Assessing the potential of mixed grazing goats with beef cattle to improve animal performance and increase the utilization of marginal pasturelands in the Appalachian coal region

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Abstract

Reclaimed coal-mined lands in the Appalachian region can be successful established and utilized for beef cattle production. Currently, these areas are underutilized partly due to an increase in invasive plant species, such as multiflora rose (*Rosa multiflora* Thunb. Ex Murr.), autumn olive (*Elaeagnus umbellata* Thunb.), and sericea lespedeza (*Lespedeza cuneata* (Dum.-Cours.) G. Don). The steep topography and low economic returns from beef cattle make conventional control methods inhibitive. Goats are effective browsing on invasive plant species. An experiment was conducted in 2006 and 2007 at the Powell River Research and Education Center near Wise, VA (77° 43' 30" west longitude, 38° 57' 30" north latitude, elevation 155.5 m) to determine the effects of an ungrazed control, cattle alone grazing, and mixed grazing goats with cattle on forage biomass, botanical composition, relative plant abundance, and animal performance. The three treatments included an ungrazed control, cattle grazing alone, and mixed grazing goats with cattle. Experimental design was a randomized complete block design with two replicates for the control and three replicates for the grazed treatments. Three times during the grazing season the following were measured, analyzed or assessed: nutritive values of pasture, autumn olive, multiflora rose, and sericea lespedeza were assessed; forage biomass was determined by clipping four 0.25 m^2 quadrants per control replicate and eight 0.25 m^2 quadrants per grazed replicate; botanical composition and relative abundance of plant species was assessed by the Double DAFOR method from five fixed points in each control replicate and ten fixed points in each grazed replicate; animals were weighed; autumn olive shrub height was measured with a clinometer from a distance of 10 m from the shrub. Branch length was measured with a tape measure from the base of the branch to the end tip. Shrub survival was measured by counting shrubs in each replicate and determining visually percent leaf-out. Each year, control and cattle alone treatments had greater ($P < 0.05$). Generally, grass content increased in the grazed treatments from spring to fall while weed content increased in the control treatment ($P < 0.05$). By the end of the two experimental years, the legume components of the pasture were low. This was more evident in the ungrazed control than the grazed treatments. The relative abundance of tall fescue and orchardgrass ($P < 0.05$) increased in grazed treatments while sericea lespedeza became a dominant weed in the control ($P < 0.05$). Goats showed high preference for sericea lespedeza and maintain this plant in a leafy, vegetative stage. This leafy, vegetative growth was found to acceptable to cattle. Cattle performance was not affected by treatment ($P < 0.05$) but total animal output was higher for mixed grazed compared to cattle alone treatments ($P < 0.05$). The nutritive values of multiflora rose, autumn olive, and sericea lespedeza were higher than pasture in most instances ($P < 0.05$). In our experiment, autumn olive was severely impacted by goat browsing. Shrub survival was lower in mixed grazing (61%) by the end of the experiment compared to over 90% for the control and cattle grazing treatments ($P < 0.05$). Overall, pastures were utilized more uniformly in mixed grazing compared to other treatments. Mixed grazing goats with cattle appear to be a viable option for livestock producers in the Appalachian coal mining region.

Dedication

To My Lord Jesus Christ

When my way growth drear, you Precious Lord lingered near;

When my life situations were hard, you heard my cry and my call;

You held my hand, lest I fell;

You took my hand and leadeth me on.

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CHAPTER I
INTRODUCTION

Coal-mined areas in the Appalachian region have been successfully restored to viable forage-based livestock systems. Cattle production on these lands is possible but returns are generally low as a result of poor soil fertility and increasing encroachment by invasive plant species (Ditsch et al., 2006). The steep topography that is characteristic to the region makes chemical and/or mechanical control treatments for invasive plant species difficult. Using biological control methods, such as adding goats to existing cow herds has been considered a viable and sustainable control option for managing invasive plant species (Luginbuhl et al., 2000; Hart, 2001).

The proliferation of non-native invasive plant species is a problem throughout the Southeastern United States (Southeast Exotic Plant Pest Council, 2007). The Virginia Department of Conservation's Division of Natural Heritage and the Virginia Native Plant Society estimates that there at least 115 non-native invasive species within the state that threaten natural areas and other lands (Virginia DCR, 2006). Many of these species cause problems in pasture management. Three invasive plant species that reduce cattle production potential on reclaimed coal mines include: multiflora rose (*Rosa multiflora* Thunb. Ex Murr.), autumn olive (*Elaeagnus umbellata* Thunb.), and sericea lespedeza (*Lespedeza cuneata* (Dum.-Cours.) G. Don). These species grow into dense stands that shade out more desirable grasses and legumes. These invasive plant species grow woody as they mature and may contain high levels of condensed tannins that render these plants unpalatable to cattle (Miller, 2003).

The demand for goat has increased in the United States and marketing opportunities are improving (Glimp, 1995). Goats desire a diet that is largely browse material (Ball et al., 2002). Therefore, it has shown potential for controlling invasive plant species in forests and pastures, reducing fuel levels for potential wildfires around communities, and improving the aesthetic value of land (Luginbuhl, 2000; Hart, 2001). Research has shown that adding goats to existing cattle operations at a rate of 1 to 2 goats per cow can improve the profitability of the cattle operation without a cost to the cattle (Luginbuhl et al., 2007). Mixed grazing different livestock species has been shown to improve utilization of existing vegetation, control invasive plant species, and possibly increase the production and profitability of these operations (Walker, 1994; Luginbuhl et al., 1996; 2000).

Mixed grazing is the grazing of two or more different species of livestock on the same pasture at the same time or within the same grazing season (Allen and Collins, 2003). Utilizing livestock with different grazing behaviors and preferences will result in greater pasture utilization when pastures contain diverse vegetation. The resultant changes in vegetation may produce a desirable botanical composition that may improve the performance of one or more grazing species (Smetham, 1990; Walker, 1994). In an experiment conducted with cattle and goats to manage vegetation, Luginbuhl et al. (2000) concluded that goats effectively reduced the encroachment of Appalachian mountain pastures by multiflora rose bushes and other woody species. The content of desirable grasses and legumes was increased.

Understanding the different grazing behaviors of grazing animals on vegetation within a pasture area is important for making grazing management decisions when more than one livestock species is present (Ditsch et al., 2006). Climate, topography, soil fertility, and management will determine the type, persistence, and productivity of the vegetation. The amount and type of vegetation may determine the stocking rate, ratio of the different grazing species, and the grazing pressure that may be imposed on a land area. As a result, mixed grazing will result in greater management requirements as each grazing species has particular needs in regard to nutrition, health, shelter, and fencing (Walker et al., 2006). Information is limited on the implications of using mixed grazing cattle with goats on reclaimed coal-mined areas.

As the demand for goat meat has increased due to a growing ethnic population, they have found widespread popularity with small land owners. The availability of information on goat management has improved but information on pasture management and nutritive value of shrubs and invasive plant species are lacking. On pastures stocked with goats, shrub species will decline rapidly unless management allows control over excessive browse pressure (Hart, 2001). In overstocked pastures, goats will alter their diet to compensate for the reduction of browse (Pond et al., 1995). They begin to graze closer to the ground and increase the chances for internal parasite infection (Familton, 2003). Goats are sensitive to internal parasites and browsing is a natural avoidance behavior. Shrubbery contains condensed tannins that are a useful in combating internal parasites (Min and Hart, 2003). There is an increased interest among producers and researchers in using browse species in goat production. Information of nutritive values and condensed tannin content is lacking for browse species found in the Appalachian region.

The overall objectives of this experiment were to determine forage biomass and botanical composition of pastures present on reclaimed coal-mined lands by three grazing treatments: no grazing control, cattle alone grazing, and mixed grazing goats with cattle. Specific objectives were to investigate the effects of the three grazing treatments on botanical composition shifts and nutritive values of pasture, autumn olive, multiflora rose, and sericea lespedeza. Also, the effects of goat browsing on autumn olive growth and survival were assessed. Animal performance was determined.

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CHAPTER II

LITERATURE REVIEW

Appalachian coal-mining region

Present and future economic impact of coal-mining in the region

Coal-mining is the major economic industry in the Appalachian region. In 1997, coal-mining generated over $200 million in payroll to over 6,500 employees. However, from 1990 to 1995, coal production declined from a record of 46.5 million tons to 35.9 million tons. Researchers concluded that 57.6% of the coal reserve had been mined in the south-west Virginia coal region by the late 1990s. It is estimated that coal production will continue to decline in this region (Westman et al., 2000).

The Appalachian region has been historically economically deprived when compared to the rest of the country. The steep topography of the region makes the transportation of products and services slow and expensive. As result, average income and education is lower and poverty is higher (10.2%) as compared to the national average. Alternative employment or income generating enterprises may be needed in this region (ARC, 2007).

Coal-mining reclamation practices

The Surface Mining Control and Reclamation Act of 1977 (SMCRA) mandates that post-mined land should be restored to its former use or to a higher use. This act requires a plant community become established and sustain a vegetative cover of 90% during the five years post-mining to prevent erosion. Therefore, proper soil creation and plant establishment practices are important in order to comply with the reclamation act.

Reconstructed soils on reclaimed coal lands in the Appalachian region are variable in pH, fertility, and water-holding capabilities. These soils normally contain very little topsoil prior to coal mining and are naturally shallow, rocky, acidic, and non-fertile. The chemical and physical properties of these soils make them difficult to manage (Daniels and Zipper, 1997).

Chemical properties of mined-soils important to vegetation establishment and persistence

Chemical features of mine soils important for plant growth include pH, soluble salts, and soil fertility. Drastic changes in pH can occur in just a few months after mining, especially if there are appreciable amounts of pyritic material exposed to the air (Daniels and Zipper, 1997). Vegetation response will be limited by soil acidity or soluble salts. Soils with a pH lower than 4.0 should be avoided as they are very difficult to revegetate. Soils with a pH of 4.0 to 5.5 will require large amounts of lime but may be able to support acid-tolerant trees, such as pine. Soils with pH of 6 to 7 are ideal for forages or other purposes. Soluble salts pose another problem as salt-sensitive species may be affected at salt levels higher than 1,250 ppm. At 5,000 ppm soluble salts, vegetation will be sparse and the land may be barren (Daniels and Zipper, 1997). Nitrogen (N) and phosphorus (P) are the most limiting nutrients in mine soils as there is little organic matter present. Both elements need to be applied as either inorganic fertilizers or by organic amendments (Daniels and Zipper, 1997). The effect of N fertilizer on plant growth is short-lived and may be apparent for two years after application. SMRCA limits the use of fertilizer for five years after the initial establishment. Therefore, maintaining populations of N-fixing legumes is critical for establishing a vigorous N cycle. The effect of P fertilization may also be short-lived. As mine soils continue to weather, the soil's ability to fix P also increases and limits plant uptake. Measures for improving this scenario are to ensure that pH is in the optimal range and develop an organic-P pool to continue long-term plant production (Daniels and Zipper, 1997). Plants that develop mycorrhizal association, such as sericea lespedeza, are able to draw P from difficult sources and add P to the system when the plant dies and decomposes (Daniels and Zipper, 1997).

Physical properties of mined-soils important to vegetation establishment and persistence

Physical features such as rock content, soil texture, bulk density, slope and topography, and stability of these mine soils will directly influence the water-holding ability and rooting depth of these soils (Daniels and Zipper, 1997). The particle sizes of mine soil are generally greater than 2 mm and are considered "coarse". Soils with a large amount of coarse fragments have large pores that prevent holding water against leaching. Mine soils are highly compacted with bulk density > 1.6 g/cm³. Compaction on these soils is due to heavy machinery traffic during soil reconstruction and grading. Soil compaction limits the long-term revegetation success as rooting depth is severely restricted in the top two feet of soil profiles. Additionally compacted soils may also become saturated during wet weather and causing anaerobic conditions. Slope and topography plays a role in post mined land use. Slopes greater than 15% are unsuitable for cropping but may be used for grazing or forestry. Reconstructed land forms are more uniform and smoother and are being considered for public uses. The chemical and physical properties of mined lands are important in determining post-mined land use (Daniels and Zipper, 1997).

Uses for reclaimed coal-mined lands

Post-mining land use varies due to reclamation methods and the intended use by the landowner. Reforestation and pastureland are the most common uses for reclaimed coal-mined lands. Establishment costs for reforestation are lower as heavy fertilization, liming, and grading requirements are less than required for the establishment of pastureland. Requirements for successful commercial forest on reclaimed areas are to use an appropriate soil (weathered sandstone), layered deep and uncompacted, and to ensure a density of 160 trees per hectare (Burger et al., 1998). Research has shown that created soils on reclaimed areas can be more productive for growing trees compared to native soils. Possible economic returns from timber production on mined-lands have been double compared to undisturbed areas in some situations (Burger et al., 1998).

Forage-livestock enterprises can be profitable when mined-land is reclaimed to desirable grasses and legumes (Gerken and Baker, 1997). Cattle production is the most common livestock use on reclaimed mine land with cow/calf operations being the most popular. Calving occurs in spring to coincide with the fast growth of cool-season grasses and legumes. Calves are raised to weaning and then sold. Stocker production is also a possibility but may require additional fencing and better quality forages compared to cow/calf. Stocker gains of 135 kg per head during the grazing season are possible (Ditsch et al., 2006a). Other farm animals that may be raised on pastures/forages established on reclaimed mined areas include horses, sheep and goats. Goats may be a viable component as they can help control weeds and shrubbery not utilized by cattle (Ditsch et al., 2006b).

Successful management of cattle on reclaimed mined-land requires skillful land and grazing management. Controlled grazing should be practiced to maintain a productive groundcover that will prevent soil erosion and compaction. Controlled grazing is the management of the forage resource to ensure adequate feeding of livestock while maintaining the persistence and productivity of the pasture (Blaser et al., 1986). Forage regrowth on reclaimed mined-land is slower after grazing compared to undisturbed pasturelands. The low water-holding capacity of mined soils also may reduce plant vigor during the summer months and overgrazing during this period can greatly reduce plant persistence and production (Thom et al., 1990). A proper stocking rate will ensure that pasture plants are not over-grazed and that cattle have adequate forage for efficient production. Research in Kentucky concluded that a stocking rate of 1.2 ha per cow compared to 2.4 ha and 3.6 ha per cow had no effect on cow body weight or reproductive performance. However, at the stocking rate of 1.2 ha per cow, grazing activity was greater, groundcover was reduced, and the grazing season was shorter compared to the other stocking rates (Ditsch et al., 2006a). The recommended stocking rate for reclaimed mined-land is suggested at 1.2 to 2.4 ha per cow and 0.4 to 1.2 ha stocker (Ditsch et al., 2006a). Rotational stocking is a grazing method that should be considered if there is adequate water and fencing. The benefits of rotational stocking include greater pasture utilization, nutrient cycling, weed control, and productivity of desirable grasses and legumes. Short grazing periods of 1-2 weeks with 4-6 weeks of rest have been found to be adequate particularly during the dry summer periods (Ditsch et al., 2006a).

Though proper grazing management can keep a pasture in a productive state, encroachment by invasive plant species that are unpalatable to cattle is still possible (Miller, 2003; Ditsch et al., 2006b). Weed control options for cattle-grazed pastures on reclaimed mine lands include conventional herbicide and mechanical treatments. However, these treatments are expensive and may not be possible on the steep slopes that are characteristic of reclaimed mined areas. Goats are also a viable weed control alternative for managing invasive plant species on steep slopes (Ditsch et al., 2006b).

Invasive plant species

Encroachment of invasive plant species and reduced survival of desired species

Invasive plant species are species that reproduce rapidly, spread over a large area, and have few natural controls (Swearingen et al., 2002; Miller, 2003). These species invade native areas, forests, pastures, and wetlands and thus reduce the habitat diversity, land productivity, and recreational opportunities of such areas. Invasive plant species share some characteristics that allow their uncontrolled growth. These characteristics include: spreading by rhizomes, producing large numbers of viable seed, and seeds are easily dispersed by animals, people, wind, and water (Swearingen et al., 2002). Forests, pasturelands, wetlands, and native areas are the most endangered by invasive plant species (Miller, 2003). In the United States, the annual combined cost of invasive species control and loss of agricultural lands is estimated to be $34.7 billion (Swearingen et al., 2002).

Most invasive plant species in the United States are non-native and may have been introduced either accidentally, for forage, or for ornamental use (Miller, 2003). After being introduced, they spread and crowd out desirable plant species and form a monoculture. In effect, they hinder land uses, such as forestry or pasture, reduce diversity, and degrade wildlife habitat (Miller, 2003). Controlling invasive plant species is compounded by the fact that they lack natural diseases, insect pests, and herbivores to keep them in check. In most cases, due to low economic return, restoration of these areas using a conventional system such as the use of herbicide and re-planting desirable species is not a viable option. Low cost, environmentally safe and economically viable invasive plant species control techniques are needed to maintain productive land uses (Swearingen et al., 2002).

Invasive plant species common to Appalachian reclaimed coal-mined lands

Invasive plant species that are common to the Appalachian coal region include: autumn olive (*Elaeagnus umbellata* Thunb.), sericea lespedeza (*Lespedeza cuneata* (Dum.-Cours.) G. Don), and multiflora rose (*Rosa multiflora* Thunb. Ex Murr.). Due to unfavorable soil and environmental conditions associated with reclaimed lands, invasive species are able to grow and out-compete more favorable species.

Autumn olive is a deciduous bushy leafy shrub introduced from China and Japan in 1830 (Miller, 2003). It grows to a height of 1 to 6 m with scattered thorny branches. Leaves are alternate, elliptic 5 to 8 cm long and 2 to 3 cm wide with silvery scaly underneath. Red berries are produced in autumn. It is a non-leguminous nitrogen fixing shrub (Miller, 2003). It is a common shrub used for revegetation of reclaimed mine sites. It is important as nesting sites and food source for a variety of birds (Samuel and Whitmore, 1976). Hence, wildlife has transported seed to increase the population of this shrub (Samuel and Whitmore, 1976). Autumn olive is found from Maine to Virginia and west to Wisconsin (Swearingen et al., 2002.

Sericea lespedeza is a warm-season leguminous perennial forb that was introduced from Japan to Arlington, VA in 1899 (Miller, 2003). It grows to a height of 1 to 2 m with numerous three leaflet leaves attached to slender branches that stem from mid-plant. Dormant brown plants remain upright during winter. It withstands a wide variety of conditions ranging from droughty, low fertility soils to occasional flood event (Miller, 2003). The plant is used for bank stabilization, soil improvement, wildlife feed, and forage. It spreads by seed that remain viable in the soil for decades. It shades out other species by growing into dense stands. Sericea lespedeza also contains tannins that when present at high levels causes it to taste bitter to livestock and wildlife and reduces palatability (Swearingen et al., 2004). For sericea lespedeza to be consumed as forage for livestock, it should be managed to remain in vegetative stage so that digestibility is high and tannin content is low (Hoveland et al., 1975b). Also, as sericea lespedeza matures and becomes woody, it has the potential of being fuel for wildfires (Jon Rockett, personal communication).

Multiflora rose is a wide spread invasive species in Appalachian pastures. It was introduced to the US from Asia in 1866 as rootstock for establishing ornamental roses (Miller, 2003). It was widely recommended in the 1930s for erosion control and "living fences" for livestock (Swearingen et al., 2004). It is a thorny, deciduous, perennial shrub with arching branches that is found in several states (Miller, 2003). It spreads by seed but may also spread when branches come into contact with the ground and root. It tolerates a wide range of soil and environmental conditions enabling the plant to invade fields, forests, and wetlands. It grows aggressively into dense clumps that can prevent bird nesting and grazing by livestock, particularly cattle (Swearingen et al., 2004).

Invasive plant species control using goats

The use of goats for vegetation management has been documented by several investigators. There is a continuing interest and potential for using goats to manage browse species in grasslands, forests, and even in public areas. Browse species control with goats is a viable alternative to mechanical or chemical measures (Hart, 2001). Goat's preference for browse species and their ability to navigate adverse terrain make them especially useful for reclaimed lands in the Appalachian region. Their ability to select a diet from a diverse plant sources allows them to adapt to different feed sources when browse availability is limited.

Hart (2001) illustrated the many opportunities involving the use of goats to control unwanted brush and invasive species. They aid in increasing diversity on native or naturalized landscapes where invasive species, such as sericea lespedeza and mulitflora rose, have encroached and crowded out more desirable forages and trees. They control invasive species by defoliation and eating seeds; thus reducing the buildup of a seed bank. Soil fertility may also be increased due to goat grazing as goats consume brush and return needed nutrients for grasses and legumes by defecation. They also aid grasses, legumes, and forbs by reducing shading by brush species (Ditsch et al., 2006b).

Hart (2001) emphasized that the increased use of goats for managing vegetation hinged on the social perspective of goats. He noted that cattle producers traditionally would not consider the use of goats for managing vegetation but rather would consider other means such as fire, chemical, and/or mechanical options. However, such options can be expensive or public perception can be low as in the case of fire or chemical use. Goats can provide small incomes if fencing is already in place and management costs are kept low. A case study conducted by Hart (2001) showed that stocker goats grazed on a sericea lespedeza dominant pasture could return $5/hd when stocked at 10 goats/ha resulting in a greater return per hectare than from stocker cattle as this legume is unpalatable to cattle most of the year.

Effective use of goats for brush and land management is dependent on goat preference of browse species and availability. Under conditions of abundant browse, the goat diet will consist of 60% browse averaged over a year but may show a greater preference for particular browse species (Ball et al., 2007; Merrill and Taylor, 1981). A deliberate attempt to eradicate brush showed that goats reduced percent canopy cover of browse species by 83% in a 4-year period. Goat showed a preference for live oak (*Quercus virginiana*), shinoak (*Quercus mohriana*), and juniper (*Juniperus* spp.) and reduced these species by over 90%. However, prickly pear (*Opuntia* spp.) and curly mesquite (*Hilaria belangeri*) were less favored and reduction of these species was only 62.5 and 77%, respectively (Merrill and Taylor, 1981). Goats show seasonal preference of shrubs also. Warren et al. (1984) evaluated the diet preferences of Spanish goat on a mixed-brush plant community in South Texas and found seasonal changes in browse use and preference. Browse was important components (>52%) during summer, autumn, and winter while grass constituted 54% of the diet during spring.

The combination of chemical or mechanical control options with browsing/grazing can have more immediate and longer lasting effects. Leafy spurge is an invasive noxious perennial weed in the western states that reduces associated forage production and causes sickness in cattle. This plant is favored by both goats and sheep compared to cattle (Walker et al., 1994). Though the grazing animals will effectively reduce leafy spurge, it requires a considerable time period to reduce leafy spurge invasion to the desired level. Lym et al. (1997) determined that the spring grazing of leafy spurge by Angora goats in combination with a herbicide application of picloram + 2,4-D in the fall had immediate and longer-lasting effects on leafy spurge than grazing or herbicide application alone. Another study found that the combination of mechanical-crushing of brush and grazing goats was a more effective method for reducing the percentage of shrubbery compared to mechanical-crushing only (Severson and DeBano, 1991).

Grazing behavior and mixed grazing

Understanding livestock grazing behavior may benefit the producer by selecting the appropriate livestock species to fully utilize a given vegetation resources. Such information can aid in effectively matching animal needs to the forage nutritive value and availability. This is important knowledge in situations where mixed grazing of different livestock species is practiced.

Sheep

Sheep are primarily grazers but may also browse small shrubs. They have a small mouth with a split lip that allows them to select a higher quality diet compared to cattle. Sheep will select a broad diet but not as broad as goats. They generally prefer broad-leaf species, particularly legumes, and green material to dead. Diet selection will be 50% grass, 30% forbs, and 20% browse (Walker, 1994). Sheep will graze very close (<2 cm) to the soil surface in situations where intake is restricted. Due to their selective nature, pasture can become clumpy due to spot grazing when pasture mass exceeds animal needs (Pond et al., 1995). As a result, dead material may easily accumulate in pastures when intake is not controlled (Rattray et al., 1987).

Goat

Goats are very active in their foraging habits. They will cover a wide range of area and select from a broad base of grasses and browse species. They are able to choose a high quality diet even in the presence of a poor quality pasture. Browse may constitute up to 60-80% of the diet depending on season (Lopes et al., 1984; Walker, 1994). They have small mouths with split upper lips that enable them to select small leaves, flowers, and fruits even in the presence of thorns. They will stand on their hind legs in order to graze leaves and tender twigs. Often a group of goats will mob a shrub or small tree seedling and bend it over in order to make browse material easier to reach. Due to these characteristics, goats are often used in pastoral systems based on steep terrain. They will generally feed on steep areas much more readily than sheep or cattle (Luginbuhl et al., 1995).

When browse becomes limited, goats will begin to select other species, particularly grasses and weeds. Goats may actively reject clover resulting in clover dominant pastures which may become beneficial to other stock (Smetham, 1990). Goats will graze a pasture very uniformly compared to other classes of stock. They are characterized as "top-down" grazers meaning they will graze the sward uniformly until close to the soil surface (McCall and Lambert, 1987).

Cattle

Cattle select a diet that is mainly grass or legume. Browse may only constitute 10-15% of their diet (Walker, 1994; Ball et al., 2007). Due to partly the anatomy of their mouth, cattle are not as selective in obtaining their diet as compared to sheep and goats. They will use their tongue to wrap and pull forage into their mouths when forage is 10 cm or greater. When forage is less than 10 cm, the bottom incisor teeth and upper dental pad will be used to clamp and pull forage into the mouth (Pond et al., 1995). Due to their grazing habit, they will consume more mature forage than either sheep or goats. They are useful in maintaining pasture quality by eating taller grasses that may inhibit the tillering of new grass or the survival of legumes (Sheath et al., 1987). Due to differences in grazing behaviors and diet preference, cattle can be mixed grazed with sheep and/or goats in a grazing system.

Mixed grazing

Mixed grazing is defined as the grazing of two or more different species of livestock on the same pasture at the same time or within the same growing season (Allen and Collins, 2003). The grazing of different species of livestock allows greater carrying capacity and vegetation utilization as each grazing species selects plants according to their preference. This results in changes of the botanical composition of the pasture which may allow improved performance of one or more livestock species (Walker, 1994).

Mixed grazing of different livestock species is dependent on diet selection overlap between livestock species and the vegetation resource of the pasture. It is largely understood that grazing animals select for leaf in preference to stem and young in preference to old plant material (Ball et al., 2007). Cattle, sheep, and goats will selective graze for green material but will do so by selecting preferred plant species. On a year-long basis, the diets of cattle, sheep, and goats will be 70, 50, and 30% grass; 15, 30, and 10% forbs; and 15, 20, 60% browse, respectively (Walker, 1994). Cattle and goats have the least dietary overlap as they will select for very different vegetation types. Cattle and sheep are compatible as long as pasture is diverse and available. Sheep will consume forage near cattle dung, whereas cattle often reject such forage (Brelin, 1979). When forage becomes limiting, sheep are better able to maintain intake while grazing closer to the ground. This will put cattle at a disadvantage (Walker, 1994). Luginbuhl et al. (1999) found that goats were able to meet their requirements from multiflora rose (*Rosa multiflora*) and other invasive species. Goat selection of these species resulted in an increase in grass and clover species that benefited the cattle.

Performance of grazing species when grazing together is usually enhanced compared to when these species are grazing separately. In some areas output per unit area has been greater than with single-species grazing (Bennett et al., 1970). Mixed grazing with cattle resulted in earlier weaning and increased lamb performance and body condition in ewes compared to sheep grazing singly. Cattle performance in that study was not affected by the addition of sheep (Abaye et al., 1995). Marley et al. (2006) also found that live weight gains by lambs were also higher when grazed in combination with cattle. A summation of mixed grazing research showed that when sheep were added to cattle operations, net productivity per unit area increased 24% whereas adding cattle to sheep resulted in a 9% increase (Walker, 1994).

In mixed grazing, the individual grazing behavior of a livestock species may cause a shift in botanical composition of the sward and thus benefiting the other species. The grazing preferences of each grazing species when mixed grazed may result in desirable changes in pasture botanical composition. Sheep prefer broadleaf species and legumes and the sward can become grass-dominant over time. As a result, the beneficial effects of sheep on herbage production from the mixed grazed sward can cause higher levels of herbage consumption by either sheep or cattle (Hodgson et al, 1987). The advantages to mixed grazing are greater where pasture composition is more complex and allow each grazing species to choose their vegetation preferences (Bell, 1970). Cattle grazing singly may result in swards increasing in levels of broadleaf species and browse over time unless such swards are managed with clipping or herbicide treatment. The addition of sheep or goats will allow such resources that may be undesirable to cattle to be more fully utilized. The addition of goats to cattle alone grazing practice where woody browse has become a problem is desirable. In New Zealand, relatively poor hill country pastures became clover dominant in two years after goat grazing. Goats selected a diet composed of browse and grass and exclude clover which would benefit either sheep or cattle (Smetham, 1990). Similar result was reported by Luginbuhl et al. (1996; 2000a). The addition of goats to cattle grazing resulted in a reduction of multiflora rose and honey locust and an increase in desirable grasses and clovers. Similarly, Harrington (1978) found that in Australian semi-arid woodlands, shrubs, forbs, and grasses were consumed evenly when goats, sheep, and cattle were present.

The Appalachian Mountain region is characterized as steep and rough terrain which renders it difficult to manage invasive browse species. In North Carolina, several experiments have been conducted with goats alone and in mixture with cattle to control woody shrubs and herbaceous weedy species. Result indicated that old pastures containing multiflora rose bushes and many other weeds grazed with goats and cattle became dominated with grass and clover after four years of grazing (Luginbuhl et al., 1999). The outcome was attributed to the grazing behavior of goats that preferably select grass over clover, prefer browsing over grazing, foraging on rough and steep land over flat, smooth land, and like to graze along fence lines before grazing the center of a pasture (Luginbuhl et al., 1996). Trees and shrubs, which represent poor quality roughage sources for cattle, because of their highly lignified stems and bitter taste, may be adequate in quality for goats. Goats do not mind the taste and benefit from the relatively high levels of protein and cell solubles in the leaves of these plants (Luginbuhl et al., 1996).

The narrow margins of profit for most single grazing species enterprises necessitate the development of methods to increase efficiency of forage use. Besides the advantages of improved vegetation utilization and animal performance, other advantages with mixed grazing include: weed control, improved animal health, reduced predation, greater net return, and reduced financial risk. Sheep and goats will eat vegetation that is undesirable by cattle and thus reduce the need for chemical and/or mechanical weed control inputs, particularly on rough land (Dabaan et al., 1997; Walker et al., 2006). Animal health may improve with mixed grazing. Internal parasites that are problematic for sheep and goats will not complete their lifecycle when ingested by cattle. Therefore cattle "clean" the pasture resource for sheep and goats (Southcott and Barger, 1975). Sheep and goats can bond with cattle and reduce the effects of predation. Greater net return and reduced financial risk may be possible as weed control and animal health inputs are reduced and the diversified enterprises allow the operation to sell more products at different times of the year (Walker et al., 2006). Disadvantages will include: larger investment in fencing, shelter, and management knowledge of different needs of stock.

Goat management

Growing market

The demand for goat products in the US has increased in recent years (Glimp, 1995). Supply to meet these needs is limiting within the country. Imports principally from Australia and New Zealand are increasing each year and has increased 139% from 1996 to 2005 (Shurley and Craddock, 2006). Continued evidence of an increase is domestic goat meat production and live weight prices have both increased 81% from 1996 to 2005 (Shurley and Craddock, 2006).

Three ethnic groups, Hispanic, Arabic (mainly Muslim), and Caribbean descent, are increasing and are responsible for this greater demand in goat. These populations principally reside in the eastern US with New York City, Detroit, Chicago, Miami, Baltimore, and Washington D.C. Los Angeles and San Francisco are cities in the western US with appreciable ethnic populations (Harwell and Pinkerton, 1995). Producers in the coal-mining region have a potential market opportunity that is created by newly establishing ethnic groups with food preferences different from the native residence.

Meat goat marketing is largely unstructured with most sales taking place on a per-head basis. It has been estimated that a majority of goat marketing is done by private treaty and that 20% of goat slaughter in the US is done privately (Glimp, 1995). Short seasonal increases in goat prices normally occur prior to certain holidays. The Easter holiday will show the sharpest increase but will only last for a short period. Ramadan and Christmas will have smaller peaks. Other holidays or events may include Fourth of July, Labor Day, and social barbeques. The Easter and Christmas market prefers a light-weight kid that is about 10 kg live weight but kids up to 18 kg are acceptable. Muslim demand is for a kid that weighs 20-30 kg that is not overly fat. Goat destined for Muslim markets must be slaughtered in Halal fashion. Hispanic demand varies across different weights with older goats accepted year round. A small goat “cabrito” may demand a premium as these are kids that weigh less than 10 kg and are used for special occasions. People of Caribbean descent prefer cuts that may be used in stews, soups, and jerky (Harwell and Pinkerton, 1995).

The opportunity is great for increasing goat production in the Appalachian region. The largest concentration of goats is found in the southern US, largely in Texas. However, large increases in herd numbers are occurring in Kentucky, Tennessee, Alabama, Georgia, Virginia, and the Carolinas (Shurley and Craddock, 2006). These areas are logical for increased marketing opportunities for goat as these areas contain abundant forage supply, long growing season, and a close proximity to eastern cities. Limitations in goat production for this region are fencing, predators, and health, namely internal parasites. Stocking rate and time of kidding are other important factors that need to be considered (Harwell and Pinkerton, 1995). Choosing an appropriate breed may also affect profitability (Luginbuhl, 2000b).

Goat breeds

Meat goat production until recent years has been small in the US. Mohair production using Angora goats was a more profitable enterprise but with the repeal of the Wool and Mohair Act in October 1993, that market has declined (Harwell and Pinkerton, 1995). The Spanish goat and crosses were considered the meat goat breed in the United States. The recent growth in the meat goat market has made it desirable to import meat goats from other countries with better growth and conformation. The Boer goat from South Africa and the Kiko goat from New Zealand are two recent breeds that have gained popularity in the US. Other breeds of goat of lesser importance include the dairy breeds and Pygmy (Luginbuhl, 2000b).

The Boer goat is a recent introduction into the United States and has met widespread popularity. Imported from South Africa in 1993, it has good conformation, docility, and meat producing capabilities (Luginbuhl, 2000b). With Boer goats, under favorable nutrition, weaning weights of 29 kg can be obtained in 120 days (Casey and Van Niekerk, 1988). As a result it has great potential in crossbreeding programs. However, greater utilization of this breed has been limited due to the expensive cost of acquiring purebred stock (Glimp, 1995).

The Kiko goat is another recent importation from New Zealand advertised as an animal with good growth and maternal characteristics. It was developed to withstand humid conditions, internal parasites, and be relatively low maintenance. Females are expected to kid and raise twins yearly (Batten, 1987). Results from Tennessee have indicated that the Kiko is tolerant to internal parasitism and foot problems resulting in increased longevity of does. Weaning crop is also high with 150% weaning percentage possible (Browning et al., 2004).

Spanish goats in the US have largely been selected by the theory of "survival of the fittest". Only recently has Spanish goats been selected for greater meat production as it was largely used for brush control and the resultant kid crop being an incentive (Luginbuhl, 2000b). It is credited as being descended from stock imported by European settlers. However, introductions of British dairy breeds and Angora have resulted in variations in type, color, and performance. Notable contribution of this type is that the Spanish goat is able to breed out-of-season, moderately parasite resistant, and does well in extensive conditions (Glimp, 1995; Browning et al., 2006).

Fencing and Predators

Fencing is an important aspect in goat production. The most common fencing types used for goats include: woven wire, barbed wire, and electric. Usefulness will depend on choice of management, livestock species present, and livestock use. Woven wire is generally the most effective and popular for goat fencing. It is, however, two to three times the cost of a 5 to 8 wire hi-tensile fence (Turner et al., 1997). A disadvantage to this fence type is that goats will sometimes get their head stuck between the stays but remedied by adding an electric offset wire about 25-50 cm from the ground to help deter the goat (Batten, 2003). Barb wire is not normally recommended but can be effective if wire is kept tight and spacings are kept close particularly below the animal's eye level. A 7 to 8 wire fence works well with the bottom wire at 8 to 10 cm from the ground to prevent digging from coyotes or dogs. This is a useful fence where fences are not checked often (Premier, 2007). Electric fencing is an effective option for containing goats and other livestock. Electric fencing produces a shock when animals touch the fence. When electric wiring is added to other types of permanent fencing, it will allow those fences to last longer by reducing animal pressure. Permanent fencing is constructed of hi-tensile, stainless steel, and aluminum wiring (Turner et al., 1997). To contain goats, a high voltage (> 4500 volts) is necessary at all times. Goats must be trained to electric fencing. It may accomplished by having a small area electric fenced and keeping the goats in the area for a week (Batten, 2003).

Predators are a major concern in small ruminant production. Common predators in the United States include wild dogs, coyotes, wolves, bears, and many others. Common methods of protecting flocks in the US include fencing, guard animals, night penning, lambing and kidding facilities, and direct predator control options. Where applicable, fencing is the most common method for inhibiting predators. Electric fencing has been considered an effective fence for predator control (Nass and Theade, 1988). Dogs, llamas, and donkeys are useful guard animals but each requires additional management needs required. Producers without guard dogs have shown lamb losses of up to 5.9 times those producers with guard dogs in Colorado (Andelt and Hopper, 2000). Night penning and birthing facilities require greater labor but are considered effective by more proactive and intensive management systems. Trapping, poisoning, contraceptive use, and shooting are predator control techniques (Knowlton et al., 1999).

Internal parasites and control strategies

Internal parasitism is the major limiting factor in small ruminant production. Severe infections cause losses in livestock gains, reproduction, immunity, and may cause death (Familiton, 2003). Internal parasites that infect the abomasum and small intestine are the greatest concern in small ruminant production. *Haemonchus contortus*, an internal parasite of the abomasum, is of greatest concern because it causes severe anemia and hypoproteinemia resulting in rapid loss in condition and possible death. In the southeastern US, eggs of *H. contortus* can account for 75–100% of the total fecal egg counts (FEC) in sheep and goats (Kaplan et al., 2004). Animals under stress, such as young animals at weaning and ewes/does in partition, are under the most risk for losses associated with internal parasites (Brunsdon, 1980).

Internal parasitism results in damage to the lining of the abomasum and small intestine. As a result, there are increases in plasma protein leakage, mucus secretion, and epithelial cell turnover (Sykes and Greer, 2003). There is a greater demand for amino acids, protein, and minerals in the gastrointestinal tract and reduced partitioning of these nutrients to other areas such as muscle and skin (Roy el al., 2003; McClure, 2003). The reduction in feed intake that is associated with parasitism will also reduce the availability of nutrients (Sykes and Greer, 2003).

Effective control of internal parasites has become more difficult recently. In the past, anthelmintic treatment was the most effective, easiest, and cheapest (Waller, 2006). However, continued use of anthelmintics has resulted in resistance issues worldwide and there is now know resistance to the three main chemical families (Terrill et al., 2001; Zajac and Gipson, 2000). The development of new anthelmintic drugs is expensive (>US$200 million) and as a result, new chemical options for the sheep and goat sector is limited (Waller, 1997).

The understanding and use of other strategies will need to increase in order for the sheep and goat production to be sustainable and efficient. Other strategies include using “safe” pasture, rotational stocking, and mixed grazing with non-susceptible species (Waller, 2006). Some plants that contain substances, such as condensed tannins, may play a role as a natural alternative to chemical anthelmintics (Min et al., 2003). Condensed tannins either have direct effects on internal parasite fecundity and/or egg hatching or indirectly by improving protein utilization in the animal (Min and Hart, 2003; Asquith and Butler, 1986). Sericea lespedeza, birdsfoot trefoil, and chicory are plant species containing condensed tannins that hold potential as natural anthelminitics (Shaik et al., 2006; Ramirez-Restrepo and Barry, 2005).

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CHAPTER III

THE INFLUNCE OF CATTLE GRAZING ALONE AND WITH GOATS ON FORAGE BIOMASS, BOTANICAL COMPOSITION AND BROWSE SPECIES

Abstract

Reclaimed mined-lands have been successfully used for forage production in the Appalachian region. However, the encroachment of undesirable invasive plant species reduces the utilization of these pasturelands by cattle and conventional control methods are not cost-effective. An experiment was initiated in spring 2006 at the Powell River Project near Wise, VA to determine the effects of mixed grazing goats with cattle on forage biomass, vegetation utilization and a shift in botanical composition. The three treatments were a no grazing control, cattle alone grazing, and mixed grazing goats with cattle. Treatments were arranged in a randomized complete block design with 3 replications of each grazing treatments and 2 of the untreated control. The treatment with cattle alone had three crossbred steers while the mixed grazing treatment utilized three crossbred steers and 15 young intact male goats. Forage biomass yield was determined in spring, summer and fall by clipping 8-0.25m² square quadrants per grazing treatment and 4-0.25m² in the control treatment to a 2.5 cm height. Prior to clipping, botanical composition and groundcover were assessed visually using the Double DAFOR scale. Autumn olive (*Elaeagnus umbellata* Thunb.) measurements included branch length, shrub height, and shrub survival. Eight shrubs were randomly identified and tagged with a letter in each treatment replication while four shrubs were used in the control treatment. On each tagged shrub, four branches were randomly tagged and numbered from ground level to 3 m. Branch length was determined by measuring from the branch base to tip. Shrub height was determined by using a clinometer from a distance of 10 m from the shrub. Shrub survival was determined by taking a count of shrubs present within a pasture and visually estimating the percent of leaf-covered canopy. In both experimental years, total forage biomass yield was greater for the control and cattle alone treatments. In 2007, forage growth was impacted by a late season frost and an extended drought. The grass component of the grazed pastures increased, weed content declined while the legume content was maintained at a low level. In our experiment, autumn olive was severely impacted by goat browsing. Shrub survival was lower in mixed grazing (61%) by the end of the experiment compared to over 90% for the control and cattle alone grazing treatments. These data indicate that mixed grazing cattle and goats is a viable practice

on reclaimed coal-mined lands. Mixed grazing resulted in greater utilization of pasture resources mainly due to the different grazing habits of goats and cattle offering opportunities for complementary pasture use.

Introduction

Post-mined land reclamation in the Appalachian coal region has resulted in successful establishment of pasture for beef cattle production (Gerken and Baker, 1997; Ditsch et al., 2006). However, maintaining desirable grasses and legumes on such sites requires appropriate grazing management, weed control, and occasionally fertilizer inputs. The steep topography that is characteristic of the region makes such operations difficult. The low fertility of the soils coupled with difficult topography has resulted in invasion of undesirable invasive plant species that reduce forage and cattle production of reclaimed coal-mined lands (Dove et al., 1997).

Invasive plant species are species that are able to reproduce and spread over large areas with few natural controls. They reduce plant diversity, forming monocultures that aggressively compete with native or more desirable plant species for nutrients and water (Swearingen et al., 2002; Miller, 2003). Invasive plant species are a problem in forests, pastures, and wetlands (Swearingen et al., 2002) and may contain physical or chemical characteristics that inhibit browsing or grazing by wildlife or livestock (Miller 2003). On reclaimed coal-mined pastures, autumn olive (*Elaeagnus umbellata* Thunb.), multiflora rose (*Rosa multiflora* Thumb.), and sericea lespedeza (*Lespedeza cuneata* (Dum.-Cours. G. Don)) are invasive plant species that hold potential for reducing pasture production. Autumn olive and multiflora rose shrubbery produce berries that are preferred by birds and may spread into pastures by seed in bird droppings (Miller, 2003). These species contain thorns that inhibit grazing by cattle. They also form thick stands that shade out desirable grasses and legumes. Sericea lespedeza, a warm season legume, has been utilized as a reclamation species on coal-mined lands as it is able to grow and tolerate the acidic, low fertility soils (Skousen and Zipper, 1997). It is grazed by cattle for a short period in early summer but as it reaches maturity it becomes woody and unpalatable. It also contains condensed tannins that taste bitter to cattle. Sericea lespedeza produces large biomass and shades out other grasses and legumes during the growing season. Leaf drop during fall and winter may also inhibit emergence of grass and legume seedlings in the next growing season (Dove et al., 1997).

Incorporating goats into existing cattle operations in this region may serve as a possible biological control for invasive plant species on these lands. Goats prefer browsing shrub species over grazing pasture and foraging on steep land over flat land. They consume plant species that contain bitter compounds, such as condensed tannins, that are unpalatable to cattle (Luginbuhl et al., 1995). The mixed grazing of goats with cattle is possible as each species selects for their preferred diet and competition between species for forage is minimal (Walker, 1994). Research in North Carolina has shown that mixed grazing goats with cattle has been successful in converting brush-infested pasture into a desirable mix of grasses and legumes beneficial for cattle. Luginbuhl et al. (1999) determined that mixed grazing goats with cattle was an environmentally friendly weed control option for multiflora rose. This species was reduced by 92% after four years of mixed grazing.

The current experiment was designed to compare the effects of mixed grazing (goats with cattle), cattle alone and a no grazing control on forage biomass yield, botanical composition, and nutritive value of pasture species present in reclaimed coal-mined pastures.

Methods and Materials

A grazing experiment was conducted during the 2006 and 2007 growing season at the Powell River Research and Education Center in Southwest Virginia (77° 43' 30" west longitude, 38° 57' 30" north latitude, elevation 155.5 m) to investigate the potential effects of mixed and cattle alone grazing on pastures infested with browse and weedy species established on reclaimed coal-mined lands. The experimental design was a randomized complete block design with pastures being the experimental unit. The three treatments included an no grazing control, cattle alone grazing, and mixed grazing goats with cattle. Three replicates were used for grazed treatments and two replicates for the control. Replicate paddocks for grazing were 1.8 ha each and control replicates were 0.2 ha each. Three steers (280 kg hd^{-1} ± 4.0 kg SE) were allocated to each grazing treatment. The stocking rate was based on 0.6 ha $steer^{-1}$. The mixed grazing treatment included 15 young intact male goats (20.3 kg hd^{-1} ± 2.5 kg SE). The assumption is that 1-2 goats per mature cow (1 animal unit) without a cost to existing cattle operations (Luginbuhl et al. 1995). The weight of the steers used equaled 0.6 animal units and in addition to large area of pasture covered in invasive browse species; five goats were added per steer. Animals were rotationally stocked among replicates by grazing one replicate for two weeks and then allowing 4 weeks rest. Water and trace minerals were provided free choice at all times. Animals were weighed three times during the growing season (spring, summer, and fall). Grazing was initiated on May 30 and ended on September 29 in 2006 for a total of 122 days. Animals were weighed in the mornings of May 30 (spring), July 31 (summer), and September 29 (fall) in 2006. Grazing was initiated on May 30 and ended on August 30 in 2007. Due to severe drought, animals were removed from treatment paddocks and grazed on adjacent pastures from July 13 to August 2. Total grazing days were 72 days in 2007. Animals were weighed on May 30, July 13, August 2, and August 30.

Pastures were evaluated for forage biomass, nutritive values, species diversity and effect of grazing on browse species during spring, summer, and fall of each grazing season. Forage biomass was determined by clipping 8-0.25m² square quadrants per grazing treatment and 4-0.25m² to a 2.5 cm height. Samples were dried in a forced-air oven at 105 ºC for at least 48 h. Results are presented on a dry weight basis. Prior to harvesting the forages within each quadrant, the area was visually evaluated by trained evaluators for botanical composition using the double DAFOR scale as described by Brodie (1985) and Abaye et al. (1997). The scale (D=dominant, A=abundant, F=frequent, O=occasional, and R=rare) is used to evaluate the relative abundance of species. Brodie (1985) described a species as dominant if most or all of the area is covered. A ranking of abundant would be given to species that cover about one half to three-quarters of the area. Frequent refers to species that are well scattered throughout the site but cover less than half the area. A species ranked as occasional occurs a few times and a rare species is one that is present only once or twice. Visual estimates of percentage ground cover and percentage of grass, legume, and weed species were also made.

Autumn olive measurements included shrub height, branch length, and shrub survival. Eight shrubs were randomly identified and tagged with a letter in each paddock in the grazing treatments while four shrubs were used in the control plot. On each tagged shrub, four branches were randomly tagged and numbered from ground level to 3 m. Shrubs were measured at spring, summer, and fall during each growing season. Shrub height was measured with a clinometer at a distance of 10 meters from the shrub. Branch length was measured with tape measure from the base to tip at the beginning and end of each sampling period (Oba and Post, 1999). Branch length was estimated as the difference between final branch length and initial branch length in each treatment during the sampling period. Total branch length was the sum of the results of the sampling periods of each year (Oba and Post, 1999). Branches that were broken or dead due to goat browsing were recorded. Shrub survival was measured in May and September 2007 by counting the number of shrubs or clumps surviving in each treatment. This procedure was modified from a technique used by Luginbuhl et al. (1999) on multiflora rose. Luginbuhl et al. (1999) visually estimated percent leaf out for multiflora rose as a means of determining survival. In our experiment, autumn olive shrubbery was visually estimated for percent of leaf-covered canopy. Shrubs without a leaf-covered canopy were given a survival value of 0, partially-covered shrubs a value of 50, and shrubs with a full canopy a value of 100.

Data were analyzed for all single effects and interactions using PROC GLM (SAS Institute, Gary, NC). Effect of treatment, block, season, and year were tested. Treatment by season, treatment by year, and treatment by season by year were also tested. Treatment effects were tested using the treatment by block interaction mean square as the error term. Significance was tested at the 5% level unless noted different.

Results

Weather

The total amount of rainfall in 2006 exceeded both 2007 and the 55-yr average (Figure 3-1). In May, June, August and September, the average rainfall exceeded the 2007 growing season and the 55 yr average while in July of 2006, average rainfall was the lowest compared with 2007 and the 55 yr average. The 2007 growing season was affected by severe drought and was drier than both the 2006 growing season and the 55-yr average. August of 2007 was the driest month compared to the 2006 growing season and the 55-yr average. The total amount of rainfall from May – August was 50.9 and 33.8 cm for the 2006 and 2007 growing seasons, respectively. The total amount of rainfall received in 2007 was 17 and 10 cm less than that of 2006 and the 55 yr average, respectively. In 2006, the average temperature was much cooler than the 2007 and 55-yr average (Figure 3-2). Overall, for the two experimental years, temperature fluctuation was less evident than rainfall.

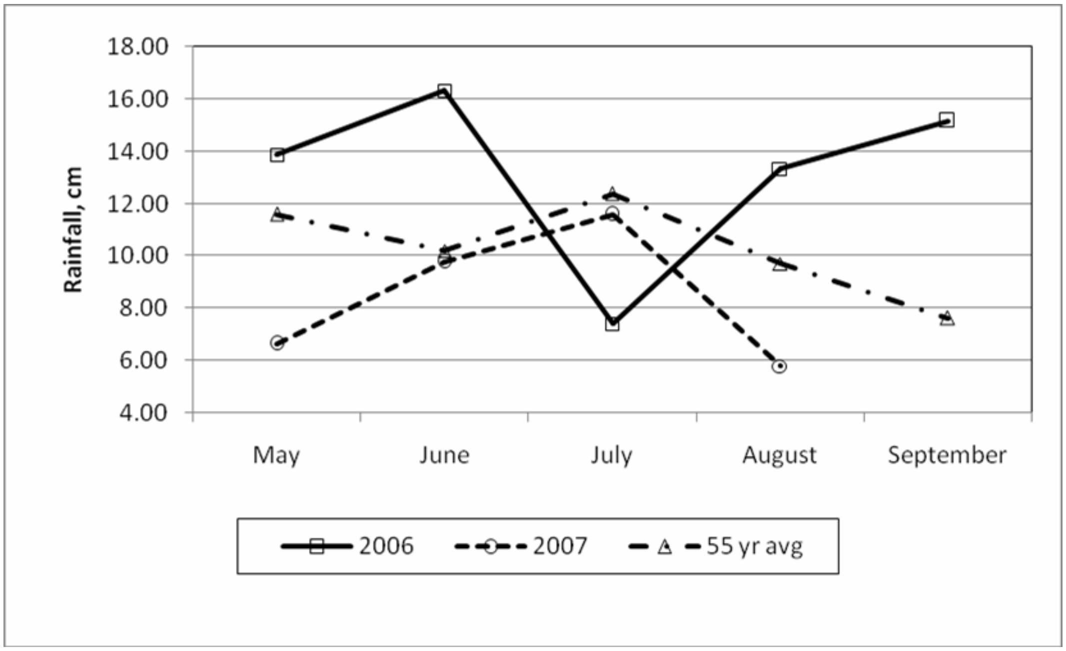

Figure 3-1. Average precipitation (cm) for Wise, VA, for the two experimental years.

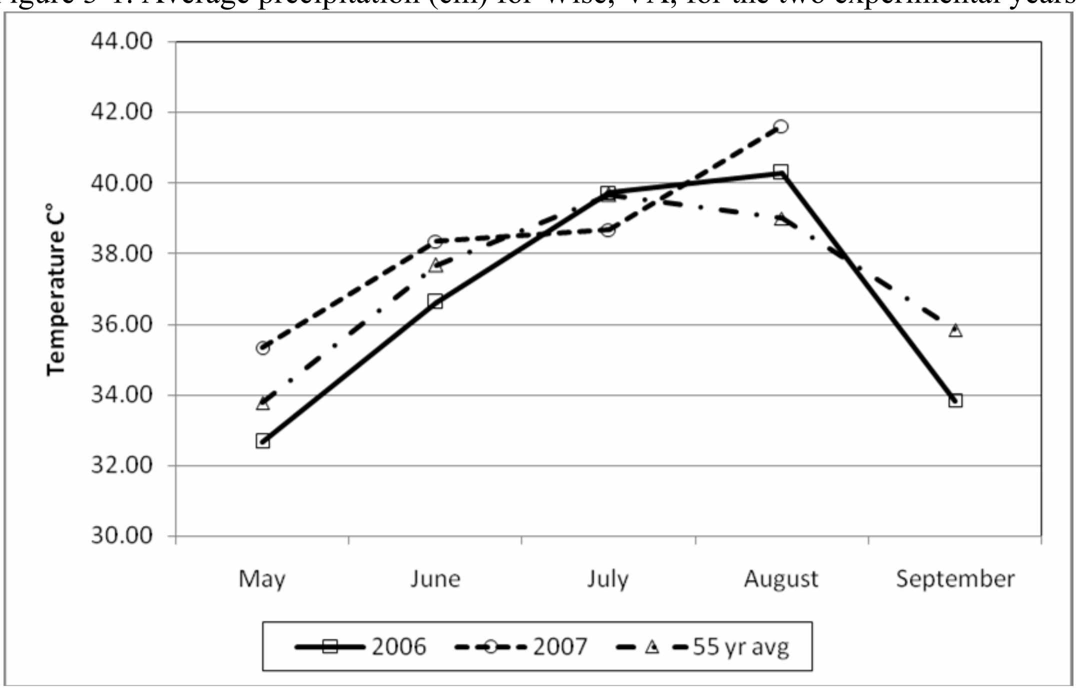

Figure 3-2. Average temperature (C°) for Wise, VA, for the two experimental years.

Forage Biomass Yield and Distribution

Forage biomass was influenced by year (P < 0 .01) and season (P < 0.1). There were year x treatment and date x treatment interactions for the experimental years (P < 0.01). Also, there was a year x treatment x date interaction (P < 0.01). Therefore, data is presented by year and season.

Overall, there were differences in average yearly forage biomass for the control and cattle alone grazing but not for mixed grazing (Figure 3-3) (P < 0.01). Forage biomass in the control and cattle alone grazing were 2233.3 and 729.8 kg/ha lower, respectively, in 2007 compared to 2006.

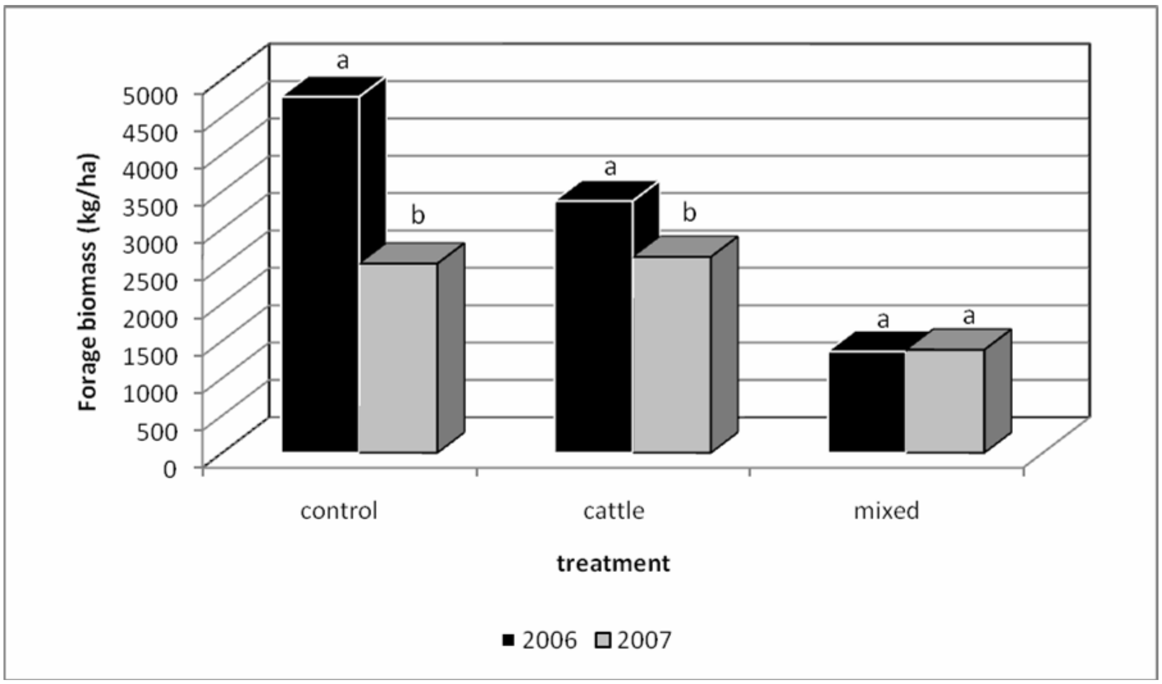

Figure 3-3. Influence of cattle alone and mixed grazing vs. no grazing control on total forage biomass by year (values followed by same letter not significant at P = 0.05)

In 2006, initially, forage biomass was similar among treatments (Figure 3-4). In summer, however, forage biomass was high in control, intermediate for cattle alone grazing and lowest for mixed grazing (P < 0.05). In the fall, forage biomass declined for all treatments. The rate of forage biomass decline was more evident in pastures where cattle grazed in mix with goats compared to cattle alone or control (Figure 3-4). The seasonal forage distribution curve for control and cattle alone grazing (Figure 3-4) reflected a warm-season forage distribution curve where most of the forage is produced during the summer months.

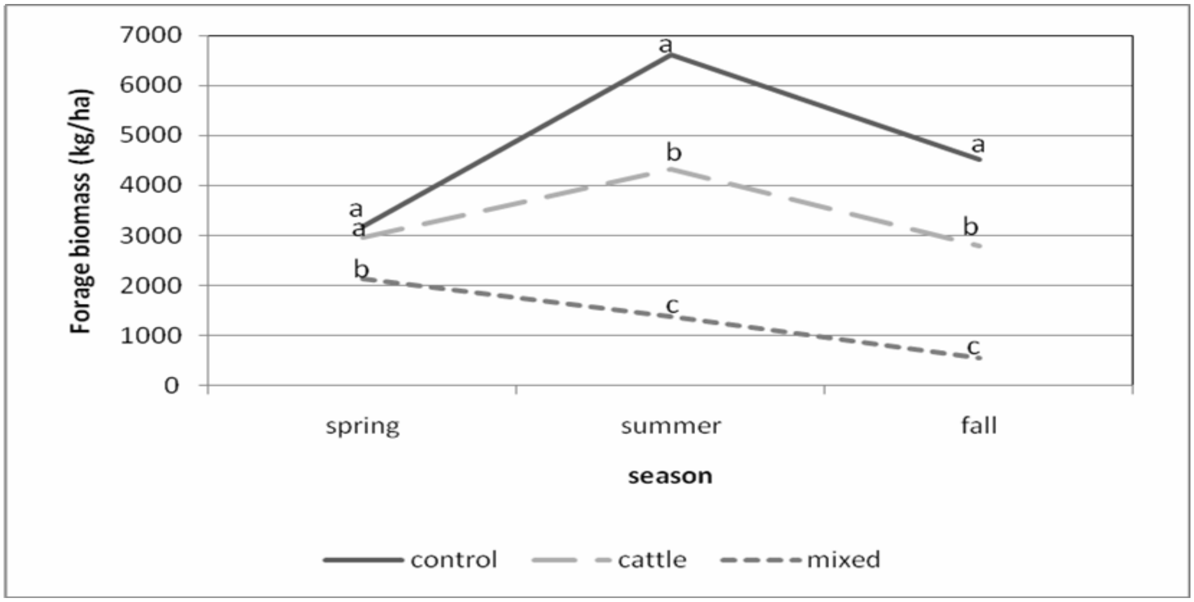

Figure 3-4. Seasonal distribution of biomass for control, cattle alone, and mixed grazing in 2006 (values followed by same letter not significant at P = 0.05 within season)

Figures 3-5 show the grass, legume, and weed components of the total biomass for the control, cattle alone, and mixed grazing treatments for the year 2006. Initially (spring) biomass yield of the control and cattle alone grazing treatments had similar composition of grass, weed and legume. Grass and weed contributed by near equal amounts to the biomass in mixed grazing but legume contributed the least. In summer, however, weeds (mostly sericea lespedeza) made up the largest proportion of the biomass in all treatments ($P < 0.05$). In the fall, weed and cool-season grasses accounted for the majority of the yield component in the control (Figure 3-5 – Control) and cattle alone treatments (Figure 3-5 – Cattle alone) while the legume component contributed the least amount to the biomass yield ($P < 0.05$). In mixed grazing treatment, the grass component made the majority of the biomass with legumes and weeds contributing only a fraction of the yield ($P < 0.05$) (Figure 3-5 – Mixed grazing).

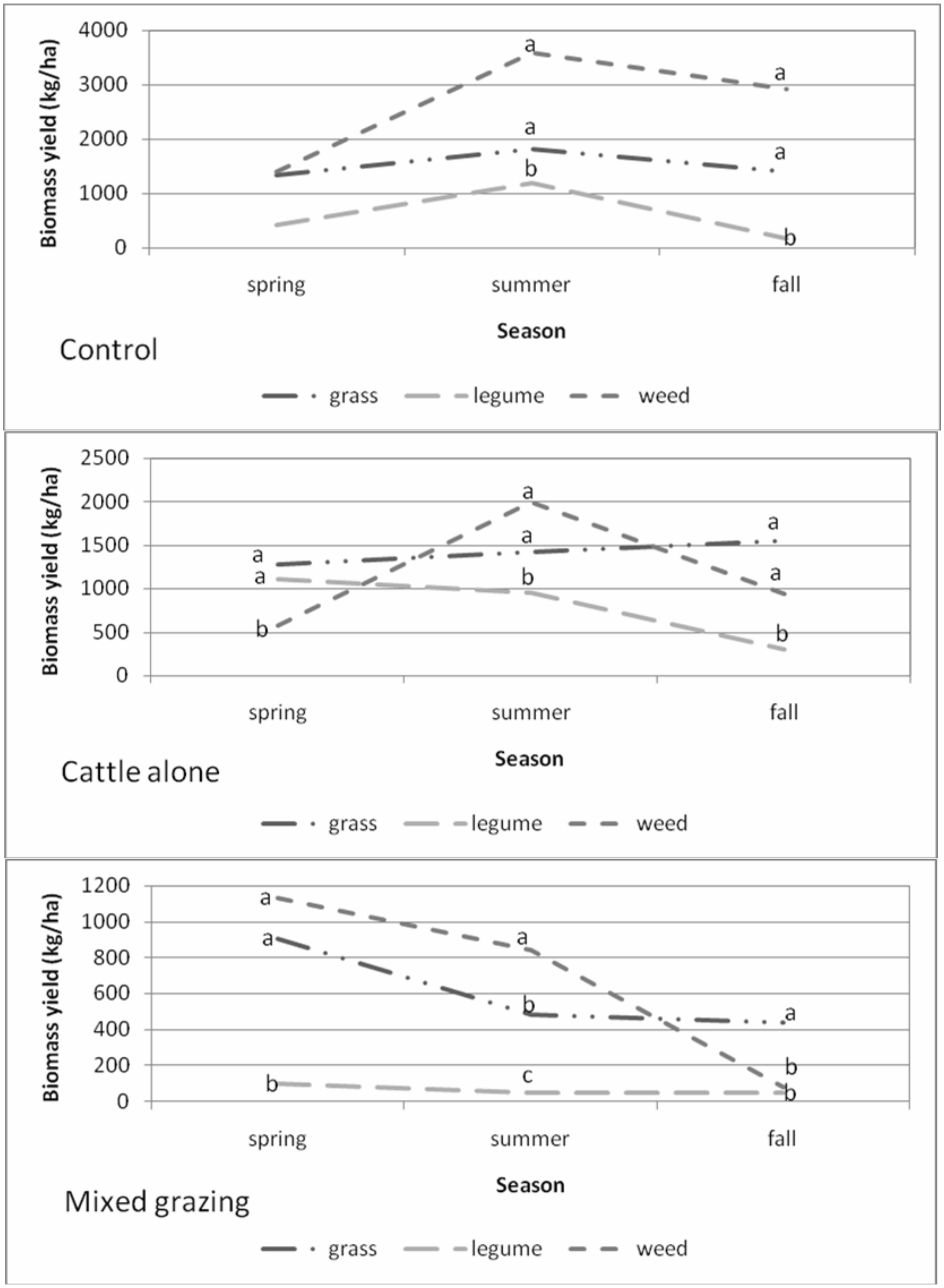

Figure 3-5. Forage biomass yield and its components for the control, cattle alone, and mixed grazing treatments in 2006.
(values followed by same letter not significant at P = 0.05 within season)

Forage biomass during the 2007 growing season was negatively impacted by the dry conditions that prevailed over much of the growing season (Figure 3-6). Forage biomass was similar for control and cattle alone grazing but was lowest in mixed grazing for all sampling dates. By summer, the decline in forage biomass was 42 and 61% in cattle alone and mixed grazing treatments, respectively (Figure 3-6). Due to the less than optimum available forage driven by the severe drought, animals were removed from pastures much earlier than the previous year. Seasonal distribution in 2007 followed that of a cool-season grass, highest in spring, declining in summer, and increasing in fall.

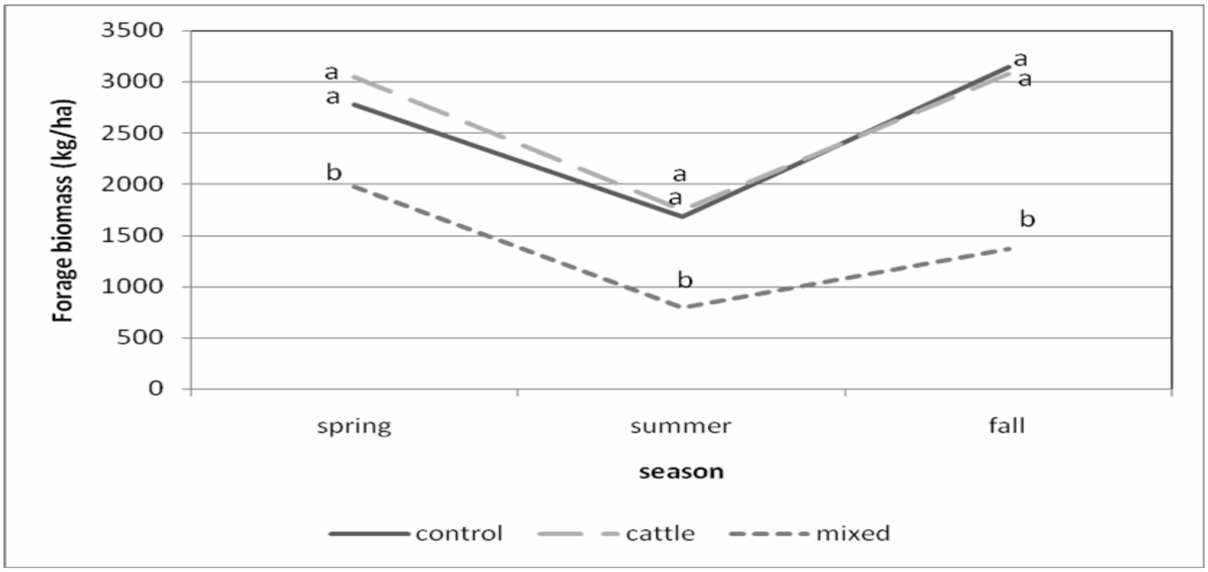

Figure 3-6. Seasonal biomass distribution for control, cattle alone, and mixed grazing in 2007. (values followed by same letter not significant at P = 0.05 within season)

In 2007, cool-season grasses made up the significant portion ($P < 0.05$) of the forage biomass for all treatments (Figures 3-7) in spring and summer. Unlike 2006, the growth and re-growth of the warm-season species (mainly weeds) was much slower in all treatments and thus ended up contributing less to the total biomass yield. In the control, weeds accounted for over 35% of the forage biomass with the remainder being cool-season grasses by the end of the growing season (Figure 3-7 – Control). By the end of the season, both grazing treatments had acceptable lower levels of weeds. Legumes contributed the least to the forage biomass for all treatments throughout the growing season ($P < 0.05$).

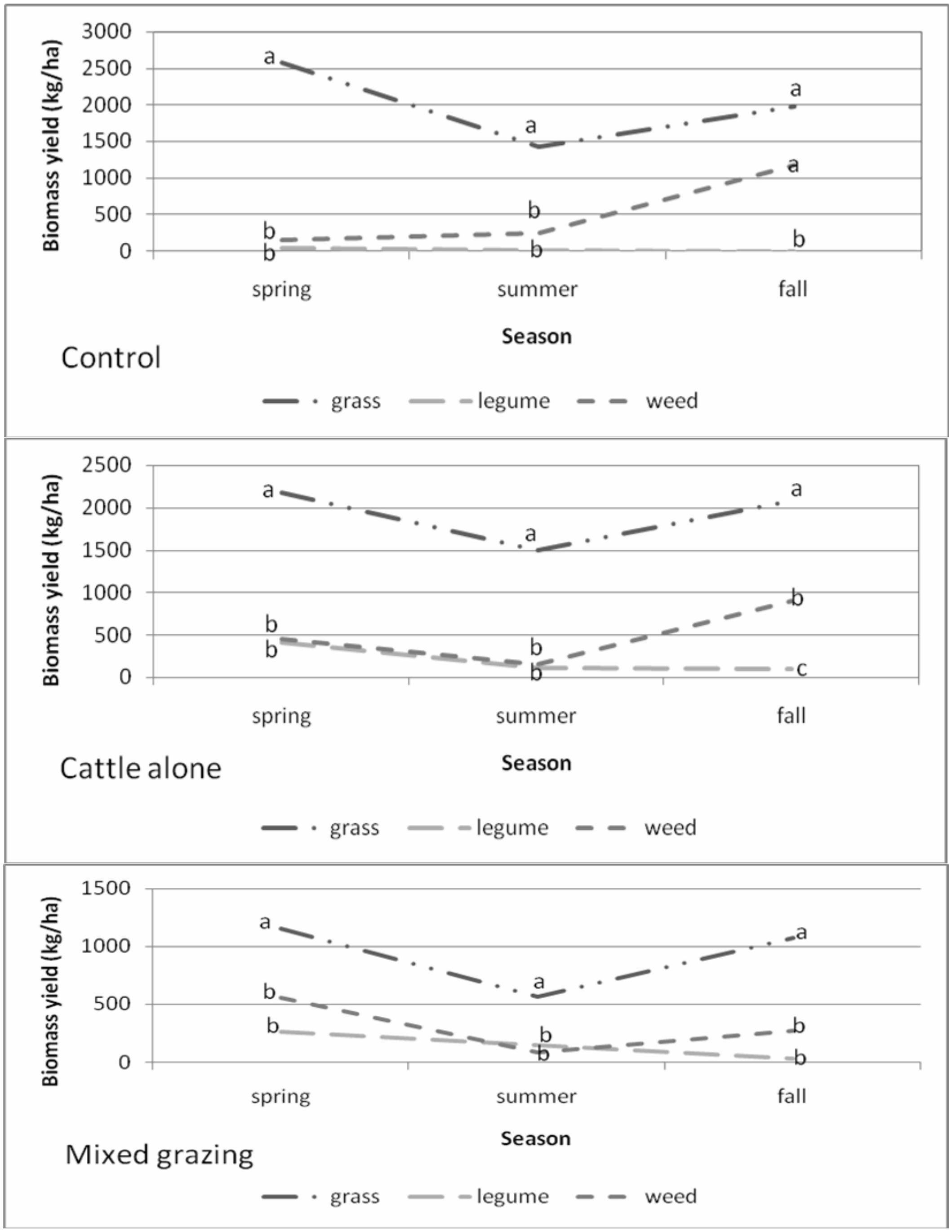

Figure 3-7. Forage biomass yield and its components for the control, cattle alone, and mixed grazing treatments in 2007.
(values followed by same letter not significant at P = 0.05 within season)

Changes in Autumn Olive Branch Length

Autumn olive branch length showed treatment and year effect ($P < 0.001$). There were also treatment x year interaction ($P < 0.01$), period ($P < 0.001$), and treatment x period x year interactions ($P < 0.001$). Therefore, data is presented by year and season. For 2006, there were significant differences in branch length during the spring-summer period ($P < 0.1$) (Figure 3-8). The growth difference in branch length was highest for cattle alone grazing, intermediate for control, and lowest for mixed grazing. During the summer-fall period, cattle alone grazing and control showed no differences but mixed grazing remained lower. Goats were observed to chew the tips of branches if branch tips were slender and tender. Therefore, during the summer-fall period, goat browsing branch tips had a negative impact on branch length. At season's end, the control and cattle alone grazing showed no significant differences but mixed grazing was very low ($P < 0.05$). Branch length growth was reduced by 82% in mixed grazing compared to the other treatments. In 2007, there were no significant differences among treatments at any point during the season ($P < 0.05$). One possible reason for the lack of differences during this growing season could be that autumn olive may go into dormancy during dry periods. However, little research has been done on autumn olive to prove this. Autumn olive growth was reduced in 2007 compared to 2006 (Figure 3-9).

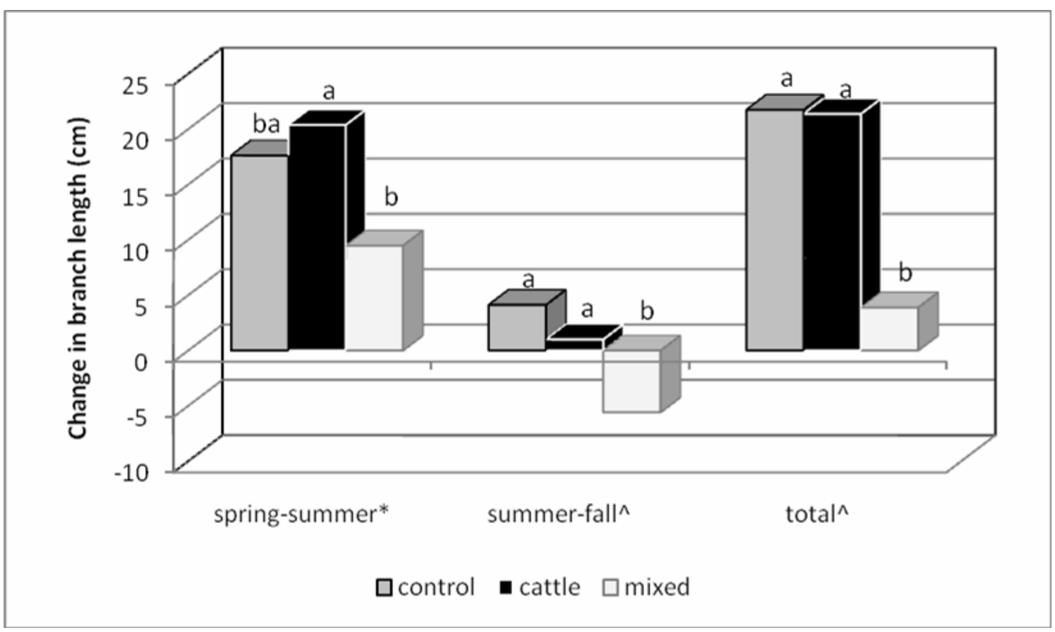

Figure 3-8. Influence of cattle alone and mixed grazing vs. no grazing control on seasonal and total change of branch length (cm) of autumn olive for 2006
(values within season followed by the same letters not significant at $P = 0.05$)

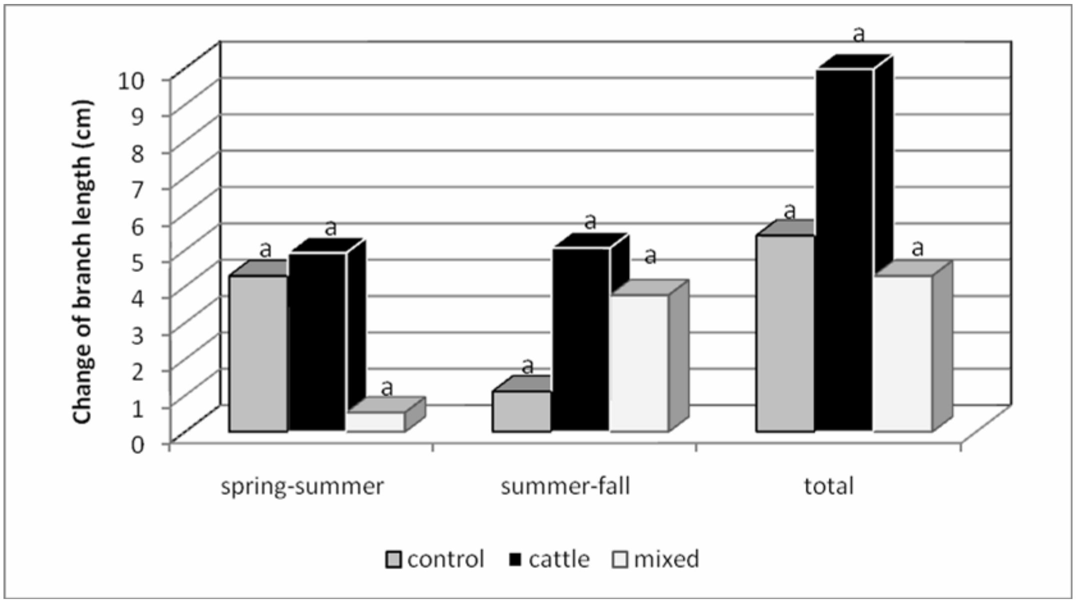

Figure 3-9. Influence of cattle alone and mixed grazing vs. no grazing control on seasonal and total change of branch length (centimeters) of autumn olive for 2007 (values within season followed by the same letters not significant at $P = 0.05$)

Changes in Autumn Olive Shrub Height

Autumn olive shrub height data showed year effect ($P < 0.09$), period effect ($P < 0.05$), and treatment x period x year interaction ($P < 0.09$). In 2006, there were no differences during the spring-summer period among treatments. During the summer-fall period, mixed grazing was significantly lower than other treatments ($P < 0.1$) (Figure 3-10). There were no differences in shrub height at the end of the 2006 growing season. In 2007, autumn olive height was highest in cattle-only grazing, intermediate in mixed grazing and lowest in the control for the spring-summer period (Figure 3-11). There were no significant differences between treatments during summer-fall period and for the growing season's total.

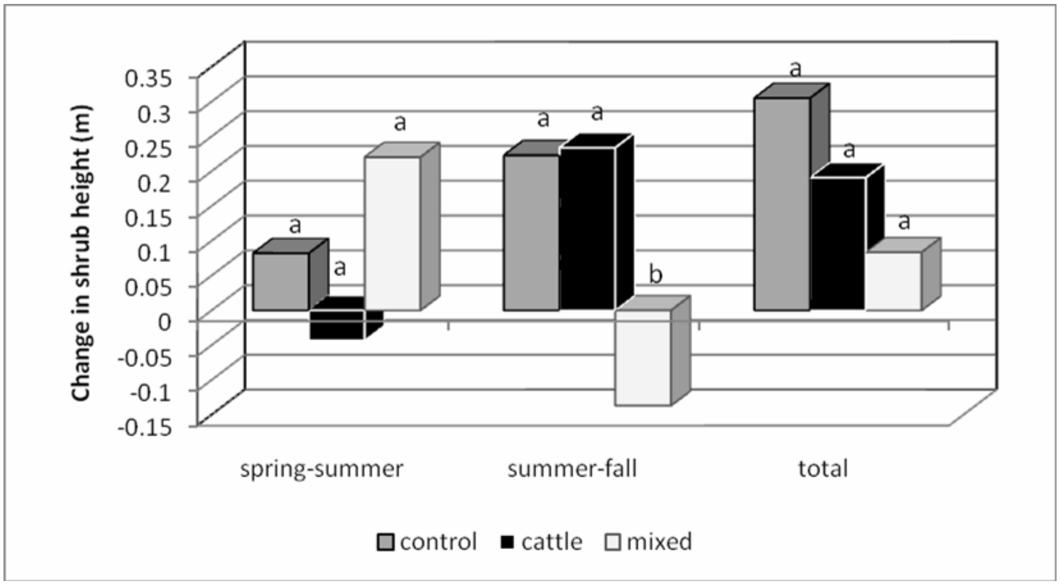

Figure 3-10. Autumn olive shrub height (meters) for control, cattle alone, and mixed grazing in 2006
(values within season followed by the same letters not significant at P = 0.05)

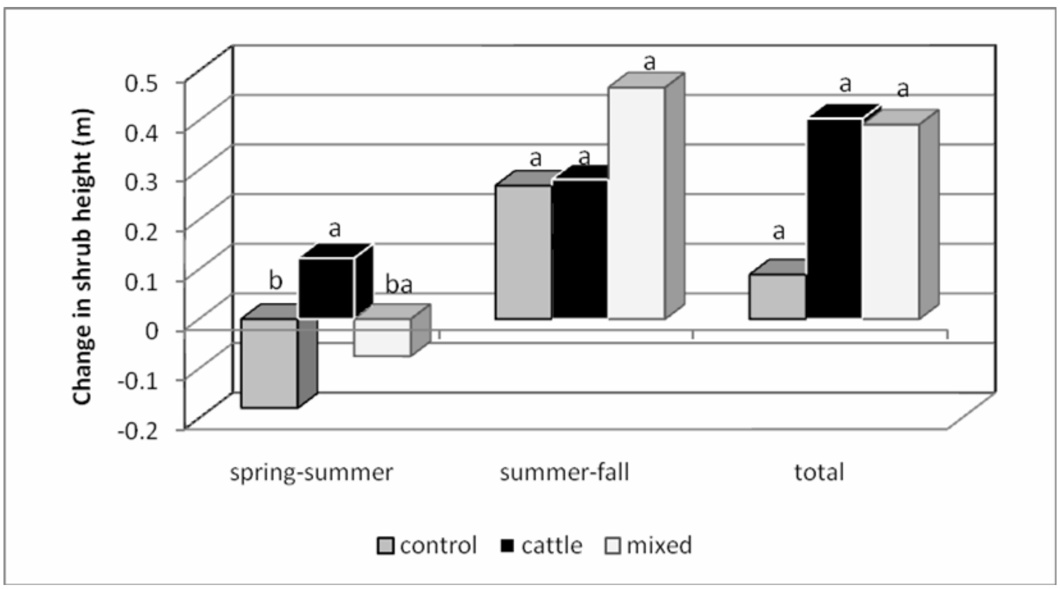

Figure 3-11. Autumn olive shrub height (meters) for control, cattle alone, and mixed grazing in 2007
(values within season followed by the same letters not significant at P = 0.10)

Autumn Olive Shrub Survival

There were no data on autumn olive shrub survival in 2006. It was assumed that goat browsing would have an effect on autumn olive growth but not kill autumn olive shrubbery within the first year. However, goat browsing coupled with late spring frost in 2007 resulted in autumn olive shrub losses. There were treatment, date, and treatment x date differences (P <

0.001) (Figure 3-12). On May 18, the control and cattle alone grazing showed no differences in autumn olive survival. However, only 73% of autumn olive shrubbery survived the first year whereas essentially no losses were found in the control (100%) and cattle alone grazing (98.9%) ($P < 0.05$). This was also true on September 21st as only 61% of autumn olive survived in the mixed grazed treatments. There were no differences between control (98.5%) and cattle alone grazing (92.8%) ($P < 0.05$). There was also a difference between dates for cattle alone grazing and mixed grazing but no difference for control.

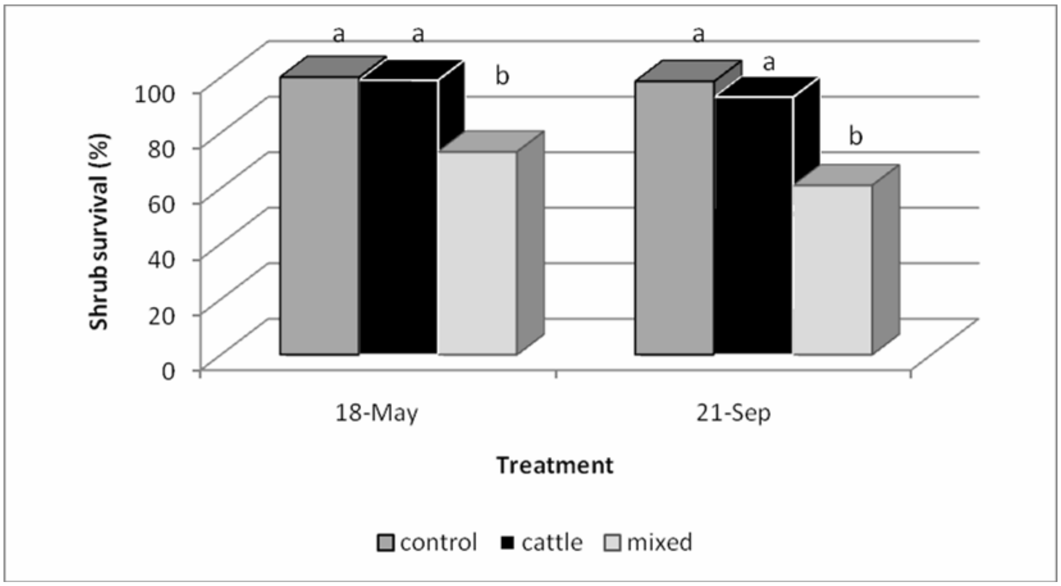

Figure 3-12. Autumn olive shrub survival of control, cattle alone, and mixed grazing (values within season followed by the same letters not significant at P = 0.05)

Discussion

Forage biomass was generally impacted by grazing treatments. In 2006, after the initial harvest, forage biomass in pastures occupied by cattle and mixed animal species was less than the untreated control. The forage biomass in the control was not grazed and thus reflects accumulated growth. The forage distribution curve in the control and cattle alone grazing resembled that of a warm-season forage. Sericea lespedeza and other warm-season weeds made up a large portion of the forage biomass yield and these species have a productive growing season from late May to October (Ball et al., 2007). Goats were observed to consume sericea lespedeza and other weed species readily and may have reduced forage biomass yield. However, in mixed grazing, the forage distribution curve was not well-defined and forage biomass yield declined to low levels.

Forage biomass yield was less in 2007 compared to 2006 due to the unfavorable growing conditions. In the control and cattle alone grazing pastures, biomass yield was reduced by over 2200 and 700 kg/ha, respectively. The lower than normal rainfall in 2007 is the likely cause. Drought conditions can be especially stressful on pasture production on reclaimed coal-mined lands as the soils typically have low moisture-holding ability (Ditsch et al., 2006). Additionally, the late spring frost that occurred in 2007 may have negatively impacted the growth of sericea lespedeza and other warm-season forbs that made up a large component of forage biomass in 2006.

In both years, mixed grazing resulted in lower forage biomass yields compared to the other treatments. Contrary to our results, Prosser (1995) and Meat and Wool NZ (2007) reported no impact or an increase in biomass due to mixed grazing (goats + cattle). The decline in forage biomass yield in the mixed grazing treatment in our experiment could be attributed to the high preference for sericea lespedeza exhibited by goats. Similar observation was made by Hart (2001) where he stated that sericea lespedeza was preferred by goats and invasive stands of sericea lespedeza could be nearly eliminated in 3 years.

In our experiment, the decline in sericea lespedeza, which was the most dominant weed species where cattle and goat grazed can be attributed to two factors: 1) goats grazing sericea lespedeza maintained the plant in a vegetative stage that in turn was acceptable to cattle thus contributing to its scarcity in the pastures; 2) the morphological and physiological characteristics of lespedeza is such that close and frequent grazing as was done by goats would have affected the stand persistence. Similar observations was made by Hoveland et al. (1975a) where they stated that maintaining good stands of sericea lespedeza is dependent on cutting height, rest period, and final harvest date. In Alabama, when sericea lespedeza was cut down to stubble heights of less than 20 cm and at intervals of less than 9 weeks, stands declined. Further declines were noted when the harvest date was in October. When harvest occurs late in the year, sufficient recovery of energy storage in the taproot is lower and affects plant vigor the next growing season (Hoveland et al., 1975a). As was observed in our experiment in the mixed grazed treatment, these tap-rooted weed species do not maintain a favorable groundcover when grazed short and frequently.

Unlike the weed component which declined over the experimental years, the grass component of the pastures were increased at best or maintained in the grazing treatments. The persistence of grasses in the mixed grazed treatment can be in part attributed to the grazing behavior of goats which is to graze a sward from top to bottom and thus reduce the shading of grasses and allow tillering (McCall and Lambert, 1987). Similar results were obtained by Luginbuhl et al. (2000) where grass frequency increased and broadleaf weeds decreased under mixed grazing goats with cattle. In the control treatment, grass content by the end of both growing seasons was either lower or equal to the weed component in yield. Reduced grass content was observed in Alabama where tall fescue and orchardgrass was managed in a mixture with sericea lespedeza for hay production (Hoveland et al., 1975b).

The legume component which was mostly clovers of the pastures was affected by the grazing treatments. Over the two experimental years, the legume content (clover) of the control treatment was not measurable. Blaser et al. (1986) stated that clover can be lost from the sward if it is shaded by grasses and weeds. The clover content of the grazed pastures was maintained or improved during the two experimental years. In cattle alone grazing, clover was more or less stable during the first growing season but declined by the end of the second grazing season. Cattle tend to select clover over grass when grazing (Ball et al., 2007). Furthermore, the reduction in clover content of the cattle pastures can be attributed to shading by grasses and weeds that resulted from spot grazing by cattle (Ball et al., 2007). In mixed grazing treatment, an increase in clover content of the pastures was observed throughout the study except in fall 2007. In our experiment, pastures were uniformly utilized by the mixed grazing treatment compared where cattle grazed alone. Close, frequent grazing impacted weeds and grass growth and may have opened the sward; allowing more light penetration into the base of the sward and thus potentially increasing the persistence of the lower growing clover (Blaser et al., 1986). Also goats have been reported to select browse and grass species over clover (Luginbuhl et al., 1995). Similar to our results, Smetham (1990) reported an increase in clover content of the sward and reduction in browse species where goats grazed shrub-infested hillsides in New Zealand over two grazing seasons.

In our experiment, the effect of goat browsing on the survival of autumn olive shrub was evident. The reduction in autumn olive shrubs where goats grazed can be attributed to the browsing pattern of the goats. When browsing, goats will stand on their hind legs and hold down branches with their weight for easy access to leaves and twigs. When a goat bends down a branch, other goats in the herd may also gather around the branch for a meal. A branch can be completely defoliated within a short period. As a result of this browsing behavior, a browse line may develop on shrubbery. In our study, we observed an average browse height of 205 cm. This was higher than the 150 cm reported for free-ranging goats browsing *Acacia tortilis* in Kenya (Oba and Post, 1999). Browsing height is likely influenced by the size of the goat. Branches were broken and killed at times, as branches became brittle from excessive browsing. As forage became limiting at the end of the growing season, goats began to strip bark on shrubs. This bark stripping can girdle and kill the shrub. This is similar to findings in New Zealand as goats were observed to strip bark from gorse (*Ulex europaeus*) (a leguminous shrub) and eventually eliminate this shrub in 4 yr of heavy browsing (Field and Daly 1990). Another cause for autumn olive loss may be that browsing the shrubbery late in the growing season can cause a reduction in energy storage in the roots needed for winter survival. Loescher et al. (1990) stated that late summer and autumn pruning of fruit or timber tree species resulted in decreased carbohydrate storage in the roots and lower production the following year.

Despite these severe and excessive browsing, autumn olive illustrated a degree of resiliency. After hard browsing and branch death, the shrub would occasionally produce numerous suckers from the base of the plant. This lush growth was highly preferred and accessible to goats. Even cattle were observed to occasionally browse on this lush growth. Luginbuhl et al. (2000) observed that cattle would browse black locust (*Robina pseudoacacia*). He stated that cattle when given opportunity or need would browse and become opportunistic browsers. Another observation of the resiliency of autumn olive was that when allowed a rest for a period of 4-6 wk, leaves would regrow to the size prior to browsing. Although considered as invasive species, the feed value of autumn olive would warrant it to be managed as a possible continual forage source for goats. Additionally, with autumn olive being a non-leguminous nitrogen fixer, it could possibly improve nitrogen cycling on reclaimed coal-mined areas. A similar suggestion (maintenance of invasive browse species in pastures) was presented for gorse (another nitrogen fixing shrub)-infested pastures in New Zealand but has not met wide-spread acceptance with producers (Field and Daly, 1990).

In our experiment, we observed a reduction in seed production from autumn olive shrubs as a result of goat browsing. Goats were observed eating seeds when it was accessible and thus could possible reduce the seed bank of autumn olive. Goats have been shown to reduce the seed production of sericea lespedeza as well (Hart, 2001). A reduction in seed production was most noticeable in 2007 but the loss in bud formation due to the late spring frost may have been responsible as is possible in fruit trees (Rodrigo, 2000).

Goats generally did not have much influence on autumn olive height. This was in agreement with the findings of Oba and Post (1999) in Kenya. Luginbuhl et al. (2000) found a reduction in multiflora rose height in North Carolina where goats and cattle grazed on steep mountainsides. Multiflora rose height was controlled in mixed grazing (0.6 m) but increased in cattle-only grazing (1.8 m) and no grazing control (2.5 m). Canopy area of multiflora rose was also reduced by mixed grazing (0.5 m^2) but increased in cattle-only grazing (0.6 to 7 m^2) and no grazing control (0.5 to 11 m^2). However, the finding of Luginbuhl et al. (2000) can not be directly compared with our results since the growth habit and pattern of multiflora rose differs from autumn olive.

Conclusions

Mixed grazing of goats with cattle can have positive influences on botanical composition and invasive plant species control on reclaimed coal-mined lands in the Appalachian region. When compared to control and cattle alone grazing, forage availability was lower for mixed grazing over the entire grazing season. Groundcover percentage tended to be lowest for mixed grazing particularly during the summer season. Goats showed a clear preference for browse species and forbs such as sericea lespedeza. The grazing behavior of goats influenced the growth pattern of sericea lespedeza from an erect, woody, less leafy plant to a shorter, more palatable, and more leafy plant. The shorter and leafier sericea lespedeza was more acceptable and thus was readily grazed by cattle. In 2006, grazed treatments resulted in a reduction in undesirable weedy species. Furthermore, by the end of the 2007 grazing season, the grazing treatments reduced the weed percentages below 30%. By the end of the two grazing seasons, the grass component of the grazed pastures increased while legumes particularly clovers declined. The change in botanical composition of the pastures due to grazing can be attributed to the grazing pattern and diet preference of the grazing animals. The grazing behavior and diet selection of goats greatly differs from cattle. This makes the mixed grazing of cattle and goats an alternative management technique for managing diverse pasture swards.

Goat browsing had negative impact on autumn olive shrubbery. In 2006, branch length was negatively impacted by goat browsing but not in 2007. Differences in autumn olive height showed differences in summer-fall period 2006 and spring-summer period 2007 but no differences in shrub height at the end of the growing seasons were noted. Shrub survival was lower in mixed grazing (61%) by the end of the experiment compared to the other treatments. Standing on their hind legs and placing their weight on branches resulted in the development of a browse line, broken, and dead branches. Bark stripping and girdling further crippled autumn olive shrub vigor.

Mixed grazing goats with cattle is a viable practice on reclaimed coal-mined lands. It resulted in greater utilization of pasture resources mainly due to the different grazing habit of goats and cattle offering opportunities for complementary pasture use. Goats provided biological control for invasive plant species, such as autumn olive. Therefore, goats could have a major role in low-input farm enterprises in the Appalachian coal-mining region. These results suggest that goats and cattle grazing together in botanically diverse pastures could maximize the efficiency of utilization of both herbaceous and woody species.

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CHAPTER IV

ASSESSING THE EFFECT OF CATTLE GRAZING ALONE AND WITH GOATS ON BOTANICL COMPOSITION AND RELATIVE PLANT ABUNDANCE OF PASTURES ESTABLISHED ON RECLAIMED COAL MINED LANDS

Abstract

The grazing behavior of animals can have a profound impact on the botanical composition, production, and persistence of plant species. A grazing experiment was conducted on reclaimed coal-mined lands during the 2006 and 2007 growing season at the Powell River Research and Education Center in Southwest Virginia. The objectives of the experiment were to compare the effects of mixed grazing cattle and goats, cattle alone and a no grazing control on shifts in pasture botanical composition and relative plant abundance. Experimental design was a completely randomized design with three replications for the grazed treatments and two replications for the no grazing control. Three times during the grazing season, changes in botanical composition of swards were determined by visual assessment of permanent observation points using the double DAFOR. The grazing treatments influenced percentage groundcover, grass, legume and weed. Generally, the mixed grazing treatment had less groundcover, more grass, less weed and maintained a reasonable amount of clover. Our results indicated that grazing was essential for maintaining weeds at low levels in pasture. Our two year research showed that mixed grazing by cattle and goats, can improve the overall utilization of pasture by reducing undesirable and increasing the more desirable species.

Introduction

The diversity of pasture plant species can have an impact on the grazing behavior and performance of livestock (Chapman et al., 2007; Soder et al., 2007). In turn, the grazing behavior of animals also can have a profound impact on the botanical composition, production, and persistence of plant species present in pasture swards (Walker, 1994; Soder et al., 2007). Mixed grazing is the practice of adding two or more livestock species to a given land area at some point in the same growing season (Walker, 1994; Allen and Collins, 2003). The practice of mixed grazing with different foraging behaviors and preferences may increase the utilization and product output per unit land area (Allen and Collins, 2003). It may also convert and maintain pasture botanical composition at levels that are beneficial to one or all classes of grazing animals present (Walker, 1994).

The benefit from mixed grazing of different animal vs. single animal species is dependent on diet selection overlap between the animal species and the vegetation resource of the pasture. It is largely understood that grazing animals select for leaf in preference to stem and young in preference to old plant materials (Ball et al., 2007). Cattle, sheep, and goats will selective graze for green material but will do so by selecting preferred plant species. On a year-long basis, the diets of cattle, sheep, and goats will be 70, 50, and 30% grass; 15, 30, and 10% forbs; and 15, 20, 60% browse, respectively (Walker, 1994). Cattle and goats have the least dietary overlap as they will select for very different vegetation types. Luginbuhl et al. (1999) found that goats were able to meet their requirements from multiflora rose (*Rosa multiflora* L.) and other invasive species. Goat selection of these species resulted in an increase in grass and clover species that benefited the cattle. Other research has indicated that clover content improves in pastures grazed by goats as they actively reject this forage (del Pozo et al., 1997; Soder et al., 2007). Subsequently, animal performance of cattle and sheep are often improved by grazing goats with these species (del Pozo et al., 1998).

Methods and Materials

A grazing experiment was conducted on reclaimed coal-mined lands during the 2006 and 2007 growing season at the Powell River Research and Education Center in Southwest Virginia (77° 43' 30" west longitude, 38° 57' 30" north latitude, elevation 155.5 m) to investigate the potential effects of mixed grazing goats with cattle or cattle alone grazing on pastures infested with browse and weedy species. The three treatments included a no grazing control, cattle grazing alone, and mixed grazing goats with cattle. Three replicates were used for cattle alone and the mix grazed treatment and two replicates for the control. Replicate paddocks for grazing were 1.8 ha each and control replicates were 0.2 ha each. Three steers (280 kg hd^{-1} ± 4.0 kg SE) were allocated to each grazing treatment. The stocking rate was based on 0.6 ha $steer^{-1}$. The mixed grazing treatment included 15 young intact male goats (20.3 kg hd^{-1} ± 2.5 kg SE). The assumption is that 1-2 goats per mature cow (1 animal unit) without a cost to existing cattle operations (Luginbuhl et al. 1995). The weight of the steers used equaled 0.6 animal units and in addition to large area of pasture covered in invasive browse species; five goats were added per steer. Animals were rotationally stocked among replicates by grazing one replicate for two weeks and then allowing four weeks rest. Water and trace minerals were provided free choice at all times. In 2006, grazing was initiated on May 30 and ended on September 29 for a total of 122 days. Animals were weighed on the mornings of May 30 (spring), July 31 (summer), and

September 29 (fall). Grazing was initiated on May 30 and ended on August 30 in 2007. Due to severe drought, animals were removed from treatment pastures and grazed on adjacent pastures from July 13 to August 2. In 2007, the total grazing days were 72.

Seasonal changes in botanical composition of swards were determined by visual assessment of permanent observation points in each treatment. Large nails were driven into the ground along transect lines as permanent observation points throughout the experiment. Ten observation points per replicate in the grazed pastures and five observation points per replicate in the control were used. A 0.25 m^2 square quadrant was placed on the north side of the nail. Plant species within the quadrant were identified and recorded by trained personnel. Botanical composition and relative abundance of plant species were determined by the Double DAFOR scale (Brodie, 1985; Abaye et al., 1997) (Table 4-1). Visual estimates of percentage ground cover and percentage of grass, legume, and weed species were also made. Sericea lespedeza (*Lespedeza cuneata* (Dum.-Cours. G. Don)) was considered a weed in this experiment due to low palatability by cattle (Dove and Zipper, 1997).

Table 4-1. The double DAFOR scale used to assess botanical composition and species diversity.

Group: _________________ Date: ____________________Recorder:

D=Dominant; A=Abundant; F=Frequent; O=Occasional; R=Rare

ID	Ground cover, %	Grass, %	Legume, %	Legume, %	FORAGES					WEEDS				
					D	A	F	O	R	D	A	F	O	R

The scale where D=dominant, A=abundant, F=frequent, O=occasional, and R=rare, is used to evaluate the relative abundance of species. Brodie describes a species as dominant if most or all of the area is covered. A ranking of abundant would be given to species that cover about one half to three-quarters of the area. Frequent refers to species that are well scattered throughout the site but cover less than half the area. A species ranked as occasional occurs a few times and a rare species is one that is present only once or twice.

Data were analyzed for all single effects and interactions using PROC GLM (v. 9.1, SAS Institute, Inc. 2002-2003). Effect of treatment, block, season, and year were tested. Treatment by season, treatment by year, and treatment by season by year were also tested. Treatment effects were tested using the treatment by block interaction mean square as the error term. Significance was tested at the 5% level unless noted different.

Results

Botanical composition

Treatment x season x year effects ($P < 0.05$) were observed for percentages groundcover, grass, and weed. Treatments x year effects ($P < 0.001$) were observed for percentage legume. Therefore, botanical composition is presented by year and season.

Initially, percentage ground cover was similar for the control and cattle grazing but was lowest for mixed grazing ($P < 0.05$) (Table 4-2). Groundcover remained low in pastures grazed by cattle and goats throughout the 2006 grazing season. Grass percentage was similar for all treatments in spring ($P < 0.05$) but the grazing treatments had higher grass contents than the control by the end of the season ($P < 0.10$). Legume content was highest in cattle alone grazing followed by the control and was lowest in mixed grazing treatment. This trend continued until the fall sampling where pastures grazed by cattle alone continued to have more legumes while legume contents in the control and mixed grazing treatment were low ($P < 0.05$). Weed percentage was initially the highest in mixed grazing treatment in spring with lower amounts in control and cattle alone grazing. However, by the summer, the control had the highest amount of weeds ($P < 0.05$). Overall, the grazing treatments had less than 17% weed by fall compared to over 43% in the control treatment ($P < 0.05$).

In 2007, adverse weather conditions had a negative effect on pasture botanical composition. The 2007 growing season started with a late spring frost in May followed by summer drought. Rainfall was 10 cm below the 55-year average. Percentage groundcover in the spring was reduced by 13.5, 9, and 14.3% in the control, cattle alone and mixed grazing treatment, respectively (Table 4-3). In the spring, percentage groundcover was highest in the cattle, intermediate for control, and lowest in mixed grazed treatments ($P < 0.05$). However, for the rest of the grazing season, percentage groundcover was highest for control and cattle grazed alone and lowest ($P < 0.05$) for the mixed grazed treatment (Table 4-3). The percentage grass content of the pastures was initially highest for control and cattle grazed and lowest ($P < 0.05$) for mixed grazed treatment. However, the effect of grazing was evident in summer and fall where the highest percentage of grass was observed in cattle and mixed grazed treatments ($P < 0.05$). Legume content was essentially zero for the control treatment throughout 2007.

Percentage legume was similar for cattle alone and mixed grazed treatments in the spring ($P < 0.05$). In summer, percentage legume was highest ($P < 0.10$) in mixed grazed followed by cattle alone grazed pastures. The drought conditions in late summer reduced legumes to low levels in all pastures and thus there was no difference in legume percentage among treatments ($P < 0.05$). Percentage weed was highest ($P < 0.05$) for control and mixed grazing treatment in spring. However, by fall, percentage weed was lowest ($P < 0.05$) at 22% of the sward in the grazed pastures. This is in contrast to the control where weeds represented over 50% of the sward ($P < 0.05$).

Table 4-2. Effect of control, cattle alone, and mixed grazing treatments on botanical composition -2006.

		Treatments	
Component	Control	Cattle	Mixed
	……………………Spring……………………….		
Groundcover	81.0a	84.2a	69.5b
Grass	44.0a	40.2a	36.8a
Legume	18.0b*	32.8a*	5.2c*
Weed	38.0b	27.0b	58.0a
	..................................Summer……………………...		
Groundcover	91.0a	85.0a	63.5b
Grass	25.0b	48.8a	55.0a
Legume	18.0ba	27.7a	9.2b
Weed	57.0a	23.5b	35.8b
	…………..……………Fall………………………...		
Groundcover	80.0a	79.7a	66.2b
Grass	52.0c*	63.7b*	76.3a*
Legume	4.5b	27.5a	7.0b
Weed	43.5a	8.8b	16.7b

Values followed by capital letter signify significance within row
*indicates significant differences at $P = 0.10$

Table 4-3. Effect of control, cattle alone, and mixed grazing treatments on botanical composition – 2007.

	Treatments		
Component	Control	Cattle	Mixed
	………………………Spring………………………		
Groundcover	67.5ba	75.2a	55.2b
Grass	72.0a	72.5a	52.7b
Legume	0.5b	19.5a	16.7a
Weed	27.5a	8.0b	30.7a
	..................................Summer……………………...		
Groundcover	63.0a	61.5a	57.8b
Grass	41.0b	77.3a	70.7a
Legume	0.0c*	8.2b*	16.5a*
Weed	59.0a	14.5b	12.8b
	…………..……………Fall………………………...		
Groundcover	83.5b	75.7a	59.7b
Grass	49.0b	83.3a	72.8a
Legume	0.0a	5.8a	5.5a
Weed	51.0a	10.9b	21.7b

Values followed by capital letter signify significance within row.
*indicates significant differences at P = 0.10

Relative abundance of herbaceous pasture species

Relative abundance of plant species measured with the Double DAFOR scale revealed treatment x season x year interactions for most of the observed plant species (P = 0.01). With the exception of annual fleabane (*Erigeron annuus* L.) and horseweed (*Conyza canadensis* L.) where treatment x season effects (P = 0.01) for annual fleabane and treatment x year effects (P = 0.01) for horseweed were observed. Therefore, results are presented by year and season.

Generally, tall fescue (*Lolium arundinaceum* Schreb.) and orchardgrass (*Dactylis glomerata* L.) were the major grasses across all treatments. While Kentucky bluegrass (*Poa pratensis* L.) and timothy (*Phleum pretense* L.) were found to be occasional to rare. White (*Trifolium repens* L.) and red clover (*Trifolium pratense* L.) were the only established legumes in appreciable amounts in treatment pastures in both 2006 and 2007. Sericea lespedeza was the major weed found in all treatments. Minor weed species noted in small amounts at various points in all the control and grazing treatments include: annual fleabane, horseweed, common ragweed (*Ambrosia artemisiifolia* L.), sedge (*Cyperus spp.*), and common chickweed (*Stellaria media* L. Vill.), and Canada goldenrod (*Solidago canadensis* L.). The relative abundance of grass, legume, and weed species are shown in Table 4-4 for 2006 and Table 4-5 for 2007. As was mentioned in the materials and methods section, the evaluation of the individual species was based on the relative abundance not on percentage dry matter basis

In spring 2006, the relative abundance of tall fescue was higher in the control and mixed grazing treatment while was lower ($P < 0.05$) in cattle alone treatment. In summer, however, the relative abundance of tall fescue was highest ($P < 0.05$) in the mixed grazing, intermediate in the cattle alone and lowest ($P < 0.05$) in the control treatments (Table 4-4). In the fall, tall fescue was dominant in mixed grazed and abundant in control and cattle alone grazed pastures ($P < 0.10$). Overall, tall fescue increased steadily in cattle ($P < 0.10$) and mixed grazing treatment ($P < 0.05$) from spring to fall. In the control treatment, however, tall fescue decreased to the lowest ($P < 0.05$) level in the summer compared to grazed pastures. Initially, orchardgrass appeared more frequently in the cattle alone ($P < 0.10$) treatment compared to the mixed grazed and control treatments (Table 4-4). In summer, the frequency of orchardgrass appearance increased in both cattle and mixed grazing treatment compared to the untreated control. Although relatively lower ($P < 0.05$), the same trend was observed in the fall. In spring, there was no difference in the relative abundance of bluegrass among treatments but in summer, the relative abundance of bluegrass was higher in the mixed treatment compared with the cattle or control treatments (Table 4-4). In the fall, although not significant among treatments, numerical increase in the relative abundance of bluegrass was observed. Generally, bluegrass went from rare in spring to occasional in fall in the grazed treatments but was rare or lower in the control ($P < 0.05$). Generally, the relative appearance of timothy declined from spring to summer ($P < 0.05$) to none by the fall season.

In the spring of 2006, white clover had a nearly zero occurrence in the control and mixed grazed treatments while rare appearance was recorded for the cattle alone treatment ($P < 0.05$) (Table 4-4). In summer and fall, the relative abundance of white clover continued to decline in the control treatment to zero while rare to almost occasional appearance was observed for the cattle alone and mixed grazing treatment, respectively ($P < 0.05$). The relative appearance of red clover was higher ($P < 0.05$) in cattle alone pastures compared to the control and mixed grazing treatment all seasons except summer where the relative abundance of red clover was similar ($P < 0.05$) between the control and cattle alone pastures.

In 2006, no difference in total weed species was observed among treatments at the initial sampling date ($P < 0.05$) (Table 4-4). However, in summer, the relative abundance of total weed increased to abundant, occasional, and frequent levels for the control, cattle and mixed grazed treatments, respectively (Table 4-4). The decline in total weed appearance was more evident from summer to fall for the cattle alone treatment ($P < 0.05$).

The relative abundance of sericea lespedeza was much higher than most all broadleaf weeds observed across treatments and seasons. Initially, sericea lespedeza was frequent, occasional and rare in the mixed, cattle and control treatments, respectively (Table 4-4). Sericea lespedeza was lower ($P < 0.05$) in cattle alone grazed pastures throughout the grazing season while the frequency appearance of sericea lespedeza remained the same for the control and mixed grazed treatments. The relative abundance of other specific broadleaf weeds species other than sericea lespedeza was relatively low across treatments (Table 4-4). Annual fleabane (*Erigeron annuus* (L.) Pers.and) and horseweed (*Conyza Canadensis* L. Cronq) were among the most noticeable weeds in all treatments across seasons. The appearance of these weeds ranged from occasional to rare.

In spring 2007, the relative abundance of tall fescue was higher in the control and cattle alone treatments compared with the mixed grazed treatment (Table 4-5). In the summer, the relative abundance of tall fescue was higher in the grazed treatments but was significantly lower in the control treatment. In the fall, tall fescue appeared at a relatively higher level in the grazed treatments and the relative abundance of tall fescue was much higher in the mixed vs. the cattle alone and control treatments. Overall, tall fescue steadily increased in mixed grazing treatment from spring to fall ($P < 0.05$) while no clear trend was observed for the control and cattle alone treatments (Table 4-5). The relative abundance of orchardgrass was higher in pastures grazed by cattle alone across seasons compared with the mixed grazed and control treatments. The range of appearance was rare, occasional, and frequent for the control, mixed and cattle treatments, respectively (Table 4-5). Bluegrass was occasional in spring and then dropped to rare in summer and fall in control and mixed grazed treatments ($P < 0.05$) while remained rare in cattle treatment throughout the seasons ($P < 0.05$). The relative abundance of timothy was rare to zero in all treatments across seasons ($P < 0.05$).

In 2007, the relative appearance of white and red clovers was zero to rare in the control treatment (Table 4-5). White clover had a higher abundance ratings in mixed grazing treatment in spring ($P < 0.05$) but declined to rare in summer and fall ($P < 0.05$). White clover was rare in cattle alone grazed pastures throughout the growing season ($P < 0.05$). On the other hand, the relative appearance of red clover was higher in the grazed pastures compared to the untreated control throughout the grazing season ($P < 0.05$). Dry conditions late in the year reduced both white and red clover to low levels ($P < 0.05$).

The late spring frost in 2007 seemed to affect warm-season broadleaf weed species and as a result, total broadleaf weed content was lower than 2006 (Table 4-5). The average relative abundance of broadleaf weed species for 2007 was 2.0 compared 2.7 in 2006 and lower weed values were noted for all treatments. Both control and mixed grazed treatments had a higher frequency of broadleaf weed appearance compared to where cattle grazed alone in spring ($P < 0.05$) (Table 4-5). In summer and fall, broadleaf weeds appeared to be highest in the control and lowest in the grazed treatments ($P < 0.05$). Weeds increased from occasional in spring to abundant in summer and fall in the control ($P < 0.10$). Weed frequency did not differ between seasons in pastures grazed by cattle alone and the relative appearance ranged from occasional to rare ($P < 0.05$). Weeds were occasional in spring and fall and lowest in summer in mixed grazed treatment ($P < 0.05$).

Among the specific weed species recorded sericea lespedeza was the most occurring species across seasons and treatment. As a warm-season species, the relative abundance of sericea lespedeza increased from spring to summer to fall (Table 4-5). Sericea lespedeza was rare in all treatments in spring with higher levels in control and mixed grazing treatment ($P < 0.10$). In the summer, however, sericea lespedeza was abundant in control but rare in both cattle alone and mixed grazing treatment ($P < 0.05$). By the end of the growing season, sericea lespedeza was abundant in control, frequent in mixed, and rare in cattle alone grazed pastures ($P < 0.05$). Besides sericea lespedeza, annual fleabane and horseweed was the two other weed species observed in a measurable amounts. Annual fleabane and horseweed were rare in all treatments throughout the 2007 growing season (Table 4-5). Higher values of annual fleabane were noted for the control in summer ($P < 0.05$) and in both control and mixed grazing in fall ($P < 0.10$). The appearance of horseweed did not differ in spring and fall among treatments but was found to be higher in control in summer ($P < 0.05$). Common chickweed was rare in mixed grazing in spring but did not appear in other treatments or in other seasons ($P < 0.05$). Common ragweed was noted in fall in control but not in other treatments ($P < 0.10$). Other weeds were found only in negligible amounts throughout the growing season.

Table 4-4. Influence of control, cattle alone, and mixed grazing on relative abundance of plant species in 2006

Species	Control	Cattle	Mixed	Control	Cattle	Mixed	Control	Cattle	Mixed
	Spring			Summer			Fall		
	……Relative abundance (1-5)……								
DAFOR I									
Grasses									
Tall fescue	2.7a	1.3b	2.0ab	0.7c	2.0b	3.3a	4.0b*	3.5b*	4.6a*
Orchardgrass	0.3c*	1.9a*	1.1b*	1.6b	2.7a	2.3ab	0.9b	2.2a	1.2ab
Bluegrass	0.3a	0.7a	0.4a	0.0b	0.6ab	1.1a	1.0a	1.5a	1.5a
Timothy	1.9a	0.6b	1.0b	1.2a	1.0a	0.0b	0.0a	0.0a	0.0a
Legumes									
White clover	0.1b*	1.1a*	0.5b*	0.0c	0.9b	1.5a	0.0b	1.2a	1.7a
Red clover	0.9b	1.7a	0.0c	1.9a	2.1a	0.4b	0.7b	1.7a	0.0c
Other forages	0.3b	1.6a	0.5b	0.7a*	0.7a*	0.1b*	0.0a	0.0a	0.0a
Weeds (various spp.)	2.6a	2.5a	3.0a	4.0a	2.3b	3.4a	3.4a	1.2c	2.6b
DAFOR II									
Broad leaf weed species									
Sericea lespedeza	2.5a	1.1b	3.0a	3.6a	1.4b	3.2a	3.6a	1.1c	2.5b
Fleabane	1.4a	0.9a	0.8a	0.7a	0.4a	0.2a	1.1ab*	0.8b*	1.7a*
Horseweed	0.7b	1.2ab	1.9a	0.2b	0.3b	1.3a	0.6a	0.4a	1.0a
Ragweed	0.0b	0.7a	0.0b	0.2ab	0.6a	0.0b	0.7a	0.1b	0.0b
Sedge spp.	0.7a	0.4a	1.0a	0.0a	0.2a	0.1a	0.0a	0.1a	0.0a
Goldenrod	0.0a	0.0a	0.0a	1.0a	0.8a	0.1b	0.0a	0.0a	0.0a
Chickweed	0.6a*	0.1b*	0.4ab*	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
Other weeds	1.1a	1.2a	0.6a	0.6a	0.1a	0.5a	0.0a	0.0a	0.1a

Visual evaluation rated on a Double DAFOR scale, where 5 = dominant; 4 = abundant; 3 = frequent; 2 = occasional; 1 = rare
Means followed by same letter within rows are not significantly different at P = 0.05
* indicates significance at P = 0.10

Table 4-5 Influence of control, cattle alone, and mixed grazing on relative abundance of plant species in 2007

	Treatments								
Species	Control	Cattle	Mixed	Control	Cattle	Mixed	Control	Cattle	Mixed
		Spring			Summer			Fall	
	……..……….………………………..Relative abundance (1-5)…..…………………………………..								
DAFOR I									
Grasses									
Tall fescue	3.5a*	4.1a*	2.5b*	0.9b	2.5a	3.4a	2.4c*	3.3b*	4.5a*
Orchardgrass	0.6b	1.6a	0.5b	1.5b	3.6a	3.0a	1.8b	3.6a	1.9b
Bluegrass	2.1a*	1.2b*	1.6ab*	0.7a	1.0a	0.5a	0.3b	1.1ab	1.4a
Timothy	0.0a	0.1a	0.0a	0.8a	0.1b	0.2b	0.0a	0.0a	0.0a
Legumes									
White clover	0.0b	0.5b	1.8a	0.0b	0.4ab	0.7a	0.0a	0.1a	0.2a
Red clover	0.1b	1.7a	0.6b	0.0b	0.7a	1.0a	0.0b	0.7a	0.5a
Other forages	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
Weeds (various spp.)	2.3a	1.2b	2.5a	3.9a	1.7b	1.4b	3.6a	1.4c	2.4b
DAFOR II									
Broad leaf weed species									
Sericea lespedeza	0.8a*	0.2b*	1.1a*	3.5a	1.0b	1.3b	3.8a	1.2c	2.6b
Fleabane	0.4a	0.2a	0.5a	0.8a	0.2b	0.0b	0.7a*	0.2b*	0.8a*
Horseweed	1.2a	1.0a	1.2a	1.4a	0.5b	0.2b	0.6a	0.3a	0.5a
Ragweed	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.6a	0.1b	0.0b
Sedge spp.	0.0a	0.0a	0.0a	0.0a	0.3a	0.0a	0.0a	0.0a	0.0a
Goldenrod	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
Chickweed	0.0a	0.0b	1.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
Other weeds	0.0b*	0.1b*	0.7a*	0.1a	0.3a	0.0a	0.0a	0.2a	0.0a

Visual evaluation rated on a Double DAFOR scale, where 5 = dominant; 4 = abundant; 3 = frequent; 2 = occasional; 1 = rare
Means followed by same letter within rows are not significantly different at P = 0.05
* indicates significance at P = 0.10

Discussion

In both years, the shifts in botanical composition were observed due to treatments. Generally, the grazing treatments increased in grass percentage and decreased in weeds. The increase in grass percentage after the two grazing seasons was 5, 43, and 36% for the control, cattle alone and mixed grazing treatments. The reverse was true for the control treatment where percentage weed increased from spring to fall. Our results are similar to Luginbuhl et al. (1999, 2000) where mixed grazing cattle with goats improved grass and legumes persistent and reduced weeds and brush compared with the single grazed treatments. Luginbuhl et al. (1999) reported that grass percentage increased from an initial 13 to 54% after four years of mixed grazing goats with cattle. Our results indicated that grazing was essential for maintaining weeds at low levels in pasture.

In 2006, the legume content (clovers) was high in cattle alone and low in mixed grazed treatments and remained relatively stable during the growing season compared to a sharp decline of 18 to 4.5% in the control. By the end of the two year grazing seasons, no legume was observed in the control treatment while a little more than 5% legume was observed in the grazed treatments. The decline in legumes in the control treatment can be attributed to lack of grazing pressure and excessive shading by grasses, weeds, and shrubs. The adverse effect of shading on clovers was reported by Ball et al. (2007) while Langer (2000), reported the importance of appropriate defoliation on the maintenance of legumes in the sward. In the summer of 2007, the legume content was much higher in mixed grazing (16.5%) compared with where cattle grazed alone (8.2%). The higher percentage of legumes in the mixed grazed treatment can be attributed to goat's preference for grasses over legumes. Similar observation was made by Smetham (1990) and del Pozo et al. (1997; 1998) where they stated that goats generally will select grass over clovers and the sward may become clover-dominant over time.

By the end of the two grazing seasons, groundcover percentage was high for the control and cattle grazed and low for mixed grazing treatment. Contrary to our results, Luginbuhl et al. (1999) reported low groundcover percentages for no grazing control compared to increasing groundcover in grazed pastures. The reason for the low ground cover in the ungrazed treatment could be the fact that that the Appalachian mountain pastures would revert to woody shrubbery and deciduous hardwood tree species over time and reduce the herbaceous groundcover

(Luginbuhl et al., 1999). This may be the case in time for our experiment as autumn olive shrubbery visually appeared to be increasing in the control treatment

In term of species diversity, tall fescue was the most abundant and persistent grass found in all treatments. This species is highly recommended for reclaimed mine areas as it is drought-tolerant and persists under grazing (Ditsch et al., 2006). We observed high relative abundance of tall fescue in spring and fall compared to midsummer. The low relative abundance of tall fescue in the summer can be attributed to its lack of tolerance to heat. As a cool season grass, the productivity of tall fescue is low in summer compared to the cool spring and fall seasons. Additionally, shading and increased incidence of warm-season weeds, such as sericea lespedeza might have contributed to the low occurrence of tall fescue in the summer. Hoveland et al. (1975a) reported that in tall fescue-sericea lespedeza mixture, a lower yield of tall fescue was associated with an increase in the sericea lespedeza component in summer. In the grazing treatments, tall fescue increased from spring to fall. Similar to our findings, Luginbuhl et al. (1999) observed a significant increase in the presence of tall fescue in pastures grazed by goats or goats with cattle over four years. McCall and Lambert (1987) stated that the selective grazing of weeds by goats and reduced shading likely improved light penetration into the base of the sward and increased tillering of tall fescue.

Unlike most of the cool season species we observed, orchardgrass appeared more frequently in the summer than in spring or fall. Ball et al. (2007) stated that the greater occurrence of orchardgrass in the summer can be attributed to its late growth in the spring compared to tall fescue. In our experiment, more orchardgrass and bluegrass were observed in the grazed vs. control treatments and this was more so in the cattle alone vs. mixed grazing. Similar result was reported by Luginbuhl et al. (1999; 2000). Like other cool-season grasses, bluegrass persistence depends on regular defoliation that reduces the competitiveness of other plant species and improves tillering (Belesky et al., 2007). Timothy was found in low occurrences in all treatments initially but declined after the first year.

In our experiment, the relative abundance of white clover was negligible in the control treatment. White clover is sensitive to shading and requires grazing management that controls grass and other species (Ball et al., 2007). The presence of goats with cattle might have helped the persistence of clover in the mixed grazing treatment. Smetham (1990) stated that goats actively select weeds and shrubbery over white clover and thus may have reduced the shading by these species. Also, goats have been observed not to graze as low into the sward as sheep or cattle and results in greater lamina-petiole production by white clover (del Pozo et al., 1997). In 2007, a dry year, the appearance of white clover was mostly related to environmental condition than the grazing treatments. In the second year, white clover was occasional in mixed grazing in spring but declined to near zero by fall in both grazing treatments as drought occurred. Red clover was occasional in cattle grazing and at least rare in the control throughout the first year. However, in 2007, red clover went from occasional to rare in cattle grazing and essentially to zero in the control treatment. Though it has fair drought tolerance, dry conditions may have been another reason for its decline (Ball et al., 2007). In the first year, red clover was hardly noticed in mixed grazed paddocks but was rare in the second year. This re-occurrence of red clover may have been the result of close grazing the previous fall that opened the sward for a seed bank of red clover in the soil to germinate (Ball, 1999).

Sericea lespedeza was the major herbaceous weed in all treatments. Each year, sericea lespedeza increased from spring to fall in the control and was rated abundant by summer. Stands of sericea lespedeza appeared very thick in control and thus shaded other species. In mixed grazing, sericea lespedeza was grazed more uniformly than where cattle grazed alone and thus showed signs of decline. When autumn olive browse became limited, sericea lespedeza was grazed aggressively by goats. This aggressive grazing by goats resulted in a plant that was shorter, multi-branched, leafy and tender. This leafy and tender sericea lespedeza was readily accepted by cattle grazed with goats than the more steamy sericea lespedeza found in the cattle alone pastures. Ball et al. (2007) stated that cattle will readily consume sericea lespedeza when growth is maintained in a vegetative stage of 25 cm or less. However, the grazing pressure in the mixed grazed treatment which resulted in short heights with frequent grazing may have reduced plant vigor. Sericea lespedeza is a tap-rooted species and depends on stored carbohydrates for regrowth and winter survival (Dove and Zipper, 1997; Ball et al., 2007). Frequent cutting at low stubble heights were shown to reduce stands and yield of sericea lespedeza in Alabama (Hoveland et al., 1975b). Additionally, the reduction of sericea lespedeza in the mix grazed treatment might have been attributed to a reduced in flower/seed production (based on visual observations). Hart (2001) reported that goats would reduce seed production of sericea lespedeza from 950 seeds/ramet to 3 seeds/ramet. Similarly, cutting sericea lespedeza more than once and to short stubble heights reduces possible seed yields by 92% (Hoveland et al., 1975b).

Annual fleabane is described as a summer annual (Uva et al., 1997) but in our experiment, its relative abundance was low in summer. Similarly, although horseweed was considered either a summer or winter annual (Uva et al., 1997), the occurrence of this weed was more prevalent in spring in all treatments. Both annual fleabane and horseweed tended to be grazed by both goats and cattle but not aggressively. Ragweed and chickweed as well as goldenrod were the other weed species found in all treatments a lesser extent. Overall, the grazing treatment reduced the appearance of these species compared to the control treatment.

Conclusions

The practice of mixed grazing goats with cattle can have an effect on the botanical composition and relative abundance of forage species in pasture swards. Percentage weeds were highest in the no grazing control compared to either cattle alone or mixed grazing treatments. The percentage of grass and legume species were either maintained or improved in the grazing treatments but declined in control. When compared to the control, the grazing treatments resulted in better persistence of grass species, such as tall fescue, orchardgrass, and bluegrass, and legume species, such as white and red clovers. Sericea lespedeza was a major weed species in the control, but due to improved palatability resulting from grazing, became one of the more desirable species in the mixed grazing treatment. The grazing treatments, especially mixed grazing, reduced the relative abundance of undesirable/underutilized species and improved overall utilization of species. Our research indicates mixed grazing goats with cattle can have a desirable influence on the botanical composition and relative plant abundance of desirable plant species present in pasture on reclaimed coal-mined lands in the Appalachian coal-mine region.

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CHAPTER V

ASSESSING THE EFFECT OF CATTLE GRAZING ALONE AND WITH GOATS ON NUTRITIVE VALUES AND ANIMAL PERFORMANCE ON PASTURES ESTABLISHED ON RECLAIMED COAL MINED LANDS

Abstract

The grazing behavior of animals can have a profound impact on the botanical composition, production, and persistence of plant species as well as forage quality and animal performance. A grazing experiment was conducted on reclaimed coal-mined lands during the 2006 and 2007 growing season at the Powell River Research and Education Center in Southwest Virginia. The objectives of the experiment were to compare the effects of mixed grazing cattle and goats, cattle alone grazing, and no grazing control on: changes of nutrient values of pasture, sericea lespedeza, autumn olive, and multiflora rose as well as animal performance. Experimental design was a completely randomized design with three replications for the grazed treatments and two replications for the no grazing control. Three times during the grazing season, forage samples for the nutrient value analysis were obtained randomly in each replicate. Animals were weighed three times during the grazing season. The nutritive values of sericea lespedeza, autumn olive, and multiflora rose generally were within the acceptable level for all livestock classes and thus animal gains were not compromised. The nutritive values of these three species were better than pasture. Cattle performance was not different among the grazing treatments. The sum of cattle and goat gains in the mixed grazing treatment resulted in greater total animal output compared to cattle grazing alone. Our two year research showed that nutritive values of undesirable invasive plant species were greater than pasture and that overall total animal output was greater under mixed grazing than cattle grazing singly.

Introduction

Invasive plant species or weeds have been generally been unacceptable for grazing livestock. This is largely due to plant defenses such as thorns or toxic chemical compounds. However, the nutritive values of these unwanted plant species are generally greater than common forage species. It has been documented that the foliage of unwanted browse species can be very high in crude protein (12-20%) with variable energy digestibilities (40-75%) (NRCS, 1994). However, these values fall within the range for maintaining beef cows (Burris and Johns, 1997). Hoveland et al. (1986) found that cool-season weeds commonly found in pastures in Alabama were of greater digestibility and crude protein than of cultivated cool and warm-season grass species. Crude protein content was marginal for cattle gains with advancing maturity of warm-season weeds. Most weed species were within general levels for maintaining or exceeding cattle requirements. They concluded that most weeds have yield and palatability limitations for efficient livestock production. Weeds would be well utilized in pasture situations if grazed at vegetative stage of growth.

Performance of different livestock species when grazing together is usually maintained or enhanced compared to when these species are grazing separately. In some areas output per unit area has been greater than with single-species grazing (Bennett et al., 1970). Mixed grazing with cattle resulted in earlier weaning and increased lamb performance and body weight condition in ewes compared to sheep grazing singly. Cattle performance in that study was not affected by the addition of sheep (Abaye et al., 1995). Marley et al. (2006) also found that live weight gains by lambs were also higher when grazed in combination with cattle. A summation of mixed grazing research showed that when sheep were added to cattle operations, net productivity per unit area increased 24% whereas adding cattle to sheep resulted in a 9% increase (Walker, 1994).

Methods and Materials

A grazing experiment was conducted on reclaimed coal-mined lands during the 2006 and 2007 growing season at the Powell River Research and Education Center in Southwest Virginia (77° 43' 30" west longitude, 38° 57' 30" north latitude, elevation 155.5 m) to investigate the potential effects of mixed grazing goats with cattle or cattle alone grazing on pastures infested with browse and weedy species. The three treatments included a no grazing control, cattle grazing alone, and mixed grazing goats with cattle. Three replicates were used for cattle alone and the mixed grazing treatment and two replicates for the control. Replicate paddocks for grazing were 1.8 ha each and control replicates were 0.2 ha each. Three steers (280 kg hd^{-1} ± 4.0 kg SE) were allocated to each grazing treatment. The stocking rate was based on 0.6 ha $steer^{-1}$. The mixed grazing treatment included 15 young intact male goats (20.3 kg hd^{-1} ± 2.5 kg SE). The assumption is that 1-2 goats per mature cow (1 animal unit) without a cost to existing cattle operations (Luginbuhl et al. 1995). The weight of the steers used equaled 0.6 animal units and in addition to the large area of pasture covered in invasive browse species; five goats were added per steer. Animals were rotationally stocked among replicates by grazing one replicate for two weeks and then allowing four weeks rest. Water and trace minerals were provided free choice at all times. In 2006, grazing was initiated on May 30 and ended on September 29 for a total of 122 days. Animals were weighed on the mornings of May 30 (spring), July 31 (summer), and September 29 (fall). Grazing was initiated on May 30 and ended on August 30 in 2007. Due to severe drought, animals were removed from treatment pastures and grazed on adjacent pastures from July 13 to August 2. In 2007, the total grazing days were 72.

Samples for the determination of nutritive value from pasture, autumn olive, sericea lespedeza, and multiflora rose were taken during each sampling period. Pasture samples were obtained by randomly clipping grab samples in a zigzag motion across paddocks. Autumn olive (*Elaeagnus umbellata* Thunb.), sericea lespedeza, and multiflora rose samples were taken by selecting mainly leaves and small twigs that would be representative of goat consumption. Samples were dried in a forced air-oven 60º C for at least 48 hours and then ground to pass a 1-mm screen using a Wiley sample mill (Thomas Scientific, Swedesboro, NJ).

Neutral detergent fiber (NDF), acid detergent fiber (ADF), total digestible nutrients (TDN), and crude protein (CP) were predicted using near infrared spectroscopy (NIRS). WINISI II software was used to select a calibration data set for wet chemistry determination (Infrasoft International, Port Matilda, PA). Levels of NDF and ADF for calibration sets were determined using the ANKOM filter bag system (ANKOM Technologies, 2003). TDN was calculated by using the equation for grass hay: 100.32 – 1.1180 x ADF (Virginia Tech Forage Lab). Total N was determined using the Dumas procedure (Carbon-nitrogen analyzer, Elementar America, Cherry Hill, NJ). Crude protein was calculated as total N x 6.25. The coefficients of determination and standard errors of calibration and cross validation for the calibration equations were, respectively, 0.93, 2.73, and 3.17 for NDF; 0.93, 1.48, and 2.09 for ADF; and 0.97, 0.74, and 0.87 for CP.

Data were analyzed for all single effects and interactions using PROC GLM (v. 9.1, SAS Institute, Inc. 2002-2003). Effect of treatment, block, season, and year were tested. Treatment by season, treatment by year, and treatment by season by year were also tested. Treatment effects were tested using the treatment by block interaction mean square as the error term. Significance was tested at the 5% level unless noted different.

Results

Nutritive value

Averaged over season and year, the ADF, NDF, CP and TDN values of pasture, sericea lespedeza, autumn olive and multiflora rose varied (Table 5-1). The ADF value of pasture was the highest followed by sericea lespedeza and autumn olive and lowest for multiflora rose ($P < 0.05$) (Table 5-1). NDF was also highest for pasture and lowest for multiflora rose with autumn olive and sericea lespedeza being intermediate ($P < 0.05$). Autumn olive had the highest CP value, followed by sericea lespedeza, then multiflora rose, and pasture being lowest ($P < 0.05$). TDN was highest for multiflora rose and lowest for pasture with autumn olive and sericea lespedeza being intermediate ($P < 0.05$). Due to various interactions (treatment x year ($P = 0.01$)) and treatment x season ($P < 0.05$) interactions for certain plant analysis and nutrient values, data will be presented by year and season.

Table 5-1. Averaged over season and year, differences in nutritive values of pasture, autumn olive, sericea lespedeza, and multiflora rose.

Forage type	Nutritive values			
	ADF	NDF	CP	TDN
Pasture	34.5a	48.1a	10.8d	61.8d
Autumn olive	24.4c	38.6b	22.3a	72.9b
Sericea lespedeza	30.2b	32.1c	14.4b	66.5c
Multiflora rose	17.7d	24.9d	12.8c	80.5a

Values followed by capital letter signify significance within column

In 2006, pasture nutritive values did not differ among treatments (Table 5-2). The only difference noted was NDF where it was lower in fall in the cattle alone grazed treatment ($P < 0.05$) compared to the control and the mixed grazed treatments. Although not significant, pasture nutritive values were numerically lower (CP and TDN) and higher (ADF and NDF) values in summer compared to spring and fall. Initially, there was no difference in nutritive value of sericea lespedeza among treatments (Table 5-2). However, in summer and fall, the mixed grazing treatment had the lowest values of ADF and NDF and the highest ($P < 0.05$) values of CP and TDN compared with the control and the cattle alone treatments.

There was no treatment effect on ADF and NDF content of sericea lespedeza in the spring, summer or fall, however the mixed grazed treatment had lower ($P < 0.05$) ADF and NDF values compared with the control and cattle alone grazed treatments (Table 5-2). Similarly, there was no effect of treatment on CP and TDN values in the spring. In the summer and fall, CP and

TDN values were higher in the mixed grazed compared to the control and cattle alone grazed treatments (Table 5-2).

In the spring and summer the ADF value of autumn olive was similar, in the fall, ADF was lower ($P < 0.05$) in cattle grazed vs. control and mixed grazed treatments. In the spring, the NDF value of autumn olive was high ($P < 0.05$), intermediate ($P < 0.05$), and low ($P < 0.05$), for the mixed, cattle alone and control treatments (Table 5-2). No effect of treatment was observed in summer. In the fall, NDF was high ($P < 0.05$) in control, intermediate ($P < 0.05$) in mixed and low ($P < 0.05$) in cattle alone grazed treatments. In the spring, CP was lower ($P < 0.05$) in the mixed grazed treatment compared with control and cattle alone grazed treatments while in the summer CP value was high ($P < 0.05$) in the control and mixed grazed treatments compared with the cattle alone. No effect of treatment on CP was observed in the fall. Initially, TDN value of autumn olive was high ($P < 0.05$) in control vs. the grazed treatments, no effect of treatment in midsummer and at the end of the grazing season TDN was high ($P < 0.05$) in the cattle alone vs. control and mixed grazed treatments (Table 5-2).

Generally, multifora rose had lower fiber and higher TDN content compared with the pasture, sericea lespedeza and autumn olive samples. Initially, ADF and NDF value of autumn olive was higher for the mixed grazed treatment compared with the control and cattle alone treatments. However, this effect was reversed in the summer (Table 5-2). Crude protein was higher (($P < 0.05$) in the cattle alone and mixed grazed treatments in the spring while this effect was only significant in mixed grazed treatment in the summer. The TDN value of multiflora rose was lower in the mixed grazed and cattle alone treatment in the spring and summer, respectively.

In 2007, The ADF and NDF values for the pasture samples generally increased from spring summer to fall (Table 5-3). In the spring, ADF was higher in the mixed grazed treatment, cattle alone treatment in summer and the grazed treatments in the fall. No treatment effect on NDF was observed in the spring but NDF was high ($P < 0.05$) in the control and cattle alone treatments in the summer and in all the grazed treatments in the fall. In 2007, CP and TDN values were generally lower than the 2006 growing season. No effect of treatment on CP in the spring and fall but the lowest CP value was recorded control compared with the grazing treatments in the summer. The TDN value of pasture samples were highest ($P < 0.05$) in the mixed grazed treatment in the spring, grazed treatments in the summer and the control treatment in the fall.

The ADF value of sericea lespedeza was lowest ($P < 0.05$) in the mixed grazed treatments in the spring and fall while the ADF value was lowest ($P < 0.05$) The NDF value of sericea lespedeza was lower ($P < 0.05$), no effect treatment effect, and lower ($P < 0.05$) in control treatments for the spring, summer and fall seasons, respectively. No effect of treatment on CP values in the spring and fall, however, the CP value of sericea lespedeza was high for the cattle vs. mixed grazed treatment (Table 5-3). There was a difference in TDN values across treatments and seasons. Generally, TDN value was higher in the grazing treatments ($P < 0.05$).

There was no treatment effect on the ADF content of autumn olive in the spring and fall but ADF value was higher ($P < 0.05$) in control than the mixed grazed treatments in the summer (Table 5-3). The NDF value of autumn olive was lower in the mixed grazed treatment in the spring ($P < 0.05$). In midsummer the NDF value was highest ($P < 0.05$), intermediate ($P < 0.05$) and lowest ($P < 0.05$) in the control, mixed grazed and cattle alone grazed treatments, respectively. The CP values stayed the same while the TDN value of autumn olive declined as the season progressed, however treatment effect (season effect $P < 0.05$). No treatment effect in CP and TDN values of autumn olive was observed in the spring and fall while CP was lower ($P < 0.05$) in mixed grazed and TDN in control treatments in the summer.

The TDN and ADF value of multiflora rose was higher than the values recorded for pasture, sericea lespedeza and autumn olive (Table 5-3). However, the CP values were higher than that of pasture and lespedeza and lower than autumn olive while the opposite was true for NDF values. Initially there was no difference in ADF, NDF and TDN values among treatments but CP content was lower ($P < 0.05$) in mixed grazed and control treatments compared with the cattle alone grazed pastures. The CP values declined as the season progressed from spring to fall. The decline in CP was more evident in summer (Table 5-3). Overall TDN values were higher in the fall (season effect $P < 0.05$) compared to spring or summer. TDN was higher in mixed grazed vs. the control treatment while was no difference in TDN between the control and cattle alone treatments.

Table 5-2. Influence of control, cattle alone, and mixed grazing on nutritive values of forages (pasture), sericea lespedeza and browse species (autumn olive and multiflora rose) - 2006.

	Treatments								
Species	Control	Cattle	Mixed	Control	Cattle	Mixed	Control	Cattle	Mixed
	Spring			Summer			Fall		
Pasture									
ADF	33.0a	33.1a	34.9a	39.8a	37.4a	38.6a	33.4a	30.4a	32.2a
NDF	46.0a	41.2a	43.7a	50.3a	49.9a	52.4a	43.0a	38.2b	47.3a
CP	10.4a	11.5a	10.5a	8.4a	11.1a	10.2a	11.9a	14.6a	12.7a
TDN	63.4a	63.3a	61.3a	55.8a	58.5a	57.2a	63.0a	66.3a	64.3a
Sericea lespedeza									
ADF	27.6a	28.0a	28.2a	30.2a	29.9a	28.3b	28.3a	28.7a	26.0b
NDF	27.2a	28.3a	27.4a	26.7a	27.0a	25.3b	29.9a	30.2a	27.5b
CP	15.5a	16.4a	16.5a	14.4b	13.1b	16.4a	11.6b	12.7b	15.5a
TDN	69.5a	69.1a	68.8a	66.6b	66.9b	68.7a	68.7b	68.3b	71.2a
Autumn olive									
ADF	22.6b	23.9a	24.2a	25.0a	25.2a	25.5a	25.5a	24.0b	25.8a
NDF	32.0c	33.9b	34.9a	37.8a	39.7a	38.5a	45.7a	38.8c	41.1b
CP	21.0ab	21.3a	20.6b	23.2a	22.1b	23.1a	20.2a	20.5a	19.2a
TDN	75.0a	73.6b	73.3b	72.6a	72.1a	71.8a	71.8b	73.5a	71.5b
Multiflora rose									
ADF	16.5b	16.7b	18.1a	14.2ab	15.5a	13.8b	13.9a	14.3a	-------
NDF	21.4b	21.6b	24.0a	31.2a	19.0b	22.0b	19.9b	21.4a	-------
CP	14.2b	17.1a	16.2a	10.7b	11.9b	15.1a	14.7a	13.8a	-------
TDN	81.9a	81.7a	80.0b	84.5ab	83.0b	84.9a	84.8a	84.3a	-------

Means followed by same letter within rows by season are not significantly different at P = 0.05

Table 5-3. Influence of control, cattle alone, and mixed grazing on nutritive values of forages (pasture), sericea lespedeza and browse species (autumn olive and multiflora rose) - 2007.

	Treatments								
Species	Control	Cattle	Mixed	Control	Cattle	Mixed	Control	Cattle	Mixed
	Spring			Summer			Fall		
Pasture									
ADF	31.1b	31.4b	32.9a	35.0b	38.1a	33.8b	34.4b	35.6a	35.3a
NDF	47.9a	48.7a	49.2a	53.1ab	58.0a	49.3b	44.9b	49.7ab	52.4a
CP	8.8a	9.2a	9.0a	9.3b	8.8b	13.0a	11.7a	11.6a	10.5b
TDN	65.5a	65.2a	63.6b	61.2a	57.8b	62.6a	61.8a	60.8b	60.6b
Sericea lespedeza									
ADF	32.4a	32.8a	30.2b	32.3a	30.5b	31.7ab	33.3a	32.7ab	32.4b
NDF	39.2a	37.2a	33.5b	35.3a	33.3a	35.4a	35.9b	36.8b	38.7a
CP	15.4a	15.2a	15.0a	12.6b	14.4a	14.7a	12.6a	13.0a	12.7a
TDN	64.1b	63.7b	66.5a	64.2b	66.2a	64.9ab	63.1b	63.7ab	64.1a
Autumn olive									
ADF	20.2a	20.9a	21.0a	26.5a	25.1ab	24.7b	26.3a	27.5a	26.7a
NDF	34.2ab	35.9a	33.7b	42.1a	39.4c	40.3b	43.5a	43.9a	42.2a
CP	24.3a	23.3a	24.1a	22.2ab	24.1a	21.0b	24.1a	22.8a	23.8a
TDN	77.7a	77.1a	76.8a	70.7b	72.3ab	72.7a	71.0a	69.5a	70.5a
Multiflora rose									
ADF	20.7a	20.5a	21.1a	22.2a	19.2b	22.2a	17.9a	16.0ab	14.8b
NDF	29.3a	31.3a	31.5a	27.7a	24.9b	28.8a	24.3a	20.9a	23.9a
CP	14.3b	15.2a	13.5b	9.5a	9.1ab	8.0b	13.0a	11.9a	11.6a
TDN	77.2a	77.4a	76.7a	75.5b	78.9a	75.5b	80.3b	82.4ab	83.7a

Means followed by same letter within rows by season are not significantly different at P = 0.05

Animal performance

In 2006 total animal output was greater for cattle grazed in mix with goats than cattle grazed alone ($P < 0.05$). This difference in total weight gain was 132 kg (Table 5-4). However, there was no difference in animal output during the summer-fall. By the end of the grazing season in 2006, cattle grazed in mix with goats gained 93 kg more than those grazed alone. In 2007, which was a drier year, cattle grazed with goats still had a much higher weight gain than those grazed alone. The difference in total weight gain was 114 vs. 158 kg more for cattle grazed in mix in the summer and year end, respectively. In 2007, gains were 39.8 and 52.5 % higher for cattle grazed alone vs. grazed in mix, respectively (Table 5-4). Goat weight gains were improved by 50% in 2007 compared with 2006 ($P < 0.05$). In 2007, due to drought, animals were removed from pasture 50 days earlier than 2006. Thus, although ADG was higher during the season, total gains by cattle and goats were much less in 2007 compared with the 2006 growing season. Treatment comparisons of the total gains by cattle vs. mixed grazing goats with cattle showed that output of animal product was more favorable for mixed grazing.

Table 5-4. The influence of grazing cattle alone and cattle plus goats on animal performance for 2006 and 2007 grazing seasons.

Treatment		Mixed grazing	
	Cattle	Cattle	Goats
2006			
Spring-summer$^{\infty}$□			
ADG (kg/hd/day)	0.7a	0.8a	0.1
Gains per animal	39.3a	47.4a	7.2
Gains by species	118.0a	142.2a	107.7
Treatment comparison†	118.0b	249.9a	------
Summer-fall□			
ADG (kg/hd/day)	0.6a	0.4a	0.0
Gains per animal	40.1a	22.0a	1.1
Gains by species	120.3a	65.9a	15.9
Treatment comparison	120.3a	81.8a	------
Yearly totals$^{\infty}$□□			
ADG (kg/hd/day)	0.7a	0.6a	0.1
Gains per animal	79.4a	69.3a	8.2
Gains by species	238.3a	208.0a	123.6
Treatment comparison‡	238.3b	331.6a	------
2007			
Spring-summer			
ADG (kg/hd/day)	1.2a	1.1a	0.1
Gains per animal	52.7a	46.7a	4.2
Gains by species	158.0a	140.0a	62.1
Treatment comparison	158.0a	202.1a	------
Summer-fall□			
ADG (kg/hd/day)	1.0a	1.4a	0.2
Gain per animal	26.7a	38.6a	5.2
Gains by species	80.2a	115.9a	78.2
Treatment comparison†	80.2b	194.0a	------
Yearly totals			
ADG (kg/hd/day)	1.1a	1.2a	0.1
Gains per animal	79.4a	85.3a	9.4
Gains by species	238.2a	255.9a	140.3
Treatment comparison†	238.2b	396.1a	------

‡ cattle alone vs. mixed grazing differs at P = 0.10; † cattle alone vs. mixed grazing differs at P = 0.05
∞ cattle-alone ADG lower in 2006 than 2007 at P = 0.05; □ cattle-mixed ADG lower in 2006 than 2007 at P = 0.05
□ goat ADG lower in 2006 than 2007 at P = 0.05; □ goat ADG higher in spring-summer than summer-fall at P = 0.05; □ goat ADG higher in summer-fall than spring-summer at P = 0.05

Discussion

The nutritive values of pasture, sericea lespedeza, autumn olive, and multiflora rose were within the acceptable range for all class of animal production. The TDN and CP requirements for 250 kg steers gaining 0.7 to 1 kg/head/day are 63-67.5% TDN and 10-11.5% CP (Burris and Johns, 1997). The requirements for young, growing goats are 65-68% TDN and 12-14% CP (Luginbuhl et al., 1995). The forages sampled generally met or exceeded these requirements. The lower TDN (avg. 58.9%) and CP (avg. 10.1%) values of pasture in summer in our experiment has the potential to reduce gains by steers and goats. This has been documented to be a problem for efficient feeding of growing animals on pasture during the summer period in temperate regions (Blaser et al., 1986; Nicol and Nicoll, 1987). The TDN and CP values of sericea lespedeza, autumn olive, and multiflora rose was more than adequate to meet the nutritional requirements of the grazing animals throughout the year. There has been several research reports documenting the nutritive value of weed or browse species to be higher or equivalent to those of forages commonly used for pasture (NRCS, 1994; Ball et al., 2007). In terms of grazing preference, although, plant maturity may have more to do than chemical or physical determinant, sericea lespedeza, autumn olive, and multiflora have been associated with having chemical or physical barriers that will limit their use by cattle. Sericea lespedeza may have high concentrations of tannins that taste “bitter” to cattle (Dove and Zipper, 1997). Autumn olive and multiflora rose have woody, spiny growth that makes the accessible of forage for cattle low due to their large mouth and use of tongue for seizing forage (Swearingen et al., 2002; Pond et al., 1995). However, goats have narrow mouths with split upper lips that give them an advantage over cattle in accessing leaves and small twigs from woody browse (Pond et al., 1995).

In our experiment cattle performance was not affected by the addition of goats. In New Zealand, goats were grazed with bulls with no impact on bull performance (Meat and Wool NZ, 2007). Abaye et al. (1995) found similar results with mixed grazing sheep with cattle. In that experiment, calf performance was not affected by the presence of sheep but lamb performance was improved and target weaning weights were achieved earlier. The goat performance in our experiment was similar to those reported by Escobar (1998) of goats grazing sericea lespedeza. They reported gains ranging from 0.03 to 0.1 kg/head/day compared to 0.07 to 0.14 kg/head/day in our experiment.

The mixed grazing of goats with cattle resulted in greater meat output compared to cattle alone grazing. Total output was 34% higher for mixed grazing. This agrees with Walker (1994) who summarized several mixed grazing studies and concluded that meat output could be increased by 24% over grazing livestock singly. These increases can be the result of improved animal performance or pasture carrying capacity or both (Walker, 1994; Allen and Collins, 2003). In New Zealand, animal products per hectare with mixed grazing goats with bulls were improved. Bull performance was unaffected but output was increased due to meat and fiber production by goats (Meat and Wool NZ, 2007). No improvements in animal productivity were noted by Abaye et al. (1995) when comparing mixed grazing sheep with cattle to grazing these species singly.

Conclusions

The high nutritive value of invasive plant species coupled with mixing grazing animals with differing grazing preferences may yield a greater output per head and or per unit land area. The nutritive values of sericea lespedeza, autumn olive, and multiflora rose generally were much higher than the samples obtained from the entire pasture. As a result, animal gains were not compromised. The combination of goats with cattle did not have a negative effect on the performance of cattle. Additionally, the economic benefit from the animal gains is an added benefit to the economically depressed coal-mind Appalachian regions of Virginia.

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CHAPTER VI

SUMMARY AND CONCLUSION

Post-mined land reclamation in the Appalachian coal region has resulted in successful establishment and utilization of pasture for beef cattle production. Maintaining desirable grasses and legumes on reclaimed mined areas requires appropriate grazing management, weed control, and occasionally fertilizer inputs. The steep topography that is characteristic of the region makes these operations difficult and dangerous. The low fertility of the soils coupled with difficult topography has resulted in invasion of undesirable invasive plant species that reduce the forage and cattle production of reclaimed coal-mined lands. Invasive plant species are species that are able to reproduce and spread over large areas with few natural controls. These species are a problem as they may possess physical or chemical characteristics that inhibit browsing or grazing by wildlife or livestock. On reclaimed coal-mined pastures, autumn olive (*Elaeagnus umbellata* Thunb.), multiflora rose (*Rosa multiflora* Thumb.), and sericea lespedeza (*Lespedeza cuneata* (Dum.-Cours. G. Don)) are invasive plant species with potential for reducing pasture production.

Incorporating goats into existing cattle operations in this region may serve as a possible biological control for invasive plant species. Goats prefer browsing shrub species over grazing and foraging on steep land over flat land. They readily consume plant species that contain bitter compounds, such as tannins, that are unpalatable to cattle. The mixed grazing of goats with cattle is possible as each species selects for their preferred diet and competition between species for forage is minimal. Research in North Carolina has shown that mixed grazing goats with cattle has been successful in converting brush-infested pasture into a desirable mix of grasses and legumes beneficial for cattle. The total animal output for mixed grazing is generally improved over single animal grazing as animal performance or carrying capacity of pasture is improved. Improvement of total animal output of mixed grazing can be as high as 24% over single animal grazing.

The mixed grazing of cattle with goats was compared with cattle grazing alone and a no grazing control. Effects on forage biomass, botanical composition, and relative plant abundance of pasture were assessed. The effect of the different treatments on autumn olive growth and survival was also determined. Forage nutritive value of pasture, sericea lespedeza, autumn olive, and multiflora rose was analyzed.

At the end of the two year study, forage biomass was lower in the mixed grazing treatment compared to cattle alone grazing and the control. Groundcover percentage also appeared to be lower in mixed grazing vs. other treatments. Weeds represented less than 30% of the forage biomass in the grazed treatments. Grass biomass tended to increase as a result of less shading by weeds in the grazed pastures. In the control treatment, legumes (clovers) were at low levels by the end of the experiment.

Goats showed a clear preference for autumn olive and had a negative impact on the growth and survival of this shrub. The behavior of standing on their hind legs and placing their weight on branches resulted in the development of a browse line and broken, dead branches. Bark stripping and girdling further crippled autumn olive shrub vigor. Shrub survival was lower in mixed grazing (61%) by the end of the experiment compared to the other treatments. In general, there was no impact on autumn olive shrub height.

In terms of the relative abundance of species, the grazing treatments resulted in a shift in botanical composition that is more desirable by both animal species than the control treatment. When compared to a no grazing control; both cattle alone and mixed grazing treatments resulted in an increase in persistence of grass species, such as tall fescue, orchardgrass, and bluegrass. At the end of the two year experiment, white and red clovers disappeared from the control but remained a small part of the pasture component in the grazed treatments. Sericea lespedeza became a dominant weed in the control treatment mostly due to the lack of grazing pressure. The high grazing preference of goats for sericea lespedeza and of other weeds influenced the morphological characteristics of these plants. The growth pattern of sericea lespedeza was changed from an erect, woody, less leafy plant to a shorter, more palatable, and leafier plant due to goat grazing. The shorter and leafier sericea lespedeza was more acceptable and thus was readily grazed by cattle.

The nutritive values of sericea lespedeza, autumn olive, and multiflora rose generally were higher than that of pasture. The total digestible nutrients and crude protein was higher for sericea lespedeza, autumn olive, and multiflora rose compared to pasture thus animal performance (weight gain) was not compromised. When cattle were grazed with goats, there were no differences in weight gain compared to cattle grazed alone. In addition to the cattle gains, gain from goats resulted in a higher animal output compared to cattle grazing alone. Total output was 34% higher for mixed grazing than cattle alone in our study.

The use of mixed grazing goats with cattle showed a great potential for improving the utilization of plants that were both established and invasive found on reclaimed coal mined lands in the Appalachian region. The preference of goats for invasive plant species and increased output per unit land area are attractive benefits of mixed grazing goats with cattle for livestock producers in this region.

Appendix A. Effect of control, cattle, and mixed grazing on seasonal change of botanical compositions - 2006.

Treatment	Season		
<u>Control</u>	Spring	Summer	Fall
Groundcover, %	81.0A	91.0A	80.0A
Grass, %	44.0A	25.0B	52.0A
Legume, %	18.0A	18.0A	4.5A
Weed, %	38.0A	57.0A	43.5A
<u>Cattle</u>			
Groundcover, %	84.2A	85.0A	79.7A
Grass, %	40.2B	48.8B	63.7A
Legume, %	32.8A	27.7A	27.5A
Weed, %	27.0A	23.5A	8.8B
<u>Mixed</u>			
Groundcover, %	69.5A	63.5A	66.2A
Grass, %	38.8C	55.0B	76.3A
Legume, %	5.2A	9.2A	7.0A
Weed, %	58.0A	35.8B	16.7C

Values followed by capital letter signify significance within row

*indicates significant differences at P = 0.1

Appendix B. Effect of control, cattle, and mixed grazing on seasonal change of botanical compositions - 2007.

Treatment	Season		
Control	Spring	Summer	Fall
Groundcover, %	67.5B*	63.0B*	83.5A*
Grass, %	72.0A*	41.0B*	49.0BA*
Legume, %	0.5A	0.0A	0.0A
Weed, %	27.5B*	59.0A*	51.0BA*
Cattle			
Groundcover, %	75.2A	61.5B	75.7A
Grass, %	72.5B	77.3BA	83.3A
Legume, %	19.5A	8.2B	5.8B
Weed, %	8.0A	14.5A	10.8A
Mixed			
Groundcover, %	55.2A	51.8A	59.7A
Grass, %	52.7B	70.7A	72.8A
Legume, %	16.7A	16.5A	5.5B
Weed, %	30.7A*	12.8C*	21.7B*

Values followed by capital letter signify significance within row

*indicates significant differences at P = 0.1

Appendix C. Plant species visually observed using the Double DAFOR scale.

Forage Species	Scientific name	Lifecycle
Grasses		
Tall fescue	*Lolium arundinaceum* Schreb.	P
Orchardgrass	*Dactylis glomerata* L.	P
Kentucky bluegrass	*Poa pratensis* L.	P
Timothy	*Phleum pretense* L.	P
Legumes		
White clover	*Trifolium repens* L.	P
Red clover	*Trifolium pretense* L.	P
Other forage species		
Weeping lovegrass	*Eragrostis curvula* (Schrad.) Nees	P
Crabgrass	*Digitaria* spp.	A
Birdsfoot trefoil	*Lotus corniculatus* L.	P
Weeds		
Sericea lespedeza	*Lespedeza cuneata*	P
Annual fleabane	*Erigeron annuus* L.	A
Horseweed	*Conyza canadensis* L.	A
Common ragweed	*Ambrosia artemisiifolia* L.	A
Sedge	*Cyperus* spp.	P
Canada goldenrod	*Solidago canadensis* L.	P
Common chickweed	*Stellaria media* L. Vill.	A
Other weed species		
Buttercup	*Ranunculus* spp.	P
Cheat	*Bromus secalinus* L.	A
Curly dock	*Rumex crispus* L.	P
Black medic	*Medicago lupulina* L.	A
Buckhorn plaintain	*Plantago lanceolata* L.	P
Speedwell	*Veronica* spp.	A
Wild carrot	*Daucus carota* L.	B

Appendix D. Influence of control, cattle alone, and mixed grazing on relative abundance of plant species in 2006

Species	Control	Cattle	Mixed	Control	Cattle	Mixed	Control	Cattle	Mixed
	Treatments								
	Spring			Summer			Fall		
	……Relative abundance (1-5)……								
DAFOR I									
Grasses									
Tall fescue	1.5b	2.0ab	2.8a	2.1ab*	1.6b*	2.8a*	3.5b	4.3a	3.5b
Orchardgrass	0.4b	2.3a	1.7a	1.4b	2.6a	2.1ab	0.6b*	2.0a*	1.3ab*
Bluegrass	0.5a	0.8a	1.2a	0.6a	0.1a	0.7a	0.8a	0.8a	1.3a
Timothy	2.0a	1.3a	1.5a	1.4a	0.3b	0.4b	0.0a	0.0a	0.0a
Legumes									
White clover	0.4a	0.1a	0.3a	0.3a	0.5a	0.4a	0.0b	0.0b	1.2a
Red clover	1.3a*	2.1a*	0.2b*	1.1b	2.1a	0.3c	1.3b*	1.9a*	0.1c*
Other forages	0.4a	0.7a	0.4a	0.0a	0.7a	0.2b	0.0b	0.8a	0.4ab
Weeds (various spp.)	3.9a*	2.7b*	3.7a*	4.0a*	2.8b*	3.5ab*	2.9a*	2.0b*	2.3ab*
DAFOR II									
Broad leaf weed species									
Sericea lespedeza	2.5a*	1.3b*	2.9a*	3.1a	2.2a	3.3a	2.8a	1.9a	2.3a
Fleabane	1.3a	0.8a	1.1a	1.8a	0.5b	0.5b	0.3b	0.6b	1.7a
Horseweed	1.0a	1.3a	1.0a	0.3a	0.1a	0.7a	0.0b	0.0b	0.7a
Ragweed	0.8b*	1.4a*	0.0c*	1.1a*	0.7a*	0.1b*	0.0a	0.4a	0.0a
Sedge spp.	0.0b*	0.2b*	1.0a*	0.3a	0.2a	0.3a	0.3a	0.1a	0.1a
Goldenrod	0.0a	0.0a	0.0a	1.1a	0.9a	0.0b	0.9a*	0.3b*	0.0b*
Chickweed	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
Other weeds	1.9a	0.1b	0.6b	0.3a	0.2a	0.5a	0.6a	0.4a	0.2a

Visual evaluation rated on a Double DAFOR scale, where 5 = dominant; 4 = abundant; 3 = frequent; 2 = occasional; 1 = rare
Means followed by same letter within rows are not significantly different at P = 0.05
* indicates significance at P = 0.10
Data taken from random locations within replicates

Appendix E. Influence of control, cattle alone, and mixed grazing on relative abundance of plant species in 2007

Species	Control	Cattle	Mixed	Control	Cattle	Mixed	Control	Cattle	Mixed
	Treatments								
	Spring			Summer			Fall		
	……..Relative abundance (1-5)……..								
DAFOR I									
Grasses									
Tall fescue	4.6a*	4.0ab*	3.5b*	3.1a	3.2a	3.8a	3.4a	3.1a	4.0a
Orchardgrass	1.6ab*	1.8a*	0.8b*	2.6a	3.3a	2.4a	2.8a	3.3a	2.2a
Bluegrass	1.8a	1.2a	1.6a	1.3a	0.1b	0.8ab	1.8a*	0.7b*	1.6ab*
Timothy	0.0a	0.0a	0.1a	0.0a	0.0a	0.2a	0.3a	0.1a	0.1a
Legumes									
White clover	0.0b	0.5b	1.6a	0.0a	0.3a	0.6a	0.0a	0.0a	0.0a
Red clover	0.3b*	1.3a*	0.5b*	0.1b	0.5b	1.2a	0.0b*	1.2a*	0.8ab*
Other forages	0.3b*	1.0ab*	1.4a*	0.5a	0.6a	0.2a	0.0a	0.2a	0.2a
Weeds (various spp.)	1.0b	1.6ab	2.4a	1.8a	1.5a	1.3a	3.9a	2.1b	3.4a
DAFOR II									
Broad leaf weed species									
Sericea lespedeza	0.0b	0.2b	1.0a	0.6a	1.2a	1.2a	2.1a	2.1a	3.3a
Fleabane	0.1a	0.6a	0.7a	0.1a	0.2a	0.0a	1.8a*	0.7b*	1.1ab*
Horseweed	1.0a	0.9a	1.1a	0.8a*	0.1b*	0.2b*	0.0a	0.0a	0.2a
Ragweed	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	1.4a	0.4b	0.0b
Sedge spp.	0.1a	0.4a	0.0a	0.0a	0.1a	0.2a	0.0b*	0.0b*	0.4a*
Goldenrod	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.5a*	0.0b*	0.1b*
Chickweed	0.0b*	0.2ab*	0.6a*	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
Other weeds	0.0b	0.3ab	1.0a	0.8a*	0.3b*	0.0b*	0.3a	0.4a	1.0a

Visual evaluation rated on a Double DAFOR scale, where 5 = dominant; 4 = abundant; 3 = frequent; 2 = occasional; 1 = rare
Means followed by same letter within rows are not significantly different at P = 0.05
* indicates significance at P = 0.1
Data taken from random locations within replicates

Appendix F. Visual examples of vegetation response to different treatments.

Goats mobbing autumn olive

Goats select for tender leaves and twigs. Crude protein is high (20%).

Goats browsed up to a height of 2 meters.

Autumn olive would reproduce leaves if allowed an adequate rest period between browsing events. Allowing a rest period longer than 4 weeks may allow this plant to be used as a long term feed source for goats.

Bark stripping and breaking of branches became evident late in the growing season.

The whole shrub may not die as individual branches attempt to continue growth.

Occasionally, new growth suckered at the base of dead plants. This growth was accessible to goats and cattle.

Goats show a high preference for sericea lespedeza

Selective grazing of sericea lespedeza by goats resulted in a shorter, highly branched, leafy plant that was acceptable to cattle. Also, grazing of sericea lespedeza opened up the sward canopy and allowed desirable grasses and legumes to increase.

When sericea lespedeza grew to maturity, it was not acceptable to cattle. Noticed that cattle have grazed around sericea lespedeza plants in this scene.

Sericea lespedeza grew thick and shaded out desirable grasses and legumes in cattle alone grazing.

More uniform grazing occurred in mixed grazing (left) than in cattle alone grazing (right).

A sharp contrast of the area outside the experiment (on the left) versus a paddock grazed by both cattle and goats (on the right).

Mixed grazing goats with cattle resulted in a desirable mixture of grass and clover.