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Comparison of Understory Chemical and Mechanical Treatments to Promote Regeneration of Desirable Forestland Species

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COMPARISON OF UNDERSTORY CHEMICAL AND MECHANICAL TREATMENTS TO PROMOTE REGENERATION OF DESIRABLE FORESTLAND SPECIES

A Masters Thesis

Presented to

The Graduate College of

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In Partial Fulfillment

Of the Requirements for the Degree

Master of Science, Plant Science

By

Rebecca R. Tyler

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Agriculture

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Master of Science

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ABSTRACT

Invasive woody plants and trees can have a negative impact on desired tree regeneration in the understory of forest stands, and forage density in grassland sites. An assessment of chemical and mechanical treatments on woody plants in the understory of forestland and in grassland is needed. Two experiments were set up in two forest stands and in two grassland/forest edge sites, with two treatment times during the growing season in the first year of the study. On the forestland sites, chemical and mechanical treatments were applied on undesired woody plants to see if they effect the regeneration of desired tree species (oak, hickory, elm, hackberry, and black walnut). Results showed that the percentage of cover of desired tree natural regeneration was significant from year 1 to year 2. On the grassland sites, I assessed forage density before/after treatments to quantify the difference in the reduction of competition from the undesired woody plants. Results showed there was an overall forage production increase from year 1 to year 2 due to the elimination of woody species the first year of the study. There was a negative forage response from the early summer treatment and a positive forage response from the late summer treatment. Results of this study will be helpful to forest practitioners and landowners that seek to mange dense understories and woody plant species in pastures.

KEYWORDS: woody plants, forage density, regeneration, forestland, grassland.

This abstract is approved as to form and content

Michael Goerndt, PhD
Chairperson, Advisory Committee
Missouri State University

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Trees and woody plants are increasingly invading land and degrading forage pasture. With more trees and woody plants encroaching on the land, forage cannot grow efficiently due to competition. Over the past 150 years, there have been more woody plants and shrubs taking much of the available forage land (Anadon et al. 2014). This rapid shift from herbaceous plants to woody plants can cause a decline in livestock production (Anadon et al. 2014). The abundance of invading trees and woody plants is dependent on climate, soil types, and disturbance (Jurena and Archer 2003). Most livestock cannot eat woody plants because it is indigestible. With woody plants suppressing the growth of more desirable forage, the forage does not produce as much yield. When the forage does not produce enough biomass, there is less forage to feed preferred livestock. Woody plants are covering the United States at an increase of 0.5 to 2% per year (Anadon et al. 2014). For every 1% increase in woody plant encroachment, there is a decrease of about one reproductive cows per square kilometer (Anadon et al. 2014). The invasion of woody plants can also be detrimental to the water resources. Control of woody plants increases water supply and groundwater recharge (Kreuter et al. 2005). If forage land is not managed to keep woody plants from taking over, it will lead to a decrease in forage and livestock production.

Competition. When woody plants start to invade a treeless site, small tree seedlings and small woody plants take over; common species include blackberry, sumac, and dogwood (Fitch et al. 2001). Tree species grow at different rates depending on the site, climate, and plant development. Elm, Osage orange, ash, and walnut became the most abundant in a study that observed the encroachment of woody plants and trees in a treeless area left untreated over 50 years (Fitch et al. 2001). All sites that were observed became woodland and two of the tall-grass prairie fields developed a closed-canopy of woody species (Fitch et al. 2001). In a closed-canopy, there are often not enough food resources for livestock or wildlife because there is no sunlight that can get to the forest floor (Lashley et al. 2011). Management practices that allow for sunlight to reach the ground and enhance forage growth is clear-cutting and shelterwood harvest (Lashley et al. 2011).

Woody plants can decrease forage yield by competing for sunlight, water, and nutrients. Researchers at Texas A&M University studied belowground competition of woody plants and grasses. Grasses were observed using resources in the soil that were closest to the surface and woody plants were observed using resources in the subsoil (Jurena and Archer 2003). Woody plants have the advantage when there is below average rainfall because the taproot can extend deeper in the soil to find available water (Jurena and Archer 2003). The survival of woody species seedlings is greater because of the root system.

Environmental stresses. Environmental stresses can benefit woody plant growing efficiency. Woody plants often increase growth when exposed to stresses at critical development stages (Kozlowski and Pallardy 2002). When woody plants go through environmental stresses such as drought, heat stress, flooding, and cold stress, they can adapt to the changes and protect themselves from injury (Kozlowski and Pallardy 2002). In a drought, woody plant seedlings can allocate photosynthate to the roots to expand the rooting system to be able to absorb more water for the plant. When flooding has occurred, woody plants are efficient in growing adventitious roots to find oxygen so the plant can survive (Kozlowski and Pallardy 2002). Some orchards encourage flooding because it has been shown to increase the development of fruit (Kozlowski and Pallardy 2002). Having the ability to tolerate and increase efficiency of the plant during environmental stresses enables woody plants to continue to be productive while most herbaceous plants are not able to adapt in such ways.

Herbicide Treatment. Brush management has been used for decreasing woody plant encroachment (Anadon et al. 2014). This is mostly done with herbicides. Using herbicides on woody plants reduces canopy cover and helps forages grow efficiently and abundantly (Lashley et al. 2011). Many rangeland objectives use herbicides for efficient land management. Individual plant herbicide treatments are the least expensive methods (Krueter et al. 2005). Different herbicide treatments used on woody plants include basal bark treatments, stump treatments, and foliar treatments. Basal bark treatments are applied by mixing the herbicide of choice with bark oil in a backpack sprayer (Kochenderfer et al. 2012). The targeted woody plant or tree needs to be dry and clear from leaves or snow. The mixture of herbicide and bark oil needs to be sprayed around the circumference of the plant up the stem about 8-12 inches from the ground (Kochenderfer et al. 2012). Bark oil helps the herbicide to enter the plant stem so it can work effectively. Stump treatments can be used to promote desirable species and release regeneration of other species (Kochenderfer et al. 2012). Stump treatments are applied soon after the woody plant or tree has been cut with a chainsaw. The sawdust needs to be removed before spraying the herbicide on the stump. The herbicide used will be mixed with a surfactant to help the herbicide absorb into the stump (Kochenderfer et al. 2012). If the stump is large, it needs to be wetted before treatment is applied. The mixture needs to be sprayed with a backpack sprayer along the outside of the stump and on top where the tree was cut. Foliar treatments are applied with a backpack sprayer. The herbicide needs to be mixed with water and surfactant (Kochenderfer et al. 2012). The mixture needs to be sprayed around the woody plants on the foliage. If the plant is large, thoroughly wet the leaves with the spray until it runs off. The surfactant is needed to penetrate the waxy surface on the leaves or cuticle (Kochenderfer et al. 2012). Sometimes a second treatment is needed to completely kill the plant. Sometimes foliar sprays can drift from target plants to other plants near it carried by the wind.

Treatment Application Time. Woody plants should be sprayed with herbicide in the early fall. This is when the plants are in the bud to bloom stage. During this time, the food supply is moving into the roots (Bradley 2014). Some woody brush species require multiple herbicide applications over several years to completely control (Bradley 2014).

Forage density. Forage density estimates the available forage pasture per acre. The more livestock individuals there are feeding on the land, the more available forage pasture is required. Where woody plants and trees are present, less available forage is produced. Good brush control increases forage and livestock production (Marquiss 1972). In Colorado, herbicide treatments were implemented to control Gambel oak in forage pasture, resulting in an increase in soil moisture (Marquiss 1972). Within five years, forage production doubled (Marquiss 1972). Increased forage production encouraged larger stocking rates of cattle on the land and improved livestock gains per acre of land (Marquiss 1972).

Tall Fescue. Tall fescue is a cool season perennial grass that is the most widely grown grass used for forage pasture and hay (Ball et al. 2015). It has high nutritive value and is tolerant of unfavorable growing conditions, such as low fertility soils and drought. It can be infected with an endophyte fungus called *Neotyphodium coenophialum* (Ball et al. 2015). This fungus can be toxic to livestock and have a negative effect on the animals' performance. Endophyte-free or novel endophyte tall fescue should be used in livestock pastures. Tall fescue grows well with clovers and alfalfa, and can be stockpiled (Ball et al. 2015).

Silvopasture. Silvopasture is the integrating of forage production under and near managed forest stands with allotted areas for forage production and forest stand. Economic returns for silvopasture systems can be great if managed well. In the short-term, there is return on land from livestock grazing on the forage. In the long-term, the landowner can harvest the forest stand if managed correctly (Klopfenstein et al. 1997). However, it is difficult to manage a silvopasture system. The land has to be compatible with this agricultural system to be efficient in forage production and timber production. The forage land has to be suitable for livestock to graze, have the right soil type for growth, be tolerant of intensive management, and be productive under the shade of trees (Klopfenstein et al. 1997). Not only does the forage have to be suitable for the area, but it also has to be highly productive in quantity and quality (Garrett et al. 2004). Livestock need enough forage to feed on in the summer months, and the nutritional value is important for gain and performance of the animal. The pattern of the trees and species of tree is also important. If there is a dense stand of trees, forage production is not going to be efficient because there will not be enough sunlight and growing space for forage

(Klopfenstein et al. 1997). Undesirable woody plant species need to be controlled in forage pasture areas to increase utilization of the forage component (Klopfenstein et al. 1997). Tree species is also important because some tree species can damage forage crop by allelopathy, which is when a plant excretes allelochemicals that inhibit the growth of another plant (Cummings et al. 2012). This would be inefficient in silvopasture systems because the forage and tree species need to be compatible with each other. Black walnut, which has allelopathic traits, can have negative effects on understory crops, such as grasses used for forage production (Cummings et al. 2012). Some species of trees can encourage the production of forage in a silvopasture setting. In the growing season, forage production under blue oak and live oak canopies was much greater than the forage production per acre in the open grassland (Frost and McDougald 1989). The forage production under the canopies tripled the amount of forage in the grassland plots. Additionally, live oak showed benefits for forage production in years with below average rainfall (Frost and McDougald 1989).

If managed with good forest stewardship and methods increasing forage production, silvopasture can be very beneficial (Garrett et al. 2004). However, it requires advanced skills in management to produce high quality forage and manage valuable timber at the same time.

Forestland

Regeneration. Woody plants in the understory of forests can have a negative effect on natural regeneration. A dense forest stand and understory can hinder natural regeneration because of competition. There are different ways of management to encourage natural regeneration to maintain or increase the value of a stand long-term. Natural regeneration in a forest ecosystem is the establishment of a new generation of trees by seed or sprouts that came from the existing trees in that forest stand. It is an essential factor of forest system dynamics, and can be influenced by light, seed availability, seed dispersal, and seed and seedling predation (Kiama and Kiyiapi 2001). Natural regeneration is preferred over artificial regeneration because it preserves the genetic stock and natural features of the area (Humphrey and Swaine 1997). In a dense forest stand, light can be the most limiting factor of the release of seedlings. Shade tolerance of the desired regeneration tree species needs to be considered when planning for management. Often a large canopy opening is needed for the regeneration of light demanding species (Humphrey and Swaine 1997; Kiama and Kiyiapi 2001). Disturbance of the forest and duration of open understory is important for shade tolerant species (Kiama and Kiyiapi 2001).

A disturbance changes the conditions on the direct site in the forest environment by increasing light, changing the temperature, creating litter, and alters soil moisture levels (Everham et al. 1996). By changing these conditions, germination of seeds can increase, and assist in the success of natural regeneration. Increasing litter and light will change the temperature and soil moisture to an optimal level for seedling development. Everham et al. (1996) found that increased light and presence of litter seem to increase regeneration. This is because litter lessens predation of seeds and controls soil moisture levels. Buckley et al. (1998) found that removal of litter decreased the height of seedlings, and the increase in light levels increased soil temperature enough to encourage the quick germination of acorns with the presence of litter. When litter was completely removed, soil temperature increased to a level where soil moisture decreased too much for the seedling to grow efficiently (Buckley et al. 1998).

Natural regeneration of desired tree species can be slowed by the suppression and overtopping of undesired woody plants and pioneer species. Some tree species, such as oak, have slow early growth and the seedlings cannot compete effectively with the other woody plants for sunlight (Thompson and Nix 1995). Competition can also occur belowground for nutrients and water (Humprey and Swaine 1997). Because of this, oak seedlings that are overtopped can reach a stage of rapid growth after they die back for 4 to 6 years (Thompson and Nix 1995). If seedlings never get to the stage of rapid growth, the long-term continuation of the stand will decrease because of the lack of successful regeneration (Humphrey and Swaine 1997). If oak seedlings can reach that stage of rapid growth and grow despite the suppression of other woody plants, they can become dominant in the canopy of the forest (Thompson and Nix 1995).

Removal of Competitors. Shrubs and trees in the understory have a large effect on competition in the understory as much as the trees in the canopy (Buckley et al. 1998). The competition from other plant species, or interspecific competition, is a major factor of decreased regeneration of oak in many areas (Buckley et al.1998). With the removal of competitors, regeneration and growth can increase. This can be done by mechanical removal, herbicides, or fire. Red oak is most productive where there is a disturbance (Buckley et al. 1998). A study by Buckley et al. (1998) found that the removal of canopy trees increased the seedling growth potential, and the highest increases of seedling growth potential was found where there was complete canopy removal, or clearcut, and where the canopy cover was only about 25 percent.There was also a downfall of complete canopy removal. With no canopy, there was a high mortality of seedlings because there was increased browsing by deer in the area on seedlings and frost damage (Buckley et al. 1998). The reason that deer were more apt to browse in the clearcut area was due to deer preferring open patches as opposed to overtopped areas. Open patches often have more forage and increased palatability of the seedlings because of the high levels of nutrients (Buckley et al. 1998).

Invasive Woody Plants. Plants can become invasive by crossing a barrier into a new area, reproducing effectively, and spreading throughout the site. Seeds from these invasive plants can be carried to new sites by animals, or intentional introduction by humans for ornamental landscaping or to control soil erosion. They are able to invade an area when the natural enemy of the plant species is no longer controlling it. They alter the structure and function of the forest (Webster et al. 2006). Invasive woody shrubs are becoming denser and will affect the long-term stability of forests due to the lack of successful regeneration. Many invasive plants are able to use resources more efficiently than native plants, and therefore, quickly growing and overtopping desired plants (Webster et al. 2006). The management and controlling of invasive plants is a costly and lengthy process. It includes the use of regular mechanical and chemical treatments, and monitoring the area for further spread of the plant (Webster et al. 2006).

INTRODUCTION

Invasive woody plants and trees can have a negative impact on desired tree regeneration in the understory of forest stands, and forage density in grassland sites. Woody plants can limit the growth and productivity of desired tree regeneration or forage crop through competition for nutrients and water, shading, and suppression. Other inhibiting factors, such as allelopathy, can also have an effect on the efficiency of seedling and forage growth (Cummings et al. 2012).

In a forestland ecosystem, forest density and woody undergrowth shade the seedlings of desired tree species. It is difficult for the seedlings to grow with little sunlight, and competition from other woody plants for nutrients and water. With the removal of the woody plants in the understory of the forest stand, there is greater opportunity for the seedling to utilize available nutrients and sunlight. Allowing for regeneration of desired species increases the value of the forest stand. In a grassland ecosystem, woody plants shade the forage, and compete for water and nutrients. The encroachment of woody plants and shrubs into grassland from forest edges are increasing annually. This causes a decrease cattle production because woody plants are unpalatable and provide little nutrition. For the increase in forage yield and livestock production, woody plants need to be managed properly so the forage is able to grow efficiently.

The assessment of chemical and mechanical treatments on undesired woody plants in the understory of a forest stand, and in grassland is needed to simulate common methods of controlling undesired woody species in Ozark habitats. In this study, undesired woody plants are treated with chemical and/or mechanical treatments in forestland and grassland sites to evaluate the difference in desired tree regeneration and forage production, respectively, after treatments were applied. This study was done in two parts. The grassland part of the study focused on assessing the effects of mechanical and chemical treatments of woody species on forage density of tall fescue, while the forestland part of the study focused on mechanical and chemical treatments of undesirable woody understory species on the abundance of desired regeneration of desired hardwood species.

In the forestland part of the study, 6 forest experimental blocks were set up. Undesired woody plants, such as blackberry (*Rubus spp.)*, gooseberry (*Ribes uva-crispa)*, greenbriar (*Smilax spp.)*, buck brush (*Symphoricarpos orbiculatus)*, spicebush (*Lindera benzoin)*, and multiflora rose (*Rosa multiflora)*, were treated with a chemical and/or mechanical treatments in each plot (Bradley 2014). Initial measurements of the height and individual number of undesired woody plant species and desired tree regeneration species will be compared with the height and individual number measurements of undesired woody plants left after treatments and the tree regeneration taken in the second year of the study. The hypothesis the natural regeneration of the desired tree species will increase with the reduction of competition from undesired woody plants in the understory after chemical and mechanical treatments are applied. Desired tree regeneration includes the following tree species: oak, hickory, elm, hackberry, and black walnut.

In the grassland part of the study, 6 grassland experimental blocks were set up near forest edges in 2 different locations. Undesired woody plants, such as Russian Olive (*Elaeagnus angustifolia)*, eastern red cedar (*Juniperus virginiana),* buck brush, and sericea lespedeza (*Lespedeza cuneata)*, were treated with chemical and/or mechanical treatments (Bradley 2014). Initial forage density measurements were compared with the forage density measurements that were taken during the second year of the study to quantify the difference presumably due to the reduction of competition from the undesired woody plants. The hypothesis is the forage crop density will be greater where chemical and mechanical treatments were applied to woody plant species.

The objectives of this study are to collect data in grassland along a forest edge, and in the understory of a forest site, conduct statistical analyses on vegetative data, discuss the results of statistical analyses and implications for effectiveness of chemical and mechanical treatments for forage production, and desired tree natural regeneration. Results from this study will be helpful to forest practitioners and landowners for managing undesired woody plant species in forestlands and pastures near forest edges.

METHODS

The grassland sites were located on Baker's Acres north of Marshfield, Missouri and Shealy Farm (300 acres) near Fair Grove, Missouri. These locations were optimal for the grassland part of the study because there are both forestland and pastureland on the properties. Additionally, the sites offered a selection of areas containing elongated strips of forestland/grassland edge for establishment of experimental blocks. The experimental areas were easily set up near the forest edge extending into the grassland.

The forestland site was in the Woodlands, a property owned by Missouri State University north of Springfield, Missouri. This was an optimal location for the study because the forest had not been managed for about 70 years and developed a dense understory where desired natural regeneration is very low.

Grassland

The grassland site of the study was completed in 2 years. It was started in May 2015. Three experimental blocks were at Baker's Acres and three were at Shealy Farm. The forage in the grassland was predominately tall fescue, while the dominant tree species on both sites was black walnut.

Study Design. The study design was set up the same way in each location. The forest edge was on one side of the block, with the plots extending into the forage. Each block had 12 plots with a 3-foot buffer in between each plot. Each plot was 20 feet in length and 8 feet wide. The subplots were established orthogonally to the plot length at 5 foot increments; 5 feet, 10 feet, 15 feet, and 20 feet away from the forest edge. The subplots were 8 feet in length (the width of the plots) and 3 feet wide (Fig. 1). In each subplot, a transect line was drawn down the center with measuring tape during data collection. In each block, there was one control plot.

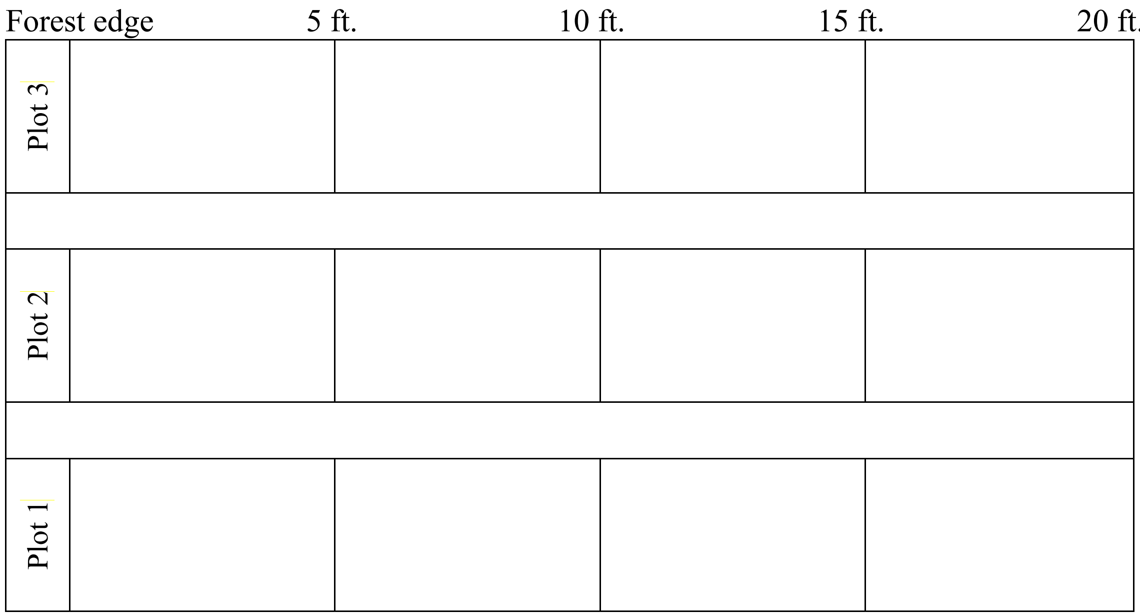

Figure 1. Example of grassland study field design.

The plots were assigned chemical or mechanical treatments randomly in each block. There were two different treatment times throughout the growing season during the first year of the study: early summer and late summer. Mechanical treatments, stump treatments, and basal bark treatments were applied during both the early and late summer treatment times. All chemical treatments were applied with a backpack sprayer with an adjustable cone nozzle. The chemical used was Remedy® Ultra (triclopyr-butotyl). This herbicide kills woody plants and broadleaves while leaving grasses undamaged. The bark treatment was a mixture of 20% Remedy® Ultra and 80% bark oil. This mixture was sprayed from the ground to 8 inches up the trunk or stem around the circumference. The stump treatment was a mixture of 20% Remedy® Ultra and 80% bark oil. The tree or woody plant was cut with the chainsaw, and sprayed around and on top of the stump with the mixture. The mechanical tool used for mechanical treatments was a chainsaw.

Data Collection. Measurements were taken the same way both the first and second year of the study. Initial measurements were taken during the first year to compare to the second year measurements. The first year measurements were taken before each treatment time. In each of the subplots, woody plant species were noted. Along the transect line, woody plant species and distance of shade was noted in inches. A measurement of transect line length was also noted in inches. Two different forage density measurements were taken in each subplot. Forage height was converted to an estimate of forage production in tonnage per acre using the grazing stick. The second forage measurement employed a rising plate meter. Both of the forage measurements were taken 4 times in each subplot. The four measurements in each subplot were averaged.

Though the direct forage measurements provide an estimate of forage height, they do not directly provide a measure of forage density. Many electronic rising plate meters have built in formulas to estimate forage density based on pre-determined parameters. It was decided that most such default formulas would be inappropriate for the purpose of this study as they are based on parameters established well outside the study's geographical range, and for other grass species. To address this issue, an equation was used that was developed by Boyer (2015), which uses forage height to estimate forage density based on coefficients estimated for fescue within the range of this study. The forage density estimates were obtained as follows:

$y = 2.40020136x + 4.075797321$

Where x = forage height in cm and y = forge density in kg per hectare.

Data Analysis. Data were analyzed using standard three-way ANOVA. The three main factors are block, treatment, and time at which the treatment was applied. The data from the first year were compared to the second year data. The response variables of interest proxies are forage, stems per acre of woody species, and percentage of cover from woody species. Both over all woody species and individual species are considered for both stems per acre and percentage of cover of woody species. Independent variables are time, treatment, block, and species of woody plants. Species of woody plants that were present in the experimental area include buck brush, sericea lespedeza, eastern red cedar, multiflora rose, and Russian olive.

Forestland

The forestland site of the study was started in May 2015. There were six experimental blocks inside the Woodlands. The understory was dense and had little desired natural regeneration. The woodlands provided two individual forest stands, which were ideal for this study. The first stand (site) was a mid-slope area dominated by black walnut and hackberry. The second stand was an upland site dominated by oak and hickory species.

Study Design. Six blocks were established within the Woodlands. Each experimental block was 35 feet in width and 140 feet in length. There were 15 plots within each block with a 3-foot buffer between each plot. Plots were split into two treatment plots for the two chemicals used. Four subplots were established within each treatment plot. The subplots had a 3-foot radius around a center point. There were two transect lines that ran across each treatment plot over the subplots (Fig. 2). In each block, there was one control plot.

The plots were assigned chemical or mechanical treatments randomly in each block. There were two different treatment times throughout the growing season during the first year of the study: early summer and late summer. Both chemical treatments were applied with a backpack sprayer with an adjustable cone nozzle. The two chemical treatments were bark treatment and stump treatment. There were 2 chemicals used, Remedy® Ultra herbicide (triclopyr-butotyl) and Crossbow® herbicide (2,4-dichlorophenoxyacetic acid and triclopyr). Both of these herbicides are post-emergent herbicides that are used for killing woody plants and broadleaves. The bark treatment was a mixture of 20% the assigned chemical and 80% bark oil. The mixture was sprayed from the ground to about 8 inches up the trunk or stem around the circumference. The stump treatment was a mixture of 20% the assigned chemical and 80% bark oil. The tree or woody plant was cut with the chainsaw and the mixture was sprayed around and on top of the stump. The mechanical tool used for mechanical treatments was a chainsaw.

Data Collection. Measurements were taken the same way for both the first and second year of the study. The first year was the initial measurements to compare to the second year measurements. In each of the subplots, woody plant species and height were noted. Along the two transect lines in each treatment plot, woody plant species and distance of shade in inches was noted. A measurement of the transect line length was also noted in inches.

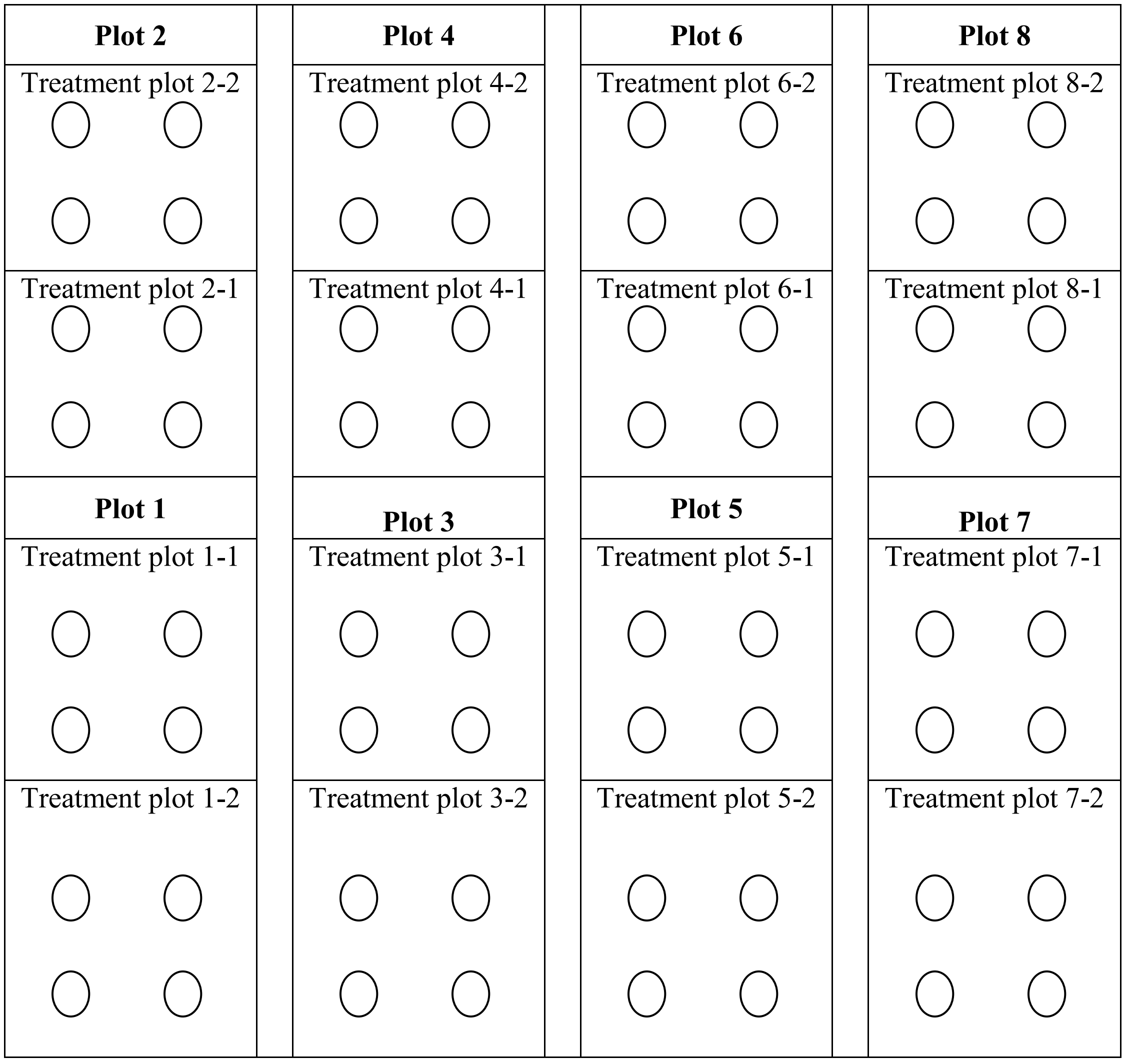

Figure 2. Example of forestland study field design. There were two treatment plots within each plot. The circles represent subplots within the treatment plot. Buffer strips are shown between each plot.

Data Analysis. Three-way ANOVA was used to analyze the data. The three main factors are block, treatment, and time at which the treatment was applied. The data from the first year were compared to the second year data.

Limitations of Study

Limitations of this study include differences in site characteristics. In the grassland site of the study, three blocks were at the Shealy Farm and three blocks were at Baker's Acres. Shealy Farm has many more honey locust trees and a greater population of sericea lespedeza than Baker's Acres. Baker's Acres has a large population of Russian olive trees, eastern red cedar trees, and the forest edge consisted of black walnut trees, and Shealy Farm did not. Multiflora rose's inconsistent presence was scattered throughout the experimental area in both grassland and forestland sites.

In the second year of the study, sericea lespedeza populations were much greater than in the first year. This was possibly due to the existing seed bank in the soil, the reduction of competition from eradicated woody species and trees the first year, or the different weather conditions. The second year of the study had more precipitation than the first year.

RESULTS AND DISCUSSION

Grassland

The grassland portion of the study focused on analysis of several different attributes: forage density, stems per acre of woody species, and percent cover density of woody species. Though assessing the effects of mechanical and chemical treatments on forage density was the primary goal, it was useful to analyze the effects the other attributes as well in order to achieve a more comprehensive assessment of the treatments on the sites as a whole.

Forage. Woody plants within the pasture had a negative effect on tall fescue growth. With the control of the woody plants, tall fescue growth will increase long-term. There was a significant change in tonnage per acre by block and treatment time (Table 1). There was a negative forage response for the early summer treatment and a positive forage response for the late summer treatment (Fig. 3).

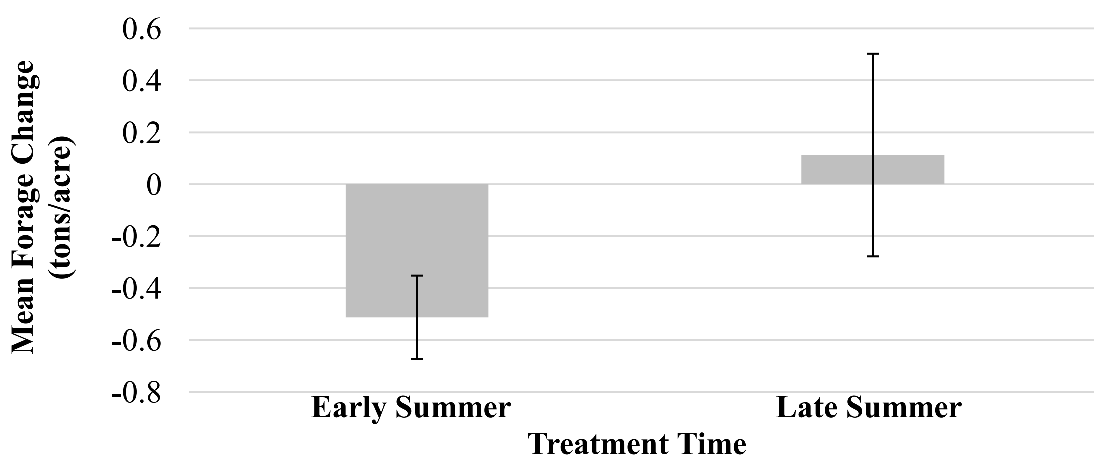

Figure 3. Mean forage response (change) from year 1 to year 2 by treatment time with standard deviations.

Treatment time had a major effect on forage because of the growth patterns of tall fescue. Tall fescue growth peaks in Missouri during April – May and September – October (Ball et al. 2015), having the greatest growth rates in late spring/early summer, and fall. The early summer herbicide treatment was applied at a time of decreasing growth rate of tall fescue production (June). Even though Remedy® Ultra is used to kill broadleaf plants, the herbicide treatment on the woody plants in the early summer may have had a stunting effect on the tall fescue due to the timing of declining of growth, resulting in less tonnage per acre. The late summer herbicide treatment was applied during the increasing growth period of tall fescue in the fall (September), having a positive effect on tall fescue growth.

Table 1. Forage ANOVA

Source	Degrees of Freedom	Sum of Squares	Mean Square	F	P
Treatment	3	1.859	0.620	4.35	0.033
Time	1	3.274	3.274	22.97	0.001
Block	5	6.128	1.226	8.6	0.002
Treatment*Block	15	6.076	0.405	2.84	0.050
Treatment*Time	2	0.314	0.157	1.1	0.370
Time*Block	5	1.505	0.301	2.11	0.147

Treatment, time, and block were all significant main effects while the block and treatment interaction was marginally significant (P=0.05). The significant effect of block was most likely due to noticeable differences in site characteristics between blocks and study sites. Recall that the blocks in this study were not used for randomization of study design as much as to capture site variability across both study sites. Two particular woody species that defined the visible difference between Shealy Farm and Baker's acres were Russian olive and eastern red cedar. Shealy farm had no Russian olive and a much lower presence of eastern red cedar when compared to Baker's acres. The marginally significant interaction effect between treatment and block indicates that the significance of treatment on forage response was at least partially dependent on block, which makes sense due to variation in response of different woody species to each treatment. However, the significant main effect of treatment on forage is of particular interest (Fig. 4).

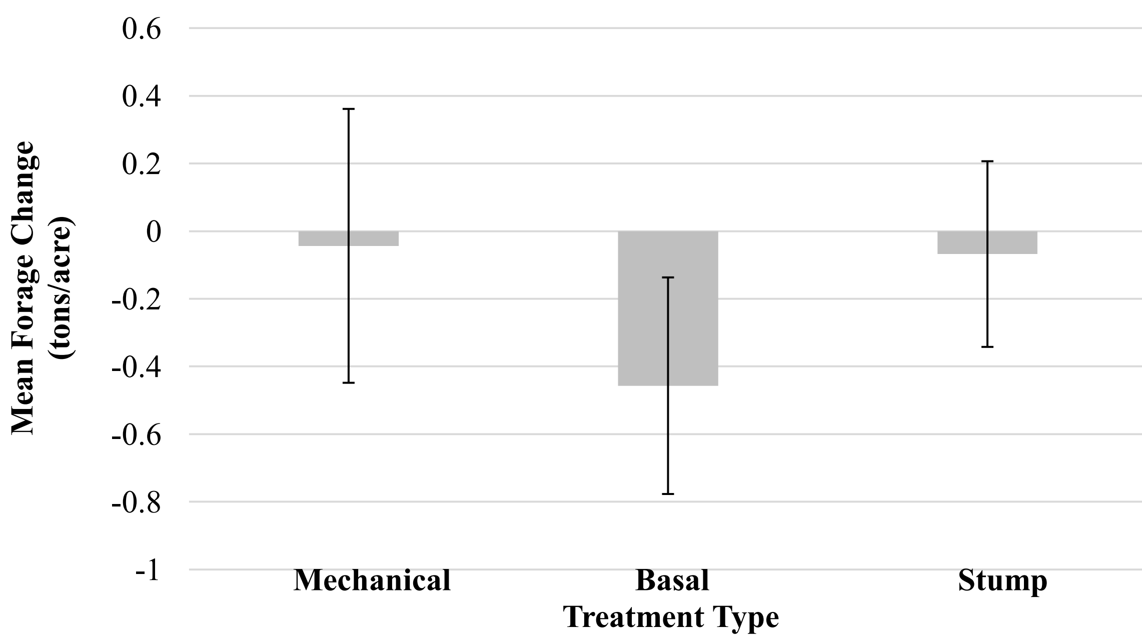

Figure 4. Mean forage response (change) from year 1 to year 2 by treatment with standard deviations.

Figure 4 illustrates the magnitude of difference between the effects of the different treatments on forage. Recall that this effect was significant based on the analysis described in Table 1. Notice that all effects are negative, indicating a decrease in forage from Year 1 to Year 2. This is not surprising as each of the treatment types causes short-term damage to forage and other site characteristics. The treatments that resulted in the least negative impact were mechanical-only treatment and stump treatment. The most plausible reason for the greater negative impact of basal treatment was the wider spread of chemical application in an oil-based mixture.

Stems per Acre. A high density of woody species within a forage pasture is undesirable. Woody plants are unpalatable for livestock and many species offer little nutrition. Controlling the abundance of woody plants is needed to maintain acceptable available forage for livestock. In this study, there were no significant main effects for stems per acre of undesirable woody plants for any species. These results may have been due to increased growth of woody species the second year from the seeds in the seed bank after competition was gone. These results also could have been due to grow back of woody species the second year. However, the initial count of woody species based on stems per acre was extremely variable. Therefore, it is unlikely that stems per acre of woody plants had as much influence on the growth of fescue as the percentage cover of the woody species.

Shade Effects. When many woody plants are present in a grassland pasture, light is the main limitation on forage growth. Woody plant leaves have a larger surface area and stems grow much taller than grasses. Shading grasses causes less growth, less yield, and less available forage for livestock to graze. Percentage of cover was calculated by the transect line measurement. Overall, there was no significant change in cover from year 1 to year 2. Russian olive and eastern red cedar had no significant effect because the trees were large and did not respond to some treatments. Russian olive trees were treated with a basal bark treatment. Eastern red cedar trees responded to mechanical treatments.

Buck brush was consistently observed in all blocks of this study. This encroachment easily showed a significant difference in presence by block from year 1 to year 2. Treatment and block interaction was also significant (Table 2).

Table 2. Percentage of cover - buck brush ANOVA

Source	Degrees of Freedom	Sum of Squares	Mean Square	F	P
Treatment	3	0.110	0.037	1.86	0.200
Time	1	0.010	0.010	0.52	0.488
Block	5	0.330	0.066	3.35	0.049
Treatment*Block	15	1.543	0.103	5.22	0.006
Treatment*Time	2	0.027	0.014	0.69	0.525
Time*Block	5	0.289	0.058	2.94	0.069

Stems per Acre and Shade Effects on Forage. It is the shading effect of the percentage cover of the woody species that ultimately influences forage growth, which stems per acre is simply part of the equation regarding percentage cover. If the number of stems per acre for encroaching woody species is controlled with mechanical and chemical treatments, percentage cover by woody species should decrease, thereby reducing negative impact on forage growth. Therefore, control of encroaching woody plants is important for providing livestock with enough available forage.

Forestland

Desirable tree natural regeneration in the Woodlands was minimal when this study began. There was not a significant time effect for any of the variables of interest. Therefore, time of application was not a significant main effect in the reduction of understory undesirable woody species or any increase in desired regeneration of oak or hickory.

Stems per Acre. Dense understories make natural regeneration of desired tree species difficult. The desired tree seedlings are suppressed and cannot establish. There was a significant main effect of treatment on total stems per acre of undesirable woody species. The undesirable woody plants were controlled by the treatments applied. However, none of the main factors, treatment, time, and block, caused a difference in the change of desired tree natural regeneration from year 1 to year 2. This was partly due to the fact that there was little desired regeneration and inconsistent throughout the blocks when the study began. The chemical and mechanical treatments most likely had a negative effect on the existing desired tree regeneration, and stunted the emergence of new regeneration the first year because of the effects the treatment had on the seed bank. Oak acorn production was observed poor during the year of 2016, which is one of the main types of regeneration that was desired.

Shade Effects. Light availability is the overriding limitation for emerging plants in a dense understory. Without sunlight, the desirable tree regeneration is unlikely to establish. In this study, there was a significant ($P = 0.027$) main effect of treatment on percentage of cover of undesirable woody species (Table 3).

Table 3. Percentage of cover - undesirable species ANOVA

Source	Degrees of Freedom	Sum of Squares	Mean Square	F	P
Treatment	3	6100	2033.4	3.64	0.027
Block	5	1519	304.0	0.54	0.741
Treatment*Block	15	6636	442.4	0.79	0.675

The reason for the difference between treatment effects is similar to the effect observed in the grassland study. Fig. 5 illustrates the difference in main effects between the treatment types on percentage cover of undesirable woody species.

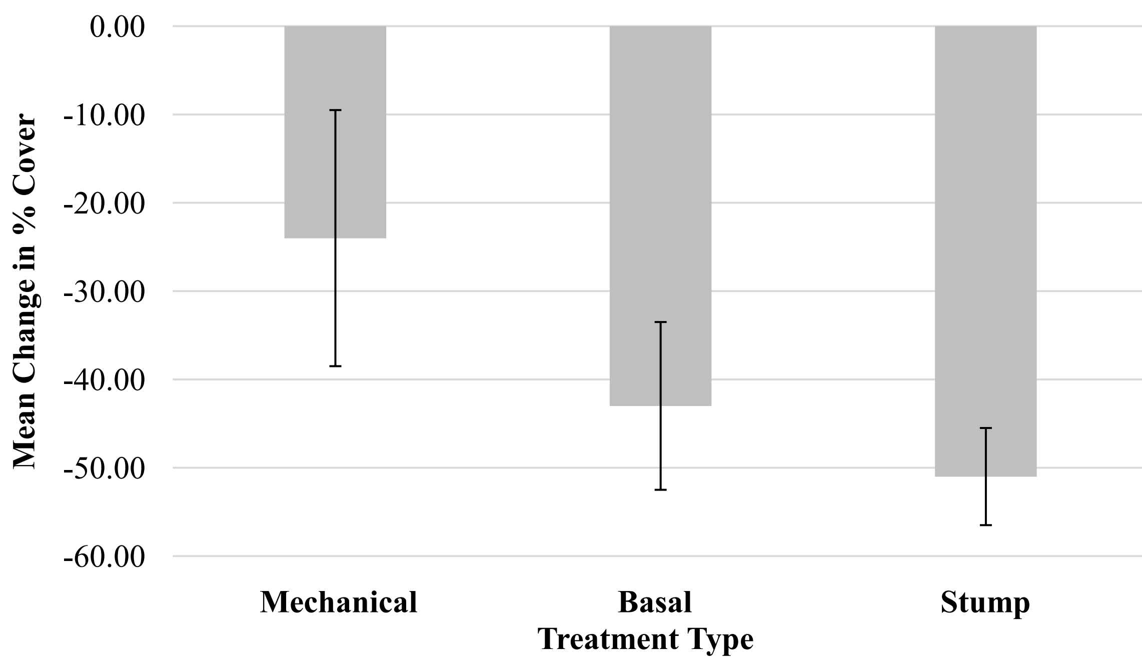

Figure 5. Change in mean percent cover of undesirable woody species from year 1 to year 2 by treatment with standard deviations.

The effect of treatment on percent cover of undesirable woody species is primarily due to differences between mechanical-only and chemical stump treatments (Table 3, Fig. 5). This is logical, as stump treatment combines the structural disturbance of a mechanical treatment with the growth inhibition effect of chemical treatment on the root systems of the plants. Notice that basal and stump treatment effects are not significantly different from each other, but it is apparent that basal treatment did not perform as well as stump treatment. This is greatly due to the fact that basal treatment on small plants such as buck brush can sometimes have limited long-term effect due to a very small available surface area on which to apply chemical. This is a disadvantage of basal application not shared by stump treatment. An overall decrease in the percentage of cover of undesirable woody plants can give desired tree species potential sunlight needed for growth and regeneration. Though treatment was the main significant effect with regard to undesired woody species as a whole, it was found that block effect was much more prominent with regard to individual woody species as described in the next section.

Percentage of cover of gooseberry and spicebush (Table 4, 5) had a significant block effect difference from year 1 to year 2. Gooseberry and spicebush populations were growing in many blocks and were killed by the treatments. More importantly, there was a definite trend between and among the blocks regarding abundance of each of these species. Gooseberry was more abundant in blocks 1 – 3, whereas spicebush was considerably more abundant in blocks 4 – 6.

Table 4. Percentage of cover - gooseberry ANOVA

Source	Degrees of Freedom	Sum of Squares	Mean Square	F	P
Treatment	3	98.8	32.9	0.80	0.508
Block	5	707.4	141.5	3.42	0.018
Treatment*Block	15	538.2	35.9	0.87	0.605

Table 5. Percentage of cover - spicebush ANOVA

Source	Degrees of Freedom	Sum of Squares	Mean Square	F	P
Treatment	3	115.5	38.5	0.18	0.909
Block	5	2851.5	570.3	2.67	0.047
Treatment*Block	15	1420.1	94.7	0.44	0.948

Desired Regeneration. Increased desired tree natural regeneration was a main goal of this study. The results indicated that the percentage of cover of desired tree regeneration had a significant (P = 0.047) block response from year 1 to year 2 (Table 6).

Table 6. Percentage of cover – desirable tree regeneration ANOVA

Source	Degrees of Freedom	Sum of Squares	Mean Square	F	P
Treatment	3	377	125	0.54	0.661
Time	1	732	732	3.15	0.096
Block	5	3473	694	2.99	0.046
Treatment*Block	15	2991	199	0.86	0.615
Treatment*Time	3	172	57	0.25	0.862
Time*Block	5	4213	842	3.62	0.024

There was also a significant (P = 0.024) time and block interaction. This is because of the site characteristics and initial condition of the blocks, the time of treatment application, and the interaction of time and block have a greater effect on the response of desirable regeneration than the treatment being applied. In this case, the time of application was an important factor. Woody plants are generally sprayed with herbicide in the fall because much of the water and nutrients in the plant are moving to the roots to prepare for winter dormancy. When the herbicide makes contact with the woody plant and is absorbed, it is taken to the roots much more quickly than it would be earlier in the season during active plant growth.

CONCLUSION

Woody plants and trees can have a negative impact on desired tree regeneration in the understory of a forest, and forage density in grassland sites. Competition for nutrients and water, shading, and suppression are all factors leading to declination of natural regeneration and forage production. In this study, undesirable woody plants were treated with chemical and/or mechanical treatments in forestland and grassland sites to observe the change in desired tree regeneration in the understory of a forest, and forage production in grassland along a forest edge after application. My objectives were to collect data in the understory of a forest site, and in grassland, to conduct statistical analyses on vegetative data, and discuss the results of the effectiveness of chemical and mechanical treatments on desired regeneration and forage production.

The grassland site of the study focused on the change of forage density, stems per acre of woody species, and percent cover of woody species. Overall forage production increased from year 1 to year 2 due to the elimination of woody species the first year. However, there was a negative forage response for the early summer treatment and a positive forage response for the late summer treatment. This is because of the growth patterns of tall fescue. There were no significant main effects for stems per acre of undesirable woody species or percentage of cover. This may be due to growing back of woody species the second year, and some trees being so large that they did not respond to the treatment. However, buck brush presence decreased significantly from year 1 to year 2.

The forestland site of the study focused on stems per acre, percentage cover, and desired regeneration. There was a significant main effect of treatment on total stems per acre of undesirable woody plants. The treatments were effective and decreased the presence of undesirable woody plant species. There was a significant main effect of treatment on percentage of cover of undesirable woody species. Mechanical-only and stump treatments were significantly different from each other in the mean change in percentage cover. Gooseberry and spicebush had a significant block effect difference from year 1 to year 2. The main goal of the forestland site of the study was increased desired tree natural regeneration. The percentage of cover of desired tree natural regeneration was significant from year 1 to year 2. There was also a significant time and block interaction. This is due to the initial condition and site characteristics.

The results of this study can be helpful to forest practitioners and landowners that seek to manage dense understories and woody plants in pastures. Finding that there was a positive forage response from the late summer treatment in the grassland site is important in application timing. Finding that in the forestland the treatments were effective in decreasing the presence of undesirable woody plants is also important.

The main goals of this study was to increase forage production in a grassland after chemical and mechanical treatments were applied to undesirable woody species, and to increase desired natural regeneration in the understory of a forest site. Both of these main goals were attained in this study.

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