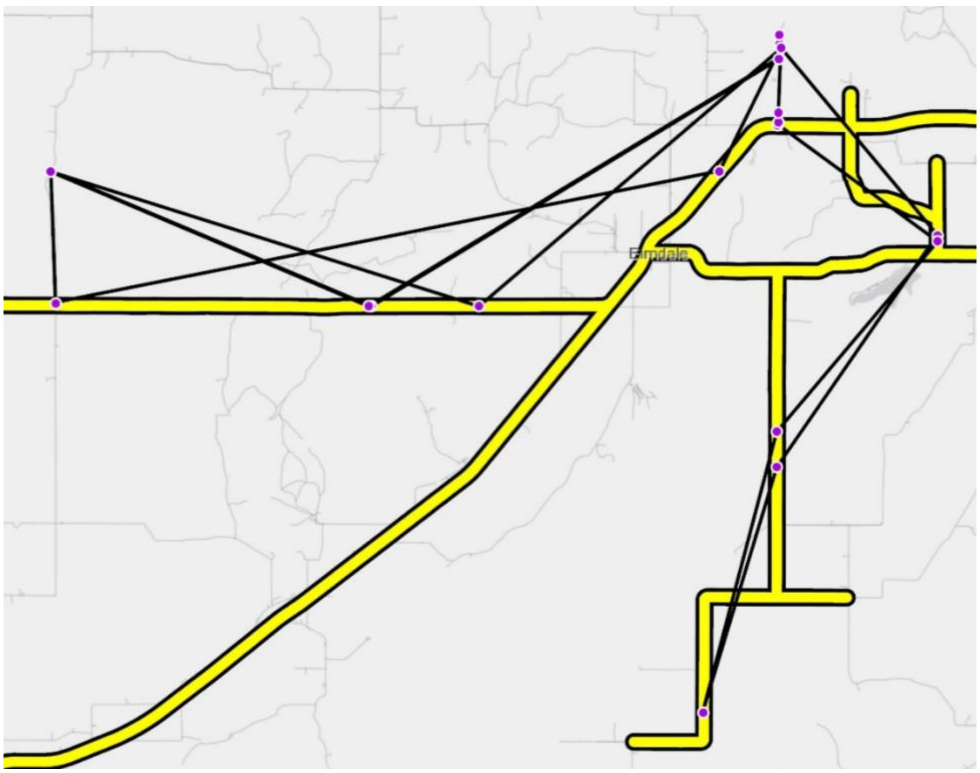

Figure 6-Incorrect Routes June 17th

The cutting of corners required that the routes be drawn in the correct paths. The correction process required that each connection follow the road network where applicable such as in the image above. Each end destination was connected to the route. The corrected routes were drawn by altering the line data using the researchers understanding of local routes and the time stamp that was present in the dataset. Figure 7 shows the same day's travel as the map above after correction.

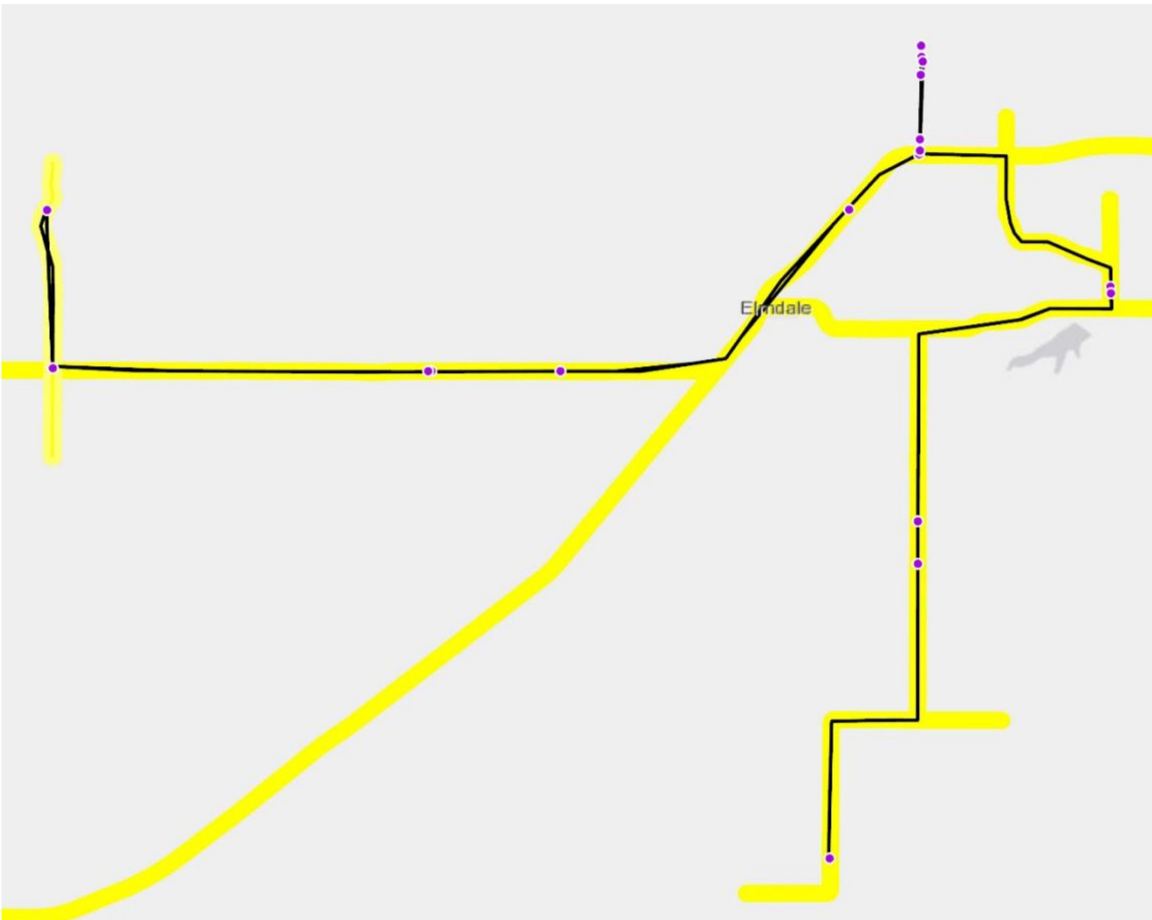

Figure 7-Corrected Data June 17th

This correction corrected the mileage for June 3rd by 42.9 miles. This a significant difference. This issue was corrected and all mileage data is accurate.

Field or Pastureland transportation

A portion of ranching travel does not occur on a traditional road network. Figure 8 demonstrates the path of a vehicle traveling through a field. This would not be the logical path of a vehicle. It is unclear what caused the tool to malfunction in this manner.

Figure 8-Incorrect data in a field June 17th

To correct this portion of the travel the time stamp of each GPS point was used to connect the points in order. There is potential for some loss in this system because the exact path is unknown and points were connected in a straight line. The issue was remedied as shown in Figure 9.

Figure 9-Corrected data in a field June 17th

This solution altered the mileage for June 17th by 24.7 miles. The difference in mileage between these two issues was once again significant and required addressing by the researcher.

Incorrect Starting vs. Ending Points

Figure 10 shows the route of a tractor that has an incorrect link between the starting and ending point. The GIS function that was used to draw the lines incorrectly connected the first and the last points of the vehicles trip. This was only discovered after the researcher examined maps that were an output of the function. It is believed that these links were created due to the GIS tools wanting to "complete" the line. This issue did not occur often but a simple check of the tool output was able to reveal the issue.

Figure 10-Incorrect starting and end point

To solve this issue time stamps were checked with each point that was incorrectly connected and that point was then deleted so that the proper route was taken. This issue occurred mostly with vehicle that were transported to a new location and left overnight.

Transportation on another vehicle

Another issue with the data occurred when vehicles were loaded either into the back of trucks or onto a trailer and transported other locations.

Figure 11-Transporting vehicles with another vehicle

Transportation of one vehicle by another was adjusted as it was clear when the vehicles were being transported as there was a time difference greater than a minute and an ignition event between departure of the ranch and the next pasture. For instance a rancher will transport a quad in the back of their pickup truck to a pasture to check fence. The quad would be turned on to load the vehicle, turned off during transport, and then turned back on when arriving at the pasture. The GIS tool would connect the travel from loading the quad and arriving at the pasture, therefore the quad would have "traveled" the distance to the pasture when it was actually the pickup that carried the quad.

Figure 12-Corrected travel for vehicle transported by another vehicle

If the incorrect routes had not been observed the data would have been severely misconstrued as the difference was 29.1 miles. It was regional knowledge and understanding of the vehicles uses that led the researcher to discover these issues.

Exporting Data Issues

The positions data was exported incorrectly from the trackers to the company server originally. This was an issue with the GPS company. It is unclear to the researcher what caused the issue. The data exported in a way that the tractors were doing 90+ miles per hour. This was obviously incorrect, but it took aggregating and averaging the data to realize this mistake.

Malfunctioning Tracker

The Semi data is simply a total of the miles from the rancher. He was able to calculate this number because of the timing of oil changes. There is no idling information for the semi due to the malfunctioning tracker. After working with the company they stated that it was a manufacturing error and the tracker would never work. Tracker was installed correctly but the tracker never recorded.

Chapter 6 - **Analysis**

This study analyzed the travel distance, trip duration, idling time and resource consumption of the ranch vehicles. The categories for analysis were chosen because these are the factors that are in rancher control. Code used for analysis and graphics creation can be found annotated in Appendix B. ArcPro was used to calculate the distances traveled by the vehicles. The data was read into ArcPro after being cleaned in R-Studio. The GPS locations were used to create point features in ArcPro using the *XY to Point Tool*. The *Point to Line Tool* was used to convert the points into the routes of the ranch. The issues that were present in Chapter 5 were resolved before moving the data to the final step. The *Summary Statistics Tool* was used to sort and aggregate the mileage data that was used in the analysis.

Many factors on a ranch are out of the rancher's control, such as weather, by focusing on factors that a rancher can influence, the study recommendations have a greater chance of being implemented. The data were split by season and travel type. Idling analysis of the ranch was concerned with the total amount, the fuel consumed and the emissions created from this idling activity. Ranch data were also split by date due to the seasonal nature of ranching. The analysis was completed to help develop recommendations for the rancher to optimize their transportation. Metrics were developed to facilitate comparisons on a temporal and regional base. Ranching techniques respond to productivity of the land and the weather. It was crucial to create a metric so that weather patterns and management techniques can be compared. The travel pattern of the ranch are skewed to the right. Figure 13 shows the entire ranch's travel. As shown in the figure the data is skewed to the right. The data shows that most of ranch travel is less than 20 miles. The data was split by Travel Type, Vehicle Classification and Season to show the relationship between these factors and the ranch's travel patterns.

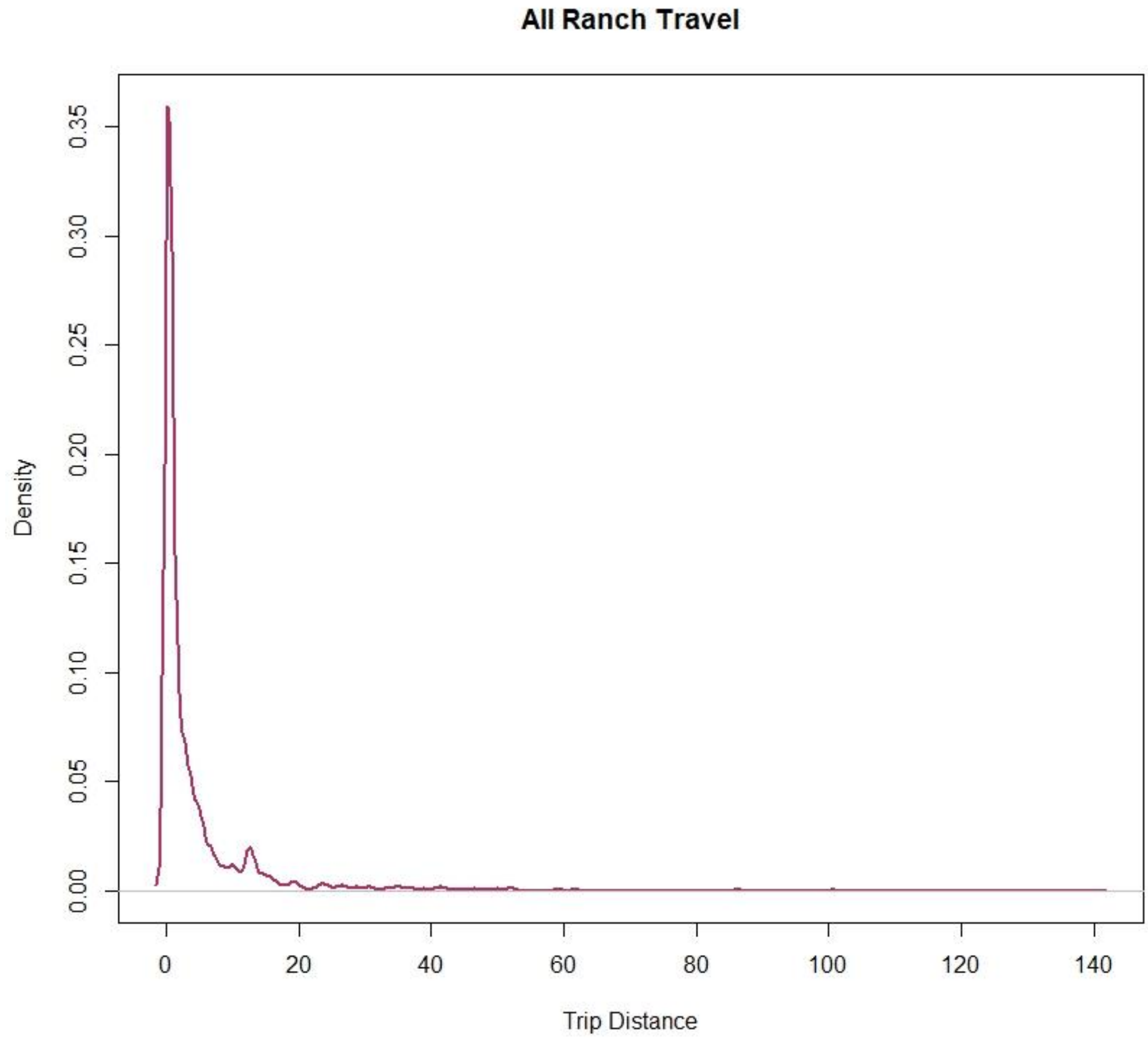

Figure 13-Density plot of entire ranch's travel

Ranch Travel: On, Off, Between Ranch

The ranch travel was analyzed using the Positions dataset. This data was brought into ArcPro as a table. The data were converted to points based on the GPS coordinates and then used to draw lines showing the ranch's routes.

The routes were split into On, Off, or Between Ranch. Parcels that are either owned or rented by the ranch were designated as On Ranch. Parcels were selected from Chase County's parcel data obtained from the county assessor's office. The Between Ranch routing was created by doing a 40-foot buffer from the State of Kansas' road centerline file for the road segments between ranch parcels, etc. The buffer was set at 40 foot to be sure to capture all of the data points along a route. Off Ranch was designated as everything that was not On or Between Ranch. The Off Ranch travel is associated with going to get supplies, meeting with partners or clients, other producers, or taking cattle to market.

The On Ranch parcels were then split as either Pasture or Field based upon the land cover and land usage. Attributing the correct travel type was accomplished by studying the trip patterns and aerial imagery. On Ranch Field travel is very different than the On Ranch, Pasture travel and this was an important distinction that needed to be made to truly understand where the rancher's miles and time was spent.

A spatial join was run to match each point to one of the four categories. A spatial join is a function in ArcPro that gives features attribute data based upon their spatial relation to other data. If a route was in a parcel type coded On Ranch, Field, the spatial join tool assigns that feature that designation. The spatial join will attribute the On Field or Pasture, Off, or Between to the data. The join allowed the researcher to calculate distances and then compile summary statistics of vehicles travel. Figure 14 shows the total and local travel coded by the travel type.

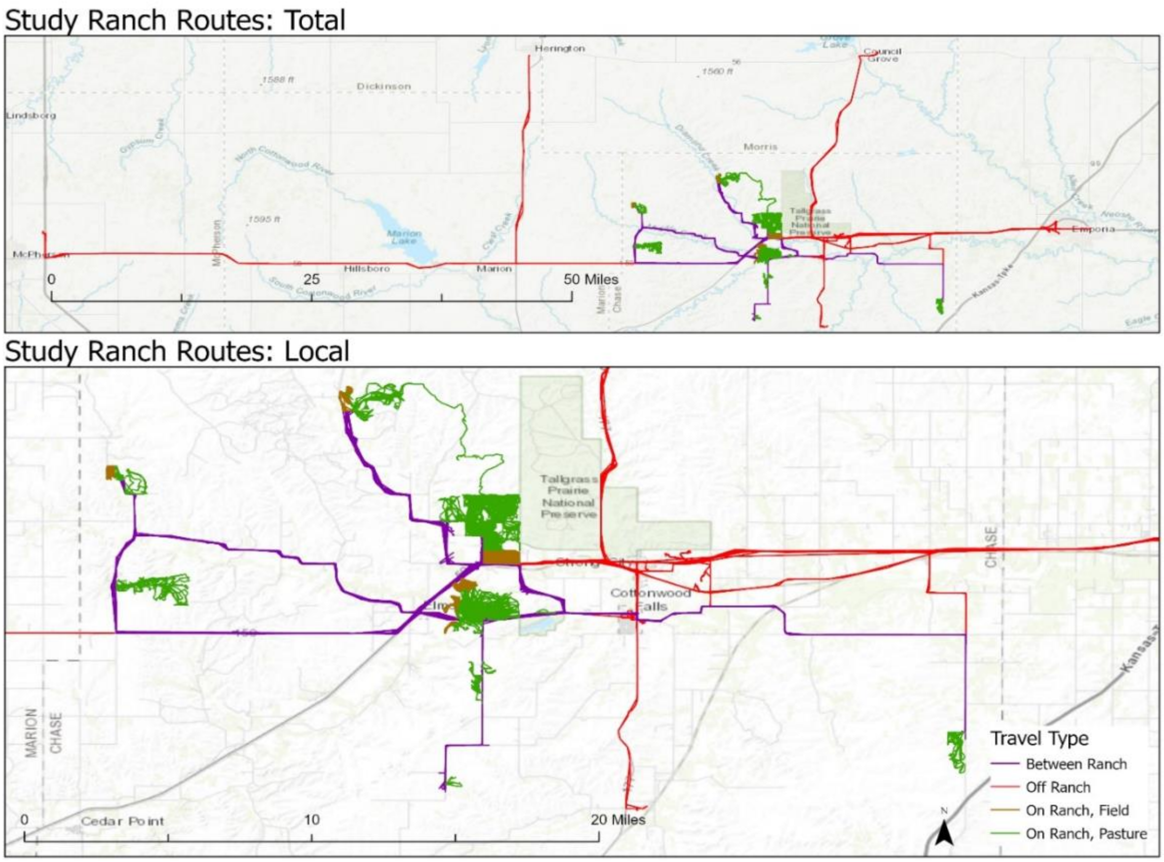

Figure 14-Travel Type Map

Analysis

The type of travel of the ranch is an important piece of information. These data shows where the majority of ranch travel is being spent, either on the ranch accomplishing tasks or traveling to other parcels. Table 7 shows the three categories with the total travel and median trip length in miles. The majority of trips were made Between Ranch and On Ranch, Pasture. On

Ranch pasture accounted for the most trips on the ranch, while the Between Ranch made up over half of the miles for the study ranch. The rancher is spending over half of his miles, and therefore his fuel resources and time, traveling between ranch parcels. While a necessity to get work done it will be important to work with the rancher to change operational habits to limit these trips. Further explanation of this idea will occur later but limited the need to feed or check certain pastures or focusing on growing the operation in a localized manner could limit the Between Ranch travel of the study ranch.

Table 6-On, Off & Between Ranch Travel Totals

Travel Type	Trip Count	Percent of Trips	Miles	Percent of Miles	Median Trip Length
Between Ranch	1653	40.7%	8705	51.1%	0.7
Off Ranch	201	4.9%	2370	13.9%	6.4
On Ranch, Field	447	11.0%	1829	10.7%	0.7
On Ranch, Pasture	1763	43.4%	4124	24.2%	0.9
Total	4064		17028		

The density plot below shows that the travel on the ranch consists of very short trips, less than 5 miles. Most of the trips for three of the categories fall under the 5 miles range. The ranch has a cluster of trips in the 10-15 mile range because the secondary location, shown in Figure 15, is approximately 12 miles away round trip.

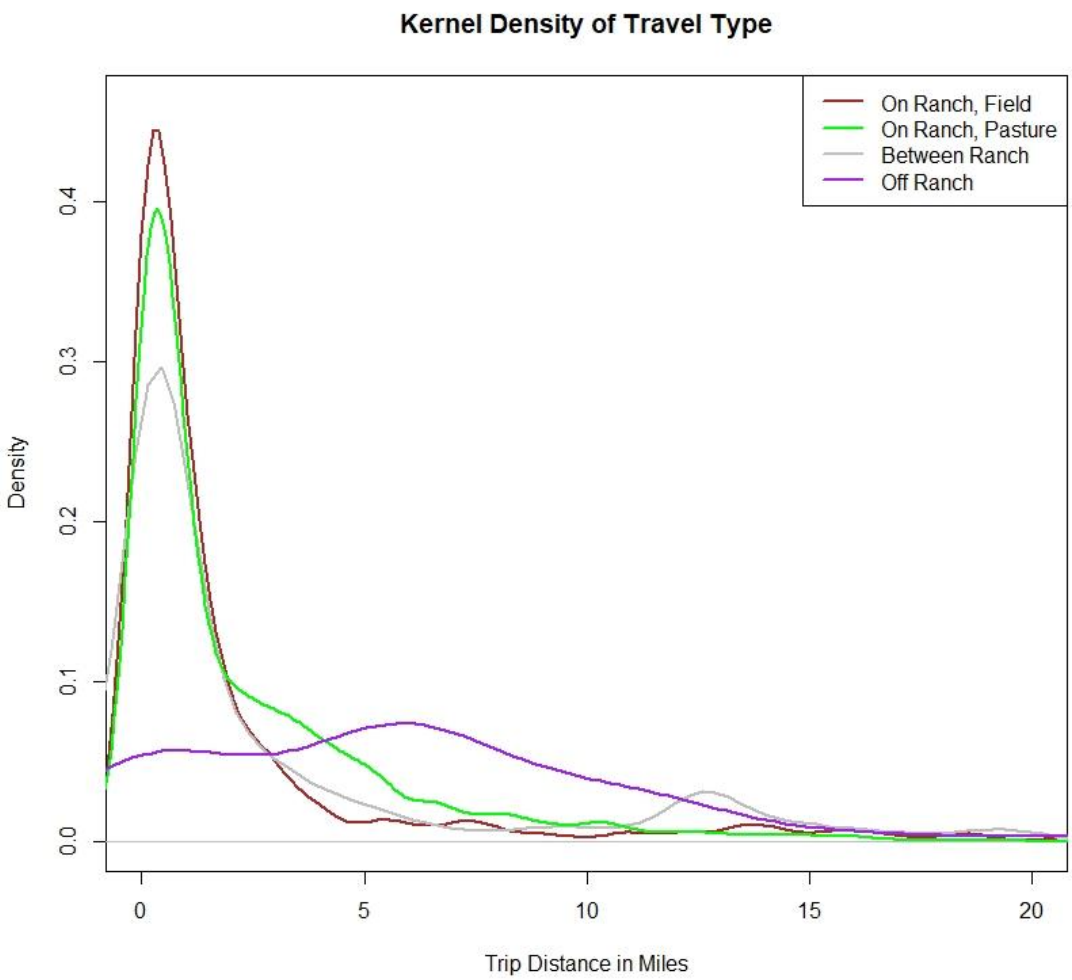

Figure 15-Trip Distance by Travel Type

The bridge outside of Elmdale was closed for construction from June 1st to August 20th. Of the two alternative options, traveling US Highway 50 was two miles shorter than taking County Road 215; however, there are benefits of taking the Road 215 with large equipment due to safety concerns.

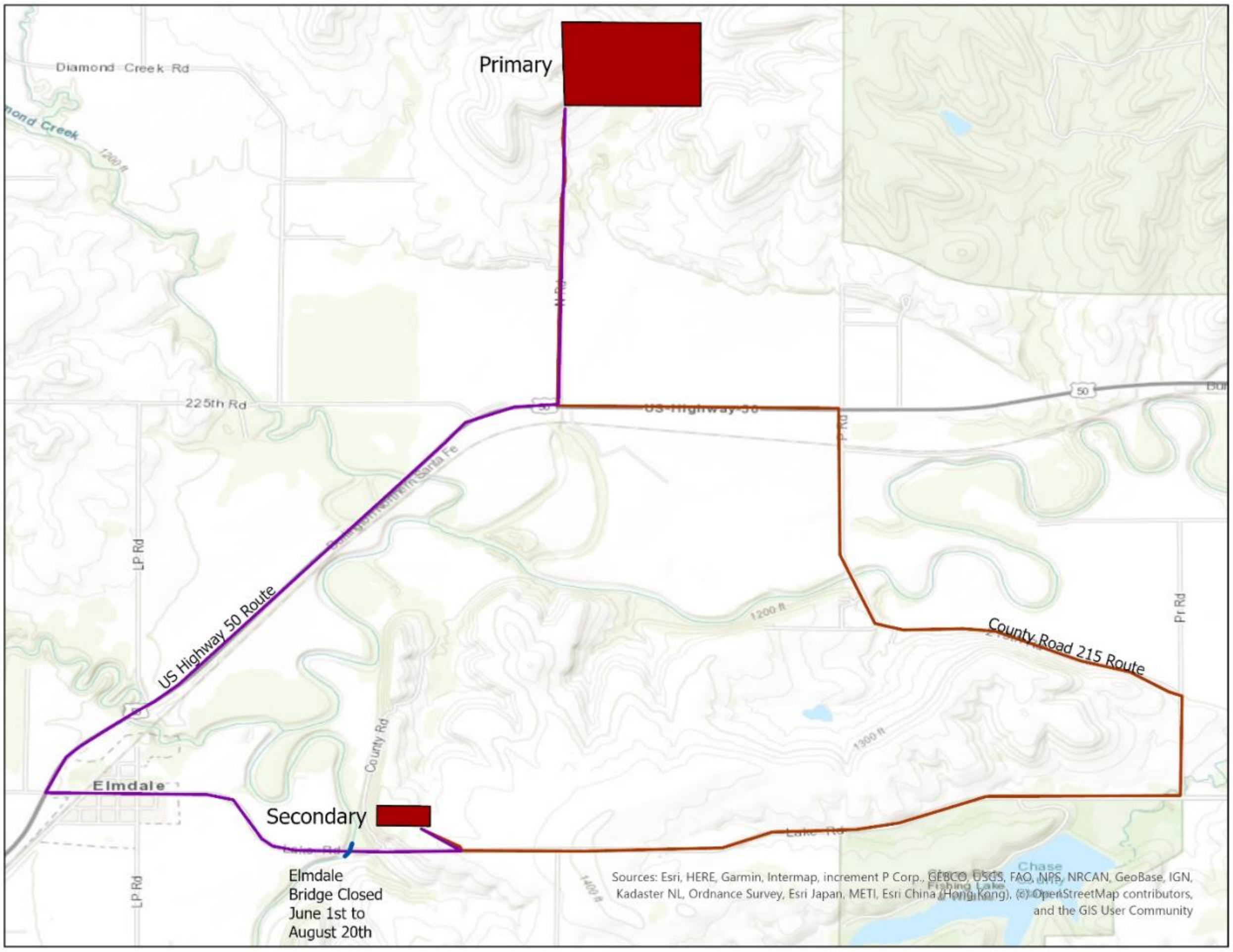

Figure 16-Bridge closing and routing to ranch bases

It is safer for the rancher to travel along the county road because there is less traffic and there is no semi-truck traffic. The lack of semi-truck travel is due to the road only providing local access and the fact it is an unpaved road. After the bridge was reopened on August 20th the rancher took 36 trips across Road 215 meaning that if the rancher had chosen the US Highway 50 he could have saved 144 miles of travel. The Pickup Classification accounted for 27 of the 36 trips. If the rancher chose to take his pickup over the US Highway 50 route, he could have saved

108 miles. The fuel economy of the pickups being 14 mpg, the rancher could have saved approximately $17 in fuel.

Ranch Travel: Vehicle Classifications

The ranch's vehicles were split by classifications. The classifications come from either primary use or from the body style of the vehicle. The classifications and which vehicle fall within are shown in Table 1. Figure 17 shows the travel total and local travel by Vehicle Classification. The image shows that the vehicle classes that are designed specifically for farm use, such as the tractor and feeding classifications, travel is centered around the ranch and do not travel great distances in a single trip.

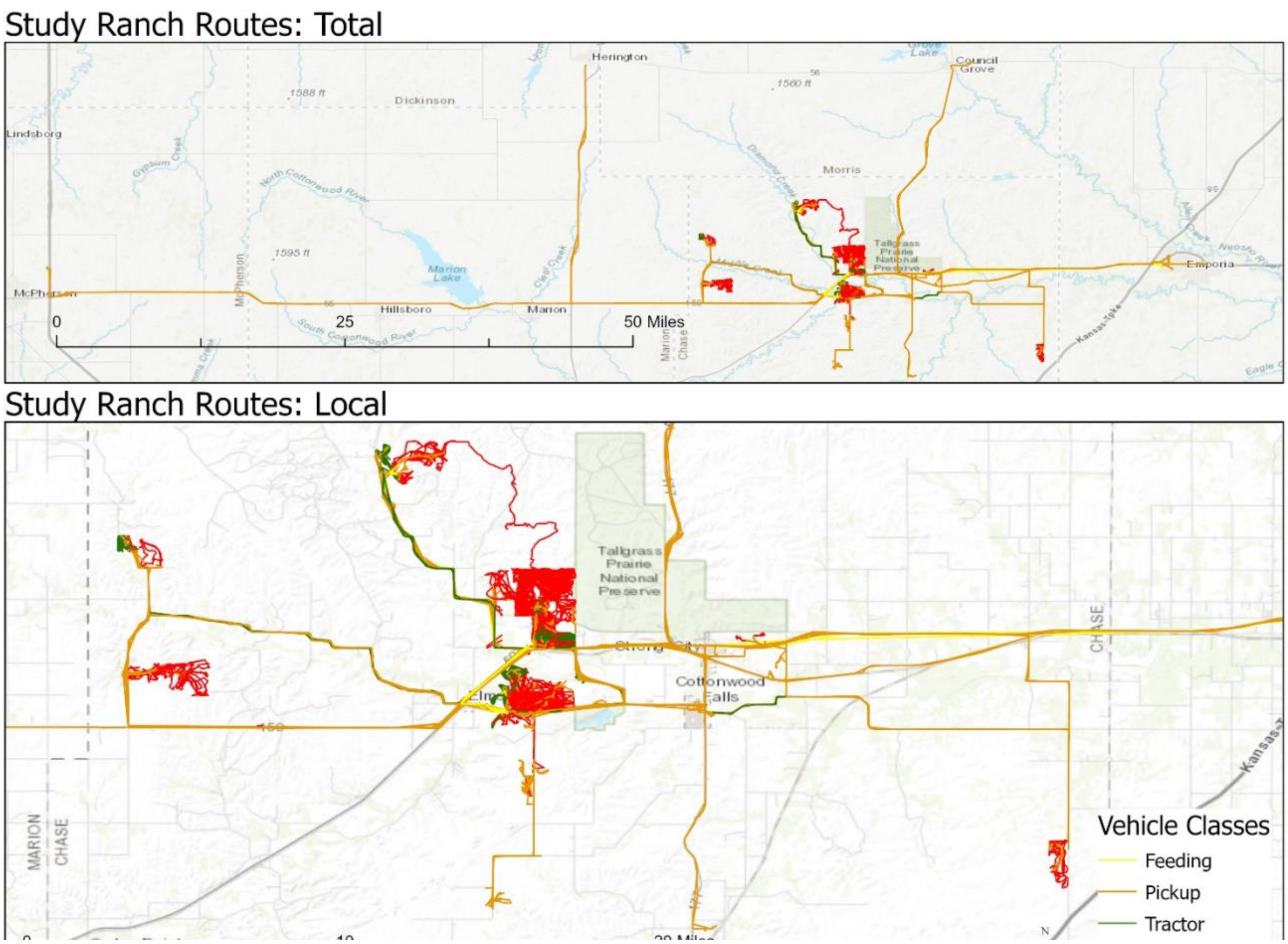

Figure 17-Vehicle Classification Map

Analysis

The vehicle classification data is important because this can begin the rancher an idea of what they can actually alter to increase their fleet efficiency. By understanding which classes do the most amount of trips or miles the rancher can begin to look at ways to change their patterns within each category. This data also helps influence the rancher's purchase decisions as their fleet needs updating. The data shows that a certain classification does a higher percentage of miles than another a greater investment may be made into updating that classification to save the rancher money over time.

Table 7-Mileage by Vehicle Classification

Vehicle Class	Trip Count	Percent of Trips	Total Miles	Percent of Mileage	Median Trip Length
Feeding	486	11.9%	1803.4	5.7%	0.8
Tractor	944	23.2%	3165.3	10.1%	0.6
Pickup	1124	27.7%	9011.2	28.7%	2.4
Utility	1510	37.2%	3048.9	9.7%	0.8
Semi	N/A	N/A	14,400	45.8%	N/A
Total	4064		31,428.9		

The majority of these miles were made with the Pickup classification as was expected. The pickup truck is the most used vehicle on the ranch as it can haul objects or trailers but also can travel at highway speeds. Table 7 shows each vehicle classification's mileage total and median. The study lasted 7 months and during this time the ranch traveled approximately 31,428 miles. Due to the variability of ranch activities during seasonal changes it is not a safe assumption to simply scale that number for a year's worth of travel. As stated above there was an issue with the semi travel as the tracker malfunctioned. Due to this percentage of trips does not include the semi numbers. The researcher was able to get an estimated mileage from the rancher using odometer changes from the start of the study to the end.

Figure 13 shows the datasets are skewed to the right. Ranching travel has outliers but as shown in Figure 18 there are some normal aspects to the ranch’s travel. These correspond to feeding in the same areas, the same field and pasture sizes and distances between the primary and secondary ranch locations. The trip distances are what changes the greatest between the different classes. To eliminate the outliers of the dataset Figure 18 was clipped to 20 miles. This was held consistent through all graphs. Figure 18 shows that most of the ranch’s travel is less than 5 miles. The short trips appear to have a normal distribution with the exception of the Feeding Classification this is because the secondary ranch base, where there is a smaller feed lot, is approximately a 12 mile round trip as shown in the data below. The feeding at the secondary location is seasonal however and that is why the frequency of the trips is lessened.

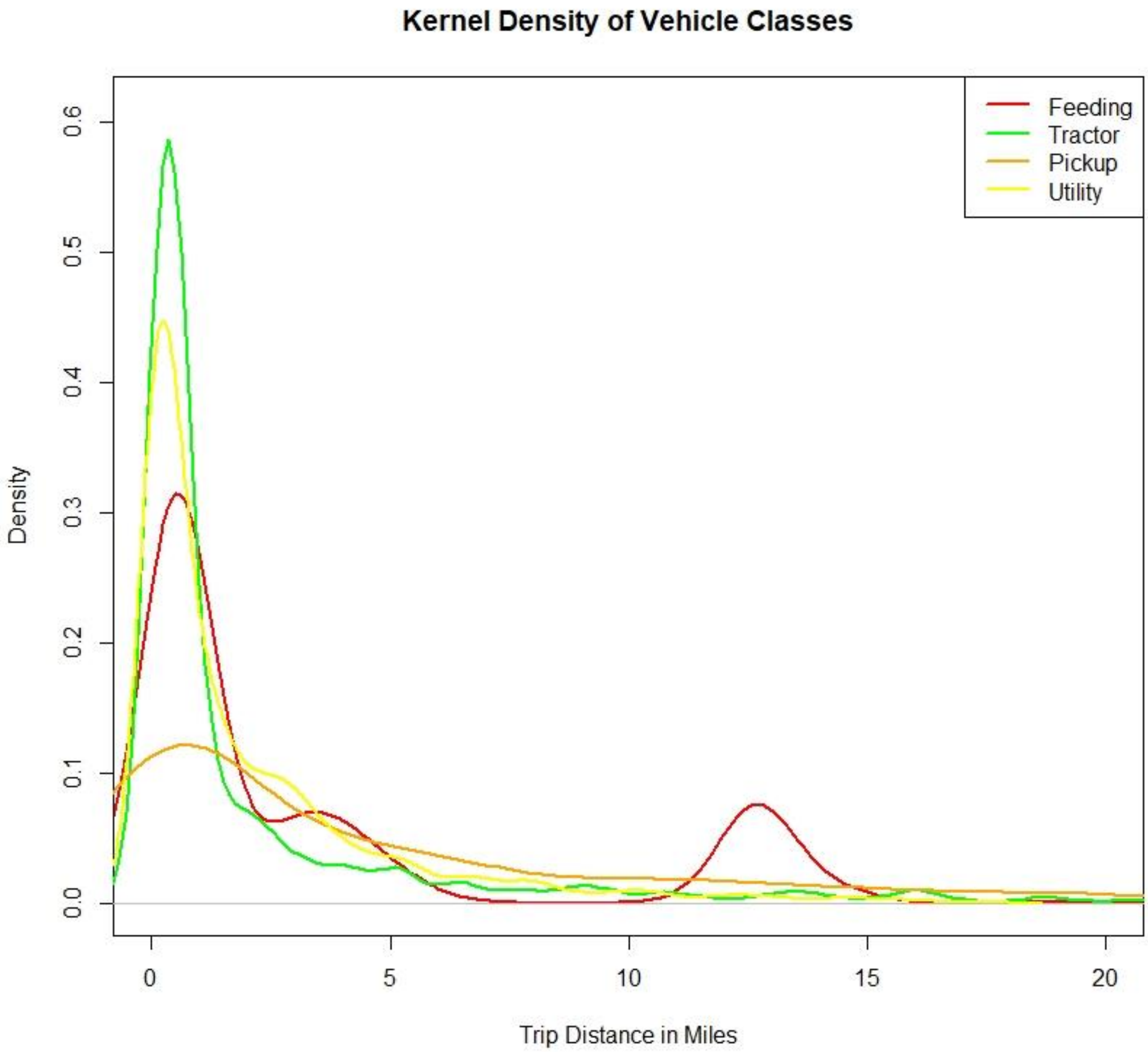

Figure 18-Density graph of Vehicle Class Travel

Figure 19 shows that the most amount of trips are made on the Utility class. The Utility class is used to move ranchers around the ranch with light loads. These trips are generally short as shown that the Utility class account for less than 20% of vehicle miles traveled. The Semi Classification makes almost half of the VMT of the ranch. The Semi is used for longer trips to haul materials or cattle to new locations. The Semi can safely travel at highway speed but has a greater ability to carry heavy loads than the pickups. Focusing on the vehicles that were able to be collected the data shows once again the dominant use of the Pickup Classification. This is an unsurprising finding of the study. The interesting part of this data is that the utility classification makes the highest percentage of total trips. These light vehicles do not need to carry much weight and are used for observational purposes mostly. Fuel alternatives for the Utility Classification, such as an electric quad, could reduce resource consumption on the ranch. An electric quad could satisfy the need to make short regular trips.

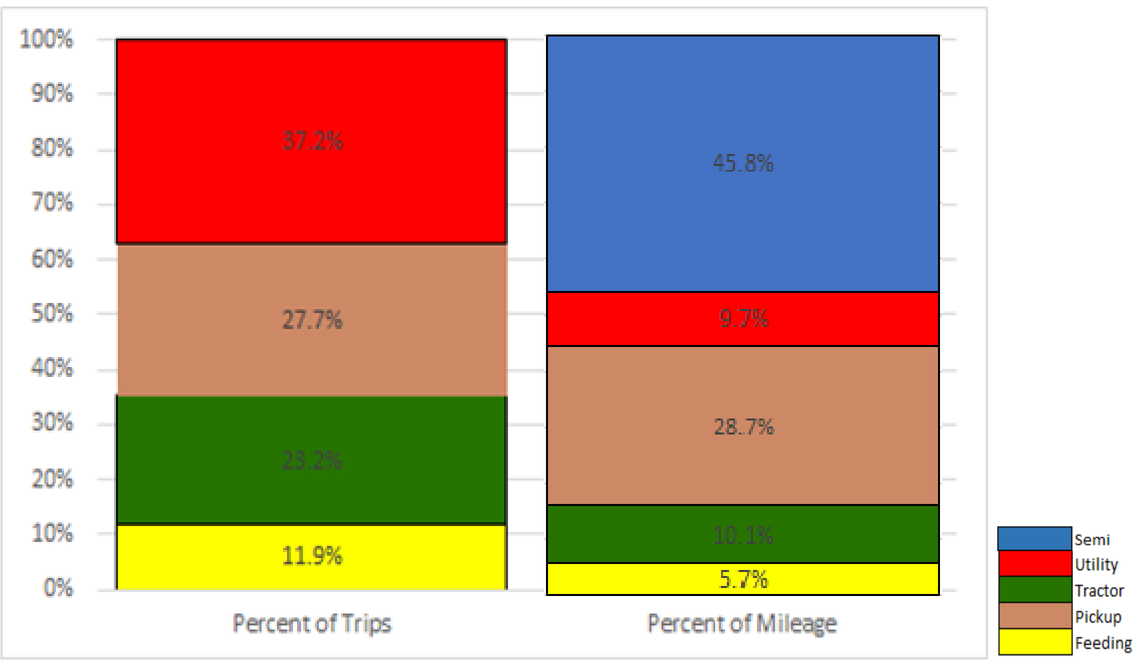

Figure 19-Percentage of trips and miles vehicle class

The percentage of trips and miles shown in Figure 19 shows what an impact on the study the semi travel has. Accounting for 45% of the travel the Semi Classification's share of the trips would be interesting to compare. Using interaction with the rancher the researcher would assume that the trip percentage is much lower than the mileage as the Semi is used for long haul trips.

Ranch Travel: Seasonal Travel

The travel of the ranch was also analyzed seasonally. The data was split at September 22nd as it was a change of a season and was approximately halfway through the study period. The data was split in this way due to the inability to collect every season in full. The dates of the split and the number of collection days are shown in Table 8.

Table 8-Seasons

Season	Collection Days
Summer	June 1st to September 22nd (86 days)
Fall	September 23rd to December 20th (78 days)

Analysis

The ranch did most of its travel in the summer season. Heavy flooding in the region potentially affected these movements. The flooding affected the total mileage of the summer season because any work that normally is completed earlier in the year was postponed due to flooding. Most of the flooding events in the region had subsided by the June 1st start date for the study. Table 9 has the data by season for all vehicles on the ranch. Table 9 and Figure 20 show there is a seasonal reduction in miles. This reduction is due to changes in operational activities. Cattle are moved around the ranch bases once pastures are unable to support them, resulting in a lessoned need to travel checking pastures. Farming activities are not productive during these times and finally the daylight hours on the ranch are shortened with the season reducing the ability of the rancher to work.

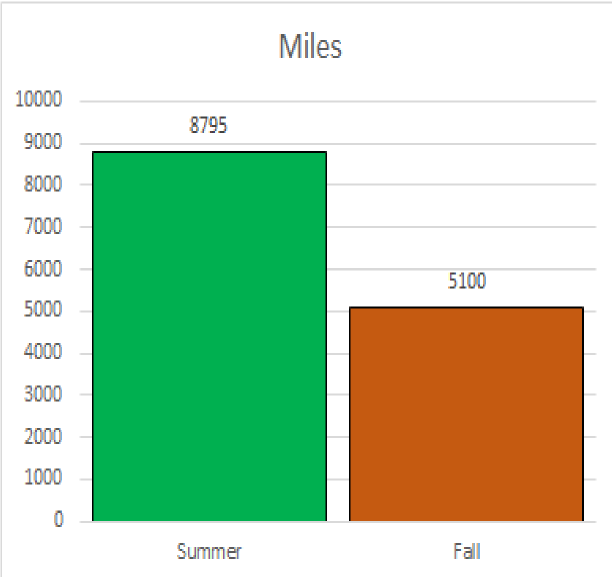

Figure 20-Mileage by season

Table 9-Seasonal Mileage

Season	Miles	Median Trip Length
Summer	8,795	0.7
Fall	5,100	3.5

The median trip length greatly increases in the fall. The assumption made from this data is that there is less time spent outside due to unpleasant weather and the rancher is trying to accomplish all of his tasks in one trip. This is also partially due to the feeding at the secondary ranch base. That trip is approximately 12 miles round trip and this would shift the median to the right as it is a trip that occurred almost daily during the fall season.

Seasonal Travel and Vehicle Classification

There is a clear pattern between vehicle use and seasonality. The summer season was the busiest potentially due to the flooding in the spring. During the fall season the Feeding classification increased in use. This was expected as pastureland begins to be less efficient as feed and the rancher needs to feed the cattle manually. Table 10 has the trip count, percent of total trips, total miles, percent of total miles and median trip length by season and vehicle class. This table the mileage total and what percentage of the work and miles are attributed to each vehicle class. The data shows that the usage of the vehicle from season to season.

Table 10-Travel Type by Season and Vehicle Class

Season	Class	Trip Count	Percent of Trips	Miles	Percent of Miles	Median Trip Length
Summer	Feeding	193	11.1%	295.9	3.4%	0.6
	Tractor	455	26.2%	2285.8	26.0%	0.8
	Pickup	476	27.4%	4592.6	52.4%	3.4
	Utility	614	35.3%	1598.8	18.2%	1.4
	Total	1738		8773.0		
Fall	Feeding	206	13.5%	1282.0	24.3%	3.9
	Tractor	335	21.9%	259.8	4.9%	0.5
	Pickup	424	27.8%	2740.9	51.9%	1.7
	Utility	559	36.7%	991.9	18.8%	0.7
	Total	1524		5274.7		

In each season the Pickup is the most used vehicle classification. The Pickup class also has the longest trips as was expected due to the Pickup's ability to travel efficiently at highway speeds. The Pickup Classification was the only classification to not to have fluctuations in use due to the season. As fall began the Tractor classification has a reduction in use while the Utility classification had its second highest use. This is due to the rancher not performing any farming activities in the fall and the increased need to check the herd to assist in calving.

The Feeding and Tractor Classifications see the greatest fluctuation in use due to the change in seasons. This is as expected due to the fairly specialized uses of these two vehicle classes. Both classes continue to see use in their off seasons greatly reduced. The percentage of miles between the Tractor and Feeding classes have an inverse reaction to the change in seasons. During the warm months, farming work is accomplished resulting in the Tractor having a greater share of the miles. Once pastures become inefficient as a feed source for the cattle the rancher must do more manual feeding resulting in the uptick in the Feeding Classifications percentage of total miles. This also corresponds with the use of the secondary feedlot at the other ranch base.

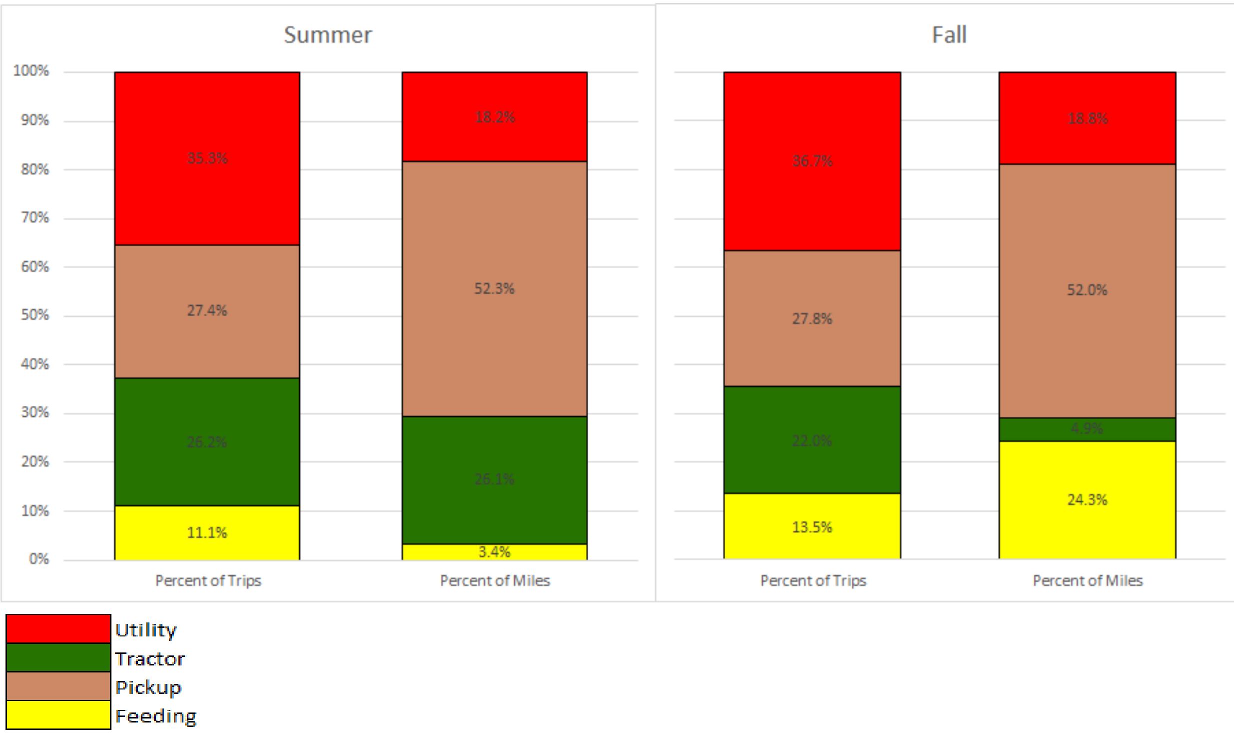

Figure 21-Percentage of Trips and Miles by Season and Vehicle Class

The total mileage between the two seasons is has a percentage of change greater than expected. The percentage of change between trip amounts and mileage can be seen in Table 11. The percent change calculated was looking at how the use of the vehicles is changed from summer to fall. As shown in Table 11 the entire fleet with the exception of the feeding classification takes a negative turn in usage. There are multiple possibilities why this happens such as, livestock are more centrally located, weather is less enjoyable to be in, daylight is limited and operational activities are changed. It was assumed that this would be observed but it was not expected that there would be such a reduction in the mileage. Overall the ranch drove only approximately a third of the mileage in the fall as it did in the summer while still making 85% of the number of trips.

Table 11-Travel Changes in Season by Vehicle Class

Vehicle Class	Trip Count (Summer)	Trip Count (Fall)	Percent Change	Miles (Summer)	Miles (Fall)	Percent Change
Feeding	193	206	6%	295.9	1282	77%
Tractor	455	335	-36%	2285.8	259.8	-780%
Pickup	476	424	-12%	4592.6	2740.9	-68%
Utility	614	559	-10%	1598.8	991.9	-61%
Total	1738	1524	-14%	8773	5274.7	-66%

Approximately the same amount of trips are taken by the rancher the overall mileage has a drastic decrease. This seems odd because the median trip during the fall period increased 5 times the summer median.

Seasonal Travel and Travel Type

The travel type by season can be seen in the Table 11. Off ranch travel had the highest median trip length every season as is expected. Once crops have been harvested and the fields will not be worked again until spring or summer the On Ranch, Field becomes the least used travel type.

Table 12-Travel Type by Season

Season	**Travel Type**	**Trip Count**	**Percent of Trips**	**Miles**	**Percent of Miles**	**Median Trip Length**
Summer	Between Ranch	653	37.6%	3972.0	45.3%	1.2
	Off Ranch	124	7.1%	1454.5	16.6%	6.2
	On Ranch, Field	255	14.7%	1434.6	16.4%	0.9
	On Ranch, Pasture	706	40.6%	1911.9	21.8%	1.1
	Total	1738		8773.0		
Fall	Between Ranch	658	43.2%	3163.5	59.9%	0.7
	Off Ranch	44	2.9%	500.9	9.5%	6.7
	On Ranch, Field	118	7.7%	78.9	1.5%	0.4
	On Ranch, Pasture	704	46.2%	1531.3	29.0%	0.9
	Total	1524		5274.7		

The ranch has a greater change in percentage of travel types than was expected. The Off Ranch travel saw the most dramatic reduction in trips than did other travel types on the ranch. The Between Ranch travel saw a greater increase in the share of mileage and while not expected this makes sense as the need to feed and manage both herds during calving season would increase.

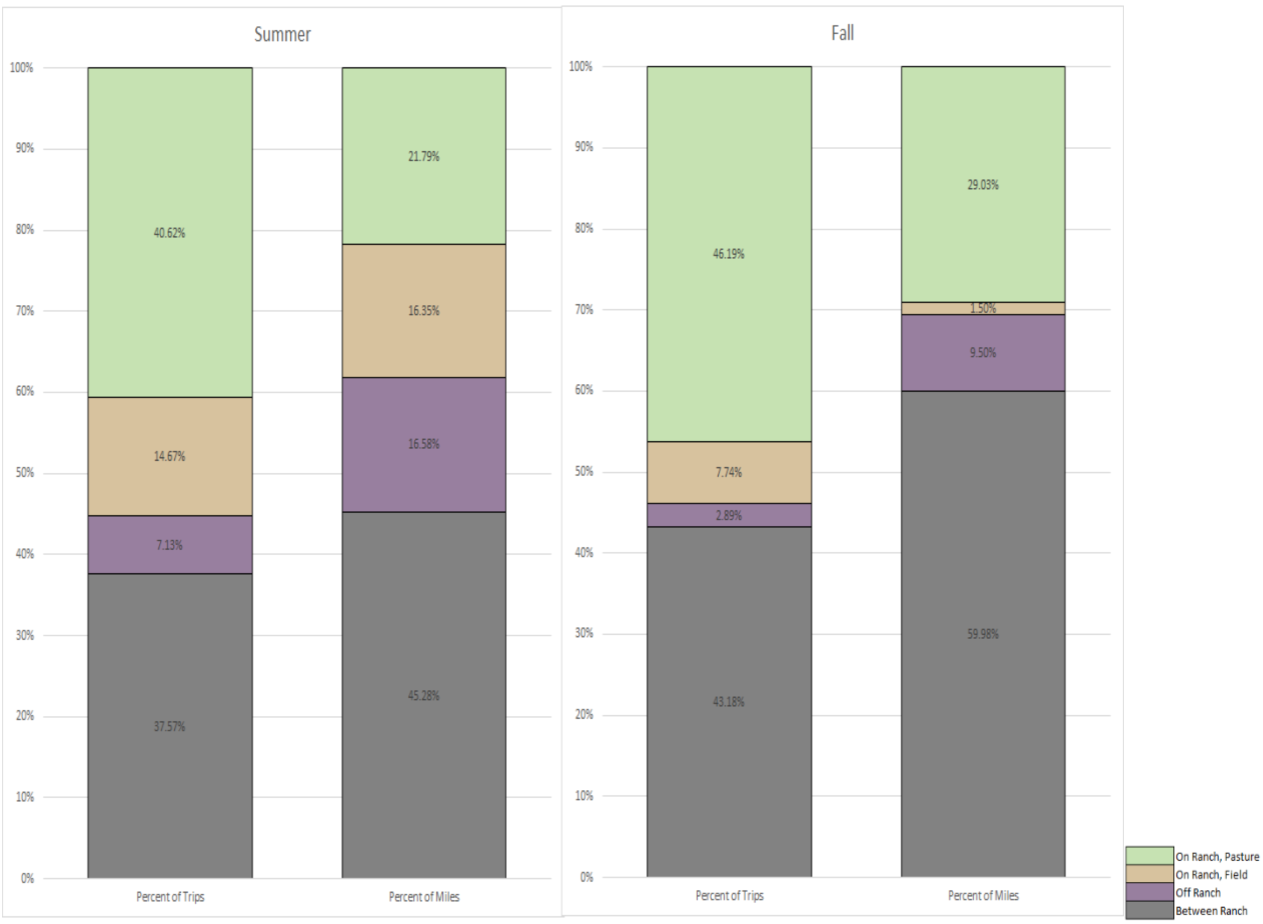

Figure 22-Percentage of Trips and Miles by Season and Travel Type

A percentage change table was created for the travel types and their seasonal travel as well. As expected, the On Ranch, Field category saw the largest seasonal change. The interesting finding from this dataset was that no matter the season the amount of trips into the pastures for the rancher remained the same. It was expected that there would need to be fewer trips into the pasture during the fall season once cattle were brought closer. It is assumed that this did not decrease as much as expected due to the need to check on the herd as they calved. The mileages for all categories decreased in the fall season. We saw the same decrease in all vehicle classes. The data shows that during the colder months the study ranch decreased travel by almost two thirds.

Travel Type	Trip Count (Summer)	Trip Count (Fall)	Percent Change	Miles (Summer)	Miles (Fall)	Percent Change
Between Ranch	653	658	1%	3972	3163.5	-26%
Off Ranch	124	44	-182%	1454.5	500.9	-190%
On Ranch, Field	255	118	-116%	1434.6	78.9	-1718%
On Ranch, Pasture	706	704	0%	1911.9	1531.3	-25%
Total	1738	1524	-14%	8773	5274.7	-66%

This raises the question of what management techniques are changed during the fall that could be incorporated into the summer season. While certain activities are exclusive to the summer or winter season it appears that all travel and all vehicles types, excluding the Feeding Class, see a reduction in travel. This would require further analysis of the habitual movements of the rancher but is a possible avenue for optimization solutions after further research.

Feeding Truck Travel

Feeding cattle is an almost daily activity for the study ranch. The rancher took the feed truck out to feed the cattle on 196 days out of the total 213-day study period. Trips were selected that crossed the feeding areas for the ranch. Cattle were studied on the tallgrass prairies of northern Oklahoma from 1989-1994 by several researchers looking at cattle performance based on feed composition and feeding frequency. There is a potential for the study ranch to change feed composition and feed less regularly (McCollum, 1997). Current feed composition of the ranch is unknown by the researcher but working with the rancher could lead to a change in the composition using the information in “Supplementation Strategies for Beef Cattle” by Ted McCollum (1997) to require less frequent feeding. There is seasonality to the feeding patterns of the ranch as the feed truck was only taken to the secondary ranch base during the fall and winter seasons. If the rancher were able to change to every other day the ranch could save 151.75 miles, as shown in Table 12.

Table 13-Feeding Truck Savings

Destination	Trip Count	Total Miles	Trips reduced	Savings if frequency altered
Hill Rd Base	64	211.1	32	$105
N Rd Base	132	93.5	66	$46.75
Totals	196	304.6	98	$151.75

The Peterbilt Feed Truck operates at, a rancher estimated, 3-4 miles per gallon. The change in feeding frequency means the rancher would have saved approximately 50 gallons of fuel. This is not direct savings potentially as there could be a higher cost of altering the feed composition. There would be a saving in the rancher's drive time and vehicles miles traveled.

Semi-Truck Travel

As stated previously there was a manufacturer error with the semi-truck tracker. An estimate, using the mileage difference between oil changes, had to be incorporated. The rancher said that the semi traveled approximately 14,400 miles during the study time. This is a major amount of travel as the rest of the ranch traveled 17,028 miles. The transportation associated with the semi is large heavy loads of hay, cattle, or other items. It is a drawback of this study that the tracker did not function as it was supposed. The assumption is made that the semi, as a large diesel machine, did have significant idling time. This study is looking to help with daily travel and the loss of the semi data is an issue in this study.

Ranch Idling

Idling is when a vehicle is sitting still, not traveling anywhere, but the vehicle is running. On a ranch this can mean several things however and does not mean that the vehicle is not being useful. The study ranch will use their tractors to power PTO, power take off, driven pumps at times. The use of the tractor in such a manner is a rare occurrence. One of the easiest ways for the rancher to see immediate savings is to limit their idling. The study ranch uses mostly diesel-based vehicles with only the quads and ranger, smaller all-terrain vehicles, being gas fueled. Diesel machines are used due to their increased power output compared to a gas fueled engine as well as longer engine life. Diesel engines require more maintenance and are more susceptible to temperature changes. Diesel fuel can thicken in cold temperatures not allowing the vehicle to start. This issue is remedied by allowing diesel engines to warm up through leaving the vehicles at idle. This practice costs the ranch considerable amounts of money.

The ranch left their vehicles, during the six-month collection period, at idle for 29.9% of the time. This was highest during the winter month. It is habitual to leave diesels at idle due to the potential for this fuel source to thicken, causing the vehicle to not restart. Winter mix diesel helps alleviate this issue, but is not sufficient enough to fix the issue completely.

Diesel engines have also long been left at idle when getting out of the vehicle for short amounts of time because of the increased wear and tear of starting. It is true that vehicles experience more wear from multiple starts. The idling duration of certain events is fairly low, say the rancher exits the vehicle to open a gate and leaves the truck on, while others are longer, leaving a truck idling while being loaded. Figure 23 shows the percent of time idling for each Vehicle Classification. Figure 23 shows that the tractor, the largest diesel engine on the ranch, idles the most. The Feeding class idles the second most.

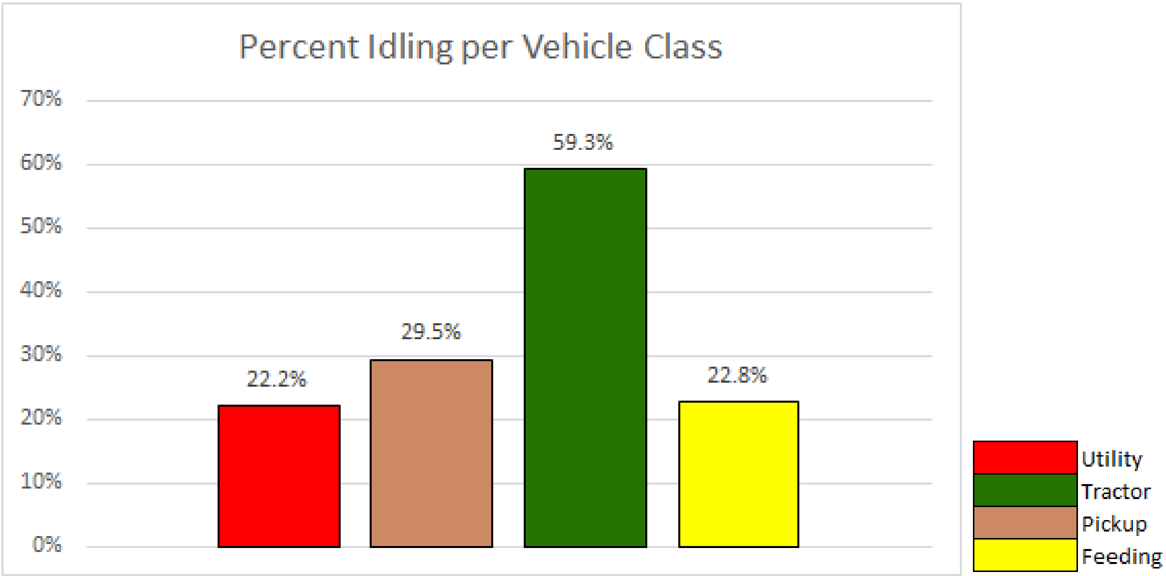

Figure 23-Percentage of idle time by vehicle class

The idling of the Feeding class is due, in part, because the vehicle must be at idle, with the PTO engaged to distribute feed to the cattle. This practice is what would be one of several activities on a ranch that would be considered a useful idle. It was impossible in this study to distinguish between a useful and a wasteful idle and moving forward would be a benefit to this research topic.

Table 14-Average length of idling event by Vehicle Class

Vehicle Class	Average Idling Time	Percent Idling Time	Total Idling Time
Feeding	29.2 min.	22.8%	413 hours
Tractor	17.9 min.	59.3%	413 hours
Pickup	13.8 min.	29.5%	179 hours
Utility	11 min.	22.2%	196 hours

Table 16 shows that the feeding classification has the longest average idling instance. This is due to the vehicle sitting at idle while dispensing feed. The vehicle is left on, unmoving, while feed is dispensed out the side. An idling event that exceeds more than 10 seconds of idling burns more fuel than starting the machine (Shancita et al., 2014). At times idling is a waste of fuel and can translate to direct loss for the ranch. There are instances on a ranch that an idling event is a necessary function of the ranch. Limiting the unnecessary idling of the ranch would be beneficial.

Figure 24 shows which vehicle class had the highest percentage of the ranch's total idle time. Figure 24 shows that the Tractor and the Feeding Classifications did the most amount of idling, over a third of the total idling on the entire ranch. These classifications make up the two most heavily used large diesel engines on the ranch.

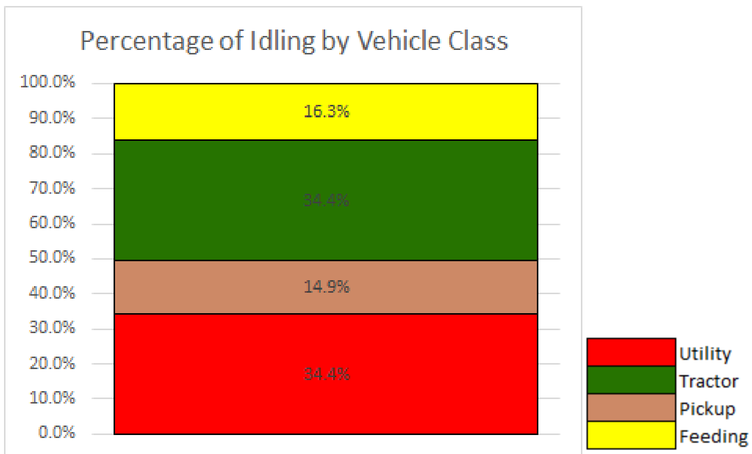

Figure 24-Total Idling Percentage by Vehicle Class

Figure 25 has a breakdown of the idling percentage of each vehicle class by season. In the fall season we see a reduction in the idling time of the Tractor Classification. This is due to lessened use of the Tractors. There is an increase in the use of the Utility Classification, this corresponds with the need to monitor the herd during the fall calving season.

Figure 25-Idling Percentage by Season

Seasonally it is expected that the fall has a higher percentage of idle than the warmer summer seasons. Figure 26 shows that the fall and winter do have a higher percentage of idle time. The difference between the spring and summer and the fall and winter is less than expected. The lower change between the warm and cold seasons could be due to running air conditioning in warmer temperatures.

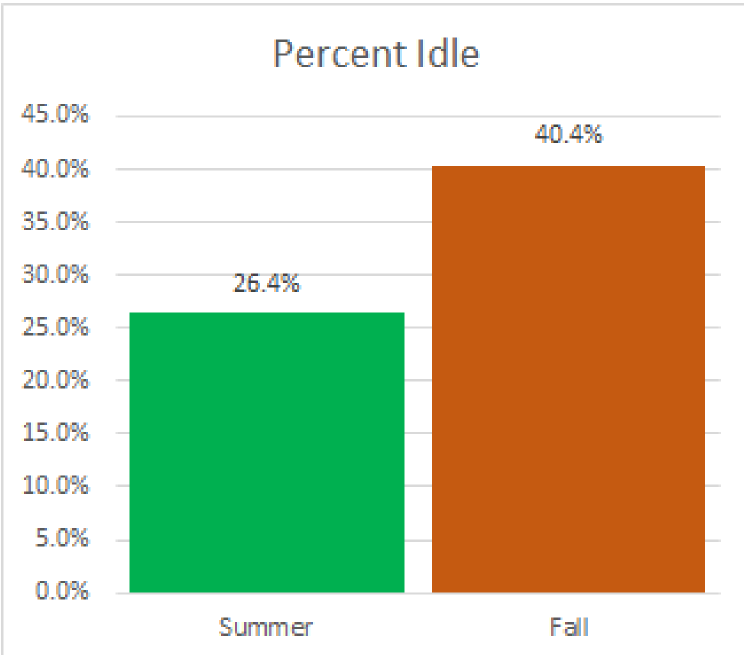

Figure 26-Percentage of Idle Time by Season

Figure 27 has the percent of idle time per Season and Vehicle Classification. Figure 27 percentages are compared to the seasonal total, so while Figure 26 shows an increase in percentage idling and Figure 27 shows all of the percentages lower than the summer the total percentage is greater. The dataset did provide some surprising findings, such as the increase in percentage idle time by the feeding classification during the summer months. Understanding the tendency of ranchers to leave diesels at idle to help with starting in cold temperatures the assumption would be made that come the warm summer months the idling percentage would reduce. The reduction was not observed however, this is potentially due to cooling vehicle through air conditioning for rancher comfort. Every season saw the Tractor classification have the highest percentage of idle time. The fact that the tractor idled the highest percentage was expected but it was not expected that the percentage of idle time would be so high. The fall percentage being high could be due to the reduction in drive time of the tractor classification. Traditionally tractor usage is limited to moving bales of hay or other large feed loads during the cooler fall seasons.

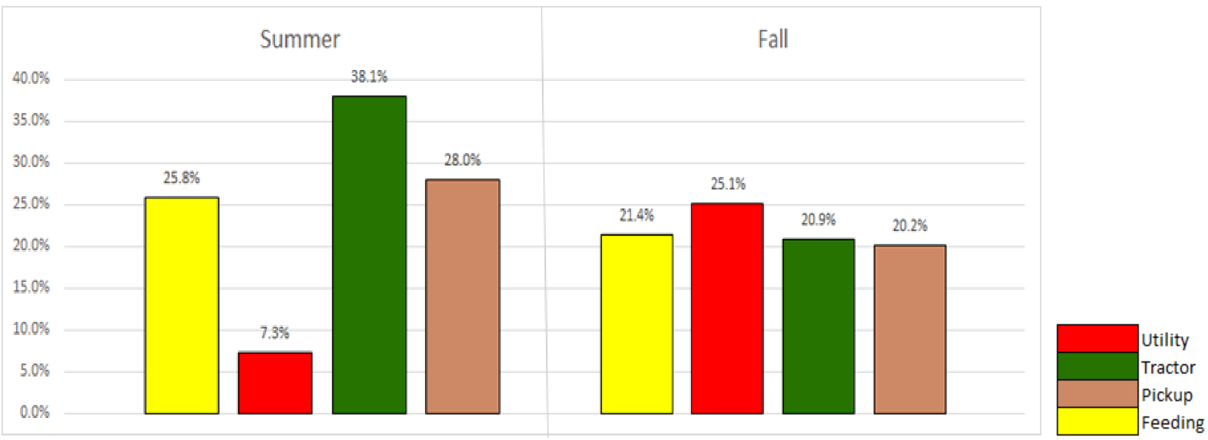

Figure 27-Percent of Idling by Season and Vehicle

Fuel Consumption During Idle

Fuel consumption data for idling vehicles was gathered from the United States Energy Information Administration for all vehicle classes excluding tractors. The idling fuel consumption for the tractors was acquired in a study by the University of Nebraska Lincoln (United States Energy Information Administation, 2015; University of Nebraska Tractor Test Labratory, 2013). The fuel consumption levels of each vehicle class are shown in Table 17:

Table 15-Fuel Consumption per Vehicle Class

Vehicle Class	Gallons per Hour of Fuel at Idle
Feeding	3.91 gal/hour
Tractor	7.18 gal/hour
Pickup	0.44 gal/hour
Utility	0.30 gal/hour

(*JohnDeere 6140M.pdf*, 2013),(United States Energy Information Administration, 2015)

The hourly consumption data was used to calculate the cost of fuel burned while the vehicles were left at idle. The number of gallons was then multiplied to find the entire monetary amount spent on fuel. Leaving these vehicles at idle showed that the ranch burned 4,718 gallons of fuel. This translates to a total of $10,637 at an average fuel cost of $2.59 per gallon.

The same number of gallons that was used to calculate the cost of idling was also used to calculate the level of emissions from idling. The emissions were calculated using the average of 22.38 lbs of carbon dioxide per gallon of diesel fuel (US Energy Administration, 2014). It was found that the ranch created 52.8 tons of CO_2 from idling.

While it is understood there are times where it is necessary that idling cannot be completely eliminated, reduction in this practice would be beneficial to the ranch both economically and environmentally. When the reduction in emissions is scaled up to the industrial farms the potential for environmental savings are significant.

Chapter 7 - **Metrics for Future Evaluations**

The study is aimed at helping ranchers become more efficient in their daily work. Due to the novel nature of the study, metrics for the rancher must be developed so that different types of ranches and operations can be compared in the future. Ranches are spread throughout the entire nation in very different ecosystems. A set of metrics was developed so that ranches can compare their travel on a yearly basis and with other operations across the nation. The rancher can observe their baseline data after their first year. Then a plan can be devised and implemented to reduce these metrics. Reduction in the metrics means that the rancher is becoming more efficient in their transportation.

These metrics provide the ability to study a ranch's travel scaled to the operation and for analysis across regions. Reducing these metrics, through either reducing travel or increasing assets (livestock or acres) translates to a more efficient ranch.

Idling metrics were created to show the impacts that idling has on the efficiency of a ranch. The idling numbers are not compared to the operational aspects, such as products or acres, because reduction in idling numbers will rely on a habitual shift more so than an operational change.

Mileage Metrics

Metrics were created to compare the production of the operation to the vehicle miles traveled. These metrics were developed so that operations that produce different products could compare within their own operation or the operations can be compared to other operations.

Vehicle Miles Traveled per Product Unit

The metric uses both rancher-only travel and the outside vendor mileage. This metric shows the rancher how many miles are associated with each animal on their operation. For this ranch the product unit is a single head of cattle but this varies by operation. This metric can be applied to different livestock, but it can also be applied to bushels of grains, or to other product units in the agriculture industry. This metric is simple in its creation but allows a rancher to understanding the cost per product to their operation. The equation for the metric is shown in Equation 1.

Equation 1-Vehicle Miles Traveled per Product Unit

$$\frac{Total\ Ranch\ Miles}{Number\ of\ individual\ product\ units} = Vehicle\ Miles\ Traveled\ per\ Product\ Unit$$

Vehicle Miles Traveled per Acre Managed

Miles per Acre uses only the producer's travel to the total acres that are used to produce the products. Acres used includes all parcels owned or rented for production, however, this measure does not include an outside vendors acreage. For example, if a producer buys hay from another rancher the acreage to produce the hay is not factored in. Livestock operations acreage consists of fields, feed lots, and pastures while farming specific operations would be only fields. This metric allows for operations that vary in size to compare to one another. Industrial farms are going to manage many more acres than family run operations on average but by comparing mileage to acres managed can show the ranchers which operation is actually more efficient. The metric equation is shown as Equation 2

Equation 2-Vehicle Miles Traveled per Acre Managed

$$\frac{Total\ miles}{Total\ acreage\ in\ production\ (leased\ and\ owned)} = Vehicle\ Miles\ per\ Acre\ Managed$$

Stocking Ratio to Miles per Acre

A stocking ratio is the amount of acres of land used to efficiently produce one head of livestock. This number varies regionally due to the productivity of grasses and other factors.

Ranchers need to maintain a balance between the number of head on a parcel and the ability of that parcel to be productive every year. An excess of livestock on a parcel can cause damage making the parcel unable to produce at an efficient level in the future. This metric allows for comparisons regionally but also to show the rancher how efficient their operation is. This metric can also compare different operations as a comparison could be made using bushels per acre or head per acre. This allows for a farmer to compare to a rancher or a mixed operation to compare between sectors. The metric equation is shown as Equation 3.

Equation 3-Unit per Acre to Vehicle Miles per Acre

$$\frac{Number\ of\ Product\ Units\ per\ Acre}{Vehicle\ Miles\ Per\ Acre} = Unit\ per\ Acre\ to\ Vehicle\ Miles\ per\ Acre$$

Idling Metrics

Idling as previously stated was an unexpected finding of the study. Idling on a ranch has a lot of different implications, some of the idling time is waste and some is useful. Useful idling encompasses such things as running hydraulics or powering other equipment. Wasteful idling is things such as leaving a vehicle at idle when exited but not using the vehicle as a source of power. To make this metric more robust it would be beneficial to devise a strategy to decipher between the wasteful and useful idling events. Limiting idling, whether beneficial or wasteful should be an overall goal of the ranch, due to resource use and the emissions that come from idling.

Idling Time

The metric adds all of idling time for a ranch and converts it into hours. This is done to show the rancher how much of their time is spent at idle. A total was used to show the impact that idling has on a ranch. These totals were significant for the study ranch and it is assumed that a total number of hours at idle would carry to other producers. This number was not scaled per head of livestock because there is not enough of an operational shift when minimal amount of head are added or subtracted. For instance, a local producer stated that the idle time per head would decrease if he were to add 30 head because his operation would not change. Changing the number of head has a low enough impact on the operation that it was discarded as a means of scaling idling time.

Idling Time per Acre

This metric takes the total idling time of the ranch and compares it to the acreage under ranch management. This allows for the rancher to scale their idling to their acreage. Acreage on a different producers' operations have different meanings. For example, the field acreage of the study ranch supports the product production but is not an end product itself. Using the entire acreage allows the rancher to see the idling time for their entire operation. Changes in acreage do have a significant shift on the operational aspects of a ranch and would affect the idling time. This will allow for a comparison between small operations to bigger and operations yearly as they grow, reduce or stay the same acreage.

Equation 4- Idle Time (minutes) per Acre Managed

$$\frac{\boldsymbol{Total\ Idle\ Time\ in\ Minutes}}{\boldsymbol{Total\ Acreage\ (owned\ and\ leased)}} = \boldsymbol{Idling\ Time\ per\ Acre}$$

Idling Time per Vehicle

This metric takes the total idling time in hours per vehicle class and divides it by the number of vehicles in that class. For example, on this study ranch there are two tractors in the Tractor Classification therefore the equation would as the total idle time divided by two. This metric will allow the rancher to see as they add vehicles to classes how it affects idling and which class is attributing the largest share of idling per vehicle.

Equation 5-Idle Time (hours) per Vehicle

$$\frac{\boldsymbol{Total\ Idle\ Time\ (Hours)}}{\boldsymbol{Number\ of\ Vehicles}} = \boldsymbol{Idle\ Time\ per\ Vehicle}$$

Percentage of Idling Time

The percent of idling metric was created to show the producer what percent of the vehicle total run time was at idle. A percentage was calculated to show the efficiency of the idling by each vehicle class or vehicle. For instance, on the study ranch the Tractor Classification and the Feeding Classification have the same total hours of idling but the Tractor Classification had a much higher percentage.

Equation 6-Percentage of Idling Time

$$\frac{Total\ Idle\ Time}{Total\ Trip\ Time - Total\ Idle\ Time} * 100 = Percentage\ of\ Idling\ Time$$

These metrics are currently baseline numbers and will lack real impact until more data is collected. To use these metrics as designed a greater diversity in time, operation, and region is desired. These metrics can be helpful to a ranch to see how they are operating currently but comparison to other metrics is where they will become most helpful to producers.

Chapter 8 - Study Ranch Metric Results

The metrics that were outlined above were applied to the study ranch to give the rancher a baseline. This current study has concluded but trackers remain in place and the rancher will be able to compare their operation from the baseline numbers collected.

Mileage Metrics

As this study is a novel approach to analyzing ranch travel metrics had to be developed that could give ranchers across the nation a way to analyze their daily operational travel. After consulting with local ranchers and Dr. Robert Weber, Professor of Animal Science Kansas State University, it was decided that the stocking ratio to miles total traveled, stocking ratio to ranch only travel, total number of cattle to total miles, total number of cattle to ranch only travel and ranch miles per acre would be the best way to compare ranch travel. Table 18-20 show the study ranch's metrics. The full formulas can be seen in Appendix A.

Table 16-Mileage Total

Travel	Miles
Rancher	17,028
Semi estimated	14,400
Outside Vendors	1,724
Total	33,152

Table 17-Metric Analysis for Study Ranch

Metric Used	Number of Cattle/Acres	Stocking Ratio	Miles Traveled	Metric Output
Miles per Cow	2,105	N/A	33,152	15.75
Miles per Cow (Rancher Only)	2,105	N/A	31,428	14.93
Acre to Miles (Rancher Only)	14,401	N/A	31,428	2.18
Stock Ratio to Acres per Mile	2.18	6.8	N/A	0.32

Table 18-Mileage Metric by Vehicle Class

Metric Used	Vehicle Class	Number of Cattle/Acres	Stocking Ratio	Miles Traveled	Metric Output
Miles per Cow	Feeding	2,105	N/A	1803.4	0.86
	Tractor	2,105	N/A	3165.3	1.50
	Pickup	2,105	N/A	9011.2	4.28
	Utility	2,105	N/A	3048.9	1.45
	Semi	2,105	N/A	14400	6.84
	Outside Vendor	2,105	N/A	1724	0.82
Miles per Cow (Rancher Only)	Feeding	2,105	N/A	1803.4	0.86
	Tractor	2,105	N/A	3165.3	1.50
	Pickup	2,105	N/A	9011.2	4.28
	Utility	2,105	N/A	3048.9	1.45
	Semi	2,105	N/A	14400	6.84
Acre to Miles (Rancher Only)	Feeding	14,401	N/A	1803.4	0.13
	Tractor	14,401	N/A	3165.3	0.22
	Pickup	14,401	N/A	9011.2	0.63
	Utility	14,401	N/A	3048.9	0.21
	Semi	14,401	N/A	14400	1.00
Stock Ratio to Acres per Mile (Rancher Only)	Feeding	N/A	6.8	0.13	0.02
	Tractor	N/A	6.8	0.22	0.03
	Pickup	N/A	6.8	0.63	0.09

Utility	N/A	6.8	0.21	0.03
Semi	N/A	6.8	1.00	0.15

The miles to cow metric shows that the ranch produces one animal per 15.75 miles total and one animal per 14.93 rancher only travel. The metrics are baseline numbers for the study ranch. Further study will be needed to observe whether the rancher's travel has been reduced and if the recommendations have been successful. These metric results are currently reduced in their importance due to a lack of comparative numbers. While it will take time to gather the comparative numbers the data shows that the rancher's most efficient vehicle, in terms of lowest miles per acre or head, is the Feeding Classification. This makes sense as the Feeding Classification is made up of specialized equipment that only serve one purpose. The other classifications have more roles to play on the ranch and therefore see an uptick in miles.

Idling Metrics

The idling metrics for the ranch will be average idling event length, total idle time, and percentage of idle time. The study ranch's idling metrics are listed in Table 21-22.

Table 19-Idling Metrics Total

Idling Metric	Study Ranch's Metric (Total)
Average Idling Time	18 min
Percent Idling Time	29.9%
Total Idling Time	1201.25 hours
Idle Time (minutes) per Acre	5 min per acre
Idle Time (hours) per Vehicle Count	120.1 hours per vehicle

These metrics show that idling on the study ranch is a large waste within their system. The ranch idles almost 30% of their drive time at an average idle length of 18 minutes. These numbers can be used to spur the rancher into action to reduce their idling but until a more detailed look is taken into this dataset it is largely unhelpful due to the variety of vehicle types and uses on a ranch.

Table 20-Idling Metric by Vehicle Class

Vehicle Class	Average Idle Time	Percent Idling	Total Idle Time	Idle Time per Acre	Idle Time per Vehicle Count
Feeding	29.2 min.	22.8%	413 hours	1.7 min.	206.5 hours
Tractor	17.9 min.	59.3%	413 hours	1.7 min.	206.5 hours
Pickup	13.8 min.	29.5%	179 hours	0.8 min.	89.5 hours
Utility	11 min.	22.2%	196 hours	0.8 min.	49.0 hours

The idling metrics were split by vehicle class to show which vehicle travel habits need to be changed. The Tractor Classification idles the most in percentage and total idle time and because of this habitual patterns need to change when the rancher drives their tractors. The Feeding Classification has the longest average idling event length. As discussed in previous sections if the number of feeding occurrences is limited, by decreasing the frequency of feeding, the idling time of the class would be limited as well.

The idling metrics that are scaled to operational factors, such as Idle Time per Acre and Idle time per vehicle count can show the rancher as their operation grows or reduces how the idling time is affected. These metrics can also help the rancher compare to other ranches within the region regardless of their operating size.

There are fleet wide changes that could be made to the ranch. The ranch could purchase more efficient vehicles, potentially a gas alternative to the diesel pickups, for between parcel travels that could reduce idling. Idling reduction is going to require several changes for the ranch. These include but are not limited to technological updates, diversifying the fleet to match trip purposes, and habitual shifts to shutting machines off when not in use. The cheapest shift for a rancher to make is simply to shut a machine off while in use. Other reductions to idling will require an expense to the rancher.

Chapter 9 - **Recommendation to Rancher for Optimizations**

The vehicular needs of the rancher regulate the amount of efficiency that can truly be achieved. This study presents some incremental changes that ranchers can make in trip decisions and vehicle choices as they update their fleet to help them be more efficient in their travel.

The prevailing idea is that these large diesels need to be “warmed” up or need to remain on while the operator is off the machine. This is no longer the case with current technology and if the rancher were to limit idling there can be an immediate savings. Idling was the biggest cost that can easily be limited by the rancher. Idling is something that simply through management practices can be reduced to help the rancher save money and resources. The rancher could shut the vehicle off when exiting and not using the vehicle as a source of auxiliary power, such as running a PTO pump.

There is a potential for savings by diversifying the rancher’s fleet. Switching to gas engines allows for purchase of a vehicle with an automatic shut off that allows the engine to shut off non necessary functions. This could be of great benefit when moving between ranch parcels as sometimes this travel does not require the power of the larger diesels. While it is convenient to stay in the same vehicle if the travel is expected to be off ranch it would improve efficiency to have a more fuel-efficient alternative to the large diesel pickups.

There are also certain technology advances that could be added to the rancher’s fleet. The Kenworth Peterbilt engine now comes with a feature called the Engine Idle Shutdown Timer that would allow the rancher to set a time limit or a specific temperature that once that temperature or time limit is exceeded the engine is shut down. This feature does not affect any PTO functions as it is programmed not to engage when it is in use. Idling is of major concern to the tractor trailer hauling industry and utilizing the technology advances on large engines could be a step in the right direction for the agricultural community.

Altering the routes that the rancher takes could also save them miles. When moving between the two base ranches it would be best to take US Highway 50 every time as it is approximately 2 miles. If the rancher is traveling to Cottonwood Falls it would save him a half a mile one way to take county road 215. While there are maintenance issues associated with always taking county road 215 saving a mile a trip as often as possible is in the rancher's best interest.

Ranching travel seems to rely heavily on short trips. There is little room for optimization on short trips as most of these occur during feeding or checking the herd. Investment into a smaller more efficient pickup could save the ranch money instead of use of the heavy diesel for these short trips.

Metric Use

The metrics that were created for this study ranch should serve as baselines. Now that a baseline has been set the criteria for the metrics made it is up to the rancher and researcher to discover ways to reduce these numbers. Other local producers have stated that simply being aware of the amount of waste in idling has caused some habitual shifts that has lowered their total idling time.

Another use of the metrics will be comparisons to other ranches as their baseline numbers are gathered. Ranchers learn a lot from working together and having comparable numbers and studying other producer's techniques that have a lower metric score than a ranch can help the producer to lower their metric scores. The metrics are devised in such a way that a path of knowledge and sharing can be created from small family farms to industrial farms. It is assumed that larger scale ranches operate at a higher efficiency but it is possible that the metrics show that smaller family farm operations operate at a higher travel efficiency per some unit and would allow the larger producers to learn from small operations. Regional comparisons can also be made. Ways of storing and dispersing hay alone is different in different regions of the United States and by identifying regions that have a low Feeding Classification to cow metric could lead to operational shifts across the nation.

Using the metrics created will become more dynamic once there is a greater dataset availability. The metrics were created for yearly comparisons or regional or operational comparisons. Currently the study ranch has a seventh-month metric number that can be used to help inform the next few months but the metric will lack real impact until multiple years of data are collected. As the dataset of metrics grows, whether this be through regionally, end products, or operational diversity, there shall be more information for producers and researchers as to what practices and regions are the most efficient, in transportation terms, in producing agricultural products.

Chapter 10 - **Potential Future Studies**

Agriculture is a crucial part of a sustainable future. This study has looked at agriculture practices through a different lens that has the opportunity to provide optimization practices in the rancher's daily travel. There were some limitations to this study. The limited time of the study did limit the factors considered and the ability to test recommendations effectiveness. The study would be better if it were able to extend for a longer duration.

It would be interesting to study a ranch that is concentrated around one base and compare it to a ranch that has parcels spread out. Comparing dispersed ranches, ranches with noncontiguous boundaries, by concentrated ranches, contiguous boundaries, could lead to a better understanding of which type of ranch is more efficient. The assumption would be contiguous boundaries would be more efficient but the needs of a ranch may extend beyond their contiguous boundary. The land adjacent to a ranch may also not be available for sale or rent. This study ranch had a mix of parcels both concentrated around a base and spread out. It would be interesting to see what travel type had the highest percentage on a concentrated ranch.

As agriculture has a diverse product base each form of agriculture should be studied. The beef industry is very diverse. Beef can be finished in a feedlot or in other manners that can be a separate study itself. Pork farms, chicken farms, pure farms with no livestock, and ranches that are purely livestock are all viable operations that could be studied. Since agriculture has not been studied in this way it really opens the doors for a bunch of data to help optimize the agricultural industry.

Outside vendors are a crucial part to a successful ranch. Some ranches have a higher use of these outside vendors. Take the ranch that was studied here, this operation did very little hay harvesting themselves while some ranchers harvest 100% of their hay. As stated above there are many different types of agriculture and many different types of products and each of these have different outside vendors that are necessary for system production. The list of supplementary professions to the agriculture industry is expansive and ever changing. This list is just a sample of professions that could be studied for potential optimization in transportation: custom harvesters, seed retailers, fertilizer companies, hay grinders, veterinarians etc. As new technologies become available new professions are being added that help optimize the study ranch, while opening the door to study all agricultural systems.

Chapter 11 - **Conclusion**

Daily ranching travel has many costs. These costs affect producers, through resource consumption, the environment, through carbon emissions from fuel combustion, and end consumers, as producers are more efficient the environment benefits and there is a potential for a reduction in price. This study took a case study methodology to catalog and analyze the daily travel of a stock ranch in the Flint Hills of Kansas. Using GPS trackers the researcher was able to track the ranch's daily travel and use ranch statistics, such as number of head and the acres managed, to develop metrics as baseline data. The metrics developed for this study ranch serve as the baseline and using the researcher's recommendations the rancher should work to limit these metrics. Reduction in the metrics has benefits for all three key elements, the producer, the environment and end consumers. As the metrics are limited the rancher is putting less into the operation, either in miles or idle time, while still producing. This means the rancher is using less fuel, reducing the carbon emissions of the travel on the ranch. The end consumer benefits because the products will become more environmentally conscious and could become cheaper.

This study was limited due to time and malfunctioning equipment, but still opens the opportunity for future studies that will increase the base data set. Studying other areas of agriculture, both regionally and in product diversification, will allow producers to compare management techniques and see where their operation lands in terms of efficiency.

Chapter 12 - **References**

2017 Honda ATV Horsepower / Torque / MPG Comparison Review | Power-to-Weight Ratio Performance Numbers. (2016, April 29). *Honda-Pro Kevin*. https://www.hondaprokevin.com/2017-honda-atv-horsepower-rating-chart-utility-4x4-race-sport-quad-2x4-four-wheeler

Ahumada, O., & Villalobos, J. R. (2009). Application of planning models in the agri-food supply chain: A review. *European Journal of Operational Research*, *196*(1), 1–20. https://doi.org/10.1016/j.ejor.2008.02.014

Akkerman, R., Farahani, P., & Grunow, M. (2010). Quality, safety and sustainability in food distribution: A review of quantitative operations management approaches and challenges. *OR Spectrum*, *32*(4), 863–904. https://doi.org/10.1007/s00291-010-0223-2

Banhazi, T. M., Babinszky, L., Halas, V., & Tscharke, M. (2012). Precision Livestock Farming: Precision feeding technologies and sustainable livestock production. *International Journal of Agricultural and Biological Engineering; Beijing*, *5*(4), 54–61.

Beauchemin, K. A., & McGinn, S. M. (2005). Methane emissions from feedlot cattle fed barley or corn diets1. *Journal of Animal Science*, *83*(3), 653–661. https://doi.org/10.2527/2005.833653x

Beauchemin, K. A., & McGinn, S. M. (2006). Methane emissions from beef cattle: Effects of fumaric acid, essential oil, and canola oil1. *Journal of Animal Science*, *84*(6), 1489–1496. https://doi.org/10.2527/2006.8461489x

Berckmans, D. (2014). Precision livestock farming technologies for welfare management in intensive livestock systems. *Revue Scientifique et Technique*, *33*(1), 189–196. https://doi.org/10.20506/rst.33.1.2273

Cattle Transport Guidelines for Meat Packers, Feedlots, and Ranches. (2008, October). https://www.grandin.com/meat.association.institute.html

Dada, P. O. O., & Abiola, O. S. (2010). *Assessment of On-Farm Travel Characteristics of Small Scale Farmers in Ibadan, Southwestern Nigeria* (Vol. 2). Journal of Natural Sciences, Engineering and Technology.

Desrochers, P., & Lusk, J. L. (2015). The inability and undesirability of local croplands to meet food demand. *Frontiers in Ecology and the Environment*, *13*(8), 409–410.

Dickinson, E., & Stanton, L. (2011). The FP Survey: The Future of Food. *Foreign Policy*, *186*, 64–65.

Duewer, L. (1984). *Changing Trends in the Red Meat Distribution System*. United States Department of Agriculture.

Eshel, G., Shepon, A., Makov, T., & Milo, R. (2014). Land, irrigation water, greenhouse gas, and reactive nitrogen burdens of meat, eggs, and dairy production in the United States. *National Academy of Sciences*, *111*(33), 11996–12001.

Farahani, P., Grunow, M., & Günther, H.-O. (2012). Integrated production and distribution planning for perishable food products. *Flexible Services and Manufacturing Journal*, *24*(1), 28–51. https://doi.org/10.1007/s10696-011-9125-0

Federal Highway Administration. (2014, November 7). *Percent of Trips and Vehicle Miles by Trip Length*. US Department of Transportation Federal Highway Administration. https://www.fhwa.dot.gov/policyinformation/pubs/pl08021/fig4_5.cfm

Gössling, S., Garrod, B., Aall, C., Hille, J., & Peeters, P. (2011). Food management in tourism: Reducing tourism's carbon 'foodprint.' *Tourism Management*, *32*(3), 534–543. https://doi.org/10.1016/j.tourman.2010.04.006

Greenhouse Gas Inventory Data Explorer | US EPA. (2018). https://cfpub.epa.gov/ghgdata/inventoryexplorer/#agriculture/allgas/source/current

Hsueh, C.-F., & Chang, M.-S. (2010). A Model for Intelligent Transportation of Perishable Products. *International Journal of Intelligent Transportation Systems Research*, *8*(1), 36–41. https://doi.org/10.1007/s13177-009-0004-y

James, S. J., James, C., & Evans, J. A. (2006). Modelling of food transportation systems – a review. *International Journal of Refrigeration*, *29*(6), 947–957. https://doi.org/10.1016/j.ijrefrig.2006.03.017

Jeyamkondan, S., Jayas, D. S., & Holley, R. A. (2000). Review of Centralized Packaging Systems for Distribution of Retail-Ready Meat. *Journal of Food Protection*, *63*(6), 796–806. https://doi.org/10.4315/0362-028X-63.6.796

Johansson, S. (2005). *The Swedish Foodprint*. Swedish University of Agricultural Sciences.

JohnDeere 6140M.pdf. (n.d.). Retrieved September 18, 2019, from https://tractortestlab.unl.edu/documents/JohnDeere%206140M.pdf

Johnson, H., & Breakiron, P. L. (1956). *Protecting Perishable Foods During Transportation by Truck*. *105*.

Johnson, K., Huyler, M., Westberg, H., Lamb, B., & Zimmerman, P. (1994). Measurement of Methane Emissions from Ruminant Livestock Using a SF6 Tracer Technique. *Environmental Science & Technology*, *28*(2), 359–362.

Laca, E. A. (2009). Precision livestock production: Tools and concepts. *Revista Brasileira de Zootecnia*, *38*(spe), 123–132. https://doi.org/10.1590/S1516-35982009001300014

MacDonald, J. M., Korb, P., & Hoppe, R. A. (2013). *Farm Size and the Organization of U.S. Crop Farming*. 61.

McGinn, S. M., Beauchemin, K. A., Coates, T., & Colombatto, D. (2004). Methane emissions from beef cattle: Effects of monensin, sunflower oil, enzymes, yeast, and fumaric acid1. *Journal of Animal Science*, *82*(11), 3346–3356. https://doi.org/10.2527/2004.82113346x

Mugnier, E., Mairet, A., & Boucher, J. (2010). *Product Carbon Footprinting – a study on methodologies and initiatives*. European Commission.

Naveed, A., Ashfaq, A., & Syed Aftab, W. (2016, March 27). *Tackling climate change through livestock*. http://link.galegroup.com/apps/doc/A447292505/ITOF?sid=lms

New Holland Series Specifications. (n.d.). Retrieved February 8, 2020, from http://pdfstream.manualsonline.com/3/368abb22-9728-44c9-b2cf-2f00b442fd4c.pdf

Pitesky, M., Stackhouse, K., & Mitloehner, F. M. (2009). Clearing the Air: Livestock's Contribution to Climate Change. In *Advances in Agronomy* (Vol. 103, pp. 1–36).

Rural Transportation Issues Executive Summary. (2008).

Sands, R., & Westcott, P. (2011). *Impacts of Higher Energy Prices on Agriculture and Rural Economies* (p. 56).

Shancita, I., Masjuki, H. H., Kalam, M. A., Rizwanul Fattah, I. M., Rashed, M. M., & Rashedul, H. K. (2014). A review on idling reduction strategies to improve fuel economy and reduce exhaust emissions of transport vehicles. *Energy Conversion and Management*, *88*, 794–807. https://doi.org/10.1016/j.enconman.2014.09.036

Skid Steer fuel mileage in General Board. (2005). The Forestry Forum. https://forestryforum.com/board/index.php?PHPSESSID=om59cnionl4phcktb401048ma3&topic=14063.0

Stackhouse-Lawson, K. R., Rotz, C. A., Oltjen, J. W., & Mitloehner, F. M. (2012). Carbon footprint and ammonia emissions of California beef production systems1. *Journal of Animal Science*, *90*(12), 4641–4655. https://doi.org/10.2527/jas.2011-4653

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., & de Haan, C. (2006). *Livestock's Long Shadow*. Food and Agriculture Organization of the United Nations.

Stoessel, F., Juraske, R., Pfister, S., & Hellweg, S. (2012). Life Cycle Inventory and Carbon and Water FoodPrint of Fruits and Vegetables: Application to a Swiss Retailer. *Environmental Science & Technology*, *46*(6), 3253–3262. https://doi.org/10.1021/es2030577

Thoma, G., Popp, J., Nutter, D., Shonnard, D., Ulrich, R., Matlock, M., Kim, D. S., Neiderman, Z., Kemper, N., East, C., & Adom, F. (2013). Greenhouse gas emissions from milk production and consumption in the United States: A cradle-to-grave life cycle assessment circa 2008. *International Dairy Journal*, *31*, S3–S14. https://doi.org/10.1016/j.idairyj.2012.08.013

Tsang, Y. P., Choy, K. L., Wu, C. H., Ho, G. T. S., Lam, H. Y., & Tang, V. (2018). An intelligent model for assuring food quality in managing a multi-temperature food distribution centre. *Food Control*, *90*, 81–97. https://doi.org/10.1016/j.foodcont.2018.02.030

United Nations. (2001). *The Role of Agriculture in the Development of LDCs and their Integration into the World Economy*. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/y0491e/y0491e00.htm#TopOfPage

United States Department of Agriculture. (2019, August 28). *USDA ERS - Sector at a Glance*. https://www.ers.usda.gov/topics/animal-products/cattle-beef/sector-at-a-glance/

United States Energy Information Administation. (2015). *How Much Fuel is Used For Idling*. United States Energy Information Administration. https://www.anl.gov/es/reference/vehicle-idle-reduction-savings-worksheet-excel

University of Nebraska Tractor Test Labratory. (2013). *John Deere 6140M Powerquad-Plus Diesel 24 Speed*.

US Energy Administration. (2014). How much Carbon Dioxide is produced by buring Gasoline and Diesel Fuel? *Monthly Energy Review*.

US EPA, O. (2015, December 29). *Sources of Greenhouse Gas Emissions* [Overviews and Factsheets]. US EPA. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

UTV fuel economy—ATVConnection.com ATV Enthusiast Community. (n.d.). Retrieved February 8, 2020, from https://atvconnection.com/forums/general-ruv-utv-discussion/367083-utv-fuel-economy.html

Van Hertem, T., Rooijakkers, L., Berckmans, D., Peña Fernández, A., Norton, T., Berckmans, D., & Vranken, E. (2017). Appropriate data visualisation is key to Precision Livestock Farming acceptance. *Computers and Electronics in Agriculture*, *138*, 1–10. https://doi.org/10.1016/j.compag.2017.04.003

West, T.O, & Marland, G. (2002). Net carbon flux from agricultural ecosystems: Methodology for full carbon cycle analyses. *Environmental Pollution*, *116*(3), 439–444. https://doi.org/10.1016/S0269-7491(01)00221-4

West, Tristram O, & Marland, G. (2002). A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture: Comparing tillage practices in the United States.

Agriculture, Ecosystems & Environment, *91*(1–3), 217–232.

https://doi.org/10.1016/S0167-8809(01)00233-X

Appendix A

Table 21-Vehicle Names, Classification and Device ID

Vehicle Classification	Vehicle	Device ID	Serial Number
Pickup	F350 White	345479	BV184001145
	Ram 3500	345447	BV184000505
Tractor	John Deere Lake Road	345452	BV184001312
	John Deere N Road	345451	BV184000428
Feeding	Peterbilt Feed Truck	345460	BV184000568
	John Deere Loader	345454	BV184000556
Utility	New Holland Skid Steer	345481	BV184000537
	Orange 4 Wheeler	345455	BV184001391
	Red Four Wheeler Honda	345475	BV184000405
	Red Polaris Ranger	345350	BV184000736

Table 22-Metric Formulas: Mileage

Metric Used	Metric Formula
Total Head to Miles	Product Unit/Total Miles Traveled
Total Head to Ranch Only	Product Unit/Ranch Miles Traveled
Per Acre to Ranch Only Miles	Total Acreage/Miles Traveled
Miles Per Acre to Stock Ratio	Miles per Acre/Stock Ratio

Table 23-Metric Formulas: Idling

Metric Used	Metric Formula
Average Idle Time	Idling Time/Number of Trips
Idling Percentage	Idling Time/Drive Time
Total Idling Time	Sum of All Idling Event
Idling Time per Product Unit	Product Unit/Idle Time in Minutes
Idling Time per Acre	Total Acreage/Idle Time in Minutes
Idling Time per Vehicle	Idle Time in Hours/Number of Vehicles in Classification

Appendix B

Cleaning Data

This code was used to classify all trackers and to give each tracker the correct vehicle name. This code creates new files in a separate folder with an additional column that has the vehicles name and classification appended to the dataset.

```
#read in required packages
library(data.table)
library(dplyr)
library(stringr)
library(reshape2)
library(tidyverse)

#create a list of the files from your target directory

setwd("C:\\Users\\scottha\\OneDrive-Kansas State University\\Thesis\\Data\\RawData\\Positions")

file_list <- list.files(path="C:\\Users\\scottha\\OneDrive - Kansas State
University\\Thesis\\Data\\RawData\\Positions")

#initiate a blank data frame, each iteration of the loop will append the data from the given file to this variable
s <- data.frame()

#had to specify columns to get rid of the total column
for (i in 1:length(file_list)){
  temp_data <- fread(file_list[i], stringsAsFactors = FALSE) #read in files using the fread function from the data.table
package##################
s <- rbindlist(list(s, temp_data), use.names = TRUE,fill = TRUE) #for each iteration, bind the new data to the building
dataset######
}

##################Gave Each individual vehicle a name in position dataset##########################
s$VehName <- factor(s$device_id,
```

```
            levels = c(345479,345465,345460,345447,345475,345452,345454,345481,345451,345450,345455),
            labels = c("F350", "FordDumpTruck", "PeterbuiltFeed", "RAM3500", "Honda4WheelerRed",
"LR_JDTractor", "JDLoader", "SkidSteer", "NR_JDTractor", "PolarisRanger","Honda4WheelerOrange"))

##################Put vehicles into the proper classes in positions dataset########################
s$VehClass <- factor(s$device_id,
             levels = c(345479,345465,345460,345447,345475,345452,345454,345481,345451,345450),
             labels = c("Pickup", "Feeding", "Feeding", "Pickup", "Utility", "Tractor", "Feeding", "Utility", "Tractor",
"Utility"))
##############################################################################################
setwd("C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\Data\\RawData\\Stops")

file_list <- list.files(path="C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\Data\\RawData\\Stops")

#initiate a blank data frame, each iteration of the loop will append the data from the given file to this variable
st <- data.frame()

#had to specify columns to get rid of the total column
for (i in 1:length(file_list)){
  temp_data <- fread(file_list[i], stringsAsFactors = FALSE) #read in files using the fread function from the data.table
package##############
  st <- rbindlist(list(st, temp_data), use.names = TRUE,fill = TRUE) #for each iteration, bind the new data to the
building dataset##########
}

###################Gave Each individual vehicle a name in Stops dataset##########################
st$VehName <- factor(st$device_id,
            levels = c(345479,345465,345460,345447,345475,345452,345454,345481,345451,345450),
            labels = c("F350", "FordDumpTruck", "PeterbuiltFeed", "RAM3500", "Honda4WheelerRed",
"LR_JDTractor", "JDLoader", "SkidSteer", "NR_JDTractor", "PolarisRanger"))

##################Put vehicles into the proper classes in Stops dataset########################
st$VehClass <- factor(st$device_id,
             levels = c(345479,345465,345460,345447,345475,345452,345454,345481,345451,345450),
```

```
                    labels = c("Pickup", "Feeding", "Feeding", "Pickup", "Utility", "Tractor", "Feeding", "Utility", "Tractor",
"Utility"))

st1<-st[,-c("device_id","device_uuid","device_nbr","device_serial_nbr")]##Finish the list of columns to remove
making a new cleaner dataset#######

write.csv(st1,file = "C:\\Users\\scottha\\OneDrive - Kansas State
University\\Thesis\\Data\\CleanedupData\\Stops.csv",row.names = TRUE)###Writing out for ArcPro Use and Data
analysis##

##########TRIPS DATA CLEANING#####################
setwd("C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\Data\\RawData\\Trips")

file_list <- list.files(path="C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\Data\\RawData\\Trips")

#initiate a blank data frame, each iteration of the loop will append the data from the given file to this variable
Trip <- data.frame()

#had to specify columns to get rid of the total column
for (i in 1:length(file_list)){
  temp_data <- fread(file_list[i], stringsAsFactors = FALSE) #read in files using the fread function from the data.table
package####
  Trips <- rbindlist(list(Trip, temp_data), use.names = TRUE,fill = TRUE) #for each iteration, bind the new data to the
building dataset#########
}
###################Gave Each individual vehicle a name in Trips dataset##########################
Trips$VehName <- factor(Trips$device_id,
                    levels = c(345479,345465,345460,345447,345475,345452,345454,345481,345451,345450),
                    labels = c("F350", "FordDumpTruck", "PeterbuiltFeed", "RAM3500", "Honda4WheelerRed",
"LR_JDTractor", "JDLoader", "SkidSteer", "NR_JDTractor", "PolarisRanger"))

#################Put vehicles into the proper classes in Trips dataset########################
Trips$VehClass <- factor(Trips$device_id,
                     levels = c(345479,345465,345460,345447,345475,345452,345454,345481,345451,345450),
```

```
        labels = c("Pickup", "Feeding", "Feeding", "Pickup", "Utility", "Tractor", "Feeding", "Utility", "Tractor",
"Utility"))

write.csv(Trips,file = "C:\\Users\\scottha\\OneDrive - Kansas State
University\\Thesis\\Data\\CleanedupData\\Trips_fin.csv",row.names = TRUE)###Writing out for ArcPro Use and
Data analysis#######
```

Drive Time and Idle Percentage per Trip

This code was used to calculate the percentage time per trip and the total drive time of the ranch. This data was later used to calculate end idling statistics for the seven-month period.

```
###read in the necessary packages###
library(data.table)
library(tidyverse)
library(lubridate)
library(plyr)
library(timetk)
library(tidyr)
library(ggplot2)
library(sf)
library(chron)
library(tibbletime)
library(reprex)

setwd("C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\TableOutputs\\Final_2_16\\DriveTime")

s<-read.csv("Stops.csv")##read in csv has already been filtered for IDLE events##

tr<-read.csv("Trips_PercDrive1.csv") ##read in csv##

s<-data.table(s) ##convert to data.table format##

tr<-data.table(tr) ##convert to data.table format##
```

```
(s1<-s[,
      .(IdleTime=sum(interval_mins)),
      by=.(stop_begin_date,VehClass)]) ##compiling the total number of minutes in

s1$JoinID<-paste(s1$stop_begin_date,s1$VehClass)##creating a join ID for the Datasets###

tr$TT_Min<-tr$duration_milliseconds/60000 #####converting from milliseconds to minutes###

(tr1<-tr[,
      .(TripTime=sum(TT_Min)),
      by=.(start_date,VehClass)]) ###aggregating data by join ID###

tr1$JoinID<-paste(tr1$start_date,tr1$VehClass) ##creating join ID###

drti<-join(tr1,s1,by="JoinID",type="left",match="all") ##Joining the datasets###

drti$Class<-drti$VehClass ##changing column name##

drti<-drti[,-c("VehClass")] ##eliminating dual columns##

drti$PerIdle<-(drti$IdleTime/drti$TripTime)*100 ###Calculating the percentage of idle time per trip####

d1<-na.omit(drti) ##eliminating N/A which is a trip with no idling occurring###

write.csv(d1,file = "C:\\Users\\scottha\\OneDrive - Kansas State
University\\Thesis\\TableOutputs\\Final_2_16\\DriveTime\\All_Percent.csv", row.names = TRUE) ##writing out for
further analysis###

setwd("C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\TableOutputs\\Final_2_16\\DriveTime")

q<-read.csv("All_Percent.csv") ##reading the total idling per trip in data##

q<-data.table(q) ## converting to data table##

(TripTime<-q[,
```

```
    .(Drive=sum(TripTime)),
    by=.(Season,Class)]) ##finding the total trip time aggregated by Season and vehicle class##

(IdleTime<-q[,
      .(Idle=sum(IdleTime)),
      by=.(Season,Class)]) ##aggregating the idle time by Season and Vehicle Class##

TripTime$JoinID<-paste(TripTime$Season,TripTime$Class) ##Creating Join ID##

IdleTime$JoinID<-paste(IdleTime$Season,IdleTime$Class) ##Creating Join ID##

Percent_Idle<-join(TripTime,IdleTime, by = "JoinID") ##Joining the aggregated data##

Percent_Idle$Percent_Idle<-(Percent_Idle$Idle/Percent_Idle$Drive)*100 ##Calculating the Percent Idle Time by
season and vehicle class###

write.csv(Percent_Idle,file = "C:\\Users\\scottha\\OneDrive - Kansas State
University\\Thesis\\TableOutputs\\Final_2_16\\DriveTime\\Idle_Data_By_Class_Season.csv", row.names = TRUE)
##Writing out dataset##
```

Idling Time

This code was used to calculate the idle time, gallons consumed, price of fuel wasted, and the carbon emissions of the ranch.

```
library(tidyverse) ##read in required packages##

setwd("C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\Data\\CleanedupData")

s<-read_csv("Stops.csv") ##read in csv##

##ensuring only Idle Stops Out
st<-s%>%filter(stop_type=="IDLE")

st$interval_mins <- as.numeric(as.character(st$interval_mins)) ##converting minutes to numeric##
```

```
(IdleMins<-sum(st$interval_mins,na.rm = TRUE)) ##summing idle minutes##

##Splitting Idle Time by Vehicle Class
st$interval_mins <- as.numeric(as.character(st$interval_mins)) ##converting minutes to numeric##

GroupedStops=aggregate(st$interval_mins, by=list(Category=st$VehClass), FUN=sum) ##summing idle minutes by
Vehicle Class##

##Creating a graph of Idle Length by Vehicle Class
tiff(file="C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\Graphs\\Minutes Idling by Vehicle
Class.tif",
    width=6, height=4, units="in", res=100)

ggplot(data=GroupedStops)+geom_bar(mapping=aes(x=Category,y=x), stat="identity", color="blue")
dev.off()

##Splitting Idle Time by Vehicle Name
st$interval_mins <- as.numeric(as.character(st$interval_mins)) ##converting minutes to numeric##

GroupedStopsName=aggregate(st$interval_mins, by=list(Category=st$VehName), FUN=sum) ##summing idle
minutes by Vehicle Name##

##Graph of Idle Length by Vehicle Name
tiff(file="C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\Graphs\\Minutes Idling by Vehicle
Name.tif",
    width=10, height=4, units="in", res=100)

ggplot(data=GroupedStopsName)+geom_bar(mapping=aes(x=Category,y=x), stat="identity", color="green")
dev.off()

##Summarizing the Vehicles by their average Idle Time
by_VehClass<-group_by(st,VehName) ##grouping idle time by Vehicle Class
```

AIT<-(summarize(by_VehClass,Average_Idle_Minutes=mean(interval_mins,na.rm = TRUE))) ##Averaging the idle time by Vehicle Class###

write.csv(AIT,file = "C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\TableOutputs\\Average Idle Time by Vehicle.csv", row.names = TRUE) ##Writing the data out for further analysis##

##TotIdleTime
TotIdleTime<-group_by(st,VehClass) ##Finding the total idle time per Class##

(MinIdling<-summarize(TotIdleTime,TotIdleTimeMinutes=sum(interval_mins,na.rm = TRUE))) ##summing the idle time by Vehicle Class and Writing to a new file for output##

write.csv(MinIdling,file = "C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\TableOutputs\\Total Idle Time by Vehicle.csv", row.names = TRUE) ##writing out that file##

##Price of Diesel from Philips 66 in Emporia
##Fuel on Tractors Alone
Tractor=st%>%filter(VehClass=="Tractor") ##Filtering Tractor Class##

(TotTract<-summarize(Tractor,IdleTime=sum(interval_mins,na.rm = TRUE))) ##Summing the Tractor Classes Idling minutes##

(MonTract<-mutate(TotTract,Money=(TotTract$IdleTime/60)*7.18*2.25)) ##Taking the total Tractor Class time in minutes multiplying by the average idling consumption per hour and then by the price of diesel to get the cost of diesel consumed##

(GalTract<-mutate(TotTract,Gal=(TotTract$IdleTime/60)*7.18)) ##Taking the total Tractor Class time in minutes multiplying by the average idling consumption per hour to get the number of gallons consumed##

write.csv(MonTract,file = "C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\TableOutputs\\Idling Stats Tractors.csv", row.names = TRUE) ##Writing file out for later use##

##Fuel For Trucks
##Number from Argonne Lab

```
##https://www.energy.gov/eere/vehicles/fact-861-february-23-2015-idle-fuel-consumption-selected-gasoline-and-diesel-vehicles
Pickup=st%>%filter(VehClass=="Pickup")##Filtering Pickup Class##

(TotPickup<-summarize(Pickup,IdleTime=sum(interval_mins,na.rm = TRUE))) ##Summing the Pickup Classes Idling minutes##

(MonPickup<-mutate(TotPickup,Money=(TotPickup$IdleTime/60)*.44*2.53)) ##Taking the total Pickup Class time in minutes multiplying by the average idling consumption per hour and then by the price of diesel to get the cost of diesel consumed##

(GalPickup<-mutate(TotPickup,Gal=(TotPickup$IdleTime/60)*.44)) ##Taking the total Pickup Class time in minutes multiplying by the average idling consumption per hour to get the number of gallons consumed##

write.csv(MonPickup,file = "C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\TableOutputs\\Idling Stats Pickups.csv", row.names = TRUE) ##Writing file out for later use##

##Fuel For Utility
Utility=st%>%filter(VehClass=="Utility")##Filtering Utility Class##

(TotUtility<-summarize(Utility,IdleTime=sum(interval_mins,na.rm = TRUE))) ))) ##Summing the Utility Classes Idling minutes##

(MonUtility<-mutate(TotUtility,Money=(TotUtility$IdleTime/60)*.3*2.25)) ##Taking the total Utility Class time in minutes multiplying by the average idling consumption per hour and then by the price of gas to get the cost of diesel consumed##

(GalUtility<-mutate(TotUtility,Gal=(TotUtility$IdleTime/60)*.3)) ##Taking the total Utility Class time in minutes multiplying by the average idling consumption per hour to get the number of gallons consumed##

write.csv(MonUtility,file = "C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\TableOutputs\\Idling Stats Utility.csv", row.names = TRUE) ##Writing file out for later use##

##Fuel For Feeding
##Fuel value figured as average of Tractor for Loader, Semi for Feed Trucks
```

```
Feeding=st%>%filter(VehClass=="Feeding")##Filtering Feeding Class##

(TotFeeding<-summarize(Feeding,IdleTime=sum(interval_mins,na.rm = TRUE))) ##Summing the Feeding Classes Idling minutes##

(MonFeeding<-mutate(TotFeeding,Money=(TotFeeding$IdleTime/60)*3.91*2.53)) ##Taking the total Feeding Class time in minutes multiplying by the average idling consumption per hour and then by the price of diesel to get the cost of diesel consumed##

(GalFeeding<-mutate(TotFeeding,Gal=(TotFeeding$IdleTime/60)*3.91)) ##Taking the total Feeding Class time in minutes multiplying by the average idling consumption per hour to get the number of gallons consumed##

write.csv(MonFeeding,file = "C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\TableOutputs\\Idling Stats Feeding.csv", row.names = TRUE) ##Writing file out for later use##

##Total
TotMon<-(MonUtility$Money+MonSemi$Money+MonPickup$Money+MonTract$Money+MonFeeding$Money)
##Adding up the total amount of money wasted on diesel fuel while idling##

write.csv(TotMon,file = "C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\TableOutputs\\Idling Stats Total.csv", row.names = TRUE) ##Writing file out for later use##

##Money Spent Total on Idling Activities
TotMon##Looking at the total amount of money wasted on diesel fuel while idling##

##Gallons spent idling
TotGal<-(GalUtility$Gal+GalSemi$Gal+GalPickup$Gal+GalTract$Gal+GalFeeding$Gal) ##Adding up the total gallons of diesel wasted on idling##
TotGal##Looking at the total amount of diesel fuel while idling##

##Emissions from Idling
##Pounds of Carbon per gallon of Diesel from the US Energy Information Administration
Emissions<-(TotGal*22.38)##Using the average Carbon dioxide emissions of one gallon of diesel to calculate carbon emissions of idling##
```

```
Tons<-(Emmisisons/2000) ##Taking pounds and making it tons##

Output<-rbind(Tons,TotGal,TotMon) ##Combining the Gallons, Money and Emissions data togather##

Output ##Observing the combined data##

write.csv(Output,file = "C:\\Users\\scottha\\OneDrive - Kansas State University\\Thesis\\TableOutputs\\Totals.csv",
row.names = TRUE) ##Writing file out for later use##
```

Graphics

Used to create the graphics for the final document. This will also be used when discussing with the rancher.

```
#####################Graphics Thesis#####################
setwd("C:\\Users\\scott\\OneDrive - Kansas State University\\Thesis\\TableOutputs\\Final_2_16")

library(tidyverse)##read in required packages##
library(sm)

d<-read.csv("Everything.csv") ##read in csv##

s <- density(d$Distance) ##returns the density data##

plot(s,main = "All Ranch Travel", xlab = "Trip Distance",lwd=2,col="maroon") # plots the results and labels them###

png(file="C:\\Users\\scott\\OneDrive - Kansas State
University\\Thesis\\Graphs\\FinalUpdated\\Graphs\\April_21\\All_Ranch.png", width = 6.5, height = 5, units = "in",
res = 256)
dev.off()##Outputs Graphic##

##################################Vehicle Class KD Graphic########################################
z<-read.csv("Everything.csv")
```

```
p<-z%>%filter(VehClass=="Pickup")##Filters desired data##

u<-z%>%filter(VehClass=="Utility")##Filters desired data##

f<-z%>%filter(VehClass=="Feeding")##Filters desired data##

t<-z%>%filter(VehClass=="Tractor")##Filters desired data##

plot(density(f$Distance), col="red",xlim = c(0, 20), ylim=c(0,.61),main = "Kernel Density of Vehicle
Classes",xlab="Trip Distance in Miles",lwd=2.3)              # Plot density of x
lines(density(t$Distance), col = "green",lwd=2.3)               # Overlay density of z
lines(density(p$Distance), col = "orange",lwd=2.3)               # Overlay density of z
lines(density(u$Distance), col = "yellow",lwd=2.3)               # Overlay density of z

legend("topright",                        # Add legend to density
    legend = c("Feeding", "Tractor", "Pickup","Utility"),
    col = c("red", "green", "orange","yellow"),
    lty =1,lwd=2.3)

jpeg(file="C:\\Users\\scott\\OneDrive - Kansas State
University\\Thesis\\Graphs\\FinalUpdated\\Graphs\\May_4\\VehicleClass\\All.jpeg", width = 6.5, height = 5, units =
"in", res = 256)
dev.off()
#################################On Off Between KD Graphic######################################
zoob<-read.csv("Everything.csv")

onf<-zoob%>%filter(OOB=="On Ranch, Field")##Filters desired data##

off<-zoob%>%filter(OOB=="Off Ranch")##Filters desired data##

bet<-zoob%>%filter(OOB=="Between Ranch")##Filters desired data##

onp<-zoob%>%filter(OOB=="On Ranch, Pasture")##Filters desired data##
```

```
plot(density(onf$Distance), col="brown",xlim = c(0, 20), ylim=c(0,.46),main = "Kernel Density of Travel
Type",xlab="Trip Distance in Miles",lwd=2.3)                # Plot density of x
lines(density(bet$Distance), col = "gray",lwd=2.3)                  # Overlay density of z
lines(density(onp$Distance), col = "green",lwd=2.3)                  # Overlay density of z
lines(density(off$Distance), col = "purple",lwd=2.3)                  # Overlay density of z

legend("topright",                              # Add legend to density
      legend = c("On Ranch, Field", "On Ranch, Pasture", "Between Ranch","Off Ranch"),
      col = c("brown", "green", "gray","purple"),
      lty =1,lwd=2.3)

jpeg(file="C:\\Users\\scott\\OneDrive - Kansas State
University\\Thesis\\Graphs\\FinalUpdated\\Graphs\\May_4\\OOB\\All.jpeg", width = 6.5, height = 5, units = "in", res
= 256)
dev.off()##Writes out the graphic##

##################################Seasonal KD Graphic##########################################
sw<-read.csv("Everything.csv")

s<-sw%>%filter(Season=="Summer")##Filters desired data##

w<-sw%>%filter(Season=="Winter")##Filters desired data##

plot(density(s$Distance), col="green",xlim = c(0, 20), ylim=c(0,.48),main = "Kernel Density of Seasonal
Travel",xlab="Trip Distance in Miles",lwd=2.3)                # Plot density of x
lines(density(w$Distance), col = "gray",lwd=2.3)                  # Overlay density of z

legend("topright",                              # Add legend to density
      legend = c("Summer","Winter"),
      col = c("green", "gray"),
      lty =1,lwd=2.3)
##############################Seasonal and VC Combined Graphic####################################
sw<-read.csv("Everything.csv")
sp<-sw%>%filter(Season=="Summer",VehClass=="Pickup")##Filters desired data##
```

```
st<-sw%>%filter(Season=="Summer",VehClass=="Tractor")##Filters desired data##

sf<-sw%>%filter(Season=="Summer",VehClass=="Feeding")##Filters desired data##

su<-sw%>%filter(Season=="Summer",VehClass=="Utility")##Filters desired data##

wp<-sw%>%filter(Season=="Winter", VehClass=="Pickup")##Filters desired data##

wt<-sw%>%filter(Season=="Winter", VehClass=="Tractor")##Filters desired data##

wf<-sw%>%filter(Season=="Winter", VehClass=="Feeding")##Filters desired data##

wu<-sw%>%filter(Season=="Winter", VehClass=="Utility")##Filters desired data##
#######################Summer Graphic###########################################
plot(density(sf$Distance), col="red",xlim = c(0, 20), ylim=c(0,1.7),main = "Kernel Density of Vehicle Classes and
Season",xlab="Trip Distance in Miles",lwd=2.3)                # Plot density of x
lines(density(st$Distance), col = "green",lwd=2.3)                  # Overlay density of z
lines(density(sp$Distance), col = "orange",lwd=2.3)                  # Overlay density of z
lines(density(su$Distance), col = "yellow",lwd=2.3)                  # Overlay density of z

legend("topright",                              # Add legend to density
      legend = c("Summer: Pickup","Summer: Tractor","Summer: Feeding","Summer: Utility"),
      col = c("red", "green","orange","yellow"),
      lty =c(1),lwd=2.3)
#######################Fall Graphic##############################################
plot(density(wf$Distance), col="red",xlim = c(0, 20), ylim=c(0,1.7),main = "Kernel Density of Vehicle Classes and
Season",xlab="Trip Distance in Miles",lwd=2.3)                # Plot density of x
lines(density(wt$Distance), col = "green",lwd=2.3)                  # Overlay density of z
lines(density(wp$Distance), col = "orange",lwd=2.3)                  # Overlay density of z
lines(density(wu$Distance), col = "yellow",lwd=2.3)                  # Overlay density of z

legend("topright",                              # Add legend to density
      legend = c("Fall: Pickup","Fall: Feeding","Fall: Tractor","Fall: Utility"),
      col = c("orange", "red","green","yellow"),
      lty =1,lwd=2.3)
```