PRIVATE BENEFITS OF EASTERN REDCEDAR MANAGEMENT AND THE IMPACT OF CHANGING STOCKER VALUE OF GAIN

By

AARON JAMES COFFEY

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Thesis Approved:

Dr. Derrell Peel

Thesis Adviser

Dr. Terrence Bidwell

Dr. David Lalman

Name: AARON JAMES COFFEY

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Abstract: The overall objective of this research is to determine the private benefits of eastern redcedar control and how those change with changing forage values. Eastern redcedar causes a reduction in forage availability for livestock producers. Three different management strategies are analyzed in this research over a 30 year period: no management, prescribed fire, and mechanical control plus prescribed fire. The research evaluates combinations of these management strategies to determine the maximum net present value of livestock production above redcedar control costs per acre during the 30 year management period.

Impacts of eastern redcedar invasions are estimated by applying a generalized redcedar population growth model to a native range site in central Oklahoma. Reduction in forage available for livestock use is calculated from the canopy coverage resulting from the population of redcedar trees by age distribution. Maximum net present value per acre is determined for five levels of cedar invasion, using three levels of value of gain, for three types of stockers.

Results show that prescribed fire is the predominant economically preferred eastern redcedar control alternative. Mechanical control was preferred only in situations of very heavy initial redcedar infestations and when the value of gain is very high. The economic analysis confirms that, while redcedar control after heavy infestations will restore a large percentage of the potential value for livestock production, controlling redcedar early to prevent invasion above management thresholds results in the highest net present value of livestock production. The research also shows that redcedar control is used more frequently and sooner when the value of stocker gain is higher.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

Wildfire was once used by Indians to suppress unwanted species such as eastern redcedar (juniperus virginiana) in Oklahoma and throughout North America. Through the years, wildfire has been suppressed reducing the once frequent burns and changing the ecosystem of the prairies. One hundred years after the historic land run of 1889, Oklahoma's rangeland and forestland are being invaded by eastern redcedar at an alarming rate (Bidwell, Moseley, 1989). Oklahoma has 17 million acres of prairie, shrubland, crosstimbers forests and other forests. Of these 17 million acres, it was estimated that by the year 2013, 12.6 million acres will be infested with at least 50 trees per acre, and 8 million acres will be covered with at least 250 trees per acres, creating a 74% loss of native prairies, shrublands, cross timbers forests and other ecosystems (Phillips, Horn, and Cole, 2011).

Eastern redcedar invasion has a variety of impacts on Oklahoma rangelands and forests including: reduced forage production; changes in wildlife habitat; increased water use; increased wildfire risk; and increased allergy impacts on human health. These impacts affect private landowners directly, but also represent a variety of additional public costs.

Eastern Redcedar kills all forage underneath the canopy of a tree. As cedar trees grow, age, and reproduce other trees, the increase in per tree canopy size and number of trees accelerate the loss of forage. In 2001, Steven Smith estimated Oklahoma is losing approximately 278,130 acres as a result of not managing cedar trees. This causes a problem to producers because of the decrease in value of the property. Reduced forage production results in lower stocking rates for cattle production systems and can increase amount of time on supplemental corn-based feeds or alfalfa.

Changing Forage Values

The U.S. beef production system has evolved away from totally forage-based production systems to one that is heavily dependent on cereal grains. The dependence on cereal grains to finish cattle has traditionally been a cheap process to finish cattle through the production system. In 2006, the United States produced 4.86 billion gallons of ethanol (Susanto, Parr, and Hudson, 2008). According to U.S. Energy resources, the United States alone consumed 10.7 billion gallons of ethanol in 2010. This production increase of ethanol is caused by the passing of the Energy Independence and Security Act of 2007 (EISA). This Act directly affects the cattle production system. With the rise in demand for ethanol, increase in acres allocated for corn use, and an increase in corn price above the historical average, beef production practices must incorporate more forage harvested by grazing beef cattle (Phillips, Horn, and Cole, 2011).

Crop values influences forage values, which have all been impacted from demand for ethanol. In the cattle industry, high feed grain values encourage switching cattle production activities to more forage-based production. As corn prices remain higher than historical averages, the opportunity cost of range management has increased for producers. Even though management of eastern redcedar can be costly, the benefits gained from managing and increasing forage for production are increasingly greater than costs of management. Management of eastern redcedar increases the private benefits received by increasing maximum pounds of forage per acre.

The purpose of this research is to measure the private benefits of redcedar control and how those change with changing forage values. An increase in forage values will yield an increase in private benefits while a decrease in forage leads to an economic loss for the landowner. The value of the loss obtained from forage reduction triggers active threshold measures to properly manage redcedar and prevent a further increase in the level of economic-injury. The objectives of this research are to:

1.) Determine the economic value of redcedar control for cattle production in central Oklahoma.

2.) Determine the impacts of changing forage values on redcedar control incentives and management strategies.

Chapter II provides an historical overview of the cattle production system, grain industry, eastern redcedar impacts on forage, and juniper growth and invasion of rangelands. Chapter III provides a summary of the economics of redcedar control, the production theory used for this model, how it is applied to an IPM approach, and different management strategies used in the model. Chapter IV describes the methodology used to build the complete model and describes how each section of the model is derived. Chapter V provides results and conclusions for the model and also provides a sensitivity discussion on what would happen if cedar canopy cover restrictions were imposed. Chapter VI describes some major areas where further research is needed for eastern redcedar.

CHAPTER II

CATTLE PRODUCTION AND CEDAR IMPACTS ON RANGELAND

Cattle Background

The word “cattle” was derived from the word “capital” meaning wealth or property (Phillips, Horn and Cole, 2011). The origin of beef cattle in the United States can be traced all the way back to the second voyage of Christopher Columbus in 1493. Cattle were fed primarily on grass from their arrival to the U.S. clear up to the early 1900’s where Midwest farmers began buying calves and yearlings in the fall and wintering cattle on corn silage for 220 to 280 days (Corah, 2008).

In the 1940’s, cattle were being fed on grain, in dry lots, to produce additional pounds of gain. The system of a grass-fed only cow that produces a calf, weaning the calf, and gaining weight until it is a finished product changed over time to a system where feeding grains, such as corn, was incorporated into cattle production systems. The general shift in cattle feeding has been attributed to two primary causes 1.) development of large-scale irrigated corn production (Corah, 2008) and 2.) the robust war economy of WWII increasing the demand for beef beyond the capacity to be utilized solely on a forage based production system (Phillips, Horn, and Cole, 2011). The cattle feeding shift ended up forming a whole new method for producing finished beef and a whole new possibility for increasing the amount of pounds put on cattle. The finished cattle are then shipped to slaughter houses for packing and fabrication and shipped throughout the

United States and to different parts of the world. The United States cattle industry has become widely known for its efficiency and ability to supply beef for the food industry.

Even though the cattle industry can be thought of as one industry, there are three complex sectors which make up the cattle industry: cow-calf, stocker, and feedlot. Each sector has its own unique characteristics and management techniques which help to create a finished animal ready for harvest. The cow-calf sector consists almost entirely of primary production activities. Cow-calf production combines forage resources and breeding practices to produce calves which are the supply for the rest of the sectors of the industry. Most of the resources used in cow-calf production are long term in nature and the majority of costs are essentially fixed in the long run (Peel, 2011) Since most of the costs are fixed, Peel states that most of the annual variation in cow-calf production are due to variations in revenue or changes in the price level for calves.

The stocker sector cannot be distinguished by a particular age, size, or class of cattle or by a particular type of production system (Peel, 2003). This sector is the intermediary between the cow-calf sector and the feedlot sector. The production value of this sector originates from providing additional weight gain and upgrading cattle quality to transform many calves from the cow-calf sector into feeder cattle as demanded by the feedlot sector (Peel, 2011). The additional weight gained is not directed towards finishing the animal, but rather is focused on gaining frame and muscle to grow the animal prior to the finishing phase. Stocker production typically varies from three to nine months in duration and provides considerable flexibility in the timing of feeder cattle in the market (Peel, 2011). This variation allows producers to decide to hold their stockers on forage longer in order to wait for a better market price or to sell quickly. Both the cow-calf sector and stocker sector primarily utilize forage available for grazing.

Cattle in the feedlot sector are cattle that are fed a high concentrate, cereal grain diet which adds pounds of finish to the animal. The feedlot sector can partially mitigate the impact of higher feed costs by increasing the size of cattle placed in the feedlot (Peel, 2011). If the feedlot only selects animals of heavier weight, then stockers are kept longer on forage in order to capture those extra pounds needed to sell. The stocker sector has always been the cushion between the cow calf and fed cattle sectors. For example, when corn prices are high, stockers can be held on forage longer to reduce the amount of corn needed to finish the steer or heifer by substituting cheaper forage. But, the continuous rise in prices of cereal grains has started to shift the industry in this direction of more forage utilization (Peel, 2011).

Beef cattle have an interesting characteristic in that they are able to convert many different types of feeds into nutrients required for maintenance and production (Coffey, 2011). Cattle are able to utilize a wide variety of feed resources as an efficient method for harvesting forage that either cannot be accessed by farm equipment or the value of the forage is not productive enough to harvest the forage for hay. This gives flexibility in cattle production compared to monogastric livestock species that are not able to deviate from a cereal grain based system. In addition to having flexibility in feed sources, cattle are also able to stay on forage longer in order to reduce the reliance upon cereal grain based diets. The production practice of increasing time on forage by the stocker sector during times of high corn prices has trickled down to cow-calf production due to a reduction in the amount of land available for use (Phillips, Horn, and Cole, 2011). Peel determines permanently high corn prices have already been reflected in short term signals to adjust forage and grain use in the industry and these will likely continue and ultimately result in long run structural changes in production systems that favor an increase in forage relative to grain use in the industry (Peel, 2011).

Stockers on forage are very valuable to the cattle industry. Stockers provide flexibility in determining how many additional pounds of gain need to be added on forage before animals are finished in feedlots. Many factors affect forage utilization of a pasture. Things such as slope, rock cover, trees and brush are all factors that reduce efficiency in a pasture. Invasive species management is one way to estimate the value of controlling brush and trees. Management of invasive species is important in times of high corn prices because forage values are partially driven from the price of corn. If corn prices are high, then it is worth more to firms in the industry to maximize forage production on properties, so that less supplement is needed and more pounds of gain are added with forage instead of corn.

Corn Background

Ethanol production has become a substantial part of biofuel production and is pushed to new horizons persistently. In 2006 the United States produced 4.86 billion gallons of ethanol (Susanto, Parr, and Hudson, 2008). According to U.S. Energy resources, the United States alone consumed 10.7 billion gallons of ethanol in 2010. This increase in ethanol production has shifted demand for cropland to an increase in the acreage utilized for corn, reducing acres available for grazing. Bouton, who tested the economic benefit of the alfalfa industry, forage/livestock systems, and switch grass use as a bioenergy feedstock, has determined that the increase in corn acreage is largely due to displacing wheat fields and other croplands rather than opening new croplands (Bouton, 2007).

Because cereal grain production requires significant fossil fuel-based inputs, beef production practices must incorporate more forage harvested by grazing beef cattle and utilize more poor quality, by-product feedstuffs to remain sustainable (Phillips, Horn, and Cole, 2008). Firms in the industry need to be aware of the changes in input costs caused by increasing the amount of forage available. If a producer needs only to consider protein supplement for the cow herd, then calculating their alternatives based on protein cost is appropriate (Childs, 2011). Forages are one of the primary protein sources used in cattle production and generally the least cost source of protein. Since acreage is being displacement for crop production, there needs to be better efficiency of forage on pasture lands and rangelands. In order for farmers and ranchers to continue improving forage in pastures, applying appropriate management techniques to prevent pastures from sustaining economic-injury levels is necessary to prevent a significant reduction in the value per acre.

Eastern Redcedar Impacts

Oklahoma rangelands are mostly comprised of native plants, including grasses, shrubs, and forbs. Proper grazing management of forage can be very important to the rangeland ecosystems. Stocking rate can influence several factors: plant composition, forage production, erosion, and livestock production (Bidwell, Elmore, and Hickman). Stocking rate or the number of animals per acre grazing the pasture for a given period of time is critical for a proper grazing management plan. Overstocking pasture causes "overgrazing" of the pasture. Overgrazing can result in a reduction in desirable forages and an increase in less palatable and nutrient rich plants or introduction of invasive species.

Currently the amount of forage available in Oklahoma is being affected by invasive species such as eastern redcedar. Cedars or junipers are native evergreen trees. There are 13 juniper species native to the United States and they are located in every state east of the 100th parallel (Knezevic, 2011). This now very common tree previously historically had been limited to areas where burning could not reach such as bluff or canyons. Eastern redcedar is very tough tree, extremely drought tolerant, and it takes around 20 years to fully mature making it appropriate for U.S. range conditions. Unmanaged eastern redcedar stands often dominate the landscape, creating monoculture-like plant communities with little plant and wildlife diversity (Smith, 2001). This pest causes a significant reduction in forage quality and forage availability due to the density and canopy of the trees.

Juniper Growth and Invasion of Rangelands

Cedar is a dioecious species, meaning there must be a male and female tree present to reproduce seeds. Owensby et al. determined trees 6 to 7 years old are capable of producing seedlings. Male trees create flowers during fall, these cones then shed quantities of pollen during early winter months. Once the cedar pollen is discarded from the cones, the pollen is carried through the air to the cones of a nearby female tree where fertilization occurs. Female trees produce cedar berries which are then dropped or eaten by animals and dropped in other areas where seedlings sprout. Horncastle et al. conducted a study in Virginia testing the different types of animals who consumed cedar berries and dispersed the seeds in different locations. The study concluded that 65% of the cones of eastern redcedar were dispersed by birds and 29% of the cones were dropped by natural causes. The study also determined birds consumed the majority of berries from branches although small and medium-sized mammals consumed cones on the ground. Birds and mammals were found to be the most likely contributors to the spread of eastern redcedar but at different scales (Horncastle et al., 2009).

A 1985 survey conducted by the Soil Conservation Service indicates eastern redcedar and ashe juniper, the most common juniper types found in Oklahoma, had invaded almost 1.5 million acres by 1950 and 3.5 million acres by 1985. Juniper encroachment in Oklahoma is currently projected at 762 acres per day (Bidwell et al., 1996). Using this estimate, Oklahoma loses 278,130 acres per year to cedar invasion. Other studies estimate holding this rate constant, by 2015, approximately 11.6 million acres will be occupied by cedar (Smith, 2001).

Juniper is a problem on grasslands around the country because it reduces forage production and livestock handling (Knezevic, 2011). When forage is reduced due to cedar invasion, the carrying capacity for cattle in a pasture declines, resulting in a decreased value of the property. Forage production is reduced or eliminated under an eastern redcedars canopy and is difficult for the livestock to graze (Wilson and Schmidt, 1990). The annual rate of forage loss beneath the crowns of 20 year-old trees is substantial (Knezevic, 2011). In a pasture invaded by cedar, forage production essentially equals zero around 80% canopy coverage (Ortmann, Stubbendieck, and Mitchell, 2007).

A study conducted by Engle and Kulbeth, of three different locations throughout Oklahoma (Eastern, Central, and Western) on eastern redcedar concluded redcedar reached 6.56 feet in height at about 8 – 14 years of age and the oldest age class of red-cedar, 28 – 29 years old, height ranged from 20.34 – 27.23 feet in different regions located throughout the state. This growth rate is very rapid and once a tree reaches the 20.34 to 27.23 feet high range, all of the forage that once grew where this cedar is located will also be lost (Engle and Kulbeth, 1992).

Another study conducted by Engle Stritzke and Claypool, examined the effect of eastern redcedar on herbage standing crop at various distances from the tree. Results confirmed the hypothesis of standing crop being negatively affected. Herbage standing crop was definitely reduced around eastern redcedar trees. The relationship of forage production being proportional to tree canopy size also applies to tall-grass prairie invaded by the species. Data from the study suggests most of the forage reduction caused by the tree was inside the drip line (Engle, Stritzke, and Claypool, 1987).

Areas with a shallow prairie soil capable of producing 3,000 pounds of native forage per acre can have forage yields reduced by 50 percent with 250 trees present with a 6 foot crown (Bidwell, 1993). In 2001, the OSU Rangeland Ecology and Management estimated a $52 million dollar loss in lease hunting due to juniper invasion. The annual economic loss in an average year in 2001 for catastrophic wildfire, loss of cattle forage, loss of wildlife habitat, recreation, and water yield was estimated to be $218 million. If no preventative control steps are taken to control invading junipers, the annual economic loss in an average year in 2013 is expected to be $447 million (Bidwell, Weir, and Engle, 2002). Along with loss of revenues, eastern redcedar does not currently have any reliable economic value. Though a number of potential products have been identified and evaluated, no consistent market value for cedar exists at this time. Occasionally it is possible for landowners to find someone who will remove cedar trees for mulch or other uses, thereby reducing the cost of cedar control. In the absence of any residual market value for the cedar trees, the costs of cedar control must be evaluated against the benefits in terms of improved forage production. Once the tree is growing on the property, there is no added value of production and once forage has begun to reduce, the value of the property decreases.

Owensby et al. conducted a study which investigated associations among cattle stocking rate, precipitation, and eastern redcedar invasion. They concluded a direct relationship between trees per acre and number of AUM's available for livestock. The increase in trees per acre decreased the amount of AUM's available or forage available for consumption for the producer (Owensby et al., 2007).

Controlling eastern redcedar can be very beneficial to firms in the industry trying to maximize forage production. There different alternatives to management have been gathered based on a 160 acre area. Chemical control is one method of controlling juniper. In order for chemical control to be implemented, a firm must apply herbicide to each tree base. Costs for this method of control are very time consuming and costly, so chemical control was not considered in this research. Another control method is mechanical clearing. Mechanical clearing is very effective and at times kills essentially 100 percent of the targeted trees. This method is also very costly, but mechanical control is included as a management option in this study. Prescribed fire is a very effective way to manage the invasion of redcedar on rangeland. Prescribed fires are by far the cheapest alternative, but kill rates change due to the size of the tree and a number of other variables. Although prescribed fire is more risky than the other two alternatives, it is by far the cheapest method of control of eastern redcedar (Owensby et al., 2007).

According to Title 2 Article 16 of the Oklahoma Forestry Code, even if the proper fire-breaks have been created, the property is not under a burn ban, and proper authorities have been contacted, firms are still liable for a fire getting out of control and damaging a neighbor's property (Peach and Burwell, 2007). All states bordering Oklahoma have protection for firms conducting a proper prescribed fire as long as all of the correct guidelines were followed. The legal liability for use of prescribed fire in Oklahoma is commonly cited as a reason why fire is not utilized more for redcedar control.

This research utilizes a cedar growth model that projects a maximum invasion of cedar trees resulting in 100 percent canopy coverage in roughly 25 years. However, management strategies for cedar depend on the initial level of cedar invasion so the growth model is extended to a maximum of 55 years to allow for evaluation of cedar management where the site is fully invaded by cedar at the beginning. By tracking the number and size distribution of cedar trees, the amount of cedar canopy coverage is calculated along with the impacts of cedar canopy coverage on forage availability for cattle grazing. The model will additionally include stocker production based on forage availability. Using value per pound of gain, the model generates a value per acre calculated as a 30 year net present value of net returns. Implementing action thresholds will estimate near optimal solutions for each year chosen over each 30 year decision horizon.

CHAPTER III

ECONOMICS OF EASTERN REDCEDAR CONTROL

Production Theory and Input Demand

Alternatives to management of eastern redcedar are tools available to cattle producers to maintain the productivity of range resources. According to classical production economic theory, the demand for inputs is derived from the production function and the value of the outputs produced by the inputs (Beattie, Taylor, and Watts, 2009). According to the production, input use should be expanded until the marginal value of output per unit of input is equal to the marginal cost per unit of input. This is shown in the following marginal conditions:

(1) MVP = r

MVP (marginal value productivity) is defined as the value of the marginal physical product multiplied by the price of the product.

(2) MVP = MPP * p

This determines the value of output based on a unit change of input. The variable (r) is defined as cost of the input. Optimality for production economics happens when the firm is operating in Stage 2 and where the marginal value productivity equals the cost of input. This illustrates how a change in management of total trees is beneficial to a firm as long as benefits are greater than costs. Over a range of input prices, r, the MVP curve represents the derived demand for the input. Increasing the cost of the input, r, results in less use of the input according to the marginal conditions in (1). However, an increase in the value of the output, p, in (2) increases the input demand and results in increased use of the input according to the marginal conditions in (1).

The production theory described above has been applied to pest management for many years as the Integrated Pest Management (IPM) approach. Sterner states in his crop research article that integrated pest management (IPM) refers to the systematic, repeated application of pest-surveillance and control technology to reduce the economic impacts of diverse insects, pathogens, nematodes, weeds and animals that damage agriculture. Eastern redcedar damages ecosystems, reduces forage available, and soaks up water in the soil profile that could otherwise be used for forage and other worthy species (Smith, 2001). This model helps to determine the economic threshold for clearing eastern redcedar from a pasture. The IPM approach is based off the conceptual framework of production economics. When management practices are chosen, they can be implemented as long as the benefits of management outweigh the costs of control.

In Sterner's research there are five parameters that determine IPM economics:

1. Crop value
2. Pest – caused crop loss
3. Cost of surveillance
4. Cost of pest control
5. Effectiveness of the damage prevention or reduction

Each of these parameters are necessary for a proper IPM approach of managing eastern redcedar. The first parameter, crop value, is the initial value of the research. This initial value is the return per acre of the property without selecting a management strategy to fight the pest invasion. Stern defines the economic-injury level as the lowest population density of a pest that will cause economic damage or the amount of pest injury which will justify the cost of control. Stern also defines action threshold as the pest density at which control measures should be implemented to prevent the value from reaching the economic–injury level (Stern, 1959). As time progresses and no management decisions are chosen, the economic injury level is crossed and losses begin to occur due to forage lost under the canopy of the pest. In year five, selecting a light weight steer with a $0.95 per pound of gain, the value per acre is $1,736.06, selecting from a five year net present value return and selecting year six, all sizes a per pound of gain constant, returns a value of $1,687.49, a $48.57 loss per acre from not managing the property. The loss has caused economic injury and management decisions or the action threshold should be implemented in order to prevent the current loss from happening and further losses incurred in subsequent years.

Knezevic states eastern redcedar is a problem on grasslands, primarily because it reduces forage production for livestock. Management control methods should be gauged more towards an actual management of the infestation rather than eradication of the species (Knezevic, 2011). As stated earlier, the pest in consideration is eastern redcedar. Other pests such as sumac or sericea lespedeza that also pose problems on native rangeland are not considered although the approach used in this research could be applied to other pests and invasive species.

Eastern Redcedar Growth and Invasion

Engle and Kulbeth conclude that cedar growing in a loamy prairie soil type grows up to 2 meters in height in ten years. This ten year old tree has canopy coverage of 0.893 M^2which results in forage lost underneath this canopy (Engle and Kulbeth, 1992). Cedar encroachment in Oklahoma is currently projected at 762 acres per day (Drake and Todd, 2002). Estimates reaching $100 million dollars was lost in annual forage production in Oklahoma due to juniper invasion (Hendrix, 2002). Cedar encroachment is a problem and if not managed properly will reduce annual forage production.

Many pest surveillance strategies can be costly depending on what the pest is and how much labor and knowledge is required for managers to implement proper action threshold techniques. For grasshopper management in a field, managers need to go out into the pasture or pay a specialist to go out and take a measurement of the amount of pests present. Determining the control needed can be time consuming and costly, but for redcedar, cost of surveillance is minimal. The pest can be seen from the roadside growing. Since it grows year-round, managers know they are in the pasture and can see management practices that need to be implemented to prevent the pasture from sustaining economic-injury.

Eastern Redcedar Management Alternatives

The costs of pest control by prescribed burning and mechanical clearing have been gathered from Mr. John Weir, a research associate with Oklahoma State University, and Mr. Brandon Reavis, USDA Natural Resources Conservation Service - Oklahoma. Costs for prescribed burning were gathered from Mr. Weir on January 23, 2013. Costs are $12.50 for a 160 acre area, $11 for 320 acres, $9.40 for 640 acres and $8.00 for areas greater than 1,000 acres. Costs for mechanical treatment are included in the chart below. They are based off of the amount of percent cedar cover on any size acreage. Costs used in the model are chosen from the W/O Cost Share column, but it is possible to apply for funding through the NRCS to reduce cost incurred from managing redcedar.

Table 3.1 NRCS Mechanical Control Costs.

	NRCS Mechanical Control Costs (Per Acre)			
% Cedar Cover	**W/O Cost share**	**With Cost Share**		
<10%	$ 36.19	$ 18.10	/Acre	
11-30%	$ 128.26	$ 64.13	/Acre	
31-50%	$ 204.85	$ 102.43	/Acre	
>51%	$ 321.22	$ 160.61	/Acre	
Fire Break	$.05/linear ft		/Acre	*Tractor with disk - 30 Ft strip
Fire Break	$.13/linear ft		/Acre	*small dozer - 150Ft. Wide Strip

The effectiveness of the two action threshold decisions differ. Fuhlendorf et al. studied the effectiveness prescribed burning has on the mortality of juniper. The intensity of fire was based upon the amount of forage available to fuel the fire. For this model, the medium fire intensity was chosen. By using the medium intensity, good years (high rainfall and forage production) and bad years (drought conditions and low forage production) are assumed to be captured. Different mortality percentages were assigned to different sizes of canopy diameter(M^2) (Fuhlendorf et al., 2008). Once canopy coverage was converted to canopy diameter, mortality rates can be assigned to all ages of trees. For mechanical control, the mortality rate is considered to be 100 percent per tree managed. Based on current management recommendations, the mechanical control option is coupled with prescribed fire as one management alternative.

Failure to control pests in isolated fields will allow reservoirs of pests to reproduce and possibly re-infest crops (Sterner, 2008). For eastern redcedar, the pest does not die on an annual basis and therefore current trees remain and seedlings are produced for management in the next year. It is necessary, therefore to consider many years to account for the amount of time needed for redcedar invasion impacts to be determined. The output from this research will determine the maximum value obtainable per acre and the importance of cost management techniques on rangeland. It will also determine the value gained or near optimal management techniques that implement management decisions (action thresholds) to prevent sustaining an economic-injury level.

CHAPTER IV

METHODOLOGY

Assumptions of the Model

This research uses a hypothetical setting of 160 acres of land in Payne County, Oklahoma, consisting of Loamy Prairie soil and native range. In this research, there are many factors held constant. A study conducted by Hohlt et al. explains that factors such as rock cover on the ground, distribution of brush, species of brush, and steepness of slope all play an important role in the availability and usability of forage in the pasture. Consideration of these variables is necessary for farmers/ ranchers to accurately assess how much forage will be available in the pasture and how much of the forage will actually be utilized. This section will be a discussion of these different variables. It will explain how they impact and modify the results of this study (Hohlt et al., 2009)

The first variable of discussion is rock cover. The rock cover data is gathered from a study conducted by Hohlt et al. which estimated the amount of grazeable acreage for cattle. The study found that if the rock coverage was greater than 30 percent, the cattle will tend to avoid those areas that are uncomfortable for walking. This study assumes rock cover is not a factor limiting grazing on the site.

Species and thickness of brush is another variable that impacts the results of this study. Brush and areas containing invasive species have proven to be damaging to pastures forage productivity. In this study, eastern redcedar is considered to have a uniform distribution in the area tested. There is assumed to be no “thickets” of cedar present until the entire field has grown thick enough to be considered a “thicket”. Also, cedar is the only invasive species considered in the study. Effects of other species such as sumac or lespedeza are not a factor considered in this research.

Steepness of on a site, impacts the amount of forage utilized by livestock. The steepness is calculated by figuring the percent slope over a 100 foot distance. Based on the Hohlt et al. study conducted cattle prefer slopes of 11 percent or less. A table was calculated to show the expected effect of slope on cattle use and illustrate the percent reduction in use. An area with a slope of 0 – 10 percent had a 0 percent reduction, 10 – 30 percent had a 30 percent reduction, 31–60 percent had a 60 percent reduction, and greater than 60 percent, had a 100 percent reduction in use. This study determines that cattle prefer flatter areas to graze and travel on. In this study, we assume that the site has less than 10 percent steepness and no reduction in forage utilization due to steepness (Hohlt et al., 2009)

Cedar Growth

A study conducted by Owensby et al. researches the invasion rate of eastern redcedar on tallgrass prairies in the Northern Kansas Flint Hills. The research investigated “associations among cattle stocking rate, precipitation, and eastern redcedar invasion, and possible control measures.” Results found “differences among years on the heavily invaded pastures showed a sigmoid population increase curve. On lightly invaded areas no similar increase occurred.” Using this determination, growth of a heavy infestation of eastern redcedar by using the sigmoid or logistic function was estimated from the publication (Owensby et al., 1973). Sigmoid functions (Richards Growth Curve) are commonly used to fit empirical data on forest growth (Alexandrov, 2013). The general equation for a sigmoid growth curve is denoted as:

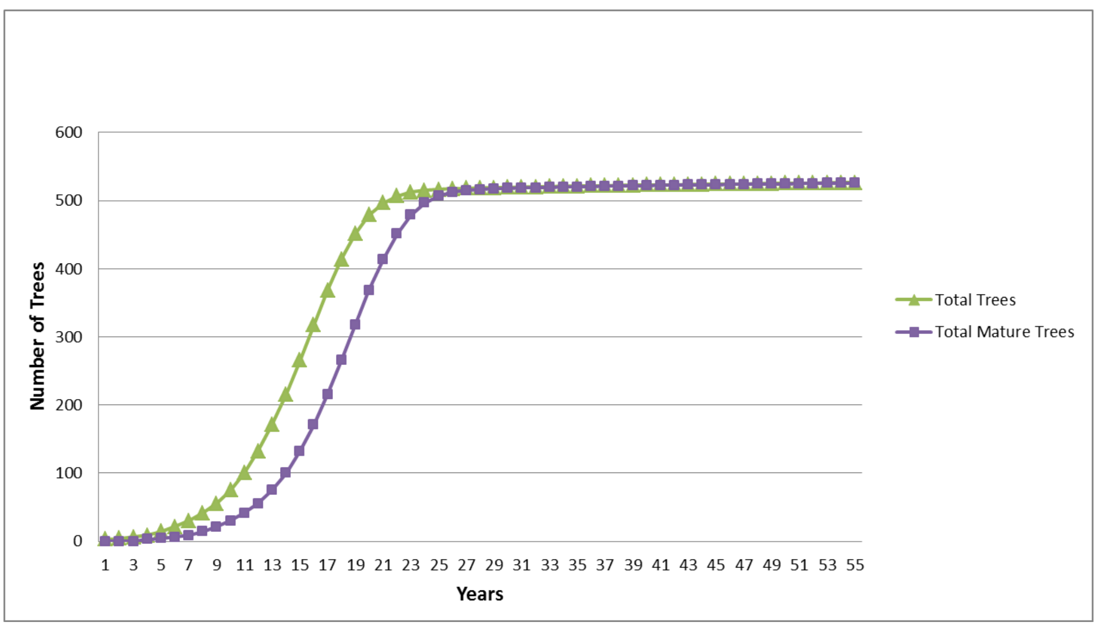
(1) $y = (\frac{1}{1+e^{\alpha * x}}) * Max$

In (1), Max is the maximum value that the function will asymptotically approach, α is a parameter and x is the time factor. No data was available to directly estimate a sigmoid function for the Central Oklahoma location. Equation (1) was parameterized as equation (2) to represent cedar growth and invasion on Loamy Prairie soil sites as indicated by available studies and expert opinion. The maximum number of trees, (Tree Max) was set as 500, based on consultation with Dr. Bidwell. The α parameter and the time factor (x) were set to reflect that maximum expansion of cedar tree numbers in a natural invasion occurs between the year 12 and 22. Equation (2) provides an estimate of the cumulative number of eastern redcedar trees found per acre in a 30 year period, by applying the sigmoid function as:

$$(2)\ Total\ Trees = \left(\frac{1}{1+e^{-.4*x}}\right) * Tree\ Max$$

to get the total increase of trees in the 30 year period. Once the total numbers of trees are calculated from equation (2), the change in number of trees each year represents the number of new trees produced each year.

Figure 4.1 Redcedar Population by Year.

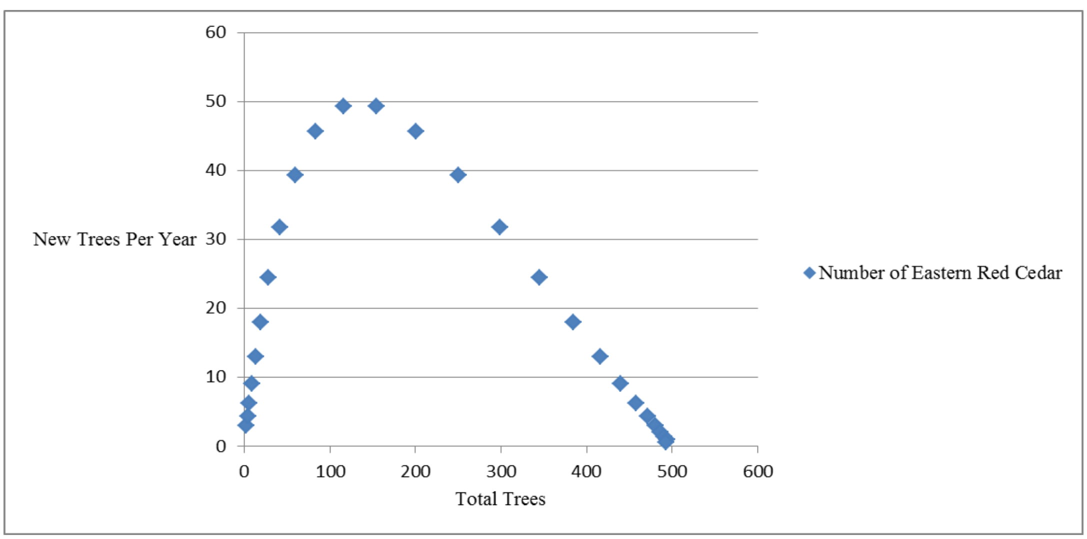


By tracking the number of new trees and accumulating trees as they age, the tree population produced by the sigmoid function can be decomposed into the number of trees by age cohort. However, the sigmoid function shows the increase in the amount of trees as a function of time. Thus, it is not possible to impose management strategies that will alter the number of trees at various points in time. Eastern redcedar trees are considered sexually mature at 6 to 7 years of age (Owensby et al., 1973). It is assumed that after initial invasion of redcedar from adjacent seed sources, the rapid spread of redcedar, indicated by the sigmoid growth curve, is the result of reproduction from trees on the site. Using the sigmoid function, we are able to estimate the number of trees present on any given year and also the number of mature trees 6 years or older. Expressing the number of new trees as a function of the number of mature trees creates the ability to implement a management strategy option for applying control measures of the invasive specie. This suggests the growth equation is represented in the general form:

(3) $\gamma = \beta_1 x + \beta_1 x^2 + \epsilon.$

Figure 4.2 shows the relationship between the number of new trees per year and the number of mature trees. The relationship between the number of new trees and the number of mature trees has a quadratic structure, reaching a peak, and then declining over the range of mature trees. However, the quadratic structure is not symmetrical due to the exponential growth that is the basis of the sigmoid growth curve.

Figure 4.2 New Redcedars as a Function of Mature Redcedar.



Therefore a square root transformation was used to estimate number of new trees as a function of the number of mature trees:

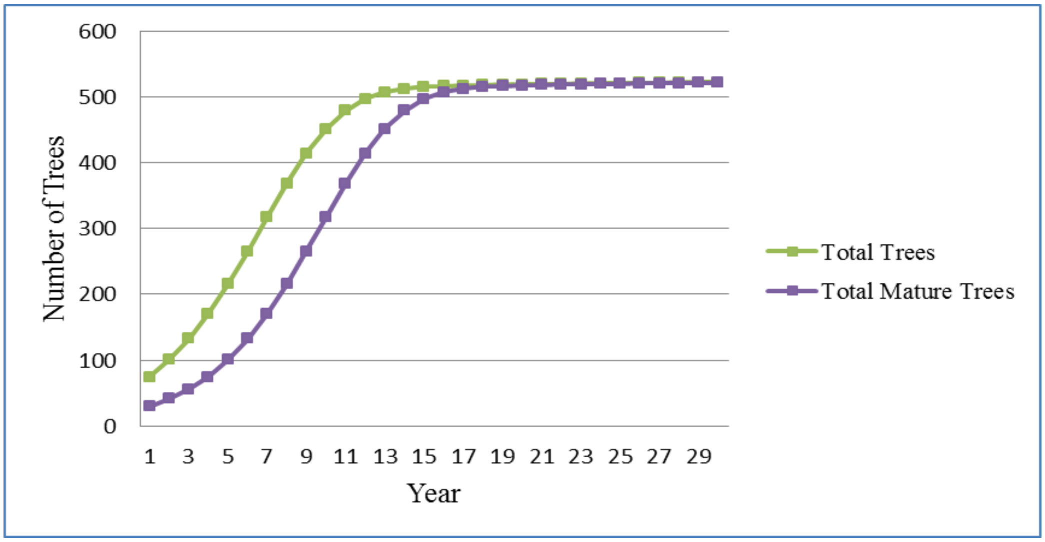
$$(4)\ \sqrt{NT} = \beta_1 MT + \beta_1 \sqrt{(MT)} + \epsilon$$

where NT is the number of new trees and MT is the number of mature trees.This transformation corrects for the exponential growth curve and makes a quadratic functional form appropriate to estimate this relationship (Kutner, Nachtsheim, and Neter, 2004). The model below explains the results from the square root transformation and the regression line illustrates the results obtained. Equation (4) was estimated with Ordinary Least Squares (OLS) as equation (5) with an R^2 value of 0.98631, indicating the regression is a good fit for the model. The estimated trasformation equation is:

$$(5)\ \sqrt{NT} = -0.3679 - 0.05464(MT) + (1.287823 * \left(\sqrt{MT}\right)$$

Results from the equation (5) were squared to determine the correct response from transforming the data.Using this formula, the number of new trees each year is estimated from trees six years or older from the previous year. This estimate allows control methods to be implemented to trees in a previous year which yield a change in number of trees reproduced in the current year. Figure 4.3 illustrates resulting model estimates for the number of total trees and the total number of mature trees six years or older for a beginning year NPV of year 10.

Figure 4.3 Redcedar Population by Year (NPV Beginning Year 10.)



Canopy Cover

A conducted by Engle and Kulbeth studied tree height and growth dynamics of crown area associated with eastern redcedar in Oklahoma. The understory herbage standing crop is defined as crown area (Engle, Stritzke, Claypool, 1987). Crown area can be described as the area consumed directly underneath a tree. In the case of eastern redcedar, crown area can be considered to be lost forage under the canopy due to shading affect and toxins released from the tree caused by a process known as allelopathy (Gray and Rosburg, 2009). Three different regions were studied across the state of Oklahoma. The study included a Western Oklahoma region, a Central Oklahoma region with Shallow Prairie as the soil type, a Central Oklahoma region with Loamy Prairie as the soil type, and an Eastern Oklahoma region. These different regions where used to show the increase of crown area determined by the age of the tree. Engle and Kulbeth concluded:

1. Trees located in the Eastern Oklahoma region reached the age where fire is able to effectively kill them more quickly than any other region.
2. Crown area growth rate was also fastest in Eastern Oklahoma.

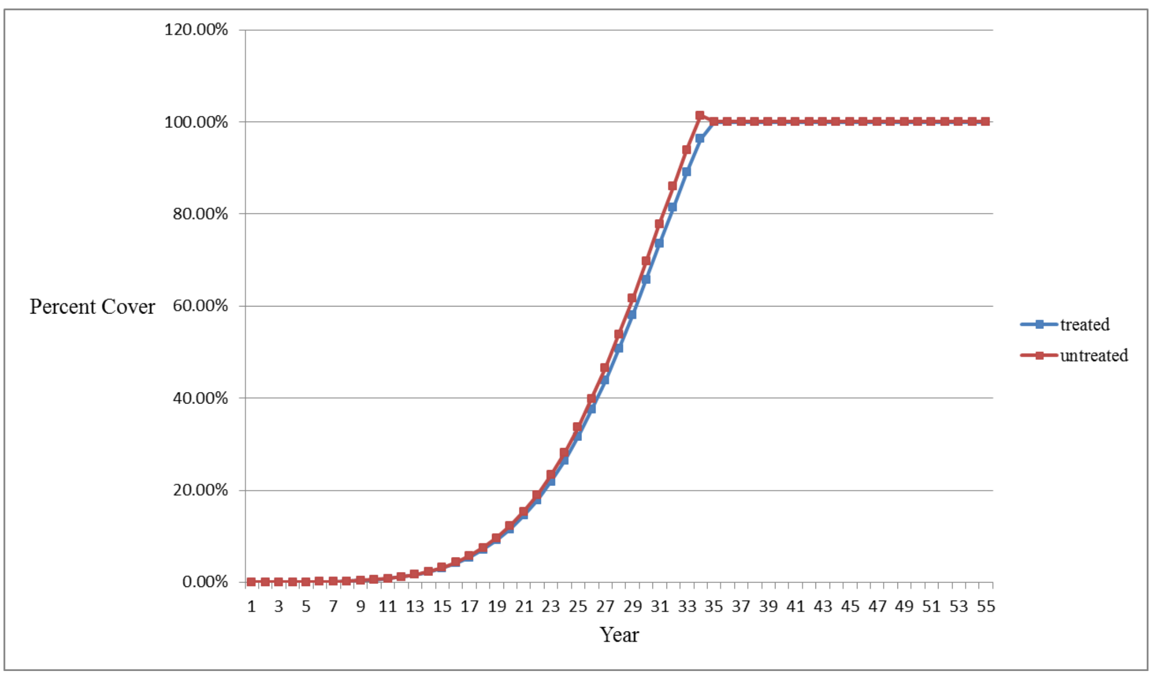
3. The annual rate of forage lost beneath the crowns of 20+ year old trees is substantial at all 3 locations (Engle and Kulbeth, 1992).

In order to determine canopy coverage in Oklahoma, a central Oklahoma loamy prairie site was chosen for the model. For this model, the formula was estimated using a Central Oklahoma Loamy Prairie soil type (Engle and Kulbeth, 1992):

(6) $y = EXP(-3.713 + .44(X) - .008(X^2)$

Using ages of cedar trees as X for this formula, we are able to estimate the crown area per tree for each age group. Summing the number of trees by age from the first section multiplied by crown coverage, results in the total canopy coverage per acre in square meters (M^2). Total canopy coverage is then multiplied by 10.7639 to convert the answer to square feet(FT^2). The canopy coverage per acre is divided by a total of 43,560 to determine the percent canopy coverage in each year and how it affects the maximum forage available per acre.

Figure 4.4 Redcedar Canopy Coverage.



Forage Production and Impacts of Cedar Invasion

Average forage production per acre for Central Oklahoma Loamy Prairie was determined by State Rangeland Specialist, Brandon Reavis, since no published data could be found (Reavis, 2013). Data on average forage values for the Loamy Prairie soil type was gathered from the Oklahoma NRCS database. Information in the database is created based upon the amount of seasonal rainfall in any given year. The seasonal forage value was determined to be 3,850 pounds of forage production per acre on all Loamy Prairie forage sites except Cotton County in Southern Oklahoma (3,325 lbs.). Payne county Oklahoma was the region chosen for this study so 3,850 pounds is used as the average forage potential for this study.

Engle, Stritzke, and Claypool determined that forage reduction due to redcedar invasion was directly proportional to canopy coverage from redcedar (Engle, Stritzke, and Claypool, 1987). Thus, forage production in the Central loamy site was determined each year as:

(7) Forage Production = 3,850 * (1 - % canopy coverage)

Figure 4.5 Forage Available.

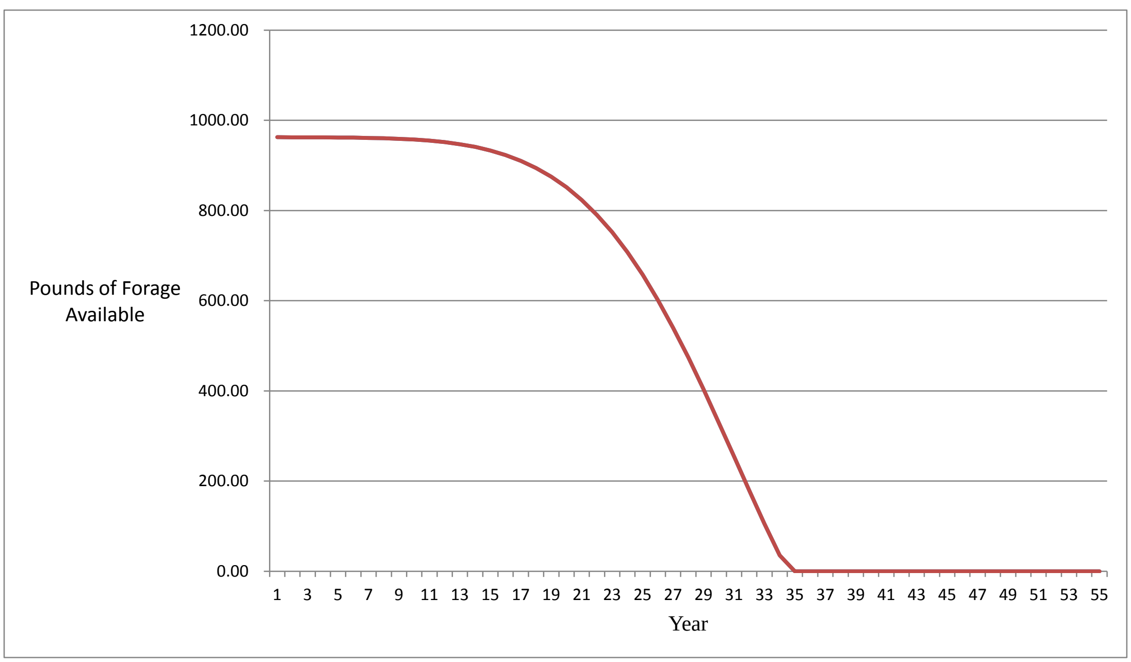


Figure 4.5 illustrates the decrease in forage available due to increasing redcedar canopy coverage and the impacts of cedar industry.

Stocker Segment

Stocker production on native range depends on the total amount of forage available for grazing. Three stocker sizes were chosen for this study to represent the range of stocker cattle typically purchased for summer stocker production in Oklahoma. The OSUNRC2010 calculator was adapted to provide the forage consumption requirements for stocker type for each stocker weight. Based on these forage consumption requirements, average daily gains, stocking rates and total livestock production can be determined for each stocker type under varying levels of redcedar invasion. In all cases, grazing was assumed to represent a 150 day grazing period, May through September (Lalman, 2013).

Also, figured into the average daily gain of stocker growth are the additional pounds of gain created from prescribed burning. A study conducted by McCollum, Engle, and Stritzke researched weight gains from stocker cattle grazing burned and unburned rangeland for a period of four years. Pastures were burned in late March or early April, consistent with the management decision alternatives in this research. Pastures are assumed to be treated at least one month before stocker cattle are purchased to ensure forage availability and safety of the animals. Research concluded a 0.21 pounds per day increase for the entire summer grazing period. This extra gain per day is figured into the program for that year only. Once a burn is implemented in management decisions, for the current year, extra weight gain is added for that year only and weight gains return to normal in following years (McCollum, Engle, and Stritzke, 1992).

The value of stocker production was based on historical and potential future values of gain for stocker weight gain. The value of stocker gain captures the gross value of adding weight to feeder cattle and thus captures market signals regarding the value of stocker production (Peel, 2011). A base rate of $0.57 per pound of gain was used as the historical value of stocker gain (Peel, 2006). In recent years, high feeder cattle prices and changes in feeder cattle price relationships have resulted in higher values of stocker gain ranging from $0.75 per pound to over $1.00 per pound. Potential values of $0.75 per pound of gain and $0.95 per pound of gain were chosen to test the impacts of higher value of gain on redcedar management strategies. The value of gain ignores costs that would not change according to feeder market conditions and would be incurred in all stocker production. For summer grazing, these include costs for vet and medicine, and mineral supplements.

Value per Acre

This section discusses costs for decision rules implemented in the model; prescribed burning and a prescribed burning plus mechanical control method. Also included will be net present value implementation in the model, time horizon, and the resulting value per acre of implementing management decisions.

Prescribed burning of tallgrass prairie is a beneficial and often economical means of suppressing eastern redcedar, other brush and undesirable plants, enhancing wildlife habitat, and improving grazing distribution (McCollum, Engle, Stritzke, 1992). Prescribed burning was chosen as a management tool because it increases weight gain of stockers during grazing season, due to improved forage quality and is a very cost effective tool for rangeland management. Costs for prescribed burning were determined to be $12.50 per acre for a quarter section, $11.00 per acre for a half section, $9.40 per acre for a section, and $8.00 per acre a prescribed burn greater than 1,000 acres. For this research, the cost of $12.50 per acre is implemented for the 160 acres site assumed in this study. Total costs for prescribed burning are thus $2,000 for a burn in any year along the timeline (Weir, 2013).

Fuhlendorf, et al., conducted a fire study on the mortality (%) assigned to juniperus size classes experiencing different fire intensities based upon canopy diameter of cedar trees. After converting tree height to size of canopy diameter, percent kill rates are determined for each height class and age of tree. The medium fire intensity was chosen because it encompasses everything from having an abundance of standing forge available to burn or drought conditions, where standing forage has fallen below average (Fuhlendorf et al., 2008).

For the mechanical plus prescribed fire management option, no research is available that shows a correlation between height of cedar trees and when mechanical control should be implemented. Trees with a basal diameter ranging anywhere from 3 to 20 inches are recommended to be used with tractors/skid loaders and a saw and bulldozers can be used on any size of eastern redcedar (Smith, 2001). Since these methods are not directly applicable to the model above, it is assumed mechanical control treatment applies to trees 14 years of age or older (>2.956 meters in height) combined with a prescribed burning to control trees younger than fourteen years of age.

Prescribed burning plus mechanical includes the total cost for a prescribed burn and adds costs for mechanical removal of trees. When the mechanical control option is selected, trees with a height greater than 2.956 meters are killed and then a prescribed burn is implemented after, but in the same year. Rates for mechanical control were gathered from the Oklahoma NRCS (Reavis, 2013).

Table 4.1 NRCS Mechanical Control Costs.

	NRCS Mechanical Control Costs (Per Acre)			
% Cedar Cover	**W/O Cost share**	**With Cost Share**		
<10%	$ 36.19	$ 18.10	/Acre	
11-30%	$ 128.26	$ 64.13	/Acre	
31-50%	$ 204.85	$ 102.43	/Acre	
>51%	$ 321.22	$ 160.61	/Acre	
Fire Break	$.05/linear ft		/Acre	*Tractor with disk - 30 Ft strip
Fire Break	$.13/linear ft		/Acre	*small dozer - 150Ft. Wide Strip

Table 4.1 illustrates costs associated with clearing cedar in Oklahoma. NRCS cost share is based on a statewide average of data collected throughout the state. Rates are not based on a per county basis but instead calculated on the percent canopy coverage within a location. These costs are applied directly in the model with cost of the mechanical plus burning option based on

canopy coverage. Costs for prescribe burning plus mechanical control, were entered as twice the cost share rates.

Total dollars per pound gained is used to calculate the net present value of the model. The dollars per pound gained less cost for any cedar management decisions are implemented. Although the no management decision does not have any actual costs associated with its selection, the model also takes into account the value lost for choosing not to manage eastern redcedar. When a “Prescribed Fire” management option is selected, the value obtained for year 1, even with costs included, increases because of the pounds gained per day difference of prescribed burning. Total cost for a producer in this model ends up being value lost for “No Management”, $2,000 for using “Prescribed Fire” as the management tool, and for “Prescribed Fire + Mechanical” costs vary based upon cedar canopy cover located throughout the years selected.

Net Present Value

Due to the long time frame to evaluate the impacts of redcedar management, a thirty year time horizon was considered and the net present value (NPV) of net returns for the period were measured for each cedar management strategy. The net present value was calculated using the formula:

(8) $\sum_{t=0}^{29} \frac{R_t}{(1+i)^t}$

where t = year, i = discount rate, and R_t = the net returns per year. The net present value formula is carried over a 30 year period and can be started in any year representing various initial levels of cedar invasion. All results for this study are based on a discount rate of 4.5 percent.

CHAPTER V

RESULTS AND CONCLUSIONS

Results

The invasion of redcedar on rangelands severely reduces forage production and lowers the value of livestock production. Without proper management strategies in place to combat growth, juniper can seriously diminish productivity of rangelands. This chapter explains some of the results found in the study and provides conclusions to the research.

The management strategies implemented in this research were:

1.) No Management

2.) Prescribed Fire (PF)

3.) Mechanical + Prescribed fire (M + PF)

As different strategies are implemented, each has a different cost required for application. Solutions were found by iteratively implementing alternative management strategies in the model to determine management strategies that maximize the net present value (NPV) per acre within the model. This search across management strategies was conducted manually and not with a mathematical optimization, so it is possible that a higher NPV management alternative exists that was not revealed. Therefore, the strategies reported in these results should be considered near optimal values obtainable within the model. Several results are presented for each near optimal solution found. Near optimal cedar management strategies were determined for several initial levels of cedar invasion; for three types of stocker animals and for three levels of stocker value of gain. Full results of near optimal solutions and actual data results are listed in the appendix.

Impact of Initial Cedar Density

The basic cedar growth model with no management intervention shows that cedar tree populations and canopy coverage will reach a maximum in roughly 25 years. Near optimal management strategies were determined for beginning conditions at years 5, 10, 15, 20, and 25, which cover a range of minimal cedar invasion and forage loss to fully invaded with zero forage production.

Table 5.1 presents near optimal results for a medium size steer with a $0.75 per pound of gain for each of the years 5, 10, 15, 20, and 25. Each result refers to a selected beginning year holding size of animal and value of gain constant. The table shows management decisions selected for each year of the 30 year period. Blanks indicate no cedar management in a given year. For example, under the 5 year beginning conditions, a PF at year 10 indicates the first time that prescribed fire is implemented. Across all beginning conditions, all strategies required either a Prescribed Fire or No Management decision option, except in NPV beginning year, where the Mechanical plus Prescribed Fire management option is used.

Table 5.1 Near Optimal Cedar Management Strategies for Alternative Beginning Cedar Inventories.

*PF = Prescribed Fire
*M + PF = Prescribed Fire + Mechanical

Management Strategies
Medium Weight &
$0.75 per lb. of Gain

YR.	NPV Beg. Year 5	YR.	NPV Beg. Year 10	YR.	NPV Beg. Year 15	YR.	NPV Beg. Year 20	YR.	NPV Beg. Year 25
5		10	PF	15	PF	20	PF	25	M + PF
6		11		16	PF	21	PF	26	PF
7		12	PF	17	PF	22	PF	27	PF
8		13		18	PF	23	PF	28	PF
9		14		19		24	PF	29	PF
10	PF	15	PF	20	PF	25		30	
11		16		21		26	PF	31	
12	PF	17		22		27		32	PF
13		18	PF	23	PF	28		33	PF
14		19		24		29		34	
15	PF	20	PF	25		30	PF	35	
16		21		26		31		36	
17		22		27	PF	32		37	
18	PF	23	PF	28		33		38	
19		24		29		34	PF	39	
20	PF	25		30		35		40	PF
21		26	PF	31	PF	36		41	
22		27		32		37	PF	42	
23	PF	28		33	PF	38		43	PF
24		29	PF	34		39		44	
25		30		35		40	PF	45	
26	PF	31		36	PF	41		46	PF
27		32	PF	37		42		47	
28		33		38		43		48	
29		34		39		44		49	
30		35		40		45		50	
31		36		41		46		51	
32		37		42		47		52	
33		38		43		48		53	
34		39		44		49		54	

Results for Table 5.1 show an increase in management strategies as the cedar infestation levels increase. In NPV beginning year five, optimal strategy is to delay prescribed burning for 5 years. This is consistent with the IPM principal that treatment is warranted only when losses of the invasive species exceed the value of production due to treatment. Once the first burn is implemented in year 10, the model recommends a burn every 2 to 3 years. For beginning conditions with greater levels of cedar invasion, (15, 20, 25), burning intensively is required in order to bring the cedar under control for management. As noted before, mechanical control is implemented only in the situation where cedar has not been manage for the first 24 years. Once the cedar reaches a high infestation level, the damage to forage is enough to justify the high cost of mechanical control.

Table 5.2 illustrates several results that correspond to the strategies in Table 5.1. Beginning total trees and beginning mature trees (6 years or older) refers to the number of trees in the pasture at the net present value beginning year. Total trees with management and total mature trees with management is the average number of trees present on the site over the 30 year management plan. Note once again that model results suggest that there is an optimal level of cedar invasion and that proper management of cedar trees does not suggest complete elimination of all cedar trees. Beginning forage available refers to the total pounds per acre of forage produced from a loamy prairie soil type with average rainfall. Forage – No Management is defined as the average yearly pounds per acre of forage produced over the 30 year NPV period without redcedar management and Forage – With Management refers to the average yearly pounds per acre of forage produced over the 30 year NPV period with redcedar management. The bottom section of Table 5.2 refers to the total estimated increase in the estimated value per acre of the model. Both Value per acre – No Management and Value per acre – With Management take the 30 year NPV and divide it by 160 acres as assumed in the study. The difference between the two values represents the increase in value per acre due to redcedar management. The percent increase in Value per acre is also shown in NPV per acre between no management and implementing management decisions.

Table 5.2 Cedar Inventory, Forage Production, and Net Present Value With and Without Cedar Management for Various Beginning Cedar Invasion Levels.

Individual Results		
Weight Class		Medium
$/lb. of gain	$	0.75

NPV Beg. Year	Beg. Total Trees*	Beg. Mature Trees*	Total Trees With Management*	Total Mature Trees With Management*
5	14	4	41	15
10	75	30	35	13
15	265	133	46	19
20	479	368	98	49
25	516	507	65	30

NPV Beg. Year	Beg. Forage Available**	Forage - No Management**	Forage - With Management**
5	3848	2880	3834
10	3829	2235	3834
15	3732	1606	3825
20	3405	997	3745
25	2630	478	3802

NPV Beg. Year	Value/Ac. - No Management	Value/Ac.- With Management	% Increase In Value/Ac.
5	$ 1,272.66	$ 1,493.33	17%
10	$ 1,078.46	$ 1,486.22	38%
15	$ 841.81	$ 1,477.94	76%
20	$ 569.25	$ 1,444.64	154%
25	$ 293.14	$ 1,431.46	388%

* Number of Trees

** Pounds Per Acre

Results in Table 5.2 indicate how beginning total trees and beginning mature trees increase with an increase in time. With near optimal management strategies implemented, the total amount of trees are kept under 100 and under fifty for total mature trees. In the next section of Table 5.2, beginning forage values per acre are gathered for each NPV beginning year. As the number of years increase, the beginning value of forage decreases, indicating a loss in forage from not implementing management strategies. Forage – No Management is a thirty year average gathered by annual forage totals per acre. There is a major reduction in average forage available between years 5 and 25. This reduction reduces stocking rate and the value per acre significantly as well. The Forage – With Management section keeps average forage levels above 3,700 pounds of forage produced per acre. This level of production indicates keeping pounds of forage per acre above 3,700 pounds of forage produced per acre is optimal. The third section of table 5.2 indicates the changes in the value per acre return with and without management strategies. Value per acre, with no management, ends up decreasing around 85 percent of its original value. Value per acre – With Management maintains NPV above $1,430 per acre when near optimal cedar management is applied. At high beginning cedar levels, near optimal strategies produce NPV that is lower than for lower invasion beginning conditions. This occurs because it requires more cost to control cedars at heavy invasion levels. Thus, while the value of cedar control is clear, even at high initial cedar invasions, these results also illustrate the value of early management to prevent invasion compared to restoration after heavy invasion has occurred. The percent increase in value increases as time increases. Years closer to the beginning years tend to yield a higher return and a lower percent increase in value because value per acre was already much higher in earlier years. The model shows a much greater increase in value, but the property will never return to previous value per acre levels. Early implementation is the best strategy.

Table 5.3 data shows the impact of different stocker weights using year 15 beginning conditions and a $0.75 per pound value of gain. Three different near optimal solution results are compared for stocker weights: light, medium, and heavy. Results for Table 5.3 indicate similar near optimal solution strategies for each size of stocker (light, medium, and heavy). The only difference, other than a one or two year switch in management strategies, is a reduction in the total number of management strategies used for the heavy steers. The model indicates it is not economically optimal to implement as much management, but value is added by not managing in some years.

Table 5.3 Near Optimal Cedar Management Strategies for Alternative Stocker Sizes.

		Steer Comparison			
*PF = Prescribed Fire		$/lb. of Gain	$ 0.75		
*M + PF = Prescribed Fire + M		Beg. YR. NPV	15		
YR.	NPV Beg. YR. Light		NPV Beg. YR. Medium		NPV Beg. YR. Heavy
15	PF		PF		PF
16	PF		PF		PF
17	PF		PF		PF
18	PF		PF		PF
19					
20	PF		PF		
21					
22	PF				
23			PF		PF
24					
25					
26	PF				
27			PF		PF
28					
29	PF				
30					PF
31			PF		
32					
33	PF		PF		
34					
35					PF
36	PF		PF		
37					
38					
39					
40					
41					
42					
43					
44					

Table 5.4 shows results that correspond to the management strategies in table 5.3. This table includes the number of beginning trees, the number of trees with management, beginning forage available, forage available with management and with management, the value per acre with and without management, and the percent increase in value per acre. It provides a comparison of the difference in results based on dollars per pound of gain.

Table 5.4 Cedar Inventory, Forage Production and Net Present Value With and Without Cedar Management for Three Stocker Cattle Types.

Steer Comparison Results		
Beg. YR. NPV		15
$/lb. of gain	$	0.75

Steer Size	Beg. Total Trees*	Beg. Mature Trees*	Total Trees With Management*	Total Mature Trees With Management*
Small	265	133	47	19
Medium	265	133	46	19
Large	265	133	94	43

Steer Size	Beg. Forage Available**	Forage - No Management**	Forage - With Management**
Small	3732	1606	3825
Medium	3732	1606	3825
Large	3732	1606	3787

Steer Size	Value/Ac. - No Management	Value/Ac.- With Management	% Increase In Value/Ac.
Small	$ 906.57	$ 1,602.30	77%
Medium	$ 841.81	$ 1,477.95	76%
Large	$ 803.00	$ 1,361.40	70%

* Number of Trees

** Pounds Per Acre

Results indicate, once again, optimal management strategies maintain total trees fewer than 100 and total mature trees fewer than 50. Forage availability remains the same throughout different size levels. Value per acre without management remains relatively close with lighter animals being of greater value. Value per acre with management mirrors the same return and percent increase in value for the animals follow this trend as well.

Table 5.5 compares the difference in near optimal solutions for different values per pound of gain. Size of the animal and year are held constant for this table. Results do not vary much for the first two sections ($0.57 and $0.75) except when the model reaches later years (30+). Results for the $0.95 pound of gain differ significantly. A more early intensive management strategy is used for the near optimal solution. This suggests there is greater value captured in early management of the property.

Table 5.5 Near Optimal Cedar Management Strategies for Alternative Dollars per Pound of Gain.

		Steer Comparison			
*PF = Prescribed Fire		Size of Steer	Medium		
*M + PF = Prescribed Fire +		Beg. YR. NPV	15		
YR.	$/Lb. Gain $ 0.57		$/Lb. Gain $ 0.75		$/Lb. Gain $ 0.95
15	PF		PF		PF
16	PF		PF		PF
17	PF		PF		PF
18	PF		PF		PF
19					PF
20			PF		
21	PF				
22					PF
23			PF		
24					
25	PF				PF
26					
27			PF		
28	PF				
29					PF
30					
31			PF		
32					PF
33	PF		PF		
34					
35	PF				PF
36			PF		
37					
38	PF				
39					
40					
41					
42					
43					
44					

Table 5.6 also compares the difference in near optimal solutions for different dollars per pound of gain. Included in results are total trees being kept under 100 and total mature tees being kept under 50. Results from this model are similar in the first two sections since trees and forage

are not linked to differences in cost. The difference happens in the value per acre section. The value of no control and implementing control yield a higher estimate with the high per pound of gain value. This shows there is more value gained in managing forage as the value of gain increases. Also, the percent increase in the value of management increases as the value of gain increases showing a higher return for higher valued animals.

Table 5.6 Cedar Inventory, Forage Production and Net Present Value With and Without Cedar Management for Three Dollars per Pound of Gain Values.

Steer Comparison Results	
Size of Steer	Medium
Beg. YR. NPV	15

$/Lb. Gain	Beg. Total Trees*	Beg. Mature Trees*	Total Trees With Management*	Total Mature Trees With Management*
$ 0.57	265	133	47	19
$ 0.75	265	133	46	19
$ 0.95	265	133	49	20

$/Lb. Gain	Beg. Forage Available**	Forage - No Management**	Forage - With Management**
$ 0.57	3732	1606	3822
$ 0.75	3732	1606	3825
$ 0.95	3732	1606	3825

$/Lb. Gain	Value/Ac. - No Management	Value/Ac.- With Management	% Increase In Value/Ac.
$ 0.57	$ 639.77	$ 1,102.07	72%
$ 0.75	$ 841.81	$ 1,477.95	76%
$ 0.95	$ 1,066.29	$ 1,896.39	78%

* Number of Trees

** Pounds Per Acre

Redcedar Density Impacts

Currently, the model has no restrictions on amounts of forage available within a pasture due to redcedar density. As the model reaches 100 percent canopy coverage, forage available is reduced, decreasing the total amount of grazeable acreage for livestock production. In the model, 25 percent of total forage is assumed to be available for livestock production. However, forage consumed by cattle production may be further reduced by cedar density. Hohlt et al. conducted a study estimating the grazeable acreage cattle are willing to graze with brushy areas present. Different constraints are discussed which inhibit proper grazing in some areas, including brush density. Hohlt et. al. attached GPS collars on cattle and studied their grazing habits of cattle in pastures containing anywhere from no brush to thickets not physically passable by animals (0-5 scale). Research concluded only 25 percent of the time cattle visited areas that were a score of 3 and completely avoided areas with a score of 4 or 5 (Hohlt et al., 2009). Ignoring the density impacts above means that the unrestricted model understates redcedar impacts on forage availability.

The brush density impacts estimated by Hohlt et al. are applied as additional restrictions to livestock production as cedar density increases. If canopy coverage is less than 40 percent, forage use at the normal usage rate of 25 percent of total forage production is available for grazing. If coverage is between 40 percent, and 50 percent, 20 percent of total forage production is available for grazing. If canopy coverage is greater than 50 percent and less than 60 percent, forage availability is limited to 15 percent of total forage production and once the canopy coverage exceeds 60 percent, then forage availability is reduced to zero. These limits reflect the fact that cattle willingness and ability to utilize forage is reduced as canopy density increases, even though forage is produced.

Impacts of Density Restrictions

Applying these restrictions suggests there is a five year difference when forage availability essentially equals zero. For the unrestricted model, forage available equals zero in year 35 and for the restricted model, forage available equals zero in year 30. This difference equates to an average increase of 181 pounds of forage available from year 30 to 35 without management.

The impact of the restrictions is relatively minor. In the unrestricted model, value per acre is estimated to be $1,041.64 without implementing management strategies. Applying the canopy density restrictions reduces the value to $1,026.69. This change in value is reduced to a $14.95 loss per acre, or a $2,392 loss for the 160 acres over the NPV operating period. Dense redcedar thickets usually only cover a portion of pastures, thus when the restrictions are applied to the entire pasture, the impacts of redcedar density are overstated.

Research has shown cattle will not pass through some areas of brush thickness to find forage. Since this research is based off a uniform distribution of trees, no information has been found showing that cattle will not pass through a uniform but very dense cedar infestation. This model and sensitivity analysis would suggest that the correct cedar coverage constraints to operate with should be located somewhere in between regular canopy coverage and the imposed restrictions. Even though there is no definite answer of whether to impose restrictions or not, the overall indication from the model would be proper management of cedar invasion to prevent these restrictions from ever needing to be considered.

Conclusions

This research helps explain the loss in forage and economic value sustained from the invasion of eastern redcedar. It also shows how value is affected historically in the cattle market and at recent levels of dollars per pound of gain. Eastern redcedar invasion has shown that the amount of forage available, with no management, essentially equals zero in 30 years. Over the 30 years, the average forage available per year is 3,316 pounds of forage available per acre and 3,850 is the original amount of forage per acre available in year 1. The loss of forage reduces the total pounds available for cattle resulting in a decreased stocking rate and a decreasing value per acre. Once a property is fully invaded, the grazing value drops to zero.

With implementation of management practices for redcedar, forage reduction is managed, preventing economic loss. For scenarios beginning in years 5, 10, 15, and most of 20, the model recommends using prescribed fire as the preferred alternative to increase forage available within the 30 year period. In year 20, using the $0.95 per pound of gain setting, the cost of using mechanical control was less than the benefits received from management. With higher value of gain potential, it is worth more to producers to not only manage cedar, but also use more expensive and efficient means to increase amounts of forage. In year 25, with almost 100% canopy cover, no matter if the dollar per pound of gain is at the historic level ($0.57) or at the other two experimental levels, it is economically efficient to implement a Mechanical Control decision as early as possible.

Using appropriate management decisions throughout the 30 year time window maximizes the NPV of land for livestock production. Even though it is possible to greatly increase the value per acre within each 30 year window, the NPV values obtained with cedar management remain below the NPV values where cedar management is implemented earlier. The earlier management is implemented, the better handle producers will have on eastern redcedar invasion resulting in higher NPV per acre.

Sharply higher corn prices in recent years changes the value of gain for stocker production. Increased stocker value of gain implies that forage is more valuable and the economic returns to better forage management are enhanced. The results of this research confirm the value of enhanced cedar management and shows that producers need to manage cedar immediately to reduce costs of management and increase the total value per acre amount obtainable.

CHAPTER VI

LIMITATION AND SUGGESTIONS FOR FURTHER RESEARCH

There are some limitations to all research projects. A model such as that developed in this study necessarily involves many assumptions. Additionally, a research project suggests additional research that extends or augments the current research. There are several areas in which additional data and research can improve and extend this study.

This study is based on available literature on eastern redcedar growth, spread and the response to management applied to one particular rangeland site. Nevertheless, there are considerable gaps in data and information on exactly how to model redcedar invasion and control. Moreover, redcedar is a problem in a wide variety of locations and range sites. Additional research is needed to understand the impact of redcedar under different range and climate conditions. More realistic site considerations, such as the impact the slope, rocks, and unequal brush density would improve the results if information were available to incorporate such features into the model. The model assumes average weather conditions and does not reflect the variability of forage production and management options that occur over many years.

This study examined the impacts of redcedar on forage production and the value of redcedar management for private landowners with respect to livestock production. Redcedar also has a variety of other impacts such as wildlife habitat, and water use, which may also affect private management decisions but also have broader public impacts. Additionally redcedar impacts such as increased wildfire risk and human health impacts extend well beyond the private landowner management considerations. Research on these important topics are necessary in addition to the current research to fully understand the impacts of redcedar in Oklahoma.

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APPENDIX

Near Optimal Solutions

Appendix Table 1 - Eastern Redcedar Management Decisions

Beg. Yr.	Weight Class	$/lb of gain	MD	MD	MD	MD	MD	MD	MD	MD	MD	MD
5	Light	0.57	PF-9	PF-13	PF-16	PF-18	PF-21	PF-24	PF-27			
5	Light	0.75	PF-7	PF-10	PF-13	PF-16	PF-18	PF-22	PF-25	PF-28		
5	Light	0.95	PF-5	PF-8	PF-10	PF-12	PF-15	PF-17	PF-20	PF-22	PF-25	PF-28
5	Medium	0.57	PF-10	PF-14	PF-17	PF-18	PF-23	PF-27				
5	Medium	0.75	PF-10	PF-12	PF-15	PF-18	PF-20	PF-23	PF-26			
5	Medium	0.95	PF-7	PF-9	PF-12	PF-14	PF-17	PF-19	PF-22	PF-25	PF-28	
5	Heavy	0.57	PF-10	PF-15	PF-18	PF-22	PF-25	PF-29				
5	Heavy	0.75	PF-10	PF-15	PF-18	PF-21	PF-25	PF-28				
5	Heavy	0.95	PF-10	PF-15	PF-18	PF-20	PF-24	PF-27				
10	Light	0.57	PF-10	PF-13	PF-16	PF-18	PF-22	PF-25	PF-28	PF-32		
10	Light	0.75	PF-10	PF-11	PF-15	PF-17	PF-20	PF-25	PF-27	PF-29	PF-32	
10	Light	0.95	PF-10	PF-11	PF-12	PF-14	PF-17	PF-19	PF-22	PF-25	PF-28	PF-31
10	Medium	0.57	PF-10	PF-14	PF-17	PF-18	PF-21	PF-26	PF-29	PF-32		
10	Medium	0.75	PF-10	PF-12	PF-15	PF-18	PF-20	PF-23	PF-26	PF-29	PF-32	
10	Medium	0.95	PF-10	PF-11	PF-13	PF-15	PF-18	PF-20	PF-23	PF-26	PF-29	PF-32
10	Heavy	0.57	PF-10	PF-15	PF-17	PF-22	PF-25	PF-28	PF-32			
10	Heavy	0.75	PF-10	PF-15	PF-19	PF-21	PF-25	PF-28	PF-32			
10	Heavy	0.95	PF-10	PF-15	PF-18	PF-20	PF-24	PF-27	PF-30	PF-34		
15	Light	0.57	PF-15	PF-16	PF-17	PF-18	PF-21	PF-26	PF-30	PF-33	PF-36	
15	Light	0.75	PF-15	PF-16	PF-17	PF-18	PF-20	PF-22	PF-26	PF-29	PF-33	PF-36
15	Light	0.95	PF-15	PF-16	PF-17	PF-18	PF-19	PF-22	PF-25	PF-28	PF-32	PF-35
15	Medium	0.57	PF-15	PF-16	PF-17	PF-18	PF-21	PF-25	PF-28	PF-33	PF-35	PF-38
15	Medium	0.75	PF-15	PF-16	PF-17	PF-18	PF-20	PF-23	PF-27	PF-31	PF-33	PF-36
15	Medium	0.95	PF-15	PF-16	PF-17	PF-18	PF-19	PF-22	PF-25	PF-29	PF-32	PF-35
15	Heavy	0.57	PF-15	PF-16	PF-18	PF-21	PF-25	PF-29	PF-33	PF-36		
15	Heavy	0.75	PF-15	PF-16	PF-17	PF-18	PF-23	PF-27	PF-30	PF-35		
15	Heavy	0.95	PF-15	PF-16	PF-17	PF-18	PF-24	PF-28	PF-32	PF-35		
20	Light	0.57	PF-20	PF-21	PF-22	PF-23	PF-24	PF-27	PF-31	PF-35	PF-38	PF-41
20	Light	0.75	PF-20	PF-21	PF-22	PF-23	PF-24	PF-26	PF-30	PF-34	PF-37	PF-40
20	Light	0.95	M + PF-20	PF-21	PF-22	PF-23	PF-24	PF-26	PF-27	PF-32	PF-37	PF-38
20	Medium	0.57	PF-20	PF-21	PF-22	PF-23	PF-24	PF-27	PF-31	PF-35	PF-38	PF-41
20	Medium	0.75	PF-20	PF-21	PF-22	PF-23	PF-24	PF-26	PF-30	PF-34	PF-37	PF-40
20	Medium	0.95	PF-20	PF-21	PF-22	PF-23	PF-24	PF-26	PF-29	PF-33	PF-37	PF-40
20	Heavy	0.57	PF-20	PF-21	PF-22	PF-23	PF-25	PF-29	PF-34	PF-38	PF-40	PF-43
20	Heavy	0.75	PF-20	PF-21	PF-22	PF-23	PF-24	PF-28	PF-32	PF-37	PF-39	PF-42
20	Heavy	0.95	PF-20	PF-21	PF-22	PF-23	PF-24	PF-27	PF-32	PF-36	PF-39	PF-42
25	Light	0.57	M + PF-25	PF-26	PF-27	PF-28	PF-31	PF-32	PF-37	PF-41	PF-44	PF-47
25	Light	0.75	M + PF-25	PF-26	PF-27	PF-28	PF-29	PF-31	PF-32	PF-39	PF-42	PF-46
25	Light	0.95	M + PF-25	PF-26	PF-27	PF-28	PF-29	PF-31	PF-32	PF-37	PF-42	PF-45
25	Medium	0.57	M + PF-25	PF-26	PF-27	PF-28	PF-31	PF-32	PF-37	PF-41	PF-44	PF-47
25	Medium	0.75	M + PF-25	PF-26	PF-27	PF-28	PF-29	PF-32	PF-33	PF-40	PF-43	PF-46
25	Medium	0.95	M + PF-25	PF-26	PF-27	PF-28	PF-29	PF-31	PF-32	PF-37	PF-42	PF-45
25	Heavy	0.57	M + PF-25	PF-26	PF-27	PF-30	PF-32	PF-33	PF-41	PF-43	PF-47	PF-50
25	Heavy	0.75	M + PF-25	PF-26	PF-27	PF-30	PF-32	PF-33	PF-40	PF-43	PF-46	PF-49
25	Heavy	0.95	M + PF-25	PF-26	PF-27	PF-29	PF-32	PF-33	PF-39	PF-42	PF-45	PF-49

* Md=Management Decision

** PF=Prescribed Fire

*** M + PF=Mechanical plus Prescribed Fire Management

**** dash #=Year Management Decisions were Implemented

Near Optimal Results

Appendix Table 2 - Eastern Redcedar Management Results						(lbs./acre)	(lbs./acre)	(lbs./acre)			
Beg. Yr.	Weight Class	$/lb of gain	Beginning Total Trees	Beginning Mature Trees	Beginning Value/ac	Beginning Forage Available	Forage No Management	Forage With Management	Total Trees With Management	Total Mature Trees With Management	Ending Value /ac
5	Light	0.57	14	4	$ 1,041.64	3848	2880	3833	42	16	$ 1,214.56
5	Light	0.75	14	4	$ 1,370.58	3848	2880	3841	26	9	$ 1,614.65
5	Light	0.95	14	4	$ 1,736.06	3848	2880	3846	13	4	$ 2,063.90
5	Medium	0.57	14	4	$ 967.22	3848	2880	3822	61	25	$ 1,123.83
5	Medium	0.75	14	4	$ 1,272.66	3848	2880	3834	41	15	$ 1,493.33
5	Medium	0.95	14	4	$ 1,559.28	3848	2880	3844	18	6	$ 1,907.28
5	Heavy	0.57	14	4	$ 922.63	3848	2880	3815	65	26	$ 1,054.14
5	Heavy	0.75	14	4	$ 1,213.99	3848	2880	3817	63	25	$ 1,399.95
5	Heavy	0.95	14	4	$ 1,537.72	3848	2880	3819	63	25	$ 1,784.28
10	Light	0.57	75	30	$ 882.69	3829	2235	3824	54	21	$ 1,206.02
10	Light	0.75	75	30	$ 1,161.43	3829	2235	3834	36	13	$ 1,609.16
10	Light	0.95	75	30	$ 1,471.15	3829	2235	3841	26	9	$ 2,061.70
10	Medium	0.57	75	30	$ 819.63	3829	2235	3823	55	22	$ 1,113.35
10	Medium	0.75	75	30	$ 1,078.46	3829	2235	3834	35	13	$ 1,486.22
10	Medium	0.95	75	30	$ 1,366.05	3829	2235	3841	24	8	$ 1,904.02
10	Heavy	0.57	75	30	$ 781.84	3829	2235	3803	80	34	$ 1,037.01
10	Heavy	0.75	75	30	$ 1,028.74	3829	2235	3801	81	35	$ 1,381.99
10	Heavy	0.95	75	30	$ 1,303.07	3829	2235	3817	58	23	$ 1,764.34
15	Light	0.57	265	133	$ 689.00	3732	1606	3811	67	28	$ 1,196.35
15	Light	0.75	265	133	$ 906.57	3732	1606	3825	47	19	$ 1,602.30
15	Light	0.95	265	133	$ 1,148.33	3732	1606	3825	50	21	$ 2,054.15
15	Medium	0.57	265	133	$ 639.77	3732	1606	3822	47	19	$ 1,102.07
15	Medium	0.75	265	133	$ 841.81	3732	1606	3825	46	19	$ 1,477.95
15	Medium	0.95	265	133	$ 1,066.29	3732	1606	3825	49	20	$ 1,896.39
15	Heavy	0.57	265	133	$ 610.28	3732	1606	3785	92	42	$ 1,018.16
15	Heavy	0.75	265	133	$ 803.00	3732	1606	3787	94	43	$ 1,361.40
15	Heavy	0.95	265	133	$ 1,017.13	3732	1606	3787	97	46	$ 1,743.23
20	Light	0.57	479	368	$ 465.91	3405	997	3745	93	46	$ 1,168.43
20	Light	0.75	479	368	$ 613.05	3405	997	3745	98	49	$ 1,566.61
20	Light	0.95	479	368	$ 776.52	3405	997	3813	69	33	$ 2,011.82
20	Medium	0.57	479	368	$ 432.63	3405	997	3745	93	46	$ 1,075.88
20	Medium	0.75	479	368	$ 569.25	3405	997	3745	98	49	$ 1,444.64
20	Medium	0.95	479	368	$ 721.05	3405	997	3744	100	51	$ 1,854.66
20	Heavy	0.57	479	368	$ 412.68	3405	997	3735	93	44	$ 983.77
20	Heavy	0.75	479	368	$ 543.01	3405	997	3742	93	44	$ 1,322.51
20	Heavy	0.95	479	368	$ 687.81	3405	997	3743	93	45	$ 1,699.17
25	Light	0.57	516	507	$ 239.93	2630	478	3801	63	29	$ 1,151.44
25	Light	0.75	516	507	$ 315.69	2630	478	3806	68	32	$ 1,556.82
25	Light	0.95	516	507	$ 399.88	2630	478	3806	69	33	$ 2,006.81
25	Medium	0.57	516	507	$ 222.79	2630	478	3801	63	29	$ 1,057.67
25	Medium	0.75	516	507	$ 293.14	2630	478	3802	65	30	$ 1,431.46
25	Medium	0.95	516	507	$ 371.31	2630	478	3806	69	33	$ 1,849.61
25	Heavy	0.57	516	507	$ 212.51	2630	478	3788	71	33	$ 965.15
25	Heavy	0.75	516	507	$ 279.62	2630	478	3791	67	31	$ 1,308.22
25	Heavy	0.95	516	507	$ 354.19	2630	478	3793	64	30	$ 1,689.79

VITA

Aaron James Coffey

Candidate for the Degree of

Master of Science

Thesis: PRIVATE BENEFITS OF EASTERN REDCEDAR MANAGEMENT AND THE IMPACT OF CHANGING STOCKER VALUE OF GAIN

Major Field: Agricultural Economics

Biographical:

Education:

Completed the requirements for the Master of Science in Agricultural Economics at Oklahoma State University, Stillwater, Oklahoma in July, 2013.

Completed the requirements for the Bachelor of Sciences in Agricultural Economics at Oklahoma State University, Stillwater, Oklahoma in 2011.