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Multi-species grazing of leafy spurge-infested rangeland in North Dakota

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(*Article begins on following page.)

MULTI-SPECIES GRAZING OF LEAFY SPURGE-INFESTED RANGELAND IN NORTH DAKOTA

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ABSTRACT

Prosser, Chadley Wayne, M.S., Department of Animal and Range Sciences, College of Agriculture, North Dakota State University, May 1995. Multi-species grazing of leafy spurge-infested rangeland in North Dakota. Major Professor: Dr. William T. Barker.

This study was conducted at Camp Grafton South in Eddy County, North Dakota, to evaluate the effects of multi-species grazing on leafy spurge-infested rangeland. Leafy spurge distribution and densities were similar among all treatments prior to the study. Cattle-only, goats-only, and cattle and goat (multi-species) treatments were initiated in 1993. Leafy spurge degree of use was highest in the cattle and goat and goats-only treatments, with means of 71.6 percent and 68.7 percent, respectively. The cattle-only treatment had a significantly ($P<0.05$) lower degree of use at 5.7 percent. Leafy spurge stem densities were reduced by 29.3 percent and 25.0 percent in the goats-only and cattle and goat treatments, respectively, but were not greater ($P>0.05$) than the 10.2 percent reduction in the cattle-only treatment. A graminoid production increase of 28.1 percent occurred in the cattle-only treatment after one year. The graminoid production in the goats-only and cattle and goat treatments were increased 53.4 percent and 47.2 percent, respectively, both significantly ($P<0.05$) greater increases than the cattle only. The goats-only and multi-species treatments were beneficial in increasing grass production while reducing leafy spurge production.

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INTRODUCTION

Leafy spurge (*Euphorbia esula L.*) is a herbaceous, deep-rooted, dicotyledonous, perennial noxious weed which infests at least 458 counties in 26 states and six Canadian provinces (Dunn 1979). Leafy spurge is distributed on several habitats ranging from xeric to subhumid and from subtropical to subarctic. It is most common in moderately moist habitats (mesic) existing in the continental climate of North America (Selleck et al. 1962).

Leafy spurge is a long-lived plant native to Europe and Asia. It was introduced to North America in 1827 and first reported in North Dakota in 1909 (Messersmith and Lym 1983). It spreads rapidly by seeds and rhizomes and forms colonies primarily in untilled agricultural land.

Leafy spurge has become a troublesome weed in the Northern Great Plains region of North America where it grows largely devoid of insect and disease pests (Messersmith et al. 1985). This weed, which is extremely persistent and competitive, has contributed significantly to economic losses to livestock producers.

Leafy spurge continues to be a serious problem in North Dakota, infesting over 405,000 hectares of land, predominately rangeland. Chemicals continue to be the primary method for control and eradication attempts. However, biological control methods with insects show great potential as a control method (Lacey et al. 1985). Sheep grazing has been a control method since the 1930s, but was utilized sparingly (Helgeson and Thompson 1939, Helgeson and Longwell 1942, Bartz et al. 1985). Goat grazing studies researching the potential to control leafy spurge are limited, but have shown potential as a control technique (Maze 1989, Hanson and Kirby 1993, Sedivec and Maine 1993, Hanson 1994, Sedivec et al. 1994).

Some knowledge of range, weather, animals, and season of the year is essential in order to determine the most desirable mix of grazing animals in any given situation. Great potential exists for use of multi-species grazing of livestock to maintain forage production and species diversity. Land managers should recognize the value of multi-species grazing and be encouraged to apply this concept to public and private lands. The manager of a livestock unit should select the mix of animals for the land unit based on type and volume of plant availability.

Shrubs or brush are reduced with a subsequent increase in forbs and grass if range is stocked heavily by goats and other animals which consume browse. If the range is grazed with sheep or other animals which graze forbs and grass, but consume limited browse, the composition of the range should shift toward a higher percentage of woody plants. Range with a heavy cover of brush usually yields a lower return of livestock products when grazed by cattle.

However, a combination of goats with cattle or cattle and sheep results in an optimum yield of usable forage and animal products (Baker and Byington 1986).

The objectives of this study were to determine 1) the effect of goat grazing on leafy spurge stem density and associated herbaceous production and 2) differences between multi-species grazing and single species grazing of leafy spurge-infested rangeland in regards to herbaceous species utilization patterns.

LITERATURE REVIEW

Leafy spurge

The plant

Leafy spurge possesses nearly all the qualities attributed to a weed (Galitz and Davis 1983). Leafy spurge is a herbaceous deep-rooted perennial weed of the Euphorbiaceae family that reproduces from seed and numerous vegetative buds on an extensive, persistent vertical and horizontal stem and root system (Watson 1985). In North America, leafy spurge has commonly been referred to as *Euphorbia esula* L., but many synonyms and taxonomic revisions have been proposed (Bakke 1936, Croizat 1945, Moore 1958, Dunn and Radcliff-Smith 1980).

Stems of leafy spurge are erect, tough, and woody from 30 cm to 1 m in height with nonflowering axillary branches common (Great Plains Flora Association 1986). Flowers are reduced and borne in a cup-like inflorescence called a cyathium. This cup-shaped structure contains one pistillate flower with 11 to 20 staminate flowers. The cyathium usually bears four, two-horned, nectariferous glands. Flowers are cross-pollinated by insects and rarely self-pollinate. The cyathea are borne terminally in an umbel-like inflorescence. The yellowish-green inflorescence appears in the spring, forms early to late May, and generally continues through mid-summer.

One flowering leafy spurge stem on native grassland will yield an average of 252 seeds (Selleck et al. 1962). Leafy spurge seeds are highly viable and germinate over an extended period. If seedlings from one germination flush do not survive, other viable seeds remain in the soil to provide seedlings for future germination. Seed may remain dormant for five to eight years (Selleck et al. 1962, Bowes and Thomas 1978). The underground portion of leafy spurge is an extensive root system with associated vegetative buds.

All leafy spurge plant parts contain latex. Upon germination, seedlings will grow rapidly and by mid-June develop a characteristic yellow-green hue, indicating that flowering is in progress and mature seeds will soon be dispersed.

History

Leafy spurge is native to Eurasia and was introduced into North America via contaminated crop seed sources and sailing ship ballasts (Dunn 1985). Batho (1931) suggested that leafy spurge was a contaminant in oat seeds brought to southwestern Minnesota by Mennonites emigrating from southern Russia about 1890. The first report of leafy spurge in North Dakota occurred in Fargo in 1909 (Hanson and Rudd 1933). Another possible source of leafy spurge introduction surfaced in a 1932 Manitoba Department of Agriculture Bulletin in which Batho (1932) wrote, "... leafy spurge is evidently introduced into new areas by seeds. Some farmers believe their infestations have come from brome grass seed."

William Oakes first recorded leafy spurge in North America from Newbury, Massachusetts, in 1827 (Britton 1921). Hanson and Rudd (1933) reported leafy spurge was most prevalent in North Dakota and Minnesota, although it had also been found in Maine, New Hampshire, Massachusetts, Connecticut, New York, Pennsylvania, Maryland, Michigan, Illinois, Wisconsin, Iowa, South Dakota, Nebraska, Colorado, Montana, Idaho, and Washington. Leafy spurge continued a westward migration, becoming a major economic concern in the northwestern and north central United States and adjacent prairie provinces of Canada by 1979.

Leafy spurge is primarily found in untilled, noncropland habitats, such as abandoned cropland, pasture, rangeland, woodland, roadsides, and waste areas. The broad range of leafy spurge is exemplified by its wide distribution in North America. It is most aggressive and competitive in semiarid habitats where interference from associated species is less intense (Selleck et al. 1962). Leafy spurge infestations occur on light sandy soils to heavy clay soils, however, they do best in coarse-textured soils (Selleck et al. 1962).

<u>Spread</u>

Leafy spurge spreads by seed and a vigorous root system. Leafy spurge is known for its seed pod dehiscence (sudden rupturing as it dries) characteristic, which can propel individual seeds up to 15 feet from the parent plant (Galitz and Davis 1983). This mechanism of early seed dispersal may account for reinfestation of the spurge patch and its rapid enlargement from one year to the next. A spurge patch can increase in diameter by 30 feet in a single season due to seed dispersal (Galitz and Davis 1983).

Humans, wild and domestic animals, birds, insects, and water are agents of leafy spurge seed dissemination (Messersmith 1983). In a mature grassland habitat, new seedlings outside the boundaries of an established leafy spurge patch will be outcompeted by the parent's growth through rootstock. The aggressiveness of this species can be related to the phenomenal ability of its roots to spread by producing horizontal roots, to propagate by profusely producing buds, and to establish long-living infestations. Best et al. (1980) claimed that patch expansion results almost entirely from lateral root spread. Selleck et al. (1962) commented, "Leafy spurge displays a remarkable capacity for vegetative reproduction."

Established stands of leafy spurge can easily infest undisturbed land due to a root system that is not disrupted by cultivation (Bybee 1976). Leafy spurge seedling establishment is encouraged within grassland bare areas created by livestock overgrazing (Selleck et al. 1962). Soil disturbances in mixed-grass prairie promote establishment of leafy spurge seedlings and displacement of native plant species by leafy spurge and other Eurasian invader plant species such as Kentucky bluegrass (*Poa pratensis* L.) and smooth brome (*Bromus inermis* Leyss.) (Belcher and Watson 1989).

As a result of competition within a leafy spurge patch, numerous indigenous flora species may disappear (Selleck et al. 1962). Grazed rangeland infested by leafy spurge densities of 50 percent or more will experience a decrease in annual graminoid production of at least 35 percent (Lym and Kirby 1987). Watson (1985) reported that small infestations will increase in size at a more rapid rate than larger infestations. Therefore, containment and possible eradication of small infestations should be a major component of an integrated management program to control leafy spurge.

Leafy spurge can be effectively controlled on cropped lands by a combination of timely cultivation, cropping with competitive crops, and herbicide applications (Watson 1985). However, most infestations of leafy spurge occur on terrain unsuitable for cultivation, with some areas not even accessible by conventional spray equipment. Large acreages of leafy spurge infestation along with the natural characteristics of the plant make it a prime target for biological control.

Morphology and anatomy

The aggressiveness of leafy spurge can be related to the phenomenal ability of its roots to spread by producing horizontal roots, to produce buds, and to establish long-living dense infestations.

Shoots. Raju (1985) summarized observations of shoot physiology and morphology. Seedlings appear in the field even when temperatures are around 0C. Morrow (1979) reported that leafy spurge displays increased vigor when growing at temperatures above 13.3C (56F). Seed germination and seedling development are observed throughout the growing season as long as soil moisture is adequate. Seedling shoots are identified by paired opposite leaves in two successive nodes, including the cotyledonary node.

Seedlings dessicate and decrease in number as the season progresses, although their underground parts persist and produce adventitious buds. These adventitious buds arise in the proximal part of the primary root and are initiated on seedlings 2 to 3 days after emergence. Root growth is more vigorous than shoot growth (Selleck et al. 1962). Approximately 11 percent of seedlings die and decay (Raju 1985). Seedling shoots may survive until the end of the first growing season when little or no competition occurs by other plants. These seedling shoots are replaced by adventitious shoots, which persist. In an established leafy spurge infestation, all shoots are adventitious (Raju 1985). Early in the season, new shoots increase until about mid-June and then reduce considerably. In early July, the number of flowering shoots increases. Fruits mature by mid- July with seed dispersal from July through August. Late- flowering shoots may also be produced with a terminal umbellate inflorescence. Both the early and late-flowering shoots produce axillary shoots that terminate in an umbellate inflorescence and are classified as early flowering and late-flowering axillary shoots. Under favorable growing conditions, more axillary shoots are formed, some terminating in a highly reduced umbellate inflorescence and others remaining vegetative. Consequently, in an established infestation of leafy spurge, flowering occurs throughout the growing season (Selleck et al. 1962, Raju 1985).

Inflorescence. The development of the inflorescence is marked by a swelling at the tip of the shoot apex 7 to 10 days after emergence (Selleck et al. 1962). Shoots attain a height of about 25 cm before the inflorescence begins to appear. Shoots emerge in early spring, eventually terminating into an umbellate inflorescence. From mid-July to mid-August, the early flowering shoots produce axillary shoots which terminate in the umbellate inflorescence. The terminal inflorescence is surrounded by a whorl of bracts. A second group of shoots are developed from persistent roots about mid-July. These shoots are generally shorter and less vigorous and may have smaller leaves due to drier conditions of mid summer.

The number of rays in the terminal umbellate inflorescence varies. According to Bakke (1936), the number ranges from 6 to 20. The bracts of the terminal inflorescence vary from linear-lanceolate to oblong-ovate.

Roots. Leafy spurge has a mature root system comprised of abundant vertical and horizontal roots laden with regenerative, adventitious buds (Raju 1985). Roots are as deep as 15 feet with an enormous reservoir of food storage, contributing to its survival during unfavorable conditions (Bakke 1936). Total available root carbohydrate reserves decline during spring growth with rapid carbohydrate storage resumed in early summer, followed by a moderate rate of storage during the remaining growing season (Arny 1932). Bakke (1936) stated the age of leafy spurge roots can be estimated by using rings, much like the stem of a tree. Rings in leafy spurge roots are formed by a layer of starch stored in parenchyma cells.

The leafy spurge seeds are very important in the initial establishment, although the underground parts of leafy spurge are equally important in perennation and propagation. Hanson and Rudd (1933) demonstrated the ability of leafy spurge to sprout new shoots from small root segments. Messersmith et al. (1985) stated that natural dispersal of leafy spurge root fragments has not been reported, but humans transport root portions by tillage, moving landfill soil, road excavations, landscaping, transplanting sod, and transplanting nursery plants.

The early seedling root system indicates a heterorrhizic pattern which has been interpreted to contain the primary root of the "long root" type and the laterals of the "short root" type (Raju et al. 1963). The long roots persist for more than one growing season, can give rise to new root and shoot buds, and are indeterminate. In contrast, the short roots are determinate, have limited growth, and usually die at the end of the first growing season.

The persistent long roots, especially in shallower depths, grow horizontally, invading new areas; produce buds; and establish new growth centers. The lateral roots of the short root type arise in the pericycle of the parent roots (Raju 1985). The entire primary root system appears white in the early stages of development, becoming yellowish-brown and eventually brown after secondary tissues have been laid by secondary meristems.

The formation of permanent long roots and transitory short roots on the heterorrhizic roots initiated in the seedling results in an intricate maze of roots (Raju 1985). The framework of the mature root system consists of abundant vertical and horizontal roots that normally do not show continuous growth. New vertical roots arise from the old roots, allowing development to penetrate vertically at greater depths (Raju et al. 1963). Horizontal spreading roots stop growing periodically when conditions are unfavorable and resume growth when favorable conditions return. Long roots organize the perennial root system despite variability in length, thickness, and capacity to regenerate roots and shoots.

<u>Buds</u>. A trait of leafy spurge that makes it a successful weed is its ability to produce a variety of morphologically different shoot buds (Raju 1985, Freeman 1995). Morphological structures such as runners or rhizomes are not present in leafy spurge; however, it does have the ability to produce numerous buds on underground rootstock. These buds are classified as axillary and adventitious types (Esau 1965). Axillary buds contribute to the branching of aerial shoots, but are not significant as buds arising from underground stems.

The adventitious buds persist longer and contribute more to annual production of new shoots. Adventitious shoot buds are produced abundantly and are important in the success of leafy spurge (Bakshi and Coupland 1959, Myers et al. 1964). Leafy spurge buds produced after an injury are termed reparative buds (Raju et al. 1966). Buds arise spontaneously without injury and are classified as additional buds (Raju et al. 1966). Both types of adventitious buds are common on underground parts of leafy spurge. Buds arise on the hypocotyl of seedlings.

The behavior of the leafy spurge plant is closely correlated to its structure and mode of growth, whether the buds are additional or reparative (Priestley and Swingle 1929). The leafy spurge root system is important for perennation and propagation (Steeves et al. 1966). Hanson and Rudd (1933) demonstrated that root buds are produced to depths exceeding 4 feet into the soil and are abundant on the horizontal roots found throughout the top 12 inches of soil. Root fragments as small as one inch contain enough energy reserves for a bud to grow and produce a viable shoot.

The persistence and rapid expansion of a leafy spurge patch is greatly enhanced by the perennial roots and crown which produce vegetative buds. These buds possess a tremendous regenerative capacity and may produce new shoots at any time, depending on what happens to the aboveground shoot portion during the growing season. In anatomical studies of seedlings, Raju et al. (1963) described the presence of shoot buds in the transition zone between the shoot and root as early as the second week after germination. These buds provide a means of shoot regeneration should initial shoot damage occur (Galitz and Davis 1983).

If the plant grows undisturbed, first buds develop into a crown just below the ground surface. These crowns are the source of new shoots in the following spring. The growth of crown buds are controlled by the plant hormone indoleacetic acid (IAA) (Galitz and Davis 1983). This growth regulator is produced in the apex of each vegetative shoot and transported toward the plant base. IAA in a stem suppresses lateral bud growth as well as crown buds (Galitz and Davis 1983). Consequently, mowing, grazing, or chemical destruction of the shoot apex reduces IAA concentration; and the remaining shoot buds begin to grow, producing a branched plant.

Allelopathy

Leafy spurge has been classified as an allelopathic plant, partially explaining the aggressive and competitive nature of the weed (Steenhagen and Zimdahl 1979). Allelopathy is defined by Rice (1974) as "any direct or indirect harmful effect by one plant (including microorganisms) on another through the production of chemical compounds that escape into the environments." Selleck (1972) confirmed that leafy spurge leaves were more toxic than stems and demonstrated that root extracts are phytotoxic. Extracts of leafy spurge infested soil inhibited coleoptile and radicle elongation. Autotoxic effects were only found with root extracts which depressed radicle elongation of leafy spurge seedlings (Steenhagen and Zimdahl 1979).

Multi-species grazing

Grazing two or more classes of livestock together on the same land unit in a single growing season is known as common-use or multi-species grazing (Nelson et al. 1991, Vallentine 1990). Common-use grazing, the concurrent use of rangeland by more than one kind of animal, has been advocated to maximize animal production (Merrill and Miller 1961). Multi-species grazing is an important concept in range management because rangelands usually consist of one or more classes of vegetation, grasses, forbs, or shrubs (Merrill et al. 1966).

A mix of plant classes and species within a plant community is desirable for multiple-species grazing. Animal species have evolved through the foraging of various plant species and types. Grazing a mixture of domestic or wild animals can often result in more even and efficient use of forage and browse, increased total animal gains per acre, and a more vigorous plant community (Nelson et al. 1991).

Different kinds of livestock and big game have individual preferences for plants and topography, making it advantageous to graze with a combination of animals and classes (Bowns 1985). Combination grazing by two or more animal species having different diets, site, or terrain preferences, and habitat requirements provides the greatest opportunities for multi-species grazing. Cattle graze uniformly, selecting desirable grass species and avoiding other plants like leafy spurge. These undesirable plant species may increase in number and density on cattle pastures due to less competition and selective grazing.

Diet selection by livestock class

A major problem of range management is balancing grazing pressure with available forage or determining an optimum stocking rate or carrying capacity. A range manager must understand the behavior of animals in diet selection and preference.

Diets of sheep, goats, and wild ungulates differ in some proportion from cattle diets and may overlap in other components (Glimp 1988). Diet selection by livestock species vary with seasonal changes as plants mature and fluctuate in availability. Dietary preferences of livestock are commonly assessed by means of esophageally fistulated animals (Van Dyne and Torell 1964).

Squires (1982) found in New South Wales that goats consumed more shrubs than sheep or cattle at all sampling periods; however, the differences failed to reach significance during some periods. Sheep maintained a high proportion of green grass in their diets during all periods, despite low levels of availability. Cattle did not harvest the sparse purple lovegrass (*Eragrostis lacunaria*), which was the major component of the sheep diet. Instead, cattle selected senescent variable spear grass (*Stipa variabilis*) when other forages were in short supply. Forbs were a minor part of the diet in all but spring periods because of low availability. Sheep maintained a higher quality diet than cattle or goats and were the most selective.

The degree of cattle, goat, and sheep diet overlap varied seasonally. Diet overlap was greatest between sheep and cattle and least between sheep and goats (Squires 1982). Degree of cattle, goat, and sheep diet overlap was lowest during the summer when the proportion of browse species was greatest in divergence and highest in the autumn when all three livestock species consumed considerable amounts of grass.

Humann (1985) reported that under a common-use cattle and sheep grazing program in western North Dakota, sheep diets were dominated by grasses, mainly blue grama. Blue grama was preferred by sheep during all grazing periods and contributed 53 to 84 percent of the grass selected with a short duration or seasonlong grazing treatment. Grass consumption increased in sheep diets throughout the 1983 grazing season. Forbs contributed significantly to sheep diets in the early seasons and decreased as availability decreased. When available, forbs were highly preferred. Half shrubs were avoided in the early summer, but preferred in the latter seasons on both treatments. Humann (1985) indicated sheep, while grazing commonly with cattle, had diets significantly higher in forb, energy, and crude protein contents. All crude protein levels met or exceeded maintenance requirements of sheep.

Hanson (1994) reported that leafy spurge and shrubs made a large portion of the goats' diet throughout the grazing season. The mean percent relative density of leafy spurge in angora goat diets ranged from 21.5 percent to 65.5 percent (Hanson 1994). These amounts were recorded on June 1 and September 23. Shrub and trees ranged from a low of 4.4 percent on June 16 to a high of 47.1 percent on August

22. Hanson (1994) concluded that leafy spurge is a preferred species for angora goats at all times of the year.

Johnston and Peak (1960) determined the effectiveness of selective grazing by sheep to control leafy spurge near Pearce, Alberta. The study site was heavily infested with leafy spurge and had previously been seeded with crested wheatgrass. Johnston and Peak (1960) reported selective grazing by sheep was an effective method in controlling leafy spurge, and at least four years of grazing was required before control was attained. The basal area of crested wheatgrass increased significantly ($P<0.01$), whereas leafy spurge showed a significant decrease ($P<0.01$).

Cook (1983) emphasized the importance of forbs in the diets of sheep on northern Utah mountain summer range. Of the total quantity of forage consumed, sheep diets included 70 percent of forbs compared to 37 percent for cattle. The weighted utilization of grasses, forbs, and shrubs for sheep was 18, 42, and 8 percent, respectively.

Diet preference of angora goats has primarily been browse and graminoid species, with lower utilization of broadleaf species or forbs (Bryant et al. 1979, Malechek 1970). Bryant et al. (1979) and Malechek (1970) reported angora goat diets consist of 40 percent browse, 48 percent graminoids, and 12 percent forbs on native range in Utah.

Goats can survive even after vegetation has been consumed by other kinds of livestock (Martin and Huss 1981). A mobile upper lip and a very prehensile tongue allow goats to eat short grass and browse, and feed in areas that offer no other choice (Huss, 1972). Since goats prefer leaves and tender twigs, they are capable of consuming young tender growth of many undesirable woody species. Coblentz (1977) proposed that goats are not primarily browsers by preference, but are opportunistic generalists that tend to consume the most palatable vegetation available.

Cattle diets reported at the Central Grasslands Research Center near Streeter, North Dakota, by Silcox (1991) and Hirschfeld (1992) found grass consumption 70.8 and 86.9 percent of their diet, respectively. Dietary consumption of forbs was 23.4 and 12.0 percent, respectively, while shrubs comprised 6.4 and 1.1 percent, respectively (Silcox 1991, Hirschfeld 1992).

The addition of livestock species that have a diet preference different from cattle could improve the biological efficiency and use of range ecosystems. Rangeland of predominately grass favors cattle. Rangeland dominated by forbs is more adapted to sheep, while goats prefer shrub dominated range. A typical rangeland ecosystem will include at least two and often three classes of vegetation. That portion of the herbage production avoided by cattle could be converted into added profit by adding new livestock classes that select for these avoided forages.

Kirby et al. (1986) concluded diets of cattle and sheep under intensive, rotational grazing of mixed-grass prairie were complementary. Grasses dominated cattle diets each season and year, while sheep grazed more selectively among forage classes and species between grazing seasons. Kirby et al. (1986) conservatively estimated that a stocking rate increase of 10 to 15 percent could be attained with the addition of sheep to a cattle pasture. This added grazing would result in more uniform use of the available forage resources while maintaining or improving forage production and diversity of the mixed grass prairie. Blackford (1985) reported that combining sheep and cattle significantly increased carrying capacity and profits.

Competition

Competition among grazing animals occurs only when there is a limited supply of one or more necessities of life. Competition can be for space, water, or cover, but most commonly for food. Dietary overlap among species is not sufficient evidence for exploitative competition (Hanley 1982, McInnis and Vavra 1987). Dietary overlap is important only if accompanied by spatial overlap. Only shared foods are in short supply, if one herbivore limits access of another, or if an absence occurs of alternative acceptable forage plants does dietary overlap become of concern.

The degree of forage competition among kinds of animals increases with (1) increased similarity of diets, (2) increased overlap of sites selected for grazing, (3) increased grazing pressures resulting from high stocking rates or low forage production, and (4) lack of alternatives beyond the most preferred forage plants and most preferred sites for grazing (Vallentine 1990). A balanced mix of animal species may largely prevent any competition for forage and prevent animal-induced vegetation trends (Vallentine 1989).

Cattle, sheep, and goats on mixed vegetation types in central Texas selected a large percentage of plants from the three major vegetation classes (Taylor 1986). As available vegetation becomes limiting, dietary overlap increases (Vallentine 1990). Competition among kinds of animals grazing seasonlong on the same range could best be summarized in terms of competition for green forage (Bryant et al. 1979).

Plant community effects

Belcher and Wilson (1989) reported frequencies of the dominant native grasses were significantly and negatively correlated with leafy spurge, while some native species were totally displaced where leafy spurge was dominant. Native species richness and diversity decreased significantly with increasing leafy spurge densities while Belcher and Wilson (1989) concluded that leafy spurge was clearly related to a decline in the abundance of the dominant species in native prairie, both on a large scale and within a single infestation. Kentucky bluegrass and smooth bromegrass were the only species that were positively correlated with leafy spurge density increases.

Decreasing the number of leafy spurge infestations on native prairie could be accomplished through the reduction of disturbances which create bare soil. Best et al. (1980) showed that 45 times more seeds of leafy spurge establish on bare mineral soil than in undisturbed vegetation. Bare mineral soil appears to be a suitable seedbed, allowing leafy spurge seedlings to establish without interference from neighbors.

Continuous grazing by one animal species can alter the plant community structure. Continual sheep grazing promotes the growth of grasses, while continual cattle use increases forb and shrub dominance. Rangeland has a greater biological efficiency when grazed commonly by either cattle, sheep, or goats. Biological efficiency of rangeland increased by 45 percent when shifted from sheep-only grazing to multi-species grazing (Cook 1985). Conversion from cattle-only grazing to multi-species grazing increased biological efficiency by 19 percent (Cook 1985). Bowns (1985) reported that sheep better utilize forbs than cattle alone or cattle and sheep grazed together. Cattle and sheep grazed together provide the heaviest use of grasses. Cattle utilize grasses heavier, while sheep grazed them the lightest (Van Dyne and Heady 1965).

These data and others support the concept that grazing with more than one kind of animal results in a more even distribution of grazing and a better use of the entire range. Cattle tend to concentrate on riparian zones and low lying areas while sheep prefer high exposed ridges (Van Dyne and Heady 1965). Multi-species grazing can ameliorate the negative aspects of each species. Walker (1991) stated "with multi-species grazing, a more even defoliation of the forage species occurs and the ability to compete for water and nutrients is more equal."

Taylor (1985), based on a 20-year study of multi-species grazing of cattle, sheep, and goats in Texas, reported gains of both cattle and sheep were greater when grazed in combination with goats than when grazed alone. This was also true of sheep when grazed with cattle. The reproductive performance of sheep when measured as percentage lamb crop was higher when sheep were grazed with cattle than when grazed as a single species (Taylor 1985). Wool production from sheep was higher when sheep were grazed in combination with cattle and goats.

Cook (1985) calculated biological efficiency of multi-species grazing was 31 percent greater than single species grazing with sheep and 67 percent greater with cattle. Biological efficiency increased by 91 percent when yearling steers were grazed with sheep (ewes and lambs) than with sheep alone and 19 percent than with steers alone. The increased efficiency attributable to multi-species grazing of ewes and lambs and cows and calves resulted from greater utilization of vegetation.

Biological control

Biological control by grazing is the application of selective grazing to accomplish a predetermined, desired directional succession in vegetation composition (Vallentine 1989). It is effective only when the right kind or combination of grazing animals, season, system of grazing, stocking density, and rate result in heavy grazing of less desirable plants to the competitive advantage of the favored plants (Vallentine 1990).

Goat grazing in the southwestern Colorado foothills left a browse line up to 7 feet on Gambel oak (Davis et al. 1975). The oak trees were not killed, but did reduce in canopy and increased opening of the understory (Davis et al. 1975). Sedivec et al. (1994) reported excessive utilization of western snowberry by angora goats, with the shrub component reduced by over 85 percent after 3 years of intensive grazing. Heavy goat browsing in southern Utah was found to be effective in the removal of spiny tips of twigs, stimulating basal sprouting of axillary buds and increasing new growth (Provenza 1978, Provenza et al. 1983).

Goats and sheep are utilized in the United States and Canada to control leafy spurge, the Northern Great Plain's Region most destructive noxious weed on rangeland. Goats readily graze leafy spurge, while cattle appear to develop conditioned flavor aversions to leafy spurge (Kronberg and Walker 1993). Goats appear to be similar to sheep in usage of leafy spurge and effectiveness in controlling its spread (Muenscher 1930, Walker 1991). However, angora goats may differ from sheep in grazing effects upon the associated plant communities. Goats appear to use more shrubs, while sheep may ingest more forbs.

Hanson (1994) stated that goats are a valid biological control for leafy spurge. After two years of rotational grazing, leafy spurge seed dissemination was eliminated; and cover percentages, heights, and biomass of leafy spurge decreased. Hanson (1994) also found that as goats graze leafy spurge, other plant classes (grasses, forbs, and sedges) were not affected or sometimes increased.

Cattle and sheep can develop feeding aversions to leafy spurge in contrast to goats (Kronberg et al. 1993a). This finding was consistent with field observations that cattle generally do not graze leafy spurge (Lacey et al. 1985, Lym and Kirby 1987) and with mixed reports that sheep will or will not readily graze it (Landgraf et al. 1984, Lacey et al. 1984, Bartz et al. 1985, Kronberg et al. 1992). This finding was consistent with field observation in southeastern Idaho that goats graze leafy spurge more willingly than do sheep (Walker and Kronberg 1992). These findings suggested that leafy spurge contains one or more chemicals that can elicit an aversive response in cattle and sheep (Kronberg et al. 1993b).

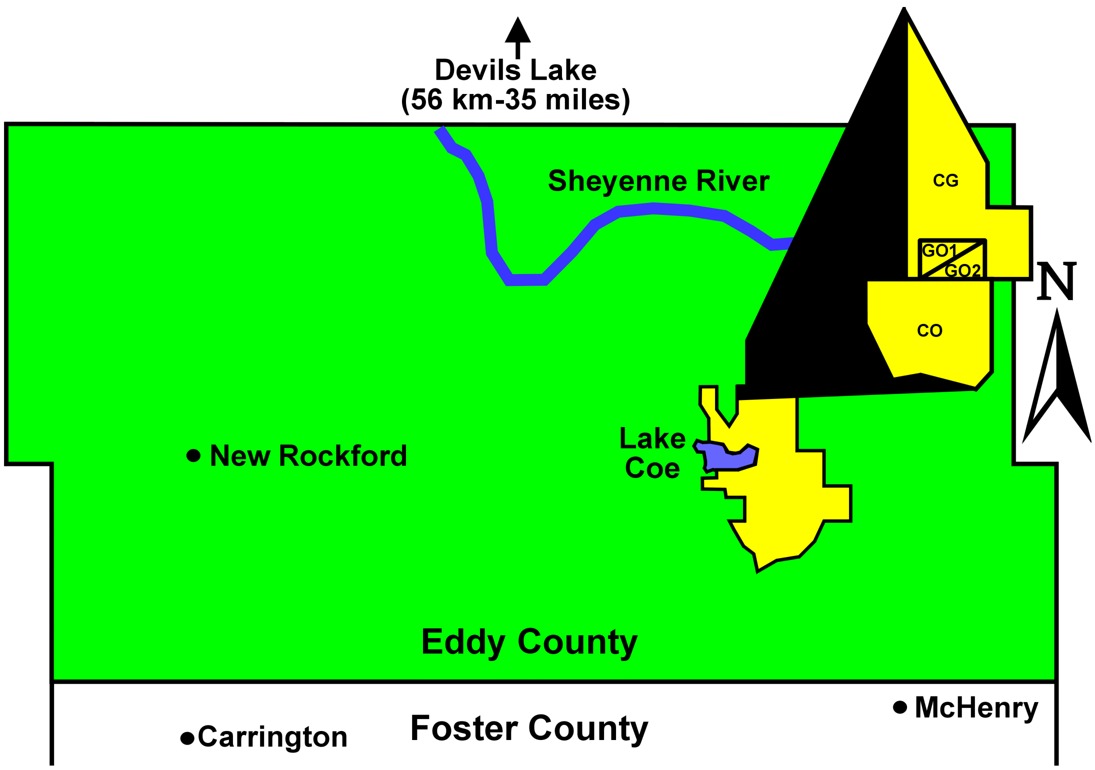
Kronberg and Walker (1993) hypothesized why goats grazed leafy spurge more readily than do sheep. If the level of aversive postingestive feedback derived from a food is low and/or delayed and its nutritional value is high and/or promptly experienced, ruminants appear to have more attraction than aversion and increase intake (Launchbaugh and Provenza 1992, Provenza and Cincotta, 1992). Leafy spurge has a high crude protein and digestible energy level, similar to alfalfa (Fox et al. 1991).

Kronberg and Walker (1993) speculated that leafy spurge offers more positive than negative stimuli for goats because of its treatment in the goat's rumen. In contrast, leafy spurge causes more negative than positive stimuli for sheep because of their ruminal treatment of leafy spurge. This suggested that differential activity in the rumen of the two species may account for differences in their diet selection. However, it is also possible that degradation of leafy spurge chemicals in the goat occurs within its own tissues (e.g., its liver) (Kronberg and Walker 1993).

STUDY AREA

Location

The study area consisted of 85.5 hectares (211.2 acres) located in Sections 12 and 13, T149N, R63W in southeast Eddy County, North Dakota. Research was conducted on mixed-grass prairie of Camp Grafton South, a facility of the North Dakota Army National Guard. The camp lies in southeast Eddy County, approximately 30.4 km (19 mi.) east of New Rockford, North Dakota. McHenry, North Dakota, is located approximately 19.2 km (12 mi.) southeast of Camp Grafton South. The camp consists of 3440 hectares (8500 acres), and most is grazed. The land was purchased to develop and conduct training for the Army National Guard. The area is predominately rangeland that has, historically, been exposed to many years of cattle grazing.



Relative Position of Camp Grafton South Within Eddy County and Location of Multi-Species Study Area

The study area consisted of a 37.3 hectare (92.2 acre) cattle-only treatment, a 41.4 hectare (102.3 acre) multi-species (cattle and goats) treatment, and two replicated goats-only treatments of 3.5 hectare (8.7 acre) and 3.2 hectares (8.0 acres), respectively. All treatments consisted of overflow and sandy range sites (Table 1). An open woodland site occurred in the multi-species treatment (Table 1).

Table 1. Range site and open woodland composition by treatment at Camp Grafton South.

Treatment	Overflow	Sandy	Open Woodland
		%	
Cattle/Goats	50.7	35.6	13.7
Goats 1	17.4	82.6	0.0
Goats 2	23.6	76.4	0.0
Cattle only	56.4	43.6	0.0

Physiography and topography

Camp Grafton South is located in the glaciated region of North Dakota known as the Drift Prairie physiographic region (Bluemle 1977). The Drift Prairie region is about 141 kilometers (225 miles) wide east to west at the Canadian border, narrowing to a width of about 47 kilometers (75 miles) at the South Dakota border.

The Drift Prairie region is an area of relatively thick glacial sediments where large-scale glacier thrusting, coupled with deposition from glacier melting, resulted in an intricate low rolling landscape (Bluemle 1977). Bluemle (1977) called this the Ground Moraine region or Undulating Collapsed Topography region. Stream systems are poorly developed and poorly integrated in the Drift Prairie with most water flow draining into numerous closed depressions, percolating to the groundwater table or evaporating. Most of the existing streams occupy channels that once carried water from melting glaciers.

The Drift Prairie is an undulating plain with low rounded knolls, numerous closed depressions, and few widely spaced streams. Within this region, four distinct moraines exist that rise from 50 to more than 100 feet above the general level of the surrounding plain (Bluemle 1977). These linear and curved hills mark either the limits at which the glacier remained stationary or are end points of the readvancing ice sheet. The moraine occupying Camp Grafton South extends east from the northeast corner of Wells County to northcentral Eddy County, curving southeast to northwestern Griggs County.

Climate

North Dakota has a subhumid continental climate characterized by warm summers and cold winters. There is great variation in daily and annual temperatures, with the timing and amount of precipitation varying by year. North Dakota's climate is affected by three source regions: the Gulf of Mexico, the polar region, and the Rocky Mountains (Jensen 1972).

The air masses moving northward from the Gulf of Mexico are usually warm and moist and are the major source of precipitation. In contrast, air masses from the polar regions and the North Pacific are generally dry, with polar air cold and Pacific air mild. Air masses entering North Dakota from the west are usually dry, due to the orographic effect during passage over the Rocky Mountains. A lack of natural barriers to air flow from the north and south and air movement from the west result in frequent and rapid weather changes, depending on the dominant air masses moving across the state at specific times (Jensen 1972).

Borchert (1950) noted that the climate of the central grasslands of North America is relatively homogenous in spite of the usually rapid weather changes. The low winter precipitation, occasional droughts in summer, and the tendency for major summer droughts to occur synchronously are characteristics of the Great Plains region.

The average annual temperature in North Dakota ranges from 2.8C (37F) in the northeast to 6.1C (43F) along the southern border. January is the coldest month with average temperatures ranging from -16.7 to -8.3C (2-17F)(NOAA 1993, 1994). July is the warmest month with average temperatures ranging from 19.4 to 22.8C (67-73F) (NOAA 1993, 1994).

The average length of the frost-free period in North Dakota is about 120 days (Ramirez 1972). Temperature in Eddy County has a 29-year average of 3.3C (38F). The average annual temperature was slightly below the long-term average in 1993 and above average in 1994 (NOAA 1993,1994). The coldest day in 1993 occurred on December 27 when the temperature was -35.5C (-32F). August 25 was recorded as the warmest temperature at 34.4C (94F). In 1994, the temperature ranged from a low of -38.3C (-37F) on January 18 to a high of 33.8C (93F) on August 25 (NOAA 1993,1994). Table

2 gives the average monthly temperature data from the weather station in Eddy County during the two-year study.

Table 2. Average monthly temperatures (C) during the study and the deviation from the 29-year average (USDC, NOAA, NCDC 1993 and 1994).

	McHenry (Eddy County),North Dakota			
	1993	1994	Month	Average
Deviation	Average	Deviation		
January	-15.7	+0.6	-21.3	-5.0
February	-13.6	-0.7	-17.4	-4.5
March	-4.9	+0.4	-1.8	+3.5
April	4.9	+0.5	5.3	+0.9
May	12.2	+0.2	14.4	+2.4
June	15.4	-1.8	18.5	+1.3
July	17.6	-2.6	18.6	-1.6
August	18.9	0.0	18.7	-0.2
September	11.6	-1.0	16.1	+3.5
October	5.1	-1.0	8.3	+2.2
November	-4.3	-0.4	-1.3	+2.6
December	-10.8	+2.1	-9.1	+3.8
Total Average	3.0	-0.3	4.1	+0.9

Precipitation at the McHenry weather station in Eddy County averaged 47.2 cm (18.6 in) annually (NOAA, NCDC 1993 and 1994). Table 3 shows the monthly precipitation totals and deviation from the 29-year average for 1993 and 1994. In 1993, more than 80 percent of the total precipitation occurred from May to August. This amount was nearly 31 cm above the average rainfall expected during this period. This high amount of precipitation continued in 1994, with an extra 48 cm of precipitation received above the average rainfall. The greatest precipitation occurred in July 1993 with 23.4 cm recorded, 15 cm above average for that month.

The greatest amount of precipitation for a 24-hour period was June 23 with 7.3 cm of rainfall. In 1994, June had the greatest precipitation, with 13.4 cm recorded. The highest rainfall total for 1 day occurred on September 16 with 4.5 cm.

Table 3. Monthly precipitation and deviation from the 29-year average at McHenry, North Dakota, for 1993 and 1994 (NOAA, 1993 and 1994).

	1993		1994	
Month	Precip.	Dev.	Precip.	Dev.
	cm			
January	0.99	-0.33	2.16	+0.84
February	0.45	-0.67	1.63	+0.51
March	1.75	-0.51	1.22	-1.04
April	2.67	-1.12	2.74	-1.04
May	10.03	+4.49	7.01	+1.47
June	18.92	+10.26	13.41	+4.75
July	23.44	+16.76	8.13	+1.45
August	9.65	+2.84	4.17	-2.64
September	1.19	-3.91	12.19	+7.09
October	0.66	-2.18	9.68	+6.83
November	2.39	+0.69	6.53	+4.83
December	2.62	+1.19	0.28	-1.14
Total	74.76	27.51	69.15	21.91

Soils

The majority of soils in the study area were Mollisols. These are mineral soils with a very thick, dark-colored, not highly leached surface horizon (mollic epipedon) (Wright and Sweeney, 1977). These soils formed under grassland vegetation and are usually considered among the world's best agricultural soils. Mollisols in the study area have no B horizon, weak cambic (B_w) horizon, or a substantial amount of subsoil development as reflected by an increase in illuvial clay of an argillic (B_t) horizon. Entisols are immaturely formed mineral soils with only the beginning of A-horizon development. These soils have only weakly developed surface horizons with no subsurface horizon development. Generally, Entisols form on exposed parent materials, on inundated areas with wave action, or on steep slopes. Omodt et al. (1968) reported that most of the soils in the transition grassland ecotone are from only two suborders, the Borolls and Aquolls. These types of soil suborders are represented by the Barnes-Buse series on Camp Grafton South in Eddy County.

The Barnes-Buse association occurs on steep slopes or hilltops that are excessively drained. The Buse soils (Udorthentic Haploborolls) occur on the steep slopes and rounded hilltops. This excessively drained series has a very thin calcareous soil. The Barnes soil (Udic Haploborolls) occupies the more moderate slopes. Buse soils differ from Barnes by having a thinner surface layer and lack a B-horizon. Barnes soils, which occur downslope from the Buse soils, are moderately well-drained. These soils store enough moisture to support mid and tall grasses.

Due to the erodibility of the steeper slopes, most of the land in this association is maintained as rangeland. Some of the gentler slopes are cultivated.

The soils on the study area are of the Heimdal-Embden-Serden association. These soils form in wind- and water- reworked glaciofluvial sediments overlying till (Wright and Sweeney 1977). This association is about 35 percent Heimdal soils, 20 percent Emden soils, 15 percent Serden soils, and 30 percent minor soils.

The Heimdal series consists of deep, nearly level to steep, well-drained soils that form in medium-textured glacial till. These soils are on sand-mantled glacial till plains. Permeability is moderate with available water capacity high.

The Emden series consists of deep, nearly level, gently undulating and gently rolling, moderately well-drained soil that form in moderately course-textured glaciofluvial deposits over course-textured glaciofluvial deposits. These soils are found on glacial outwash plains and on glacial till plains that are mantled with sand. Permeability is moderately rapid with available water capacity moderate.

The Serden series consists of deep, nearly level to gently rolling, excessively drained soils that formed in coarse-textured glaciofluvial deposits. These soils are found on glacial outwash plains and sand-mantled glacial moraines. Permeability is rapid with available water capacity very low.

Minor soils of this association are in the Esmond, Egeland, Hecla, and Maddock series. The Esmond soils consist of deep, well-drained loam soils that form in medium-textured glaciofluvial deposits. Esmond soils are on glacial till plains located on convex slopes. Egeland soils form in moderately coarse textured deposits and are found on knolls or hillsides on upland prairie. The Egeland series consists of deep, well-drained soils on convex and steep slopes. Permeability, water capacity, and organic matter are all moderate in this series. The Hecla series is usually found in low drainage areas and around places of water collection. It is often found in low drainage areas and on concave slopes. The Maddock series is a well-drained soil series found on gently sloping to steep upland prairie hillsides. The Maddock series in this area is a loamy sand occurring in wind-worked sediments.

Vegetation

Vegetation on the study area was primarily mixed-grass prairie (Whitman and Wali 1975, Barker and Whitman 1989). Kuchler (1964) classified the potential natural vegetation of this northern transition grass prairie as a moderately dense, short to medium tall Wheatgrass-Bluestem-Needlegrass (*Agropyron-Andropogon-Stipa*) association. This transitional grassland type lies between the Bluestem prairie to the east and the drier Wheatgrass-Needlegrass association to the west. On drier sites or where grazing has occurred, the more xeric Wheatgrass-Needlegrass type may become dominant, including western wheatgrass (*Agropyron smithii*), needle-and-thread (*Stipa comata*), and blue grama (*Bouteloua gracilis*) as well as other more xerophytic species. Throughout the Wheatgrass-Bluestem-Needlegrass association, Kentucky bluegrass (*Poa pratensis*) has increased and comprises a major component of the vegetation.

Dominant graminoids found on the mixed-grass prairie in east central North Dakota include western wheatgrass, blue grama, Kentucky bluegrass, smooth brome (*Bromus inermis*), needle-and-thread, green needlegrass (*Stipa viridula*), quackgrass (*Agropyron repens*), prairie sandreed (*Calamovilfa longifolia*), and various upland sedges (Carex spp.) (Barker and Whitman 1989). Other graminoid components include little bluestem (*Schizachryium scoparium*), prairie Junegrass (*Koeleria pyramidata*), and slender wheatgrass (*Agropyron caninum* subsp. *majus* var. *unilaterale*) (Barker and Whitman 1989).

Forb species include fringed sage (*Artemisia frigida*), white sage (*Artemisia ludoviciana*), silver-leaf scurf pea (*Psoralea argophylla*), white aster (*Aster ericoides*), dotted gayfeather (*Liatris punctata*), prairie coneflower (*Ratibida columnifera*), and stiff sunflower (*Helianthus rigidus*). The dominant shrub species is western snowberry (*Symphoricarpos occidentalis*). Other shrub species include silverberry (*Eleagnus commutata*), prairie rose (*Rosa arkansana*), chokecherry (*Prunus virginiana*), northern hawthorne (*Crataegus rotundifolia*), and lead plant (*Amorpha canenscens*) (Barker and Whitman 1989).

Range sites

Two major range sites were identified on the study area. These range sites were the sandy and overflow sites (USDA Soil Conservation Service 1984, Sedivec et al. 1991).

A mixture of warm- and cool-season grasses occur on these sites throughout the growing season.

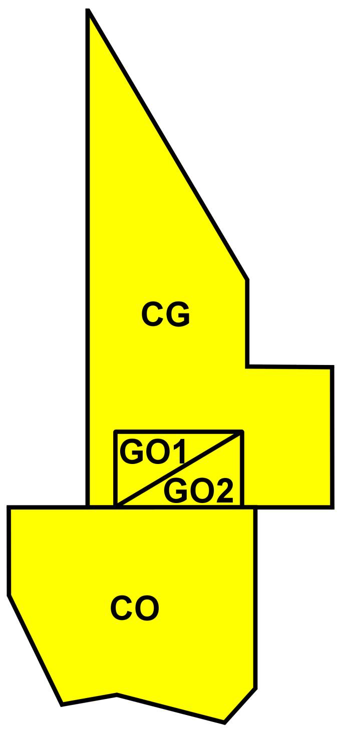
Overflow range sites occur on nearly level swales and depressions and on residual and glacial uplands (U.S.D.A. Soil Conservation Service 1984, Sedivec et al. 1991). Slopes are commonly one to three percent. Soils are deep, well-drained, medium, and moderately fine-textured and regularly receive additional run-in moisture from higher land. Herbage production is approximately 4040 kg/ha (Sedivec et al. 1991). Permeability is moderate with available water capacity high to very high.

Vegetation dominating this range site is both tall and mid grasses. The major species are Kentucky bluegrass, western wheatgrass, green needlegrass, and smooth brome. Other associated species include big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), northern reedgrass (*Calamagrostis stricta*), porcupine grass (*Stipa spartea*), needle-and-thread, prairie cordgrass, slender wheatgrass, and quackgrass. Dominant shrubs and forbs include western snowberry, prairie rose, white sage, and white aster.

Sandy range sites occur on nearly level to hilly topography (USDA Soil Conservation Service 1984, Sedivec et al. 1991). The soils are deep, well-drained, with moderately coarse textured surface soil, overlying coarse- to medium-textured subsoil. The major vegetation in this range site are prairie sandreed, needle-and-thread, prairie junegrass, western wheatgrass, and blue grama. Herbage production in this range site is approximately 3250 kg/ha (Sedivec et al. 1991).

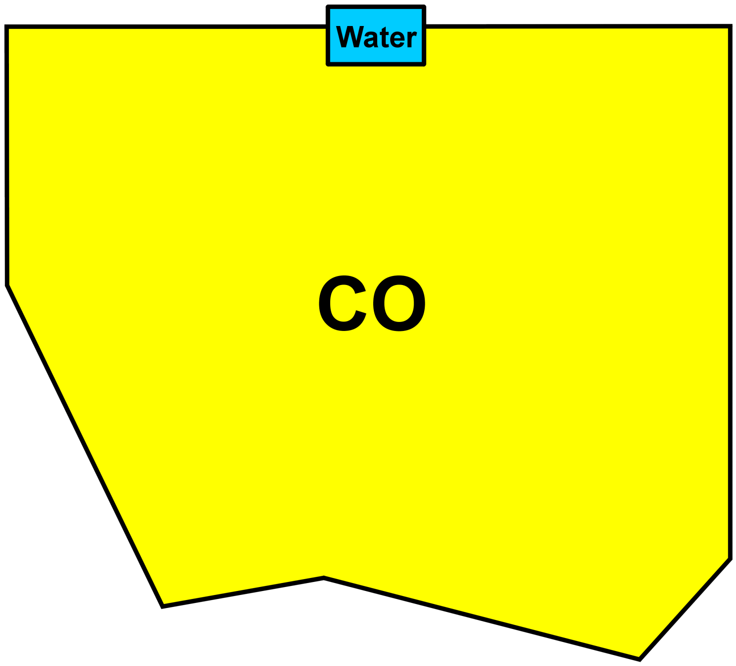
Description of grazing treatments

The study area consisted of three grazing treatments including cattle-only, multi-species (cattle and goats), and goats only (Figure 1). The cattle-only pasture consisted of 37.3 hectares (92.2 acres) and was grazed by 21 cow/calf pairs in 1993 and 1994 (Figure 2). The grazing season was June 15 to November 1, with a 140-day grazing season for both years. The stocking rate was 0.39 ha/AUM (0.97 ac/AUM) for both years.



Treatment - Location for the Multi-Species Grazing at Camp Grafton South, 1993 and 1994

Figure 1. Design and location of the cattle-only (CO), replicated goats-only (GO1, GO2), and cattle and goat treatments (CG) at Camp Grafton South for 1993 and 1994.



Design of the Cattle only (CO) Grazing Treatment at Camp Grafton South, 1993 and 1994

Figure 2. Design of the cattle-only (CO) treatment at Camp Grafton South for 1993 and 1994.

Area: 37.3 ha (92.2 ac)

Grazing Schedule for 1993 and 1994
21 cow/calf pairs were grazed from June 15 to November 1 for both years.

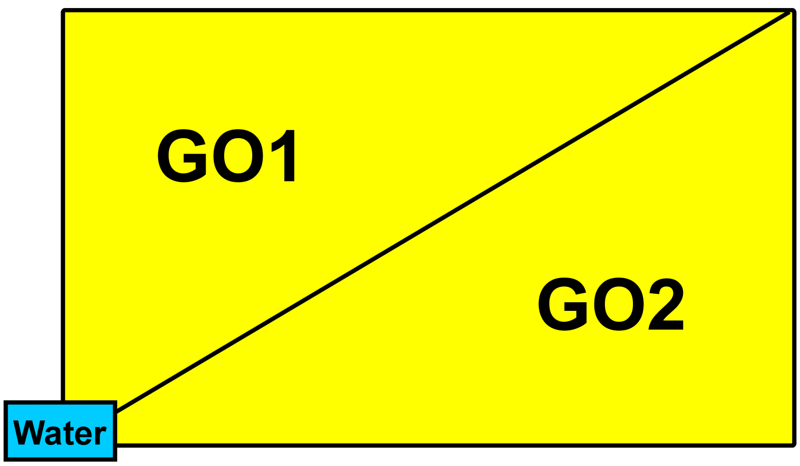
Stocking Rate: 0.39 ha/AUM (0.92 ac/AUM)

The goats-only treatment consisted of two replicated cells, 3.2 hectares (8.0 acres) and 3.5 hectares (8.7 acres), respectively (Figure 3). The goats-only treatment was grazed by 15 angora goat nannies in each cell in 1993 and 16 angora goat nannies per cell in 1994. The stocking rates of the goats- only trials were 0.42 ha/AUM (1.03 ac/AUM) and 0.38 ha/AUM (0.95 ac/AUM), respectively, in 1993 and 1994. The grazing dates were May 27 through September 11, 1993, and June 1 through September 1, 1994.

The multi-species treatment was established in 1993 on 41.4 hectares (102.3 acres) (Figure 4). In 1993, the 41.4

hectares was grazed by 21 cow-calf pairs from July 15 through November 1 or 109 days (0.55 ha/AUM or 1.36 ac/AUM). The same treatment was grazed by 191 Angora goat nannies from May 27 through September 11 or 107 days (0.36 ha/AUM or 0.9 ac/AUM).

There were 21 cow-calf pairs grazing from June 1 through November 1 or 153 days (0.39 ha/AUM or 0.97 ac/AUM) in 1994. The same treatment was grazed by 156 angora goats from June 1 through September 24 or 116 days (0.43 ha/AUM or 1.07 ac/AUM). Angora goat stocking rates were adjusted downward in 1994 due to overuse of leafy spurge in 1993.

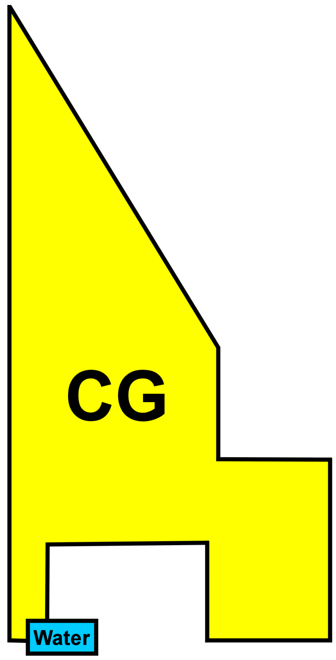


Design of the Goats only (GO) Grazing Treatment at Camp Grafton South, 1993 and 1994

Figure 3. Design of the replicated goats-only (GO1, GO2) treatment at Camp Grafton South for 1993 and 1994.

Area: 6.7 hectares (16.7 acres)
<u>1993 Grazing Schedule</u>
15 angora goat nannies were grazed in each cell from May 27 to September 11.
Stocking Rate: 0.42 ha/AUM (1.03 ac/AUM)

<u>1994 Grazing Schedule</u>
16 angora goat nannies were grazed in each cell from June 1 to September 1.
Stocking Rate: 0.38 ha/AUM (0.95 ac/AUM)



Design of the Cattle and Goats (CG) Grazing Schedules at Camp Grafton South, 1993 and 1994

Figure 4. Design of the cattle and goat (CG) treatment at Camp Grafton South for 1993 and 1994.

Area: 41.4 hectares (102.3 acres)

<u>1993 Grazing Schedule</u>
21 cow/calf pairs were grazed from July 15 to November 1 or 109 days.
191 angora goat nannies were grazed from May 27 to September 11 or 107 days.

1993 Cattle Stocking Rate: 0.55 ha/AUM (1.36 ac/AUM)
1993 Goat Stocking Rate: 0.36 ha/AUM (0.9 ac/AUM)

<u>1994 Grazing Schedule</u>
21 cow/calf pairs were grazed from June 1 to November 1 or 153 days.
126 angora goat nannies were grazed from June 1 to July 7 or 37 days.
156 angora goat nannies were grazed from July 8 to September 24.

1994 Cattle Stocking Rate: 0.39 ha/AUM (0.97 ac/AUM)
1994 Goat Stocking Rate: 0.43 ha/AUM (1.07 ac/AUM)

Stocking rates of angora goats were adjusted downward in 1994 due to overuse of leafy spurge early in the growing season in 1993.

METHODS

The paired-plot clipping technique was used to determine forage production and degree of use for leafy spurge, graminoids, shrubs, and other forbs (Milner and Hughes 1968). Plant species nomenclature follows The Great Plains Flora (Great Plains Flora Association 1986).

Peak herbage standing crop in each treatment was calculated by total harvest of herbage from two .25m^2 quadrats within each of 32 2.5m by 5.0m exclosures in 1993 and 1994. In 1993 and 1994, two .25m^2 quadrats were clipped inside and outside each exclosure. Exclosures were stratified on sandy and overflow range sites depending on relative abundance of each site in a treatment. The paired grazed and ungrazed caged plots were clipped in early August when standing crop was near maximum. Herbage was hand clipped to ground level in each quadrat. The samples were oven dried at 60 degrees Celsius for 48 hours and weighed to the nearest 0.01 gram. In 1993 and 1994, the samples from each quadrat were divided into leafy spurge, graminoids, shrubs, forbs, and litter.

Utilization or herbage disappearance was estimated using the difference between peak standing crop inside the portable exclosures and standing crop remaining outside the exclosures. Disappearance of forage from paired grazed plots was used to determine utilization.

Permanent transects were systematically designed for leafy spurge stem counts on a representative sample of sandy and overflow range sites for each treatment. Metal disks were used to mark the end points of each transect with small permanent pins utilized within each transect. There were 15 permanent pins per transect. Leafy spurge stem counts were conducted before the introduction of angora goat grazing on May 25 and 26, 1993, to achieve initial stand counts. Leafy spurge stems counts were conducted in late May, 1994, to compare differences between the two years. Stems were counted using $0.1m^2$ frames on 20 line transects in the spring of the year before grazing. Fifteen systematically placed $0.1m^2$ quadrats per transect were used to determine forb and shrub composition per stand. Species were identified and densities recorded. Relative frequency and relative density were computed and summed to produce importance values. Density data represent individual plants or ramets within a genet. Basal cover and forb density data were collected on all transects in 1993 and 1994.

Graminoid composition was determined by the points method (Levy and Madden 1933) as modified by Smith (1959), with 500 points collected per transect. Only those culms intercepted at ground level were identified and recorded as hits. The basal contact system was described by Whitman and Siggeirsson (1954).

Frequency and basal cover were calculated for plant species, litter, and bareground using a point frequency (Mueller-Dombois and Ellenberg 1974) frame with ten pins approaching the ground at a 60-degree angle on 32 transects.

Frequency and basal cover were estimated on 12 transects in each of the goats-only trials. For comparison, four transects were located in the cattle-only treatment and 16 in the multi-species trial. Data were collected in August of each year. A 50-m tape was stretched along the transect, and basal cover was measured at two m increments. Categories recorded included bareground, litter, rock, feces, and all plants by species.

STATISTICAL METHODS

Leafy spurge plant communities were evaluated to determine if leafy spurge patches were clumped, random, or uniformly distributed using the POISSON.BAS and NEGBINOM.BAS (Ludwig and Reynolds 1988). A d-statistic was computed and accepted at the P>0.05 level. If the absolute value of d is between 1.96 and -1.96, agreement with a Poisson series (a random dispersion) is accepted. If the d-statistic is less than -1.96, a regular dispersion is suspected; and if the d-statistic is greater than 1.96, a clumped dispersion is accepted (Elliot 1973). Statistical analysis for leafy spurge stem densities and degree of use for graminoids, leafy spurge, and western snowberry was attained using Multi-Response Permutation Procedure (MRPP) (Biondini et al. 1988) at the 95 percent confidence level. MRPP allows evaluation on nonnormality and absolute differences which are resistant to outliers. A standard t-test (Student 1907) modified from Zar (1984) was used to evaluate percent change in grass, leafy spurge, and western snowberry production at a confidence level of 95 percent.

Treatments were separated into sandy and overflow range sites and species composition tested using principal component analysis (PCA.BAS)(Ludwig and Reynolds 1988). Principal component analysis reduces the dimensionality of the matrix and orders independent sources of underlying variation. Significant principal components (PCs) determine what variables represent most of the variation and not a result of random patterns. This program calculates the first three PCs. Significant PCs were determined using Fischer's Proportionality Test at P<0.05. MRPP was used to determine if sampling units differed between treatments and years.

RESULTS AND DISCUSSION

The Poisson distribution and negative binomial distribution models were used to determine if the leafy spurge patches were clumped, random, or uniform. When evaluating the analysis, all transects had a clumped spatial pattern within the patches of leafy spurge. The d-statistic value in all cases was higher than the 1.96 guideline (Table 4).

Table 4. D-stat values for each transect by treatments, testing for a random, clumped, or uniform pattern for each of 10 transects.

(d-stat) Transect #	Stem Density	Cattle-Only	Goats-Only	Cattle and Goats
#1	9.94	5.901		
#2	15.56	12.257		
#1	10.33		3.506	
#2	6.33		3.689	
#3	18.31		9.908	
#4	11.50		3.004	
#1	22.06			4.458
#2	7.86			2.613
#3	8.33			2.760
#4	11.38			8.608

Leafy spurge stem density counts

Leafy spurge stem densities on the cattle-only treatment were numerically reduced from 12.8 stems to 11.5 stems per $0.1m^2$ or a 10.2 percent reduction after one year; however, no significant (P>0.05) differences were noted between years (Table 5). The leafy spurge stem densities on the goats-only treatment were not significantly reduced (P>0.05) after one year with 11.6 stems in 1993 to 8.2 stems in 1994 or 29.3 percent lower. Stems densities on the cattle and goat treatment were not significantly reduced (P>0.05) after one year in the cattle and goat treatment with 12.4 stems in 1993 to 9.3 stems in 1994 or 25.0 percent lower.

Numeric reductions in leafy spurge stem densities were observed after one year of grazing for all treatments; however, no significant (P>0.05) differences noted. No significant (P>0.05) differences were noted between treatments for either year, 1993 and 1994 (Appendix B). These results are consistent with other research that has shown at least two years of goat grazing was needed to significantly reduce leafy spurge stem densities (Sedivec and Maine 1993, Sedivec et al. 1994). Two years of grazing had occurred on this trial; however, stem densities will not be recorded until late May, 1995.

Herbage production changes

Leafy spurge herbage production in the cattle-only treatment was reduced by 11.2 percent after one year of the trial (Table 6). Herbage production of leafy spurge in the goats-only treatment was reduced from 1959 kg/ha to 1294 kg/ha or a reduction of 33.9 percent. Leafy spurge production in the cattle and goat treatment was 1718 kg/ha in 1993 and 1033 kg/ha in 1994 with a reduction of 39.8 percent.

Table 5. Leafy spurge stem density counts (stems/0.1m^2) before goat turnout at Camp Grafton South, 1993 and 1994.

Treatment	1993[1]	1994[2]	Percent Reduction	P-value
Cattle Only	12.8[a]	11.5[a]	10.2	0.84
Goats Only	11.6[a]	8.2[a]	29.3	0.67
Cattle/Goats	12.4[a]	9.3[a]	25.0	0.63

[1] Mean leafy spurge stem densities by treatment followed by the same letter are not different (P>0.05).

[2] Mean leafy spurge stem densities by year followed by the same letter are not different (P>0.05).

Leafy spurge production had a significantly (P<0.05) greater reduction in the goats-only and cattle and goat treatment than in the cattle-only treatment after one year (Table 6). Hanson (1994) observed in a herding practice with angora goats that they consistently sought concentrations of leafy spurge. Grazing pressure by angora goats stresses the leafy spurge plant community allowing graminoids to compete and utilize soil moisture and nutrients otherwise extracted by the extensive root system of leafy spurge. These results supported other research findings regarding multi-species grazing as a management tool to improve range health (Squires 1966, Glimp 1988). In this case, flowering and, thus, seed production of an aggressive noxious weed was being controlled; and stress to the plant was clearly exhibited by the decreased percentage of herbage production.

Table 6. Leafy spurge production and percent change in production by treatment at Camp Grafton South, 1993-1994.

Treatment	Year	Leafy Spurge (kg/ha)	Percent Reduction[1]	S.E.
Cattle Only	199	3938.7		
	1994	3498.0	11.2[b]	.02
Goats Only	1993	1959.4		
	1994	1294.3	33.9[a]	.07
Cattle/Goats	1993	1718.9		
	1994	1033.7	39.8[a]	.09

[1] Percentages followed by the same letter are not different (P>0.05).

Herbage production of all graminoid species in the goats-only treatment was 4587 kg/ha and 7036 kg/ha in 1993 and 1994, respectively (Table 7). The cattle-only treatment had a significantly ($P<0.05$) lower increase in graminoid production from 1993 to 1994, compared to the goats-only and cattle and goat treatments, increasing from 3850 kg/ha to 4932 kg/ha in 1993 and 1994, respectively. The cattle and goat treatment had 5080 kg/ha in 1993 and 7476 kg/ha in 1994 or an increase of 47.2 percent.

The increased herbage production in 1994 among all treatments may have been due to above average precipitation during the 1994 growing season and less competition from the stressed leafy spurge community due to angora goat grazing in the goats-only and cattle and goat treatments. A significant (P<0.05) increase in graminoid production occurred only where goats were present as compared to the cattle-only treatment (Table 7). The goats-only and cattle and goat treatments were not different (P>0.05) in percent increase of graminoid production (Table 7).

Table 7. Production and percent change of all graminoid species for each treatment at Camp Grafton South, 1993 and 1994.

Treatment	Graminoids Year	Percent (kg/ha)	Increase[1]	S.E.
Cattle Only	1993	3850.5		
	1994	4932.4	28.1[a]	.05
Goats Only	1993	4587.9		
	1994	7036.0	53.4[b]	.06
Cattle/Goats	1993	5080.7		
	1994	7476.8	47.2[b]	.03

[1] Percentages with the same letter are not different (P>0.05).

Western snowberry production in the cattle-only treatment was reduced 33.9 percent from 1346 kg/ha in 1993 to 889 kg/ha in 1994 (Table 8). The goats-only treatment was reduced from 1768 kg/ha to 1359 kg/ha or 28.6 percent. The cattle and goat treatment was reduced from 1415 kg/ha to 1126 kg/ha or 20.4 percent. There was no treatment effect (P>0.05) on western snowberry production after one year of grazing (Table 8).

Table 8. Production and percent change of western snowberry for each treatment at Camp Grafton South, 1993 and 1994.

Treatment	Year	Western Snowberry (kg/ha)	Percent Reduction[1]	S.E.
Cattle Only	1993	1346.3		
	1994	889.5	33.9[a]	.03
Goats Only	1993	1767.7		
	1994	1358.4	28.6[a]	.06
Cattle/Goats	1993	1414.4		
	1994	1125.9	20.4[a]	.03

[1] Percentages with the same letter are not different (P>0.05).

Herbage utilization

Hanson (1994) reported that leafy spurge made a large portion of the goats' diet throughout the grazing season. Sheep and goats prefer to eat more broadleaved plants than do cattle. They also strip leaves from many forbs and shrubs, leaving the more fibrous stem material. Sheep and goats can assist by consuming plants that are toxic or irritate cattle such as leafy spurge and larkspur.

Leafy spurge utilization or degree of use in the cattle-only treatment was 7.2 percent in 1993 and 4.2 percent in 1994 or a mean degree of use of 5.7 percent (Table 9). Leafy spurge utilization in the cattle and goat treatment was 74.6 percent and 67.8 in 1993 and 1994, respectively, or a mean degree of use of 71.6 percent. Leafy spurge utilization in the goats-only treatment was 67.0 and 70.4 percent for 1993 and 1994, respectively, or a mean degree of use of 68.7 percent. Hanson (1994) reported the mean relative density of leafy spurge in angora goat diets ranged from 21.5 percent ot 69.5 percent. There was no (P>0.05) year effect on leafy spurge utilization among the treatments, allowing for years to be combined. Leafy spurge degree of use was greater (P>0.05) in the goats-only and cattle and goat treatments compared to the cattle-only treatment (Table 9).

Table 9. Degree of use (percent) of leafy spurge by treatment and year at Camp Grafton South, 1993 and 1994.

Treatment	1993[1]	1994	Mean[2]
Cattle Only	7.2	4.2	5.7[a]
Goats Only	67.0	70.4	68.7[b]
Cattle/Goats	74.6	67.8	71.6[b]

[1] No differences (P>0.05) occurred between years for either treatment (Appendix B for statistical analysis).
[2] Means with the same letter are not different (P>0.05) (Appendix C for statistical analysis).

Angora goat grazing left a leafy spurge stem devoid of leaf or flowering parts. Goat grazing caused significant reductions in biomass compared to the cattle-only treatment. Greater grazing pressures appear to stress leafy spurge although further research is needed to determine the extent of density reduction from various grazing pressures over several years.

Graminoid utilization in the cattle-only treatment was 10.1 and 6.4 percent in 1993 and 1994, respectively, with a mean of 8.3 percent (Table 10). Anderson et al. (1990) reported cattle diets contained an average of 57 percent grass, 35 percent forbs, and 8 percent shrubs in New Mexico. Silcox (1991) and Hirschfeld (1992) found grass consumption 70.8 and 86.9 percent of their diet, respectively. Dietary consumption of forbs was 23.4 and 12.0 percent, respectively, while shrubs comprised 6.4 and 1.1 percent, respectively (Silcox 1991, Hirschfeld 1992).

The goats-only treatment had a degree of use of 7.5 percent and 10.4 percent in 1993 and 1994, respectively, and a mean of 9.0 percent. Taylor (1985) reported that angora and Spanish goat diets in Texas averaged 50 percent grass, 10 percent forbs, and 40 percent browse. The cattle and goat treatment had a grass degree of use of 27.8 percent and 19.3 percent in 1993 and 1994, respectively, and a mean of 23.5 percent.

Our hypothesis was that the graminoid degree of use on the cattle and goat treatment should be significantly greater than the other two treatments. This hypothesis was not rejected, with greater ($P<0.05$) graminoid use occurring on the cattle and goat treatment than on the cattle-only and the goats-only treatments (Table 10).

Leafy spurge contains one or more chemicals that can elicit an aversive response in cattle. The heavy leafy spurge infestation in the cattle-only treatment may be hindering the behavioral response to cattle grazing in heavily infested sites. Graminoid degree of use was lowest in the cattle-only treatment, indicating a general avoidance by the cattle from a flourishing and vigorous leafy spurge plant community.

Table 10. Degree of use (percent) of graminoid species on leafy spurge-infested rangeland by treatment and year at Camp Grafton South, 1993.

Treatment	1993[1]	1994	Mean[2]
Cattle Only	10.1	6.4	8.3[a]
Goats Only	7.5	10.4	9.0[a]
Cattle/Goats	27.8	19.3	23.5[b]

[1] No differences (P>0.05) occurred between years for either treatment (Appendix D for statistical analysis).
[2] Means with the same letter are not different (P>0.05) (Appendix E for statistical analysis).

Diet preference of angora goats has primarily been browse and graminoid species, with lower utilization of broadleaf species or forbs (Bryant et al. 1979, Malechek 1970). The degree of use or utilization of western snowberry in the cattle-only treatment was 17.5 percent in 1993 and 24.5 percent in 1994 (Table 11). The goats-only treatment had a degree of use of 18.9 and 28.0 percent, in 1993 and 1994, respectively. Sedivec et al. (1994) reported excessive utilization of western snowberry by angora goats, with the shrub component reduced by over 85 percent after three years of intensive grazing.

Western snowberry utilization on the cattle and goat treatment was consistent for the two years of grazing with a degree of use of 31.2 and 32.7 percent, respectively. No differences (P>0.05) occurred between years for either treatment, and no difference (P>0.05) occurred among treatments. Davis et al. (1975) reported only a 5 percent overlap in cattle and goat diets on southern Colorado mountain brush range, consisting of about 50 percent grass and 50 percent shrubs. This amounted to a potential doubling of stocking rate compared to a single-species grazing, which is what the stocking rates were in this trial.

Table 11. Degree of use (percent) of western snowberry on leafy spurge-infested rangeland by treatment and year at Camp Grafton South, 1993 and 1994.

Treatment	1993[1]	1994	Mean[2]
Cattle Only	17.5	24.5	21.0[a]
Goats Only	18.9	28.0	24.0[a]
Cattle/Goats	31.2	32.1	31.7[a]

[1] No differences (P>0.05) occurred between years for either treatment (Appendix F for statistical analysis).

[2] Means with the same letter are not different (P>0.05) (Appendix G for statistical analysis).

SUMMARY

The study evaluated multi-species grazing on leafy spurge-infested plant communities. No differences ($P>0.05$) in plant species composition changes were noted within treatments between 1993 and 1994. Changes in graminoid, forb, shrub, and leafy spurge frequency varied in their response to each grazing treatment. Among all treatments, a negative correlation existed between the introduced plant species (Kentucky bluegrass, smooth brome, and leafy spurge) and native plant species. As the introduced plant species increased, the native species decreased. This finding was similiar with other research which showed a decline in the abundance of the dominant species in native prairie, both on a large scale and within a single infestation.

Leafy spurge stem densities were numerically reduced on all treatments from 1993 and 1994. The treatments where goats were present (goats-only and cattle and goat treatments) showed higher reductions in stem densities than did the cattle-only treatment. Angora goats appear to be a biological control agent for leafy spurge.

Leafy spurge production was significantly reduced ($P<0.05$) in the goats-only and cattle and goat treatment than in the cattle-only treatment after one year. Herbage production of the graminoids was increased after one year. A greater ($P<0.05$) increase in graminoid production occurred on the goats-only and cattle and goat trials than on the cattle-only treatment. No difference ($P>0.05$) in degree of use of western snowberry occurred among treatments, indicating there was no treatment effect after one year. Leafy spurge degree of use was greater (P>0.05) in the goats-only and the cattle and goat treatments compared to the cattle-only treatment.

Greater (P<0.05) graminoid degree of use occurred on the cattle and goat treatment than on the cattle-only and goats-only treatments. These results supported previous research findings (Bowns 1985, Nelson et al. 1991) that multi-species grazing can be used to maximize plant species use.

CONCLUSION

Multi-species grazing exploits the complementary aspects of herbivore species, while reducing the negative aspects of each by decreasing the impact of selective use of preferred plants and areas. When the plant community is diverse, such as most native rangelands, multi-species grazing can improve plant diversity. This is possibly due to diet selectivity and animal species grazing behavior. An understanding of each species' behavior when utilizing range resources allows maximum potential for animal and plant species. Multi-species grazing using angora goats and cattle did not significantly reduce leafy spurge density after one year of grazing; however, it did provide more available grass for cattle.

Using more than one animal species could greatly increase red meat production from a given rangeland acreage containing various plant communities. An increased stocking rate may occur in future years with this grazing management practice. A proper stocking rate of various species promotes a diverse mixture of rangeland vegetation and generally increases vegetative production. This could lead to increased profitability due to diversification for range managers. Control of existing and potential noxious weeds might be realized.

Continued monitoring of grazing is needed to evaluate its usefulness in reducing leafy spurge stands and allowing associated plant species to effectively compete. The stocking rates were successful in minimizing leafy spurge flowering and seed production. This trial is scheduled to continue three more years to increase the data base on changes in species composition, yields, stem density reductions, and utilization of leafy spurge-infested rangeland.

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Appendix A. Scientific and common names of plant species found on the Camp Grafton Study Area, 1993 and 1994.

Grasses	
Agropyron caninum	slender wheatgrass
Agropyron repens	quackgrass
Agropyron smithii	western wheatgrass
Andropogon scoparius	little bluestem
Bouteloua gracilis	blue grama
Bromus inermis	smooth bromegrass
Calamovilfa longifolia	prairie sandreed (black-root)
Carex eleocharis	threadleaf sedge
Carex heliophila	sun sedge
Carex praegracilis	clustered-field sedge
Dichanthelium wilcoxianum	wilcox dichanthelium
Koeleria pyramidata	junegrass
Muhlenbergia cuspidata	plains muhly
Poa pratensis	Kentucky bluegrass
Sporobolous asper	rough dropseed
Sporobolus cryptandrus	sand dropseed
Stipa comata	needle-and-thread
Stipa spartea	porcupine grass
Stipa viridula	green needlegrass
Forbs	
Artemisia ludoviciana	white sage
Astragulas agrestis	field milk-vetch
Aster ericoides	white sage
Chrysopsis villosa	golden aster
Erysimum asperum	western wallflower
Euphorbia esula	leafy spurge
Euphorbia serpyllifolia	thyme-leaved spurge
Helianthus annuus	common sunflower
Liatris punctata	dotted gay-feather(blazing star)
Medicago lupulina	black medick
Melilotus officinalis	yellow sweet clover
Sisyrinchium angustifolium	blue-eyed grass
Taraxacum officinale	common dandelion
Shrubs	
Amorpha canescens	lead plant
Eleagnus commutata	silverberry
Prunus virginiana	chokecherry
Rosa arkansana	prairie wild rose
Symphoricarpos occidentalis	western snowberry(wolfberry)

Appendix B. Statistical analysis (P-value) of leafy spurge stem density counts (stems/0.1m^2) by treatment and year at Camp Grafton South, 1993-1994.

TRT	n	1993	P-value	TRT	n	1994	P-value
CO	4	12.8	CO	4	11.5		
GO	6	11.6	0.77	GO	6	8.2	0.19
CO	4	12.8	CO	4	11.5		
CG	8	12.4	0.52	CG	8	9.3	0.35
GO	6	11.6	GO	6	8.2		
CG	8	12.4	0.82	CG	8	9.3	0.74

Appendix C. Statistical analysis (P-value) of leafy spurge degree of use by treatment and year at Camp Grafton South, 1993-1994.

Treatment	n	Year	Percent	P-value
Cattle Only	3	1993	7.2	
	3	1994	4.2	0.47
Goats Only	6	1993	67.0	
	6	1994	70.4	0.54
Cattle/Goats	10	1993	74.6	
	10	1994	67.8	0.66

Appendix D. Statistical analysis (P-value) of the mean leafy spurge degree of use by treatment at Camp Grafton South, 1993-1994.

Treatment	n	Mean	P-value
Cattle Only	6	5.7	
Goats Only	12	68.7	0.000021
Cattle Only	6	5.7	
Cattle/Goats	18	71.6	0.00002
Goats Only	12	68.7	
Cattle/Goats	18	71.6	0.11

Appendix E. Statistical analysis (P-value) of graminoid degree of use (percent) by treatment and year at Camp Grafton South, 1993-1994.

Treatment	n	Year	Percent	P-value
Cattle Only	3	1993	10.1	
	3	1994	6.4	0.57
Goats Only	8	1993	7.5	
	8	1994	10.4	0.62
Cattle/Goats	10	1993	27.8	
	10	1994	19.3	0.22

Appendix F. Statistical analysis (P-value) of the mean graminoid degree of use by treatment at Camp Grafton South, 1993-1994.

Treatment	n	Mean	P-value
Cattle Only	6	8.3	
Goats Only	16	9.0	0.12
Cattle Only	6	8.3	
Cattle/Goats	16	23.5	0.006
Goats Only	16	9.0	
Cattle/Goats	16	23.5	0.01

Appendix G. Statistical analysis (P-value) of western snowberry degree of use (percent) by treatment and year at Camp Grafton South, 1993-1994.

Treatment	n	Year	Percent	P-value
Cattle Only	3	1993	17.5	
	3	1994	24.5	0.41
Goats Only	5	1993	18.9	
	5	1994	28.0	0.59
Cattle/Goats	5	1993	31.2	
	5	1994	32.1	
0.54				

Appendix H. Statistical analysis (P-value) of the mean western snowberry degree of use by treatment at Camp Grafton South, 1993-1994.

Treatment	n	Mean	P-value
Cattle Only	6	21.0	
Goats Only	10	24.0	0.25
Cattle Only	6	21.0	
Cattle/Goats	10	31.7	0.32
Goats Only	10	24.0	
Cattle/Goats	10	31.7	0.37

Leafy spurge presents special problems to rangeland and pastureland owners. It can reduce livestock carrying capacity by as much as 75 percent (Reilly and Kaufman 1979). Reilly and Kaufman (1979) believe that two thirds of the 75 percent reduction in cattle carrying capacity results from a in herbage production reduction due to competition from leafy spurge. The other one third can be lost due to poor utilization by cattle, either totally or partially avoiding leafy spurge infested sites(Reilly and Kaufman 1979).

The goats only replication one, sandy range site in 1993 showed significance at the first PC level. Kentucky bluegrass, smooth brome, and leafy spurge are negatively correlated with native species in this transect. The sandy range site in the goats only replication two was significant at the first PC. Smooth brome, Dicanthelium wilcoxianum and carex species were negatively correlated with leafy spurge and agropyron caninum. The overflow range sites in the replicated goats only treatments were significant at three PCs for both years. Kentucky bluegrass, carex heliophila, and symphoricarpos occidentalis, were related inversely to the remaining species. For PCII, stipa spartea, carex eleocharis, and carex filifolia had a strong inverse relationship with bromus inermis, and leafy spurge. PCIII showed the strongest relationships with bromus inermis, carex eleocharis, leafy spurge, and symphoricarpos occidentalis. Kentucky bluegrass, and smooth brome accumulated for 74.6 percent of the variation on this transect.

GO2 SA 93 Kentucky bluegrass, leafy spurge and symphoricarpos occidentalis have a strong positive correlation with each other, however, an inverse relationship exists among all other species.

GO2 SA 94 The sandy range site in the goats only replication two treatment was signficant at the first PC. Kentucky bluegrass, smooth brome, leafy spurge, symphoricarpos occidentalis, and rosa arkansana exhibit a strong negative correlation with the other species, specifically the native species.

GO2 OV 93 Significant at all three PCs

GO2 OV 94 Carex heliophila, prairie sandreed, and Kentucky bluegrass were related inversely to the other species at the first PC. PCII western wheatgrass, aster ericoides and dicanthelium wilcoxinum are related inversely to the other species. PCIII stipa spartea, stipa viridula, carex heliophila, prairie sandreed, aster ericoides, and muhlenbergia cuspidata were related inversely to the other species. The stipa species accounted for 86.9 percent of the variation.