ASSESSING EASTERN REDCEDAR ENCROACHMENT AND ENVIRONMENTAL FACTORS IN OKLAHOMA BY REMOTE SENSING AND GIS

By

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Bachelor of Science

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Nanjing, Jiangsu, China

2009

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 2011

ASSESSING EASTERN REDCEDAR

ENCROACHMENT AND ENVIRONMENTAL

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CHAPTER I

INTRODUCTION

Woody plant invasion in semi-arid and arid ecosystems is a global environmental problem. The invasion refers to the increase in the density of woody plants and shrubs in the grasslands and savannas (Auken 2009). The United States Environmental Protection Agency (EPA) defines invasive species as “a plant or animal that is non-native (or alien) to an ecosystem, and whose introduction is likely to cause economic, human health, or environmental damage in that ecosystem. Once established, it is extremely difficult to control their spread” (US EPA 2011). Woody plant invasion has hydrological, biogeochemical, and socioeconomic consequences. It is necessary to understand the invasion since almost one half of the Earth’s surface is covered with semi-arid and arid landscapes (Huxman et al. 2005). Throughout the last 50-300 years, this widespread phenomenon has occurred in parts of North America, South America, Africa, and Australia (Golubiewski 2008). The large scale of woody plant invasion is affecting landscape patterns, and changing soil carbon and nitrogen, two important elements related to climate change (Martin et al. 2003, Jackson et al. 2002, Frank 1984).

A great number of invasive plants in the plant kingdom are woody, such as shrubs, trees, and lianas. The invasion of woody plants reduces native herbaceous vegetation, which plays an important role in controlling local climate. It is difficult to attribute one single reason as the cause of woody plant invasion. The causes of the invasion include changes in climate, fire frequency, competition between grasses and woody plants, spread of seed, decline in biodiversity, as well as combinations of these factors (Auken 2000, Golubiewski 2008).

Eastern Redcedar in Oklahoma

One of the most invasive woody plants is the eastern redcedar (*Juniperus virginiana* L.), a species of juniper that is native and widely distributed from the eastern Great Plains (especially in Kansas, Oklahoma, and Texas) to the Atlantic coast (Briggs et al. 2002). In those areas, eastern redcedar is an invasive plant, even with the potential to live for two hundred years. It can be well adapted to dry areas with thin and acidic soil (Barlow 2004). The cedar invasion reduces land production for livestock, which affects the balance of the environment and the economy. Based on the National Resources Inventory Rangeland Resource Assessment provided by the Natural Resources Conservation Services in 2010 (NRCS 2010), eastern redcedar makes up 20.4% of the plant cover in non-federal rangeland in Oklahoma. In 2000, the Oklahoma NRCS estimated that by 2013 eastern redcedar is expected to cost Oklahoma $447 million through the loss of cattle forage, catastrophic wildfires, as well as threatening water supplies if no effective steps are taken to control them (The Oklahoma NRCS 2008). Even worse than that, about 278,130 acres of landscapes are replaced by invading junipers in Oklahoma every year (Smith 2011). If the invading rate keeps as this, by 2015 approximately 11.6 million acres of juniper will cover 26% of Oklahoma landscape (Smith 2011). Eastern redcedar has become a common part of the landscape, due to its expansion to towns and cities. In addition, eastern redcedar contains explosive oils that make it very flammable under the certain conditions (Smith 2011).

Although recent research has shown that some woody plants in arid areas may keep rivers flowing (Wilcox and Huang 2010), landowners have been worried about the invasion into their lands. As a result, the expansion of eastern redcedar is a major concern of landscape management in the central United States. Figure 1.1 shows the eastern redcedar tree invasion in Oklahoma (Oklahoma News 2009). The trees are long-lived evergreen species, with rapid growth and high reproductive output in a short period (Briggs et al. 2002), and they are often found along line roads and highways near cities (Barlow 2004).

Figure 1.1 The Eastern Redcedar Tree Invasion in Oklahoma

Research Questions

Research questions considered in this thesis include 1. What human and environmental factors significantly contribute to the eastern redcedar encroachment in Oklahoma? 2. How do these factors help to predict the future eastern redcedar encroachment? The answers will help people understand the expansion of eastern redcedar and its relationship with the physical environment in Oklahoma. Improved understanding of invasive woody species will lead to more effective landscape management and better control of future invasion.

Research Objectives

The objectives of this study include quantifying eastern redcedar cover in Oklahoma and evaluating the relationships between eastern redcedar and human-environmental factor. The environmental factors include climate conditions, land cover types, and elevation variation. The human component includes the land use, representing how land is used by humans. Eastern redcedar may provide the evidence of past land use such as agriculture. The Oklahoma NRCS has been using satellite imagery to create maps showing the percentage of eastern redcedar for a number of counties in Oklahoma. The maps developed by the NRCS are used to assess the spatial distribution of eastern redcedar based on approximate canopy cover and identify main cedar cutting areas. This mapping project is supported by the Oklahoma Department of Agriculture, Food & Forestry and the Oklahoma Department of Commerce. The maps show the spatial relationships of different canopy densities in a county. The NRCS does not assess the number or size of individual trees.

Thesis Organization

Chapter 1 is a brief introduction of this study including the background of eastern redcedar, research questions, and research objectives. Chapter 2 is the literature review on the woody plant encroachment, eastern redcedar invasion, and technologies and methodologies applied in the recent research. Chapter 3 discusses the data sources, preparation, and detailed methodology. Chapter 4 contains findings and results from the imagery analysis and regression analysis. Chapter 5 discusses conclusions, limitations, and recommendations for future research.

CHAPTER II

LITERATURE REVIEW

Woody plant encroachment in arid and semi-arid systems is a widespread phenomenon with biogeographical and hydrological consequences (Huxman et al. 2005, Golubiewski 2008). This problem challenges both land management and ecosystem protection. It is still difficult to predict the amount and the distribution of invasive species, due to the large spatial scale of exotic invasion and complex species-environment relationships, (Seabloom et al. 2006, Ganguli et al. 2008). However, current research and technologies (e.g. remote sensing and geographic information systems) for invasive species provide the basis for overcoming those challenges in the future. These efforts may help to reduce invasive species to more acceptable levels and prevent their re-emergence (The National Invasive Species Council 2005).

The literature on woody plant encroachment mainly focuses on three aspects. Firstly, studies discuss growth dynamics and eco-hydrological characteristics of invasive woody plants (Jackson et al. 2002, Coppedge et al. 2004, Huxman et al. 2005, Scott et al. 2006). Secondly, remote sensing and geographic information systems (GIS) are two powerful tools to evaluate the effect and risk of woody plant encroachment in ecosystems (Briggs et al. 2002, Martin et al. 2003). Thirdly, by building regression models, researchers focus on examining the relationships between the environment (e.g. climate, landscape, and avian community change) as well as human activities(e.g. changes in land use and ownership patterns) and the extent of woody plant encroachment (Coppedge et al. 2001, Schmidt and Wardle 2002, Asner et al. 2003, Smith and Johnson 2004).

In this chapter, I review the literature and progress in the studies of woody plant encroachment. Firstly, I discuss the background of woody plant encroachment, including the causes and effects of this phenomenon. Secondly, I focus on a highly invasive species, eastern redcedar, and its implications for the environment. Finally, I discuss the methodologies applied in the research.

Background of Woody Plant Encroachment

The causes and effects of woody plant encroachment in semi-arid grasslands have been much discussed (Auken 2000, Jackson et al. 2002, Bradley and Mustard 2006). Changes in climate and land use are the causes of the encroachment of woody plants. Recent research has specified why woody plants have increased during the last 50-100 years (Auken 2000, Norris et al. 2001, Asner and Vitousek 2005). The climatic factors, such as precipitation, soil temperature, soil moisture, and the cycling of carbon or nitrogen can affect the expansion of woody plants. By doing regional assessments, some researchers have focused on the relationships between precipitation and woody plant abundance (e.g. Jackson et al. 2002, Asner et al. 2003). For example, Scott et al. (2006) have found a positive relationship between ecosystem evapotranspiration and woody plant cover. The precipitation is a main component of the water budget (e.g. evapotranspiration, groundwater) in the ecosystem, meanwhile, the water budget is a useful tool to examine the variation in woody plant cover (Wilcox 2002).

Changes in land cover and land use are complex processes for woody plant encroachment. During the past hundred years, land cover types have been altered mainly by human activities. Early reports indicate that before the advent of modern land use the southwestern U.S. was not pure grassland (Golubiewski 2008). Land use has changed significantly in this region over the past few centuries. Recent research shows that cultivation may have a negative impact on the physical landscape, because crops affect plant diversity by reducing native species (Iverson and Prasad 1998). In addition, fires and heavy grazing are two principal causes of woody plant expansion. Livestock grazing reduces the competition among herbaceous species, which leads to the rapid growth of woody plants. Grazing also decreases fire frequency, which makes woody plants grow faster (Golubiewski 2008). The reduction of fire frequency in tallgrass prairie is the primary reason of increasing woody plants in the Great Plains, because burning is necessary to reduce the establishment of woody plants (Auken 2000, Briggs et al. 2002). Brooks et al. (2010) point out that some young woody trees are fire intolerant, allowing the fire to control the young trees. Since the beginning of European settlement in North America, fire has been reduced, which makes woody plants expand outside of the protected areas (Smith 2011).

On one side, changes in land cover and land use influence the growth of woody plants; on the other side, the expansion of woody plants also brings changes to the land cover types, especially in altering the hydrological characteristics (Scott et al. 2006). Woody plants change the soil moisture and potential evapotranspiration through modifying the water budget in different ways. Many biologists and ecologists have focused on the relationships between woody plant encroachment and carbon (or nitrogen) cycling in the soil (Jackson et al. 2002, Martin et al. 2003, Smith and Johnson 2004). Smith and Johnson (2004) have found that in terms of slowing soil respiration, the encroachment of woody plants also slows soil carbon cycling in woodlands. Similarly, Martin et al. (2003) examine the effects of woody plant encroachment on soil nitrogen oxide emissions. Their results show that when the grasslands are invaded by woody vegetation, nitrogen oxide emissions will increase. Even worse, the recent decline of bird species in the southern Great Plains is associated with the increasing woody plants in this area (Chapman et al. 2004).

Woody plant encroachment affects the environment and ecology at different levels and scales. As a result, the control of woody plant invasion is related to a wide range of issues in different disciplines, such as landscape dynamics, plant diversity, and avian community dynamics (Wilcox 2002, Coppedge et al. 2004, Scott et al. 2006).

Invasion by Eastern Redcedar

Eastern redcedar is an invasive woody plant and is widely distributed throughout the Great Plains (Briggs et al. 2002). This tree destroys the balance of the hydrology and affects the economy. Controlling the growth of eastern redcedar is a main concern for landscape management. The knowledge of growth dynamics of eastern redcedar is helpful to manage rangelands that are invaded by this species (Engle and Kulbeth 1992).

Recently researchers have achieved a variety of progress in the studies of eastern redcedar in Oklahoma. Ganguli et al. (2008) evaluate the relationships among eastern redcedar invasion, plant diversity, and plant composition. The study area includes three locations in north central Oklahoma and those locations contain different types of vegetation (tallgrass, old-field and oak forest). The old-field was former farmland that was eroded by cultivated crops during the first half of the 20^{th} Century. They build regression models to examine both eastern redcedar seedling growth and survival. The results suggest that there is a positive relationship between seedling growth of eastern redcedar and species richness of all three locations, and a positive relationship between seedling survival and species composition in old-field. However, Briggs et al. (2002) find that there is a significant negative relationship between eastern redcedar density and herbaceous species diversity (Briggs et al. 2002). The different outcomes of the relationships between the number of species and plant diversity might be due to the choices of different spatial scales, environmental factors influencing invasion, and response variables (Ganguli et al. 2008). Engle and Kulbeth (1992) focus on growth dynamics of eastern redcedar in Oklahoma through the tree crowns. Their studies suggest that the invasion of eastern redcedar in central Oklahoma, where eastern redcedar has smaller crowns, might be a result of the genetic influence other than the environment itself. They also test the method of burning to control eastern redcedar, and the results show that although burning is an economic way of controlling, it can only effectively kill trees with heights less than 1.0 m (Engle and Kulbeth 1992).

Why Eastern Redcedar Densities Increase in the Grasslands

From the results of this study and other literature, the herbaceous cover (or grassland) is easily encroached by eastern redcedar. The grassland is a valuable place for the land use, such as grazing cattle. Eastern redcedar absorbs large amounts of nutrients in the soil that otherwise would be consumed by grasses for grazing (Brooks et al. 2010). Auken (2009) points out that, at the lower elevation areas, woody plant encroachment into the arid grasslands is usually associated with expansion of the dry lands of the deserts. As a result, the increase of the dry lands might be a reason of eastern redcedar encroachment in the grasslands, in which the elevations are lower than 1000m. The desertification shifts the dominance between herbaceous and woody plants (Jackson et al. 2002).

Another land use explanation of eastern redcedar encroachment is the heavy grazing on grasslands and its interaction with fire frequency. Briggs et al. (2002) point out that the interaction between grazing and fire frequency is the key point for woody plant encroachment. Since the grasses provide adequate fuel for fires, the oversized grazing leaves little vegetation that could support the fires to kill young eastern redcedar in the following spring (Golubiewski 2008).

Technologies in Managing Woody Plants

The control and management of invasive species can be accomplished by modern resource management methods (The National Invasive Species Council 2005). The amounts or density of invasive woody plants and the data of environmental factors are often obtained from three resources. Firstly, the images of woody plants are from historical aerial photos (Coppedge et al. 2004, Asner et al. 2003). These photos can show the land cover changes during a period. Secondly, current remote sensing imagery (e.g. Landsat 5 and 7) provides more accurate information on vegetation cover. Thirdly, field observation and measurement is another key approach (Asner et al. 2003, Briggs et al. 2002, Wilcox 2002). Remote sensing has provided effective ways to classify the vegetation and map the distribution in the places that people do not have easy access.

Remote sensing imagery can also offer useful and detailed information of hydrological and biogeochemical consequences of woody plant encroachment (Asner and

Vitousek 2005). Remote sensing techniques can obtain information about vegetation in the areas that have severe conditions. For example, Chopping et al. (2008) use satellite remote sensing data to map woody plant cover in desert grasslands. Their studies show that remote sensing data is a useful measurement of woody plant cover within large areas. However, this technique still has some limitations. The correlation between high resolution and moderate resolution data is low, and it needs to be improved. In addition to the investigation of woody plants, remote sensing also plays an important role in other land cover types in a large region (Afinowicz et al. 2005). Remote sensing provides different techniques from landscape to stand scale (e. g. forest stands, including vertical and horizontal patterns of the forest) assessments. Innes and Koch (1998) apply remote sensing in a forest biodiversity study. Their assessments are at different scales, due to the complex ecosystem of the forest. They point out that, at the landscape scale, satellites can capture the structural diversity of the forest; at the intermediate scale, satellite data is quantitatively useful to assess edges, which affect forest diversity; at the stand scale, satellites can get more information about different types of vegetation in the forest.

Remote sensing can also be applied at larger scales. Turner et al. (2004) build remote sensing models from the landscape scale to the regional scale. The problems such as carbon cycling, land use, and climate change can be solved, due to the proper resolutions of remote sensing. Besides assessing woody covers at different levels, remote sensing can also be used to classify regions into a wide variety of land cover types (Afinowicz et al. 2005). Although my study area contains only 16 counties in Oklahoma, this technique is helpful in studying both small and large regions that are not easily mapped by traditional methods. With future improvements, the accuracy of remote sensing imagery will be increased, and it will also be a more effective tool for studying woody plant encroachment (Afinowicz et al. 2005).

GIS combined with remote sensing have been widely used in data models, vegetation analysis, and natural resource management (Goodchild 1994, Masera et al. 2006, Troy and Wilson 2006). With the increasing use of GIS, as well as the availability of environmental datasets, various kinds of data such as vegetation type, species richness, road network, drainage, and zonation map can be evaluated (Ravan and Roy 1997, Troy and Wilson 2006). When all the original data from diverse sources are input into ArcGIS, a single vegetation map can be derived and reveal environmental information (Demers 1991, Troy and Wilson 2006). In addition, the combination of GIS and geodatabase technology provides new ways of integrating spatial information (Masera et al. 2006). Like remote sensing, GIS can also explore plant diversity. Iverson and Prasad (1998) use GIS models to estimate plant biodiversity in Illinois. Their model includes the data of climate, soil, land type, and socioeconomic factors at the county level. Their studies reveal that plant diversity is associated with the landscape. There is a positive relationship between plant diversity and forest land type and a negative relationship between plant diversity and agricultural land type. Moreover, GIS can include detailed information of the change in a selected area during a certain period (Demers 1991), which is useful to measure the growth rate of the vegetation.

The combination of remote sensing and GIS plays a prominent role in biodiversity conservation and environmental monitoring (Salem 2003). Since it is impossible to measure changes in vegetation types using ground-based instruments, remote sensing is the only effective method to detect and map vegetation cover (Chopping et al. 2008).

Moreover, remote sensing can be used more effectively in building models even though some scientists view it as a basic instrument of collecting data (Jensen 1983). Different types of vegetation show different characteristics on remote sensing imagery due to leaf shape, size, and water content, and remote sensing imagery can be decomposed based on different features. For example, Landsat digital image, derived from earth-observing satellites, contains a simple matrix that has the reflectance of all kinds of vegetation in the study area (Frank 1984).

Statistical Methods Applied in Research

In the studies of the relationships between woody plant encroachment and the environment, statistical methods are common approaches and simple linear regression analysis is often used (Wilcox 2002, Martin et al. 2003, Huxman et al. 2005). By building regression frameworks, researchers can obtain numerical description on how woody plants, the environment, and the land use effect on each other. For the present, studies mainly focus on the relationships between woody plant encroachment and 1. *Hydrologic processes*: Wilcox (2002) examines various components of hydrologic cycling including evapotranspiration, runoff, and groundwater flow to establish the linkage between shrub control and streamflow. His results indicate that the removal of shrub cover may lead to an increasing streamflow. The shrub canopy absorbs the water so that the water cannot move into the soils. Huxman et al. (2005) also use two water-balance models to investigate the effects of woody plants on water yield and evaporative processes; 2. *Carbon and nitrogen cycling*: some studies have pointed out that the encroaching vegetation influences carbon and nitrogen storage in surface soils. Martin et al. (2003) use statistical analysis to assess the correlations between nitrogen oxide emissions and other variables. They have found that there is a positive correlation between temperature and soil nitrogen oxide emissions temporally. Other studies show that there is a "negative relationship between precipitation and changes on soil organic carbon and nitrogen content" (Jackson et al. 2002, 623); 3. *Avian community*: Coppedge et al. (2004) establish avian species and population models to see how landscape changes affect avian community dynamics. Their models predict that the avian community will change when landscape changes in northwestern Oklahoma. Although this study has nothing to do with the avian community, the literature on woody plant encroachment and avian species are useful for understanding the relationships between the invasive plants and human-environmental factors.

Summary

Woody plant encroachment is an essential part of environmental change. This phenomenon is in part caused by human activities (Asner and Vitousek 2005). The literature related to the investigation of woody plant encroachment crosses many social and economic issues. As a result, there must be an integrated effort among all involved academic disciplines, such as geography, biology, and ecology, to control the encroachment.

Although research on invasive woody plant is a relatively new field, the current literature has obtained some valuable results for future study. Research on growth dynamics mainly focuses on the plants themselves, such as their population, heights, and rings. Some studies are about the innovative tools of examining the vegetation, such as remote sensing, GIS, and how they perform in research. Another important study in this field is to evaluate the relationship between environmental factors and the amount of woody plants, such as how precipitation and soil affect the growth rates and reproductivity of woody plants (Lawton and Cothran 2000).

Study areas of invasive woody plants are located all over the world. However, the research of eastern redcedar is mainly located in South and West U.S., such as Kansas and Oklahoma, because in the Great Plains region, the invasion by eastern redcedar is a serious problem. Through the last century, the cover of woody plants in those areas has increased (Norris et al. 2001). Compared to the traditional methods, remote sensing and GIS techniques help people get more knowledge of woody plants in some inaccessible areas. Thus, researchers have made some progress in the mechanisms of woody plants, as well as environmental impacts (Briggs et al. 2002, Scott et al. 2006).

CHAPTER III

DATA AND METHODOLOGY

In this study, I examine the relationships between eastern redcedar encroachment and environmental factors as well as land use in Oklahoma. Environmental factors include climate conditions, land cover types, and elevation change. I have obtained eastern redcedar cover maps and shapefiles at no cost from the Oklahoma NRCS. Except climate data, all the other data are processed in ArcGIS and Earth Resource Data Analysis System (ERDAS). The ERDAS Imagine software package is widely used in land cover and land use classification (Afinowica et al. 2005). Then I build regression models using the quantitative data obtained from ArcGIS and ERDAS. In the regression analysis, the dependent variable is the percentage of total eastern redcedar cover, and the independent variables are the average annual temperature and precipitation, land cover types (including herbaceous cover, open water, and deciduous forest), land use (cultivated crop), and the elevation change (Table 3.1).

In the following parts, I describe the study area and explain the data sources, collections, and how to analyze the original data. I also explain why I chose those four land cover types for the regression analysis.

Table 3.1 Variables in the Regression Analysis

Dependent Variable	***Data Source***
total eastern redcedar coverage	The Oklahoma Natural Resources Conservation Service
Independent Variables	
10-year average temperature 10-year average precipitation	The Oklahoma Mesonet
percent herbaceous cover percent cultivated crop percent open water percent deciduous forest	The National Land Cover Database
elevation change	The National Elevation Dataset

Study Area

The Oklahoma NRCS has the data for eastern redcedar cover for 18 counties in Oklahoma, including 16 contiguous counties and two separate counties (Cimarron County located on the state boundary and Murray County). To be consistent, the study area in this project covers 16 contiguous counties, most of which are located in central and western Oklahoma.

Figure 3.1 shows the study area, which is mainly classified as Sandy and Shallow Prairie range sites (Engle and Kulbeth 1992), containing both urban and agricultural lands. The U. S. Department of Agriculture (USDA) defines the Sandy Prairie as "Deep, moderately sandy uplands occurring on hummocky or gently to steeply rolling topography. Some skunkbush and other woody species are usually associated with this site"; and defines the Shallow Prairie as "Gently sloping to moderately steep shallow prairie soils. Rock usually appears on the surface, often over 15 to 20 percent of the area, and occurs in the profile. The site occurs along ridges or ledges, often adjacent to Loamy or Red Clay Prairie sites" (USDA).

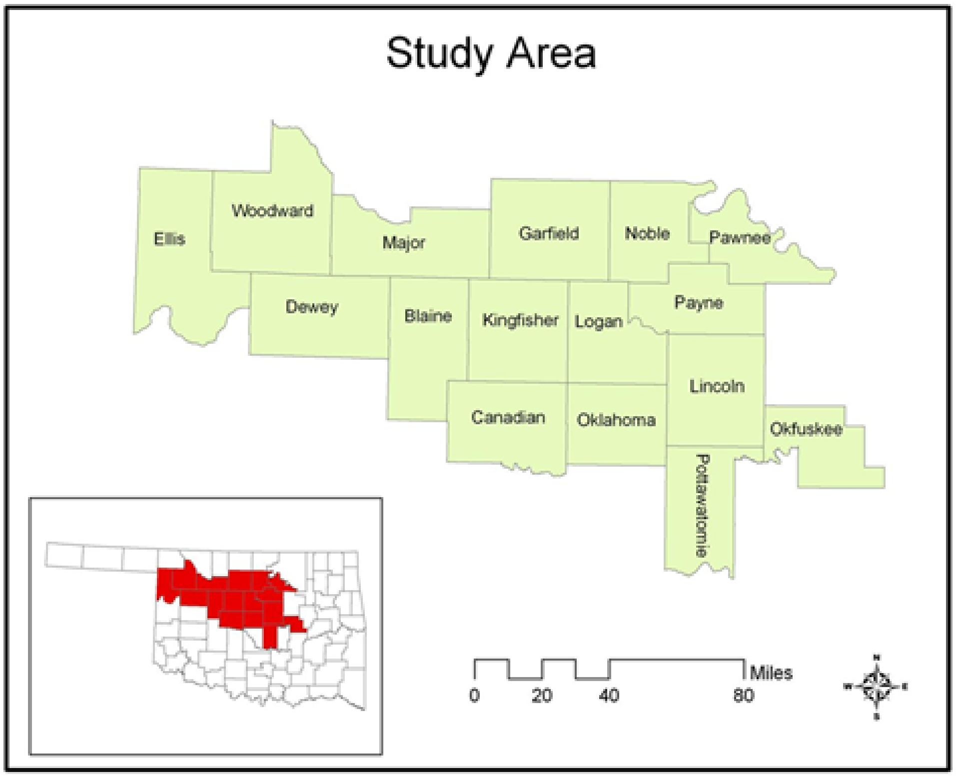

Figure 3.1 Study Area

Sample Sites

To evaluate relationships between the amount of eastern redcedar and environmental factors, and to do a regression analysis, I build five-mile buffers in ArcGIS centered on the Oklahoma Mesonet stations in the study area. The Oklahoma Mesonet is a mesoscale network for the environmental monitoring. Each county in Oklahoma has at least one station. A five-mile buffer is appropriate because some counties have two or more Mesonet station that are close to each other, and larger than five miles will make buffers have more overlap. Moreover, some Mesonet stations are located near the boundary of the study area, so larger buffers will cover the areas that do not have eastern redcedar data. There are a total of 26 Mesonet stations in the 16 counties, so there are 26 sample sites in this study. Figure 3.2 shows the sample sites and the five-mile buffer at each site covered by eastern redcedar. Figure 3.3 shows the buffers in Oklahoma County. There are four Mesonet stations in Oklahoma County. Although the buffers within one county have overlap, each buffer is independent and has its own percentage of eastern redcedar cover.

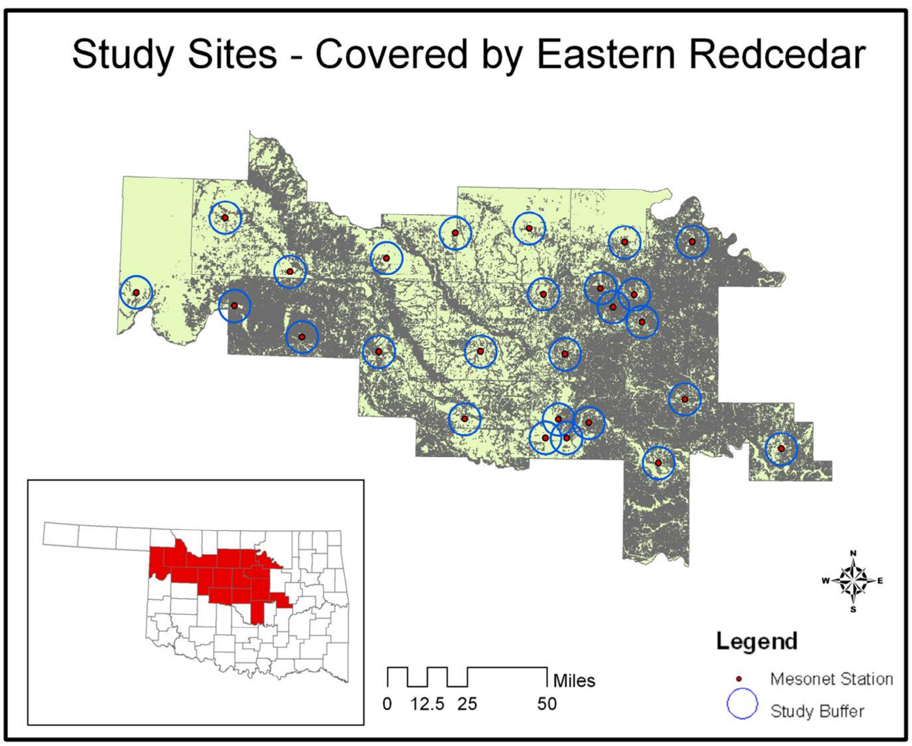

Figure 3.2 Sample Sites

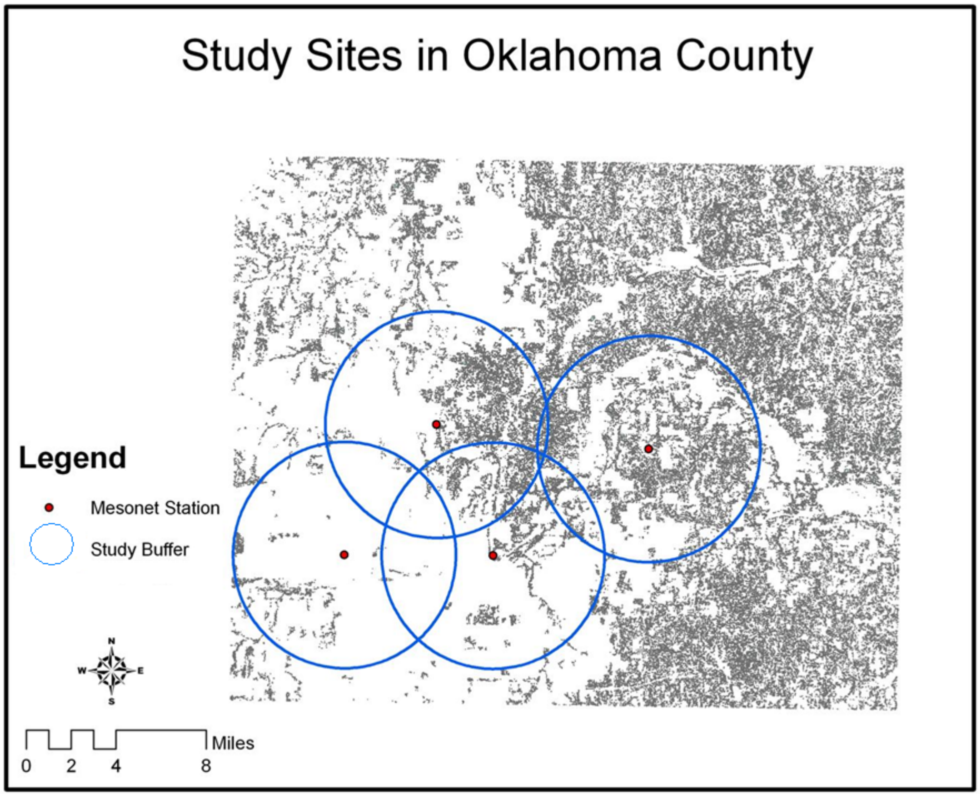

Figure 3.3 Sample Sites in Oklahoma County

Data Source, Collection, and Analysis

Eastern redcedar

The maps of eastern redcedar are obtained from the Oklahoma NRCS (2010). They are mainly derived from Landsat 5, but a few are from Landsat 7 using a Normalized Difference Vegetation Index (NDVI) layerstack. The NDVI has been used to measure and monitor a variety of vegetation characteristics for many years, such as plant growth, extent, and biomass production from multispectral satellite data (The U.S. Geological Survey 2010). There are four kinds of data on the original maps and shapefiles: percent canopy cover 10-30%, percent canopy cover 30-70%, percent canopy cover >70%, and oak/cedar mix. The percent canopy cover means the proportion of eastern redcedar in one pixel of remote sensing imagery (30m*30m resolution) and it also represents the different eastern redcedar densities.

In ArcGIS, the attribute table of each buffer shows the areas (unit: square meter) of eastern redcedar at different densities. The total eastern redcedar is the sum of its areas at three different densities: 10-30%, 30-70%, and >70%, then I change the unit (square meter) to square miles. By dividing the buffer area ($\pi*5^2$ square miles), I obtain the percentage of total eastern redcedar in a buffer.

Climate data

There are nine climate divisions in Oklahoma. First, I consider the county as a whole unit and evaluate the eastern redcedar percentage in different climate divisions to obtain a general idea that which division has the most eastern redcedar. Then I use the climate data, including temperature and precipitation, obtained from the Oklahoma Mesonet (2009) for the regression analysis. The Oklahoma Mesonet has monthly climatological data summary for each station. The monthly average temperature is based on the daily data. The Mesonet determines the average daily temperature as: "using all available 5-minute observations during the day. It is calculated by adding all of the temperature observations and dividing by the number of observations for the day". Total monthly precipitation is a sum of the daily precipitation totals (unit: inch). Totals also include "any frozen precipitation (snow, ice, hail) which may accumulate in the gauge and then melt during the current day" (The Oklahoma Mesonet 2009).

10-year average annual temperature and precipitation can be calculated based on those summaries. I use 10-year averages because that is the approximate time for eastern redcedar to mature (Smith 2011). The choice of a 10-year period depends on when the satellite imagery is obtained. For example, if the eastern redcedar imagery of one county is obtained in 2004, the 10-year period for that county is from 1995 to 2004. However, some stations are relatively new, having been founded less than 10 years ago. As a result, the data of those stations are less than the 10-year average.

Land cover and land use

Land cover and land use data are from the National Land Cover Database (NLCD) 2001. The NLCD data, representing general land cover types, are used because of their established accuracy (Afinowica et al. 2005). There are three different land cover data obtained in different years: NLCD 1992 data, NLCD 2001 data, and NLCD 2006 data. The use of 2001 data is reasonable because the eastern redcedar imagery is obtained in 2002, 2004 and 2005. By overlaying the NLCD raster imagery with eastern redcedar cover, the relationship between these two variables will be built.

To connect eastern redcedar with land cover type, I clip the land cover raster data in ArcGIS within the study buffers. Then I use ERDAS to examine the clipped images based on their pixel values to find which land types are dominant in one buffer. By examining land cover imagery through ERDAS, I found that herbaceous cover is the main land cover type and cultivated crop is the dominant land use in the study sites. Another major land use, pasture, which is used for grazing, is not included in this study since the control of eastern redcedar on pastures or rangelands depends on the land owners and the value placed on livestock management. There is also a potential for a commercial harvest of the larger size redcedars (Wilson and Schmidt 1990). I also chose two different types – open water and deciduous forest. Open water is related to hydrology, and I chose it because woody plant encroachment has a hydrological impact on semiarid landscapes (Wilcox 2002, Huxman et al. 2005). Originally I planned to use wetlands to represent the hydrological characteristics of land cover. However, only a few sample sites in the study area have wetland cover. The forest is an important plant community in the ecosystem. I chose deciduous forest because it is dominant in the study sites. Figure 3.4 shows a land cover image in the buffer of Chandler Station, Lincoln County. Different colors represent different land types. Land cover images cannot be clipped into a round shape because they are raster data.

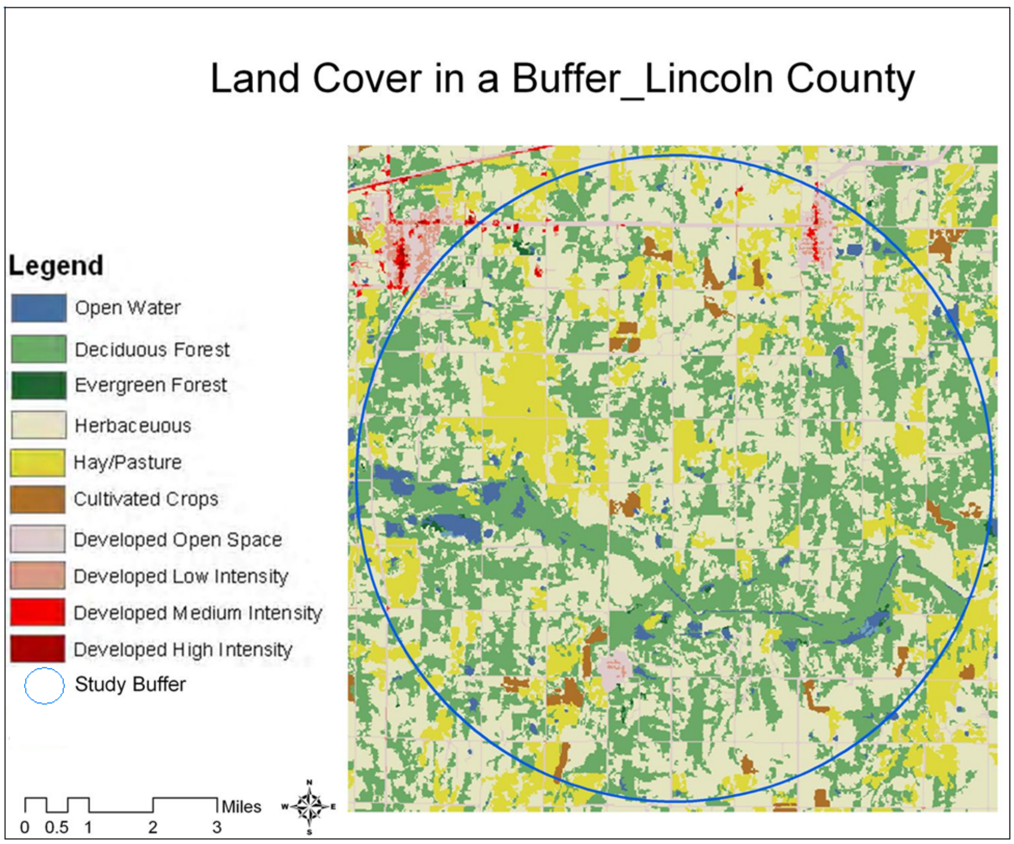

Figure 3.4 Land Cover of Chandler Station, Lincoln County

Elevation

Elevation data are from the National Elevation Dataset (NED). The NED is the primary elevation data produced by the U.S. Geological Survey (USGS). Like land cover data, the elevation data are also originally in a raster format. Table 3.2 shows the resolutions of different variables. In this study, I use the elevation imagery with the resolution of 10m*10m, because the resolutions of both eastern redcedar and land cover imagery are 30m*30m, which is the closest to 10m*10m.

Table 3.2 Resolutions of Different Types of Data

Data Type	Eastern Redcedar	Land Cover	Elevation
Resolution	30*30m	30*30m	3m*3m, 10m*10m, and 60*60m

Figure 3.5 shows the original elevation imagery from the NED. Different shades in the imagery represent different elevations. For the calculation of the variation of elevation, raster images will be first clipped in ArcGIS within the study buffers. Then the clipped raster images will be changed into points, which cover eastern redcedar within a buffer, and each point has a value of elevation. Finally, ArcGIS will calculate the standard deviations of those points, which reflect the elevation change in areas that are covered with eastern redcedar. Figure 3.6 shows eastern redcedar cover within a buffer, and Figure 3.7 shows the elevation points covering eastern redcedar. In the two figures, the eastern redcedar cover and elevation points can be exactly matched, so the standard deviation of the elevation in a buffer will exactly represent the elevation change of the areas that are covered with eastern redcedar.

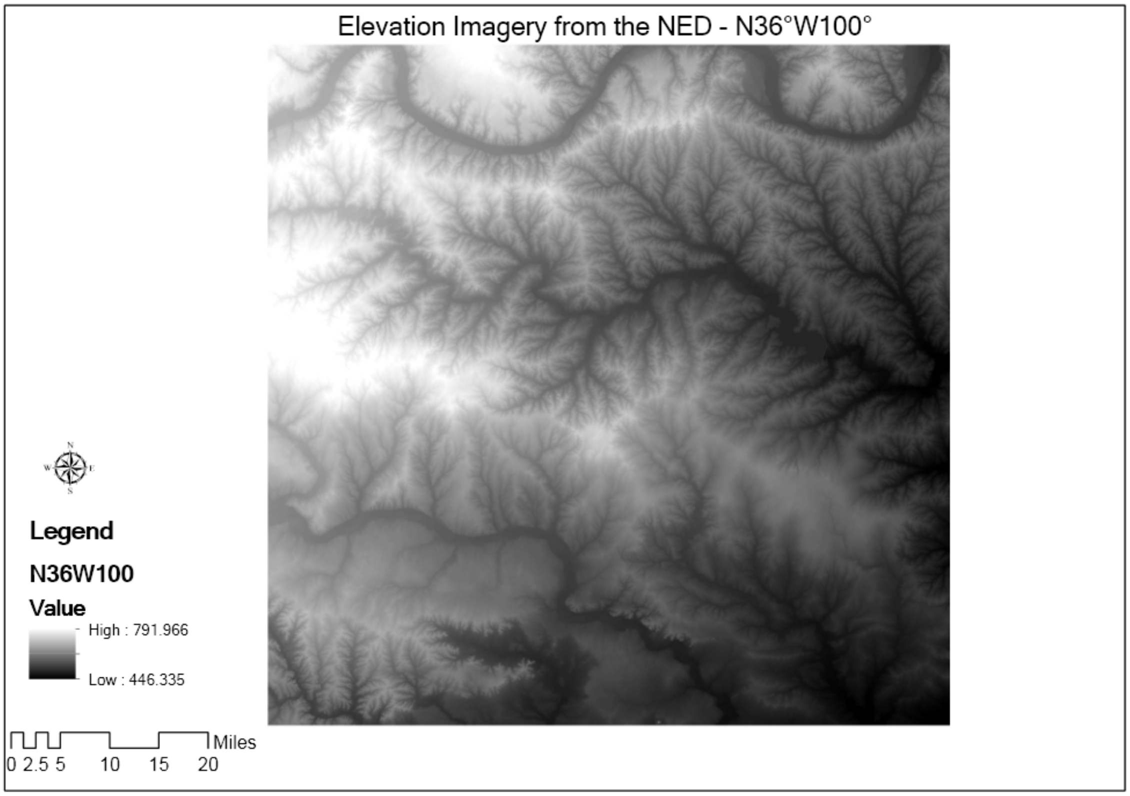

Figure 3.5 The Elevation Imagery from the NED

Figure 3.6 Eastern Redcedar Cover in a Buffer

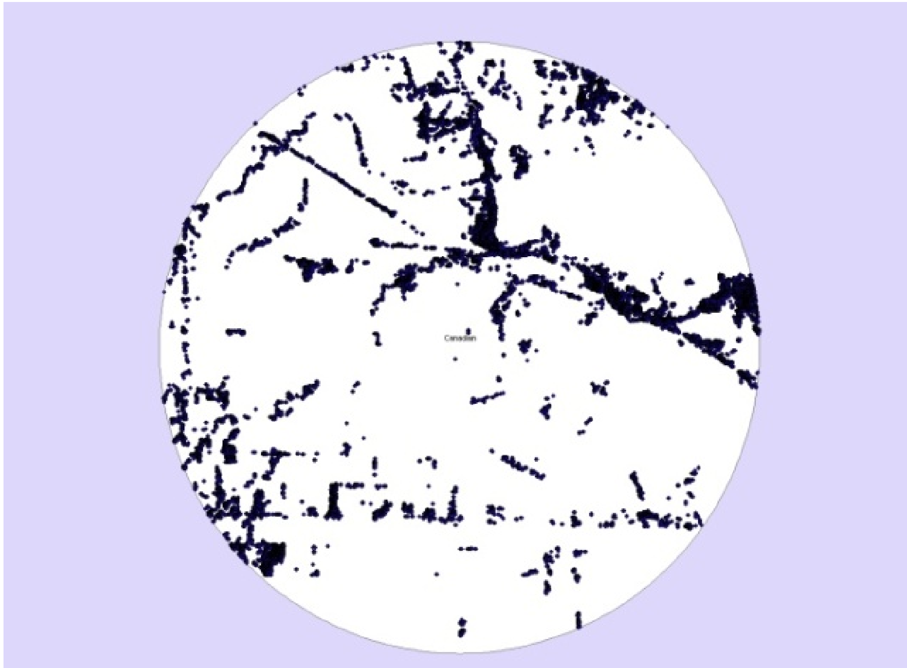

Figure 3.7 Eastern Redcedar Covered by Points of Elevation

Regression analysis

Building regression models is a common approach in eastern redcedar research, because they are useful at determining the differences in species composition among different plant communities (Ganguli et al. 2008). For example, Lawton and Cothran (2000) use univariate logistic regression and stepwise multiple logistic regression to explore what factors influence reproductive activity of eastern redcedar in Tennessee. The regressions suggest that reproductive activity of eastern redcedar is associated with land type, tree size, growth rate, and shading areas.

To build relationships between eastern redcedar and environmental factors as well as land use, I will do regression analysis in the Predictive Analytics SoftWare (PASW, also called SPSS). Regression analysis helps explain both the current encroachment situation and the future trends (Masera et al. 2006). This approach will answer such question as:

What is the most significant factor that affects the amount of eastern redcedar (Lawton and Cothran 2000). I will build three models, because there are three kinds of environmental factors (climate conditions, land cover, and elevation change). The dependent variable is total eastern redcedar cover in all three models. Table 3.3 shows the independent variables in three models.

Table 3.3 Independent Variables in Three Models

Model	Independent Variables (Predictors)
1	All the three land cover types and land use
2	All the three land cover types, land use, and elevation change
3	All the six environmental factors (climate, land cover, and elevation change) and land use (cultivated crop)

CHAPTER IV

FINDINGS

Eastern Redcedar Coverage in Different Climate Divisions

Figure 4.1 shows the nine climate divisions in Oklahoma (Oklahoma Climatological Survey 2000). The study area in this research covers parts of five climate divisions (Panhandle, West Central, North Central, Central, and Northeast). The eastern redcedar cover values are directly from the maps that the Oklahoma NRCS created. Table 4.1 shows the percentage in different divisions. The northeast and west central have higher percentages of eastern redcedar cover than other divisions.

Table 4.1 Eastern Redcedar Coverage in Different Climate Divisions

Climate Division	Counties Included	Total Eastern Redcedar Coverage (Acre)	Percentage
1-Panhandle	Ellis	32,650	4.14%
2-North Central	Woodward, Major, Garfield, and Noble	152,280	5.95%
5-Central	Kingfisher, Logan, Payne, Lincoln, Okfuskee, Pottawatomie, Oklahoma, and Canadian	323,950	7.95%
4-West Central	Dewey and Blaine	218,170	17.51%
3-Northeast	Pawnee	84,645	22.22%

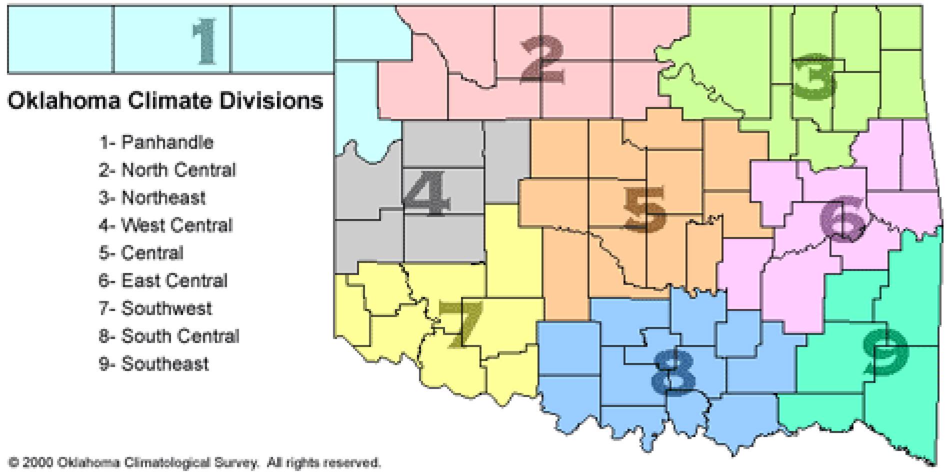

Figure 4.1 Map of Oklahoma Climate Divisions

Climate Conditions

Figures 4.2 and 4.3 show the distributions of 10-year average annual temperature and precipitation. The values of climate conditions in each county are represented by the values calculated from the climate summaries of the Mesonet stations in each county. In the study area, the average annual temperature has a decreasing tendency from the southeast to the northwest, however, the decreasing tendency is not quite evident and the values range from 58 to 61 °F. The average annual precipitation has a decreasing tendency from the east to the west, and the values change tremendously throughout the study area, ranging from around 25 to 42 inches. The sharp decrease in precipitation from the east to the west is a dominant feature of the precipitation spatial distribution in Oklahoma. Based on the Oklahoma's Climate Overview, only in the summer months (especially July and August) can one see this gradient (Oklahoma Climatological Survey). There is a potential problem in calculating the averages. For example, there are four Mesonet stations in Oklahoma County (see Figure 3.3); however, three of them

(Oklahoma East, North, and West) were newly built in 2007, so it is impossible to calculate the 10-year averages for them. Another station (Spencer) in this county was built in 1994. Since every station needs its own average values, as a result, in Oklahoma County, the climate data of all the four stations are represented by the averages of Spencer Station.

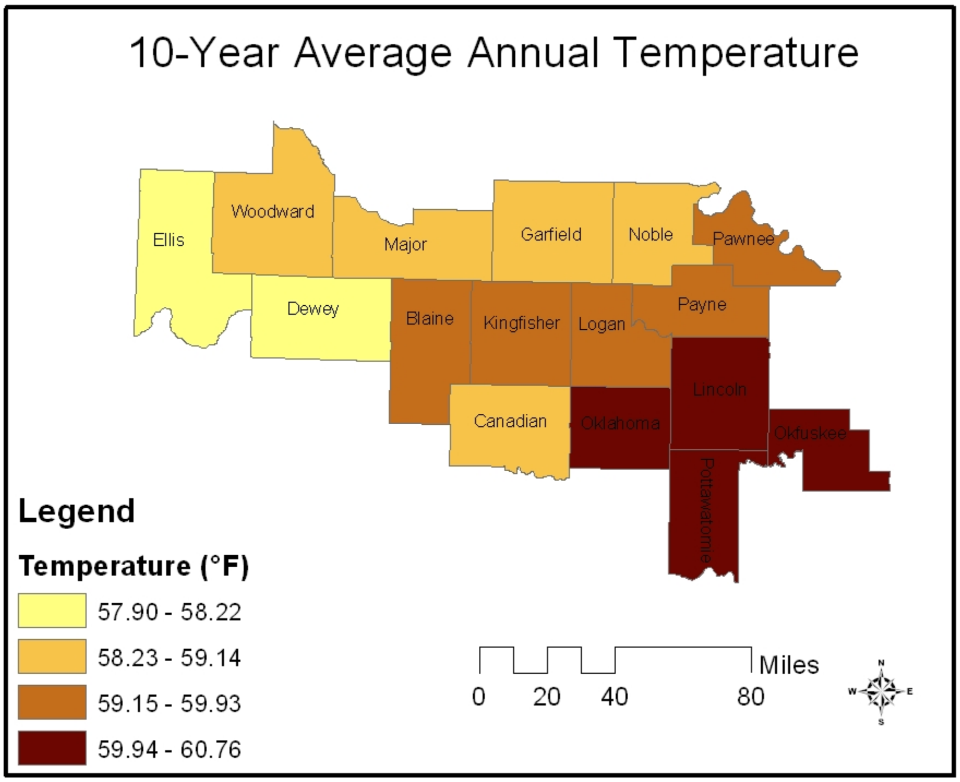

Figure 4.2 10-Year Average Annual Temperature

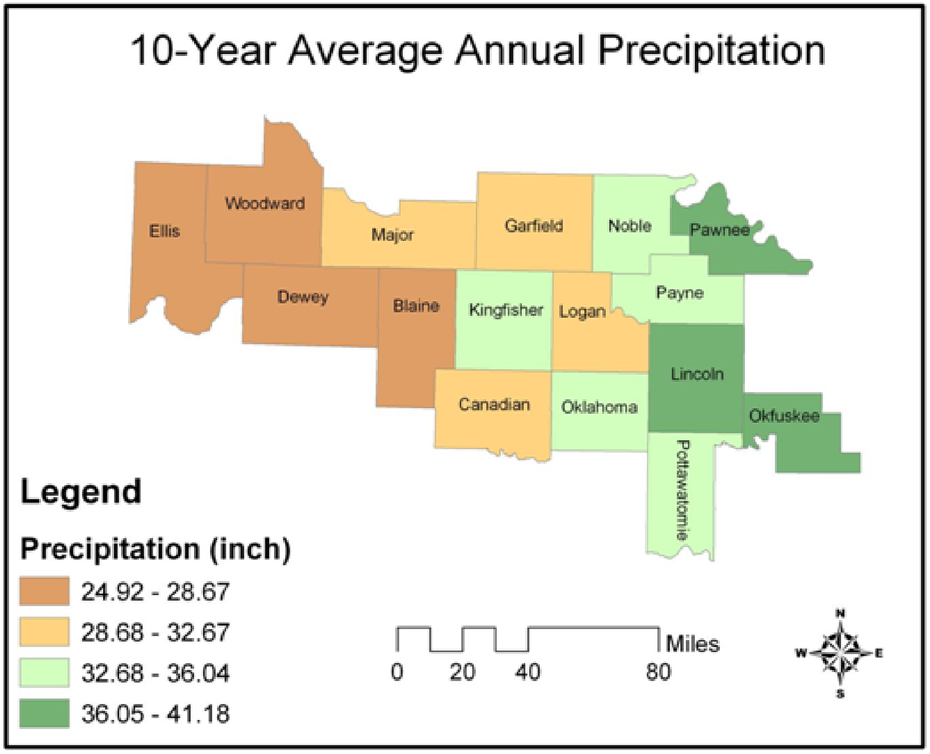

Figure 4.3 10-Year Average Annual Precipitation

Land Cover and Land Use

Figure 4.4 shows the clipped land cover imagery within the whole study area. The clipped imagery does not match the study area quite well since it is in the raster format. However, it still shows the general land cover types throughout the study area. I use the ERDAS to evaluate the land cover types in this clipped imagery. The major two types of land cover are herbaceous cover (42.77%) and deciduous forest (16.27%). The cultivated crops represent the land use, accounting for 24.15% of the total area. Based on the colors, cultivated crops are mainly located in the central part of the study area, and deciduous forests are mainly located in the eastern part of the study area.

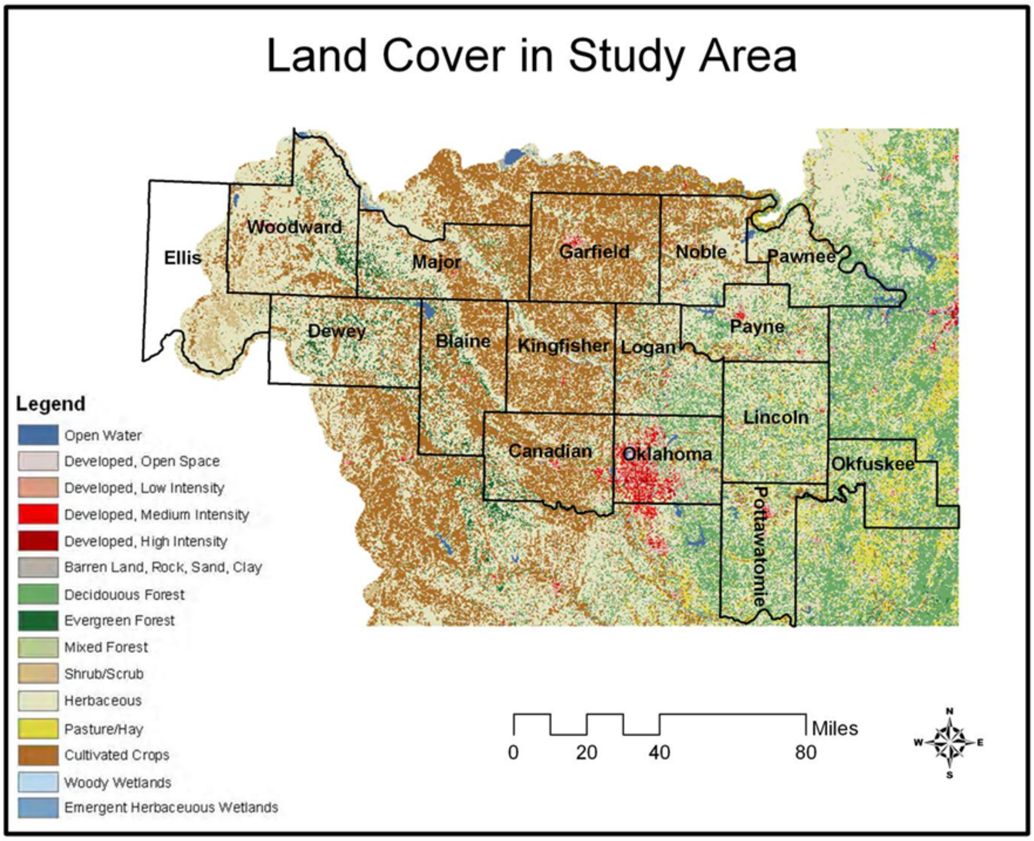

Figure 4.4 Land Cover in Study Area

Elevation

Oklahoma is located in the southwestern part of the Great Plains. The terrain varies from nearly flat in the west to rolling in the east. The mean elevation in all the sample sites ranges from 260m to 720m (the data is from the Oklahoma Mesonet), and it has a general slope upward from east to west of the study area as well as the State of Oklahoma. First, I evaluate the relationships between the mean elevation and other environmental factors in all sample sites. The average annual precipitation decreases with the mean elevation. However, there is no evident correlation between eastern redcedar cover and mean elevation. So in this study, I use another factor, elevation change, to measure the relationship between the topography and eastern redcedar encroachment.

Relationships between Eastern Redcedar and Human-Environmental Factors

Table 4.2 shows the results of descriptives and normality test from SPSS. In the study area, the canopy cover of eastern redcedar ranges from 1% to 25%. The central part (Garfield, Kingfisher, and Canadian County) and the western part (Ellis and part of Woodward County) have lower percentages (lower than 10%) of eastern redcedar cover. The herbaceous cover ranges from 6% to 70% and the deciduous forest ranges from 0 to 32%. From the mean values of the land cover types in Table 4.2, it is clear that the herbaceous land cover (41.84%) and the land use of cultivated crops (23.48%) are two main land types throughout the sample sites. The Shapiro-Wilk test tests the null hypothesis that a variable is normally distributed. This test is appropriate when the sample sites are small (26 in this study). If the significant value of the Shapiro-Wilk Test is greater the .05, then the data is normally distributed; otherwise the data significantly deviate from a normal distribution. Moreover, the values of skewness also reflect the asymmetry of the distribution of the variable. If the value of skewness is close to zero, the variable is evenly distributed such as a normal distribution on both sides of the mean. So based on the Shapiro-Wilk test and skewness, average temperature, average precipitation, and pct herbaceous cover are normally distributed.

Table 4.2 Descriptives and Normality Test

	Mean	Std. Deviation	Skewness	Shapiro-Wilk Test	
				Statistic	Sig.
Pct Total Redcedar	9.29	7.05	.856	.896	.012
Average Temperature	59.62	0.89	-.389	.925	.061
Average Precipitation	32.76	4.44	-.203	.937	.113
Elevation Change	16.29	6.43	1.323	.843	.001
Pct Cultivated Crop	23.48	23.19	.935	.832	.001
Pct Herbaceous Cover	41.84	18.65	-.080	.961	.404
Pct Open Water	1.31	1.16	1.916	.823	.000
Pct Deciduous Forest	10.29	10.76	.785	.850	.001

Then I create the scatter plots in SPSS to obtain a virtual view on the relationships between eastern redcedar and the environmental factors (Figure 4.5 - 4.11). For each scatter plot, the X-axis variable is the environmental factor (the independent variable) and the Y-axis variable is eastern redcedar (the dependent variable). The scatter plot can indicate various kinds of correlations between variables. If the data points tend to move from the lower left to the upper right, it indicates a positive correlation between the variables. If the pattern slopes from the upper left to the lower right, it indicates a negative correlation. Figures 4.7, 4.8, and 4.9 suggest that there are slight positive correlations between eastern redcedar and elevation change, herbaceous cover, and deciduous forest, although there are some outliers in Figure 4.7. There is no evident pattern between eastern redcedar and the average temperature and precipitation, open water, and cultivated crops. The dots in those scatter plots are randomly distributed.

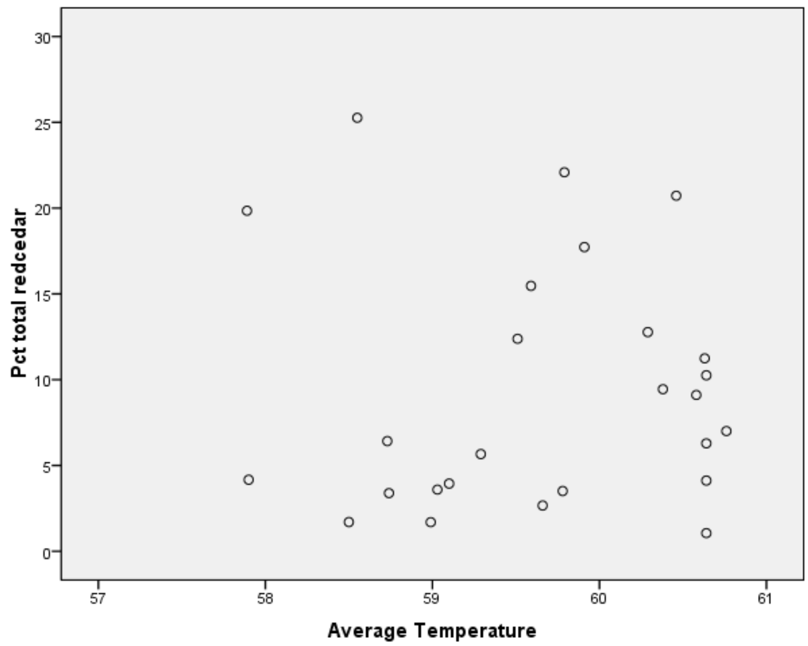

Figure 4.5 Scatter Plot of Eastern Redcedar and Average Temperature

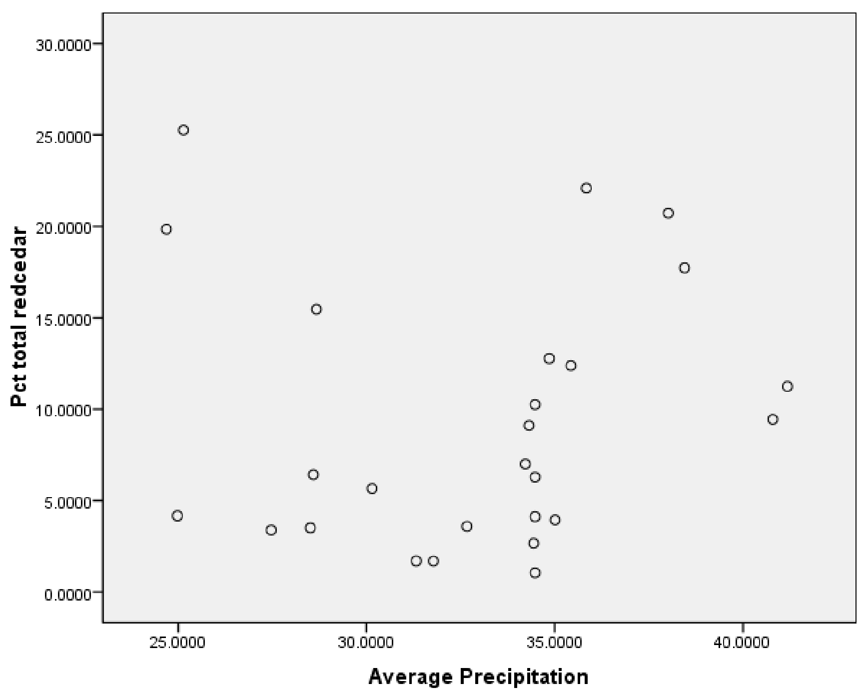

Figure 4.6 Scatter Plot of Eastern Redcedar and Average Precipitation

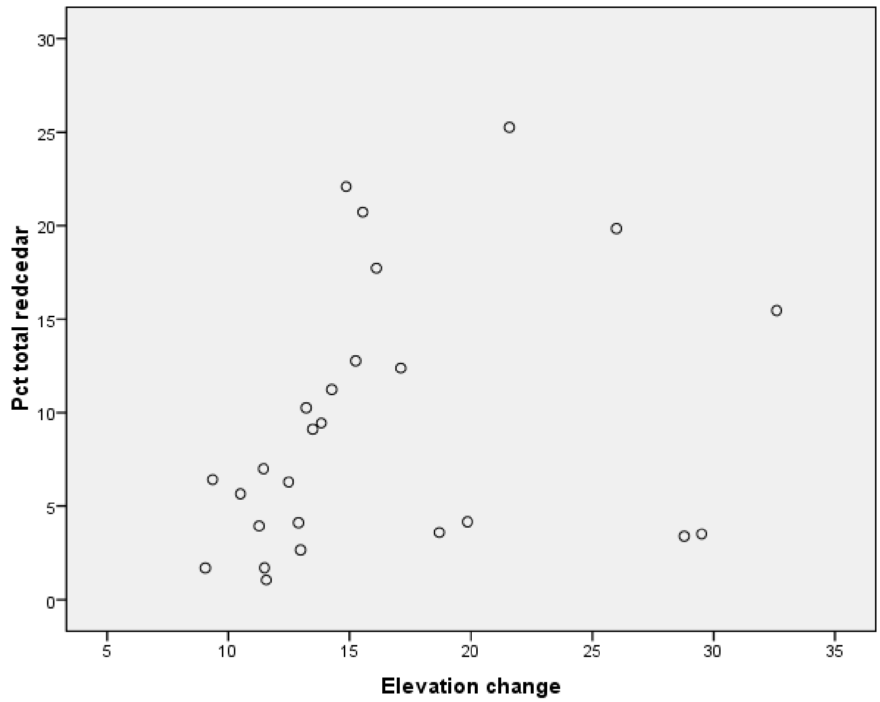

Figure 4.7 Scatter Plot of Eastern Redcedar and Elevation Change

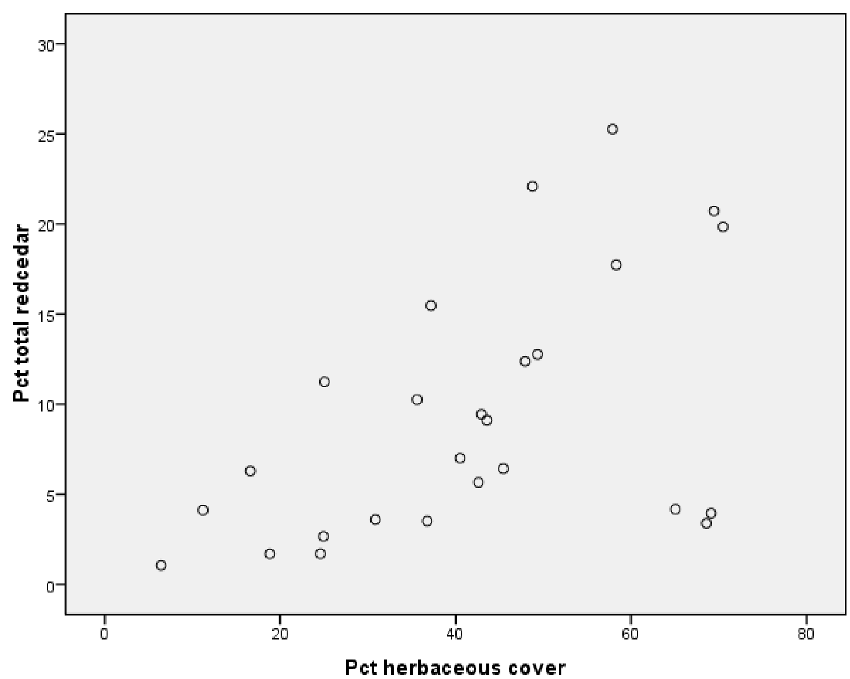

Figure 4.8 Scatter Plot of Eastern Redcedar and Pct Herbaceous Cover

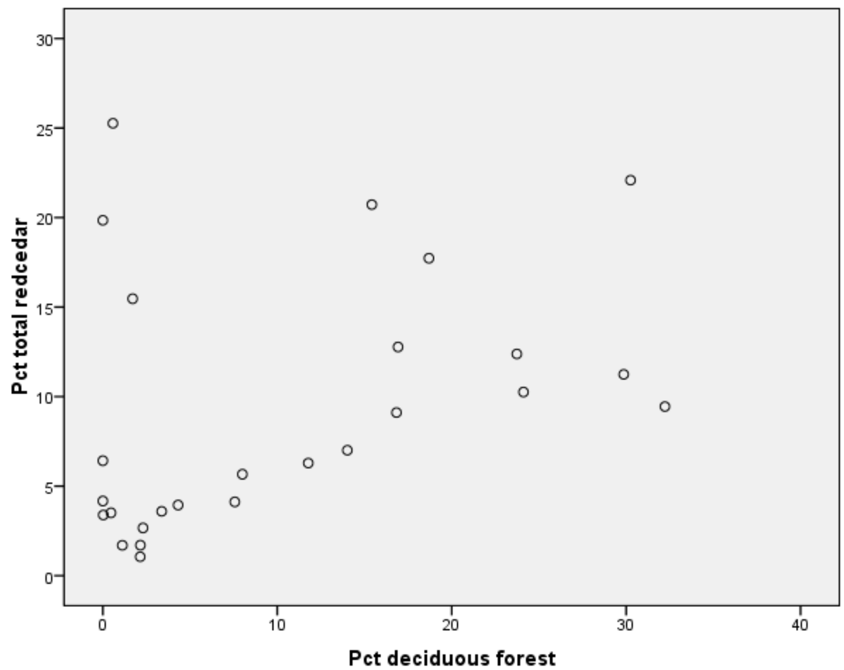

Figure 4.9 Scatter Plot of Eastern Redcedar and Pct Deciduous Forest

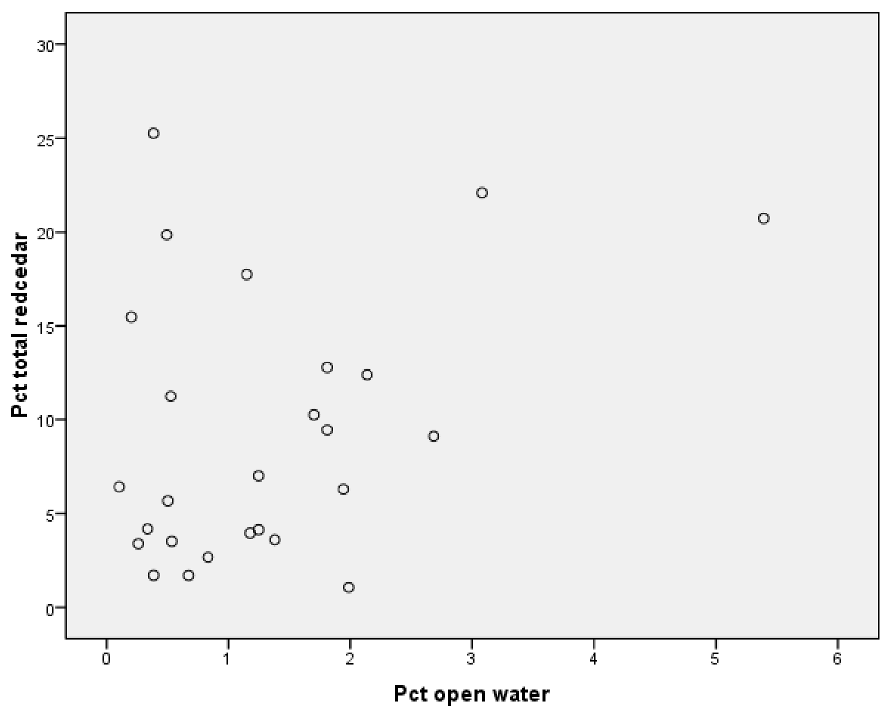

Figure 4.10 Scatter Plot of Eastern Redcedar and Pct Open Water

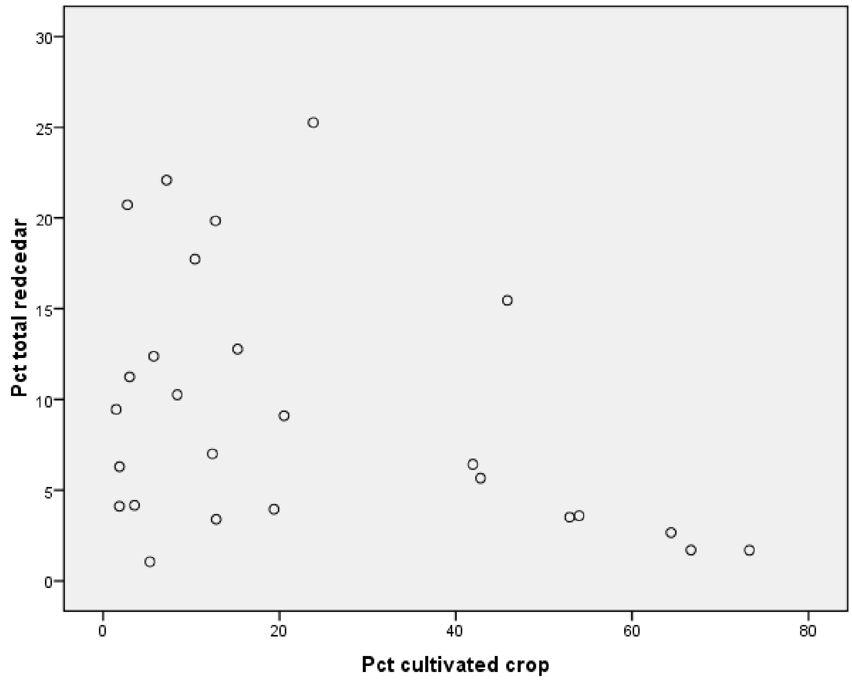

Figure 4.11 Scatter Plot of Eastern Redcedar and Pct Cultivated Crop

I use both Pearson and Spearman's correlation coefficients to examine the relationships between eastern redcedar and environmental factors. Both of the two types of correlation coefficients measure the strength and direction of the relationship between two variables. Pearson's correlation is more appropriate when (1) the variables are normally distributed; (2) there is a linear relationship between two variables (Sweet and Grace-Martin 2008). Spearman correlation is defined as the Pearson correlation coefficient using the ranked variables instead of raw variables (Jerome and Well 2003). Based on the results from Table 4.2 and Figure 4.4, three variables are normally distributed (average temperature, average precipitation, and pct herbaceous cover), and some of the relationships between eastern redcedar and environmental factors are not linear. So I examine the relationships through both Pearson and Spearman's correlation coefficients using SPSS. Since the dependent variable (eastern redcedar) in this study is not normally distributed, the Spearman's correlation coefficients may be more reliable.

Table 4.3 shows the detailed results from the two types of correlation coefficients. Pct herbaceous cover is positively significant at the .01 level in both correlation tests, which means there is a positive correlation between herbaceous cover and eastern redcedar. Since the land cover imagery is obtained in 2001, and the eastern redcedar imagery is obtained from 2002 to 2005, the positive correlation illustrates that the herbaceous cover is easily encroached by eastern redcedar. In Spearman's correlation, elevation change and pct deciduous forest are positively significant at .05 level, so these two factors have positive correlations with eastern redcedar, which means the areas with more elevation changes and covered with more deciduous forest are easily encroached by eastern redcedar.

Table 4.3 Pearson and Spearman's Correlation Coefficients

	Eastern Redcedar			
	Pearson's r	Sig.	Spearman's rho	Sig.
Average Temperature	-.042	.838	.080	.697
Average Precipitation	.001	.995	.250	.218
Elevation Change	.291	.150	.424*	.031
Pct Cultivated Crop	-.385	.052	-.352	.078
Pct Herbaceous Cover	.512**	.008	.559**	.003
Pct Open Water	.348	.081	.176	.407
Pct Deciduous Forest	.379	.056	.407*	.039

**. Correlation is significant at the 0.01 level   *. Correlation is significant at the 0.05 level

Regression Model

The model summary shows the prediction power of the model. In the first model (Table 4.4, independent variables including three land cover types and land use), the adjusted R square is .309, which means all the four predictors can predict more than 30% of the future eastern redcedar encroachment. In the multiple variable regression, the adjusted R square is examined instead of the R square, because adding the unrelated independent variables to a model will raise the value of R square (Sweet and Grace-Martin 2008). The adjusted R squares compare which of several models is the best. The ANOVA (analysis of variance) F statistics tests whether the whole model is significant. Table 4.5 shows that the significant level (Sig. Column in the table) is less than .05, so there is less than 5% chance that the relationships found in the model are not significant. The detailed tables of Coefficients are listed in the Appendix. In the first model, based on the significant level, pct herbaceous cover is the most significant factor (.011) and pct deciduous forest is the second most significant factor (.187).

Table 4.4 1st Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.648a	.420	.309	.05856

Table 4.5 1st Model ANOVA

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	521.442	4	130.360	3.801	.018a
Residual	720.243	21	34.297		
Total	1241.685	25			

a. Predictors: (Constant), Pct herbaceous cover, Pct deciduous forest, Pct open water, Pct cultivated crop

In the second model (Tables 4.6 and 4.7), another environmental factor – elevation change is selected. Compared to the first model, both R square and adjusted R square are a little improved. The adjusted R square is .346 compared to .309 in the first model. Table 4.8 shows that the significance of the whole model is .013, which is also a little more improved than the first model. Pct herbaceous cover and pct deciduous forest are still two significant factors (sig. = .053 and .098). Elevation change is the third significant factor, with the significance of .110.

Table 4.6 2nd Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.701[a]	.491	.364	0.05621

Table 4.7 2nd Model ANOVA

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	609.875	5	121.975	3.861	.013a
Residual	631.809	20	31.590		
Total	1241.685	25			

a. Predictors: (Constant), Pct deciduous forest, Pct herbaceous cover, Pct open water, Pct cultivated crop, Elevation change

The third model contains all seven factors in this study (Tables 4.8 and 4.9). The adjusted R square is smaller than the second model. The significance for the model is .029, so this model is less significant than the first and second model. In this model, only pct deciduous forest can be considered as significant (sig. =.045). The significance values for all the other variables are greater than .10.

Table 4.8 3rd Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.732[a]	.536	.356	0.05648

Table 4.9 3rd Model ANOVA

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	666.106	7	95.158	2.976	.029a
Residual	575.597	18	31.977		
Total	1241.685	25			

a. Predictors: (Constant), Pct deciduous forest, Pct herbaceous cover, Pct open water, Pct cultivated crop, Elevation change, Average temperature, Average Precipitation

Linear regression has a key assumption that the residuals are normally distributed. The residual is the vertical distance from the predicted value to the actual observation (Sweet and Grace-Martin 2008). I evaluate the residuals of the second model (with the highest adjusted R square) to see if they are normally distributed. In SPSS, I choose "Histogram" and "Normality probability plot" under "Plots" selection. These two plots compare the distributions of standardized residuals to a normal distribution. Figure 4.5 shows that the histogram of the residuals is symmetric, and the residuals are close to the ideal line in the P-P plot. Thus, the residuals are approximately normally distributed, and the linear regression meets the assumption.

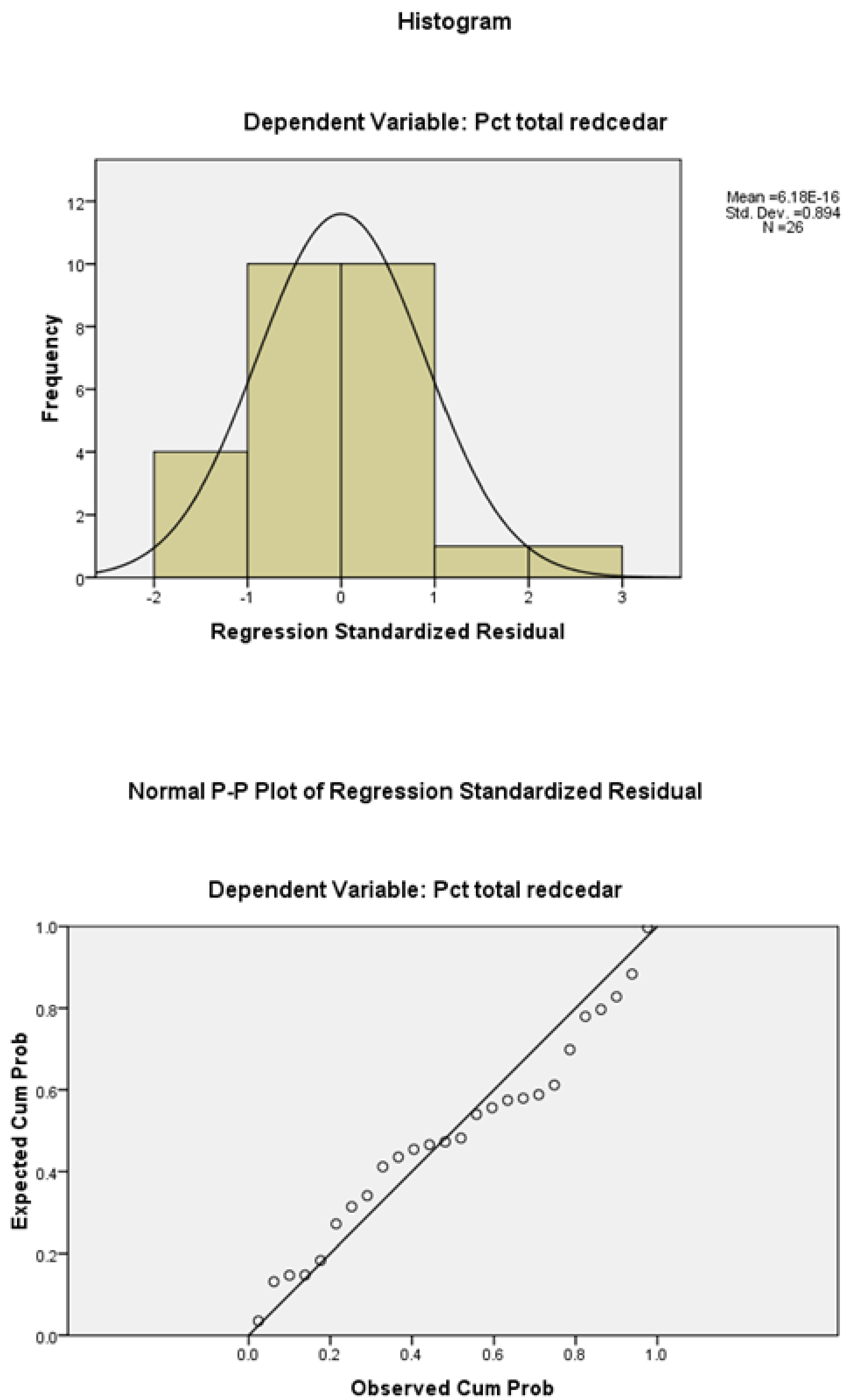

Figure 4.12 Charts of Regression Standardized Residuals

There are different ways to evaluate the contribution of each predictor variable. To obtain a better knowledge of the variables, for each regression model, I also use the "stepwise" methods in SPSS. The stepwise regression picks up the variable with the highest correlation (R^2) first; then it tries each of the remaining variables until it finds the two variables with the highest R^2; then it tests all of the remaining again until it finds the three variables with the highest R^2, and so on. The overall R^2 gets higher with each added variable (Hopkins 2009).

In the "stepwise" methods, two factors – pct herbaceous cover and pct deciduous forest, are entered in all three models. All three models have the same model summary (Table 4.10). Pct herbaceous cover is the first variable entered the model and pct deciduous forest is the second. These two factors predict 35.5% of the encroachment based on the adjusted R square. As a result, these two factors are two significant factors of eastern redcedar encroachment.

Table 4.10 Stepwise Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.512[a]	.262	.231	6.1798113
2	.637[b]	.406	.355	5.6614017

Summary

The results of the correlation coefficients (Table 4.3) provide the basic relationships between eastern redcedar encroachment and the environmental factors. The regression models indicate how the environmental factors predict the encroachment. Of all the land cover types, herbaceous cover is the most significant predictor, and cultivated crop is not significant in any of the three models. This means the herbaceous cover is the most easily encroached by eastern redcedar and the cultivated crop cover is not affected by the encroachment. When the elevation change enters the model, the model is improved. So the eastern redcedar encroachment is also related to the slopes of the landscape. The adjusted R squares in those three models range from about .309 to .364, which are not quite weak. This may be due to the predictors I chose, as well as the limitation of the sample size. So the current models provide some guidelines for the future improvements, and the next chapter includes some recommendations for the future research.

CHAPTER V

CONCLUSION

Invasive woody plants threaten the biological integrity on the grasslands. Although eastern redcedar is a native species, it has greatly expanded and created land management challenges (Smith 2011). It has spread throughout most grasslands and rangelands in Oklahoma and Texas. As a result, the growth of eastern redcedar is an urgent problem in these areas. There is no effective way to control it right now except burning because of their fast growth.

The analysis of this research suggests that the herbaceous land cover types and the variation in topography are important factors associated with eastern redcedar encroachment in Oklahoma. The type of herbaceous cover is the most easily encroached by eastern redcedar. The deciduous forest is another type that is also easily encroached by the cedars. The open water and cultivated crops are not affected by eastern redcedar. Compared to the other land cover types, the cultivated crops are more related to the human activities. Under the management, less eastern redcedars are grown in the areas that are covered with the crops. The results also show that there is a positive relationship between eastern redcedar encroachment and elevation change, which means eastern redcedar may prefer areas with greater variations in elevations such as slopes along stream channels.

Climate conditions do not affect the encroachment of eastern redcedar in this study. Although climate change may influence the proportions of woody species (Auken 2000, Golubiewski 2008), most of the research use the level of CO_2 or NO as an indicator other than directly using temperature or precipitation patterns (Martin et al. 2003, Asner et al. 2003). Some research (e.g. Jackson et al. 2002) shows that there is a positive relationship between the precipitation and woody plant encroachment; however, this study does not show similar results. This is probably because 1. The study area is located in a relatively dry area in Oklahoma; 2. The precipitation varies greatly throughout the study area, and there are only 26 sample sites in the study. The limitation of sample size may lead to the relationship that is not strong.

CHAPTER VI

LIMITS AND FUTURE DIRECTIONS

Limits and Potential Problems

There are some limits of the original data, which may affect the final result of this research. First, the remote sensing images of eastern redcedar are only for a single year; as a result, it is impossible to examine the growth tendency and rate during a particular period.

Second, the remote sensing images in different counties are not obtained in the same years, which might affect the accuracy of the results in the regression analysis. Three of the counties' imagery is from 2002; nine of the counties' imagery is from 2004; and others are from 2005. To address this problem, as I mentioned above, the choice of a 10-year period of average annual temperature and precipitation varies in different counties. However, this will not be problematic, because the imagery of 13 of the 16 total counties is obtained from 2004 and 2005, and only three counties' imagery is from 2002.

Third, at the beginning of my research I planned to use the soil moisture as another climate factor besides temperature and precipitation. However, the climate summaries in the Oklahoma Mesonet do not have the long-term soil moisture record. Although it has long-term sod and bare soil temperature record, the average soil temperatures in most of the sample sites are around 60 °F. Since most of the sample sites have similar values, I do not use the soil moisture as a climate factor in this research. In addition, Limb et al. point out that the measurements of relationships between the herbaceous cover and woody plants usually "require species-by-species examination because of variation in canopy structure, nutrient uptake and release, and root/shoot ratio in tree and shrub species" (Limb et al. 2010, 639). However, in this study, I take the herbaceous cover as one type, and I do not consider the different species on the herbaceous cover. As a result, the relationships between eastern redcedar and the land cover and land use are not completely linear.

Recommendations for Future Research

One recommendation for this research in the future is that using the eastern redcedar data in different years to see at what rate are the trees invading in Oklahoma. However, this highly depends on the future plans of the Oklahoma NRCS, since they provide the eastern redcedar imagery. Based on the R squares from the regression models I built, the environmental factors I use in this research can predict about 35% of the future encroachment in Oklahoma. However, the factors I use cannot be controlled by human activities. So another recommendation for the future research is to add some factors that are more related to human activities, such as grazing and fire frequency. Moreover, recent research shows that eastern redcedar cover is also related to the population growth and housing expansion (Brooks et al. 2010). As a result, it might be useful to consider population census data in the future research.

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APPPENDIX

1st Model Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.360	4.617		-.295	.771
	Pct herbaceous cover	.186	.067	.492	2.780	.011
	Pct deciduous forest	.195	.143	.298	1.364	.187
	Pct open water	.800	1.213	.132	.660	.516
	Pct cultivated crop	-.008	.065	-.025	-.116	.909

2nd ModelCoefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-6.369	5.347		-1.191	.248
	Pct herbaceous cover	.142	.069	.376	2.052	.053
	Pct deciduous forest	.244	.140	.373	1.738	.098
	Pct open water	1.216	1.190	.200	1.022	.319
	Pct cultivated crop	.002	.063	.007	.033	.974
	Elevation change	.341	.204	.312	1.673	.110

3rd Model Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	43.460	152.171		.286	.778
	Pct herbaceous cover	.096	.097	.255	.988	.336
	Pct deciduous forest	.431	.200	.658	2.156	.045
	Pct open water	1.915	1.380	.315	1.388	.182
	Pct cultivated crop	.005	.069	.015	.067	.947
	Elevation change	.261	.226	.238	1.155	.263
	Average Temperature	-.477	2.643	-.061	-.180	.859
	Average Rainfall	-.641	.575	-.413	-1.115	.279

a. Dependent Variable: Pct total eastern redcedar

VITA

Er Yue

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Scope and Method of Study: The study area in this project covers 16 contiguous counties, most of which are located in central and western Oklahoma. The maps and the shapefiles of eastern redcedar are from remote sensing imagery. I use ArcGIS and ERDAS to analyze the shapfiles and the imagery of the redcedar, land cover and the elevation. To examine the relationships between eastern redcedar and environmental factors and the land use, I build three regression models in SPSS.

Findings and Conclusions: This research evaluates the relationships between eastern redcedar and environmental factors as well as the land use. The analysis of this research suggests that the herbaceous land cover and the variations in topography are important factors associated with eastern redcedar encroachment in Oklahoma. The type of herbaceous cover is the most easily encroached by eastern redcedar. The deciduous forest is another type that is also easily encroached by the cedars. The climate conditions (including average temperature and precipitation), open water, and the land use (cultivated crops) are not affected by eastern redcedar.

ADVISER'S APPROVAL: Dr. Jianjun Ge