UTILIZATION OF CROSS TIMBERS RANGELANDS BY ANGORA GOATS

By

SABINYANO MBAE BAUNI

Bachelor of Science
Nairobi University
Nairobi, Kenya
1978

Master of Science
Colorado State University
Fort Collins, Colorado
1983

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Thesis Adviser

Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Major factors limiting livestock production from most grazing lands are (1) the common practice of using a single livestock species, particularly cattle, and (2) the suppression of woody species to convert woodlands into grasslands. Management of the edible browse might be a practical approach toward optimizing biological efficiency at the primary producer level. Woody species have a negative effect on the potential productivity of herbaceous vegetation. But, the total feed production (herbaceous and browse) increases with brush density up to a point beyond which reduction in the herbaceous component decreases the overall feed production.

Browse species are potentially important for livestock and wildlife partly due to their ability to maintain high nitrogen content and moderate organic matter digestibility throughout the non-growing period (Wilson, 1977; Otsyina and McKell, 1985). Protein and energy are the most limiting nutrients for range animal productivity and the most expensive to supply through supplementation (Holechek et al., 1989). Therefore, browse species complement grasses in many livestock production systems and should be evaluated in the light of their potential usefulness to the livestock industry.

Understanding vegetation composition and utilization by different livestock species is central to increasing production in the Cross Timbers. This resource area occupies nearly 12 million acres in Oklahoma, Texas, and Kansas

(SCS, 1981). The Cross Timbers of Oklahoma are characterized by dense stands of woody species with little understory. Production of timber and woody products is not economically viable in these areas, but there is great potential for livestock grazing. However, forage production is suppressed by the stands of hardwoods dominated by *Quercus stellata* (post oak) and *Quercus marilandica* (blackjack oak) (Engle et al., 1992; Engle and Stritzke, 1992). Suppression of the herbaceous layer limits the cattle grazing capacity of Cross Timbers.

Forage production can be enhanced by reducing the brush cover through mechanical methods (Scifres, 1980) and herbicide application (Scifres and Mutz, 1978); Scifres et al., 1981a, 1981b; Engle et al., 1991). A decrease in overstory canopy increases the diversity of the understory vegetation which in turn increases the grazing capacity of the area. In addition to the increase in dry matter yield, the quality of the forage increases (Scifres et al., 1981b; Masters and Scifres, 1984; Bogle et al., 1989).

The opening of the canopy not only increases the herbaceous yield, but also gives rise to secondary brush (Engle and Stritzke, 1992) which is of major concern to many brush management programs. Secondary brush is generally abundant and difficult to control. Rising operating expenses have prompted some interest in alternative control methods (Green et al., 1978). The use of goats could possibly be a more effective and economical alternative for suppressing many resprouting woody species (Martin and Huss, 1981). Goats consume browse and are not subject to liability costs associated with fire or the environmental concerns with herbicide application (Green et al., 1978). Goats have been stocked in many parts of the world to utilize woody vegetation (Davis et al., 1975; Merrill and Taylor, 1976; Wilson et al., 1976; Green et al., 1978; Martin and Huss, 1981; Fierro et al., 1984; Wood, 1987; Brock, 1988; Severson and Debano, 1991). Use of goats in brush management is more effective when the browse species are placed within the reach of the goats. Therefore, conventional methods can be used to lower the canopy to an accessible height.

Goats are typically browsers. But, when the availability of the preferred species is limited, they often turn to alternative classes of forages (Scifres, 1980; Merrill and Taylor, 1981). This suggests that grass may become an important food component when the availability of the preferred browse species becomes limiting. Thus, stocking rate is an important aspect in the brush management using goats. In order to avoid competition between goats and cattle, the stocking rates of goats must be adjusted downward relative to the decreasing browse availability.

Although considerable research has been conducted on mechanical methods, herbicide application, and fire, very little research in the Cross Timbers rangelands has focused on goats. Therefore, a grazing study was initiated as a departure point for research on the integration of goats into production systems in the Cross Timbers. The primary objectives of this study were to evaluate:

(1) The effects of stocking rate (head/hectare) and season on utilization of individual brush species and nutrition of Angora goats.

(2) The effects of season on chemical composition of individual brush species.

CHAPTER II

LITERATURE REVIEW

Forage Quality

Animals and plants are interdependent. The nutrients in forage are essential for the survival and productivity of grazing animals. The maturation process involves changes in morphological and chemical characteristics of the forage which affect the nutritive value. Increased fiber and decreased crude protein content are consequences of the maturation process. When dietary crude protein falls below 7%, ruminal microbial fermentation is impaired and voluntary feed intake and animal performance subsequently decline (Van Soest, 1987). Holechek et al. (1989) pointed out that protein and energy are the most limiting nutrients for range animal productivity and the most expensive to supply through supplementation. Some of these limitations could be alleviated through careful manipulation of rangeland resources, such as the use of palatable shrubs (Robinette, 1972; Dietz, 1972; Otsyina and McKell, 1985) to improve forage production and quality in grazing areas of the world.

Browse Species

Woody plants are a common feature on many grazing lands. The management of the palatable shrubs is central to increasing the quantity and quality of forage for livestock and wildlife production. However, inadequate management systems have failed to make use of the valuable browse species for livestock production (Otsyina and McKell, 1985). Shrubs are important sources of nutrients for most classes of domestic and wild herbivores. Browse becomes increasingly important during seasons of plant dormancy, which occurs in winter in temperate areas and dry seasons in the tropics (Robinette, 1972). Browse provides complementary feed when herbaceous forage is in short supply and essential nutrients (protein, phosphorus, and carotene) when forbs and grasses are below the minimum requirements for the maintenance of livestock (Dietz, 1972; Otsyina and McKell, 1985).

The value of browse is best described by comparative studies, but information comparing grasses, forbs, and browse is scarce. Generally, the concentration of crude protein, phosphorus, carotene, and cell solubles is higher during dormancy in browse than forbs and grasses. Nelson et al. (1970) reported the chemical composition of forage grazed by cattle on the Jornada Experimental Range in southern New Mexico. The chemical composition of the three plant types studied indicated a decrease in protein, phosphorus, and carotene, but an increase in fiber and lignin with maturity. During the dormant period, forbs and browse species were higher in protein, phosphorus and ash than grasses. Protein content of hand-plucked composite samples representing the diet of the grazing animals indicated that forbs and shrubs supplemented protein deficiencies in the grasses. Therefore, consumption of forbs and shrubs prevented the potential nutrient deficiencies and need for supplemental protein during the dormant season for grasses.

The chemical composition of the diets selected by deer on southern upland range in Texas was reported by Short (1971). The average crude protein content of grasses, forbs, and browse was 11%, 12%, and 10%, respectively. The nutritive value of forbs was slightly higher than browse, but short-lived.

Forbs were more digestible than browse plants which in turn were more digestible than grasses. Crude protein, ash, and cell contents of the three forage classes diminished with maturity, while the concentration of acid detergent fiber (ADF) and cell wall contents increased. Declining forage quality with maturity had a negative impact on deer performance.

Nutritive value of plants growing in the Edwards Plateau of Texas was reported by Huston et al. (1981). Results from this study indicated that forbs (14%, 0.18%) and browse (12%, 0.15%) plants contained higher levels of crude protein and phosphorus, respectively, during the growing season than grasses (7%, 0.11%). Browse plants contained more digestible organic matter than either grasses or forbs. Nutrient concentration was highest during spring and declined with maturity for the three plant groups.

Severson (1982) determined the nutritive value of plants in the understory of Aspen stands in the Black Hills of western South Dakota and northeastern Wyoming. In this study, forbs (9%) and shrubs (8%) contained more protein than grasses (7%). Shrubs and forbs were slightly more digestible than grasses, although shrubs contained more lignin. The author also noted that the selective feeding habit of the resident deer may have precluded nutrient deficiencies, even though the understory vegetation was marginal in protein and phosphorus.

Krysl et al. (1984) estimated the nutrient content of diets selected by horses and cattle in the Red Desert of Wyoming. The average crude protein content of the hand-plucked composite sample of grasses, forbs, and shrubs was 8%, 13% and 11%, respectively. Percentage crude protein and in vitro dry matter disappearance declined through summer for all forage classes, with grasses and sedges having the lowest values.

The presence of tannins has been reported in many woody species (Kumar and Vaithiyanathan, 1990). Plant tannins are complex phenolic polymers which vary in chemical structure and biological activity. There are two types of tannins: (1) hydrolysable tannins which occur in fruits and plant galls, and (2) condensed tannins commonly found in forages (McLeod, 1974; Mangan, 1988). Both hydrolysable and condensed tannins readily interact with dietary proteins, salivary proteins, and digestive enzymes to form a complex unlikely to undergo normal metabolism (Haslam, 1979; Kumar and Vaithiyanathan, 1990). In view of the above circumstances, dietary crude protein content of browse species may only serve as an indicator of the relative nutritional value for animal production.

Tannins reduce the efficiency of forage utilization by depressing voluntary feed intake and dry matter digestibility (Donnelly and Anthony, 1969; Burns and Cope, 1974; McLeod, 1974; Mitjavilla et al., 1977; Kumar and Singh, 1984; Cooper and Owen-Smith, 1985; Robbins et al., 1987a; Kumar and Vaithiyanathan, 1990). The mechanism involved in voluntary feed intake depression is not very well understood. Some animals have developed mechanisms for overcoming the adverse effects of tannins by synthesizing proline-rich salivary proteins in response to tannin containing diets (Robbins et al., 1987b). Methods to inactivate tannins have been suggested, but most results to date are inconsistent (Kumar and Singh, 1984; Kumar and Vaithiyanathan, 1990).

Effects of Herbicide Application on Forage Quality

Brush management using herbicides not only affects botanical composition of the plant species and dry matter yield, but also the quality of the forage. Suppression of plant growth has often been associated with an increase in nitrogen content and reduction in cellulose content. Allison and Peters (1970) reported elevated crude protein in forages as a result of application of simazine-2-chloro-4, 6-bis (ethylamino)-s-triazine. They also pointed out that cultivars least tolerant to simazine were more responsive in terms of crude protein. In another experiment, atrazine was associated with the delay to maturity of some tallgrass species in late summer (Baker et al., 1980). The extended vegetative phase of the forage grasses concomitantly maintained high crude protein levels for a longer period. Atrazine and fertilizer combined increased crude protein content of actively growing tallgrass prairie vegetation during two successive dry years. According to Scifres and Welch (1981), tebuthiuron application significantly increased crude protein content of foliage in Texas. However, the increased crude protein was realized only during the growing season of the application. Tebuthiuron application to seeded and native stands (Masters and Scifres, 1984) did not affect the in vitro digestible organic matter content, but significantly increased the foliar crude protein in the grasses. Similar results were more recently reported on tebuthiuron-fire-savannah environments by Bogle et al. (1989). In this study, a higher forage quality in tebuthiuron treated sites appeared to vary more among forage classes and within grazing season than among environments. The increase in crude protein content of forbs and grasses in the first half of the growing season was attributed to the reduced overstory canopy, while high protein levels of the late season forages were due to the greater availability of moisture and nutrient release from decomposition of roots of woody species.

Diet Selection by Different Animal Species

Proper allocation of forage to animals in a multiple-use program is a major constraint and an obvious challenge to many research workers involved in rangeland studies. Multiple-use management is possible on rangelands, but to do so requires a more comprehensive understanding of food habits (Casebeer and Koss, 1970). The optimum mix of animal species on a grazing area, for example, is extremely difficult to determine without a sound knowledge of their food habits (Taylor, 1985; Merrill, 1985).

Grazing animals select their daily consumption from different plant groups that include grasses, forbs, and shrubs. Diet selection varies among animal species and is determined by a complex set of factors that are not well understood. The dietary proportion of each food category is not only animal species dependent, but is also influenced by season and location (Van Dyne et al.,1980). Published reports also differ in methodology and analyses (Hansen and Reid, 1975) which requires more cautious interpretation and application of the data. Comparative food habit studies are scarce but essential from the standpoint of vegetation management, livestock nutrition, wildlife habitat, and net returns.

Some early research work on food habits was reported by McMahan (1964). Observations were made on a tame white-tailed deer (*Odocoileus virginianus*), a goat, a sheep, and a cow in the Edwards Plateau region of Texas. Grasses formed more than 50% of the cow diets. The diets of the goat consisted of more than 50% browse. Results from this experiment indicated moderate to heavy competition for browse between deer and goats during all seasons, and between deer and all three classes of livestock in the winter. The validity of this report may be questionable, because the diet selection was based on a single animal of each species.

Harrington (1986) studied diet selection of feral goats in a shrub-dominated *Eucalyptus populnea* woodland of New South Wales, Australia. In this study, the diet of goats was largely determined by the availability of the preferred forage species. On heavily grazed pastures, the use of browse declined with time as the goats removed the acceptable browse. In the paddocks where forage availability was not limiting, goats spent 63% of their time grazing and 28% browsing. In instances of a short supply, goats often made use of less acceptable browse species.

Diet selection by Angora and Spanish goats grazing in the shinnery oak-dominated ranges of Texas was reported by Villena and Pfister (1990). Consumption of oak by the two species of goats increased from 31% in June to 55% in August. Grass consumption remained constant over time, averaging 40% of the diets throughout the study period. More recently, Papachristou and Nastis (1993) reported the botanical composition of goat diets on oak shrublands with varying percentage cover in northern Greece. During spring grazing, the herbaceous component contributed more than 50% to the diets in the low brush pasture, 46% in the medium brush pasture, and 40% in the high brush pasture. For the remaining part of the grazing period, browse dominated the diets by contributing 48% to 66% on the low brush pasture, 54% to 77% on the medium brush pasture, and 66% to 80% on the high brush pasture.

Diets selected by sheep grazing in Wyoming were reported by Strasia et al.(1970). Botanical composition of the diets consisted of 44% grass, 52% forbs, and 4% shrubs. The authors noted that sheep were more fastidious toward grasses and sedges than individual forb species.

Wilson et al. (1975) studied the feeding habits of sheep and feral goats in New South Wales, Australia. Goat diets consisted largely of browse, although a large proportion of herbaceous material was occasionally consumed. A partial complementary feeding strategy was observed between the two herbivore species.

Botanical composition of the diets of sheep, Angora goats, Spanish goats, and white-tailed deer (*Odocoileus virginianus*) in the Edwards Plateau of Texas was reported by Bryant et al. (1979). The diet of the sheep consisted of 60% grass, 22% browse, and 18% forbs. On the average, goats consumed 46% grass, 41% browse, and 13% forbs. Deer spent more time on browse (61%), closely followed by forbs (31%). Grasses were least (8%) preferred. There was some degree of diet complementarity among the herbivores, even though competition for green forage could not be ruled out.

Uresk and Rickard (1976) reported the botanical composition of the steer diets grazing on a shrub-steppe rangeland in south-central Washington. Grasses accounted for 73% of the diets, while forbs and half-shrubs contributed 26% of the diets. Botanical composition of the diets shifted with changing availability and maturation of the forage.

Casebeer and Koss (1970) studied forage selectivity by cattle and three species of wildlife grazing Kenya rangelands. Grasses formed the bulk of the diets selected by the four herbivores, while forbs and shrubs contributed less than 1% of the total diets. The botanical composition of the diets indicated high selectivity for *Themeda triandra*, *Pennisetum mezianum*, and *Digitaria macroblephara*. The greatest diet similarity was realized between cattle and zebra. However, cattle diets remained more consistent across the seasons than any of the wildlife species.

Hansen and Reid (1975) reported the seasonal dietary overlaps for cattle, mule deer, and elk in Colorado. Deer diets primarily consisted of browse, except in summer and early winter when significant amounts of grasses were consumed. Grasses were highly preferred by elk and cattle in almost all seasons, except summer when elk consumed a significant amount of browse.

Diet overlap ranged from 3% to 48% between elk and deer, 12% to 38% between deer and cattle, and 30 to 51% between elk and cattle.

Hubbard and Hansen (1976) determined the diets of cattle, wild horses, and mule deer. Wild horses and cattle preferred grasses and sedges, whereas the mule deer preferred browse species. Diet composition and overlap for cattle, wild horses, elk, pronghorn antelope, and sheep in southwestern Wyoming was reported by Olsen and Hansen (1977). All animal species selected a variety of plants each season, but the bulk of the diets consisted of very few plant species. The largest percentage of the diets consumed by wild horses, cattle, and elk was comprised of grasses. The antelope preferred sagebrush, regardless of the season. The diets of domestic sheep were more similar to diets of cattle and least similar to those of antelope. The highest dietary overlap was realized between wild horses, cattle, and elk. However, diet overlap differed among seasons and species of herbivores, suggesting that the herbivore species select food in an independent manner.

Van Dyne et al. (1980) summarized several diet estimates by calculating seasonal, yearlong, or treatment means from published literature (Fig. 1). Based on these averages, cattle consumed 70% grass, 15% forbs, and 15% shrubs while the diets of sheep consisted of 50% grass, 30% forbs, and 20% shrubs and goats consumed almost 60% shrubs, 30% grass, and 10% forbs. White-tailed deer (*Odocoileus virginianus*) selected a diet containing about 60% browse, 30% forbs, and 10% grass. Based on this study, cattle are best categorized as grazers, while goats and deer are classified as browsers or concentrate feeders. Sheep are intermediate feeders. Several other researchers have classified goats as browsers (Sidahmed et al., 1981; Warren et al., 1984) while others have categorized them as intermediate feeders (Migongo-Bake and Hansen, 1987) or opportunistic generalists with a tendency

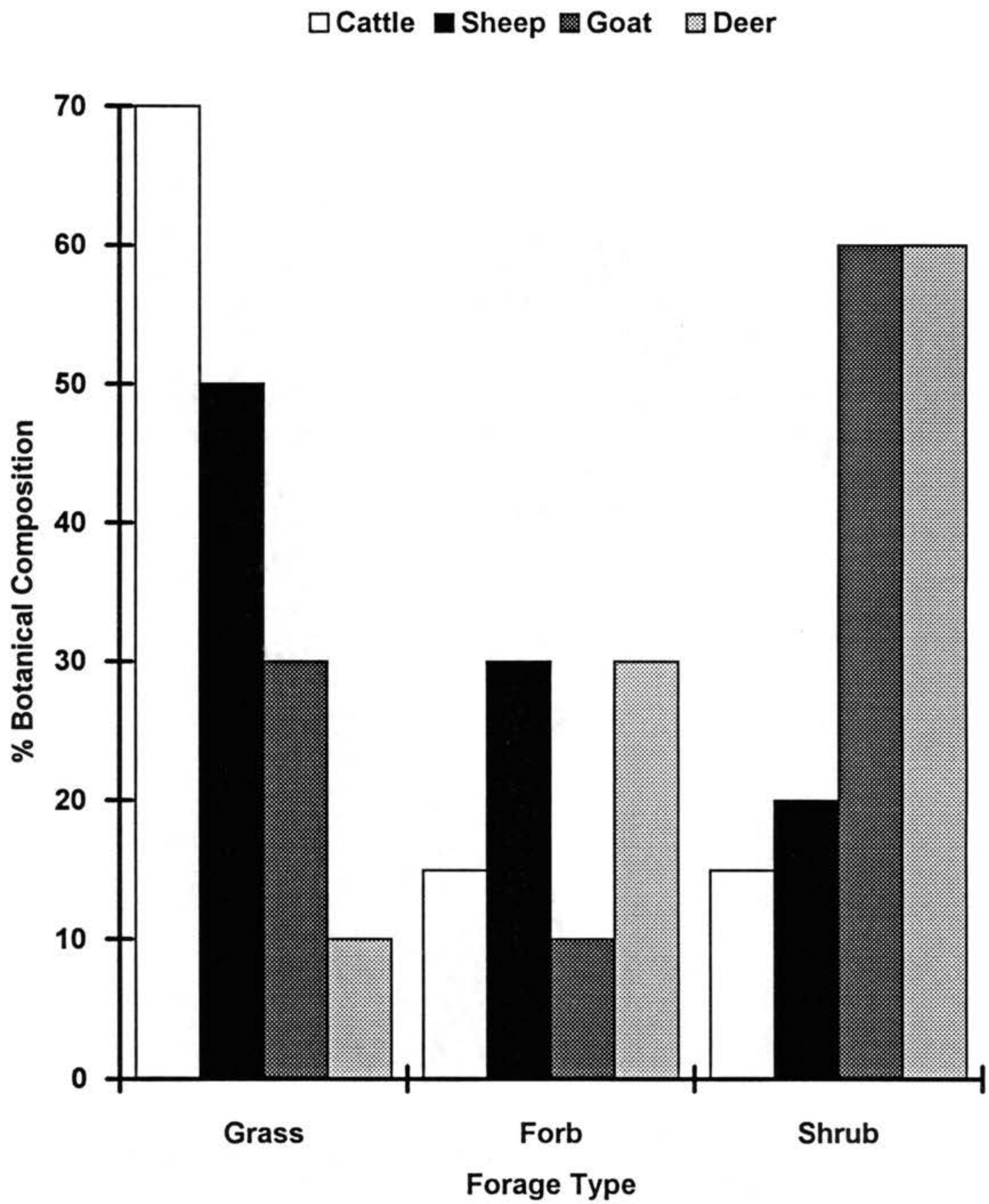

Figure 1. Percentage Botanical Composition of the Diets Selected by Cattle, Sheep, Goats, and Deer (adapted from Van Dyne et al., 1980)

to consume the most palatable vegetation available (Coblentz, 1977; Villena and Pfister, 1990). When the availability of the preferred browse species is not limiting, goat diets can be additive when stocked with cattle and non-additive when stocked with white-tailed deer.

Goats

General Information

Goats are among the earliest domesticated animal species and are valuable for milk, meat, fiber, and leather. They are complementary when stocked with other domestic livestock species partly due to their ability to utilize shrubs and other woody species receiving little or no use by cattle and sheep. The inquisitive behavior of goats and their small body size allows them to utilize areas of rugged terrain, giving them a wider distribution over terrain than any other domestic livestock species (Winrock, 1976). Their small body size and early maturity gives goats an economic advantage favorable to small land holders (Gall, 1981; Devendra and McLeroy, 1982). Goats eat more browse than sheep and cattle (Wilson, 1969) and are therefore used for biological brush control (Merrill and Taylor, 1976).

In spite of the uses to mankind, goats have been considered agents of environmental degradation. However, they have been defended on the grounds that the vegetation deterioration is not due to goats per se, but rather to uncontrolled grazing (Merrill and Taylor, 1981; Martin and Huss, 1981). Mackenzie (1970) argued that "the goat is blamed for the murder simply because of being found beside the corpse." This explains the use of the term "scapegoat." Grazing observations in the Edwards Plateau of Texas have shown that horses and sheep are the most destructive of all the grazers, followed by cattle, with goats doing the least damage to rangelands (Merrill, 1975; Merrill and Taylor, 1976). Therefore, prejudice against goats exists due to the preconceived ideas and lack of reliable information about this species (Mackenzie, 1970; Gall, 1981; Martin and Huss, 1981; Lopes and Stuth, 1984).

Use of Goats for Brush Management

There are two types of goats used for brush control and management in the United States: (1) Spanish goats (meat-type goats), and (2) Angora goats (mohair-type goats). The Spanish goats were most likely introduced to the North American continent by early Spaniards. These goats are often used for brush control because of their ability to browse to the height of seven feet or more (Merrill and Taylor, 1976).

According to Devendra and Burns (1983), Angora goats originated in central Asia and were brought to Anatolia in Turkey in the 13th century. They were imported to North America from Turkey between 1849 and 1876, and from South Africa between 1925 and 1976. Angoras are raised in many states, but the primary concentration is in the Hill Country and the Edwards Plateau of Texas (Gray, 1959; Mason, 1981). Angora goats were developed primarily for mohair production, which may contribute to the ranching income (Merrill and Taylor, 1976). In addition, they are used for brush management and are slaughtered for meat. They are good climbers and travelers, and have been used for brush management by ranchers in the Edwards Plateau of Texas for many years (Gray,1959).

The expense of the traditional methods of brush management has forced the reevaluation of biological methods to manage secondary brush (Green et al., 1978; Hanselka and Paschal, 1992). Goats would possibly be a more effective and economical alternative for suppressing many resprouting woody species (Martin and Huss, 1981). Goats consume browse and are not subject to liability costs associated with fire or the environmental concerns with herbicides (Green et al., 1978).

Magee (1957) reported on the economic evaluation of 11 ranches in Texas which used goats for secondary brush control. Angora goats were added to the ranch operations to control regrowth and possibly provide additional income. Goats not only retarded the regeneration, but also paid the original cost of brush clearing within a period of five years.

Use of brush species by goats in Oklahoma rangelands was reported by Briggs and Beall (1946). Angora goats consumed browse, resprouts, and weeds coming up in the pastures, with a subsequent increase in the carrying capacity in woody dominated areas in central Oklahoma.

Merrill (1975) studied the use of goats in the management of woody species on the Sonora Research Station in southwest Texas. In this study, mechanically treated pastures were stocked with Spanish goats for a period of five years. The goats utilized all palatable browse species, such as *Quercus virginiana* (live oak), *Quercus havardii* (shinnery oak) and *Celtis sp.* (hackberry), and placed considerable stress on less palatable species, such as *Prosopis spp.* (mesquite) and *Juniperus spp.* (juniper). Live oak, shinnery oak, and hackberry were defoliated up to the maximum reach of the goats. The author noted that a grazing rate of 1 to 2 Spanish goats per acre would pay the cost of chaining in four years, while making an additional amount of money equal to that normally obtained from 1 goat per 2 acres. Other results on brush management using goats in Texas were reported by Gray (1959) and Merrill and Taylor (1976). According to these authors, goats relished many brush species, including

Quercus stellata (post oak), *Ulmus spp.* (elm), *Smilax bona-nox* (saw greenbriar), and *Rhus spp.* (sumacs), in addition to those reported by Merrill (1975).

Davis et al. (1975) reported a successful reduction of *Quercus gambelii* (Gambel oak) resprouts in Colorado. Mechanical treatment of the brush increased the effectiveness of goats, while defoliation at the time of low carbohydrate storage, gave the most effective results. A minimum of two defoliations per year using high stocking rates over a short time period was recommended for control.

Goats have been used as an alternative to conventional methods of brush management on California chaparral (Green et al.,1978). Two years of observation indicated a considerable decrease in woody species. Optimum and uniform brush utilization was achieved by concentrating goats in smaller areas. Use of goats in the management of Arizona chaparral was recently reported by Severson and Debano (1991). This study involved four stocking rates in a short duration grazing system. Goats significantly reduced browse cover, with the best results being realized in mechanically treated pastures.

Wood (1987) compared the effectiveness of sheep, goats, and cattle in biological control of brush species in abandoned farmlands. Goats significantly reduced the brush cover within one year and essentially eliminated the brush species in two-year period. The habit of debarking trees and saplings contributed to the rapid elimination of woody vegetation.

Goats have been stocked in other parts of the world for the management of woody species. In the semi-arid areas of western Australia, feral goats effectively pruned and stunted brush species (Wilson et al., 1975, 1976; Downing, 1989). The highly and moderately preferred species were imparted during the first and third year of use, respectively. In another trial (Peirce, 1991), goats were useful in removing or opening up blackberry thickets, especially in the areas inaccessible to machinery used for herbicide application. Other studies include the use of goats in: (1) suppressing woody species in the rangelands of northern Mexico (Fierro et al., 1984), (2) reduction of *Rosa rubiginosa* shrubweed in New Zealand (Holgate, 1984), and (3) controlling bush regrowth and reinfestation of the grasslands of South Africa (Du Toit, 1972). Continuous grazing by goats in the bushveld of South Africa resulted in a higher mortality of trees and more efficient control of regrowth than did rotational grazing (Du Toit, 1972).

Influence of Forage Availability on Browse Utilization by Goats

Goats are selective feeders and their diets are largely dictated by availability of preferred species. There is a widespread misconception that goats will not eat grass. Malechek and Leinweber (1972) reported the available forage and botanical composition of Angora goat diets on lightly and heavily stocked pastures in the Edwards Plateau of Texas. From this study, goats were classified as grazers rather than browsers. There was more grass and browse left in the lightly stocked pastures than in the heavily stocked pastures. Grass was the primary forage class consumed on both grazing treatments throughout the period from June to mid-October. In late autumn, browse proportionally increased in the goats' diets. *Quercus virginiana* (live oak) was the major species in diets on both treatments in January and early February, while *Quercus harvardii* (shinnery oak) replaced other browse species from the time of leaf emergence in early April until frost-kill in early November. Decreased availability of the preferred species eventually prompted the Angora goats to make heavy use of *Juniperus spp.* (junipers) and *Opuntia leptocaulis* (tasajillo).

Nge'the and Box (1976) described the Galla goats of Kenya as animals that readily consume both grass and browse. In an Acacia-grassland community, the goats consumed almost similar amounts of grass and browse, with very few species comprising the bulk of their diets. However, it was interesting to note that *Themeda triandra* was the most abundant species in the area, but it was an insignificant component of the goats' diets. As the season advanced toward the dry season, the preference tended more to browse species. *Acacia tortilis* was the most abundant woody species but moderately preferred until late in the season when most of the browse species had shed their leaves.

Sidahmed et al., (1981) described goats as browsers. This researcher collected data from a brushland dominated by *Adenostoma fasciculatum* (chamise), *Quercus dumosa* (scrub oak), *Arctostaphylos glandulosa* (eastwood manzinata), and *Ceanothus greggii* (ceanothus). Scrub oak was the most preferred species and was consumed in excess of 80%. Decreased availability of scrub oak resulted in heavy use of chamise. In this study, there was no relationship between shrub preference and availability, because manzanita and ceanothus were the most abundant but the least preferred browse species.

The apparent deviation from the popular opinion that goats are browsers may be attributed to the deficiency of forage availability data in most food habit studies. These deficiencies are not only subject to erroneous conclusions, but also impose difficulties in deciding whether the selected food category is due to the goats preference or because there is nothing else available (Malechek and Leinweber, 1972). Goats are selective feeders and, in view of the circumstances surrounding most of the food habit studies, it is rather difficult to reconcile different opinions.

Stocking Rates

Goats may consume large amounts of browse. But, when the availability of the preferred species is limited, they may turn to alternative food resources (Merrill, 1975; Scifres, 1980). Stocking rates are, therefore, an important aspect in brush management using goats. Holechek et al. (1989) pointed out that the correct stocking rate is important from the standpoint of vegetation, livestock, wildlife, and economic returns. Stocking pastures for brush management should be viewed in the light of the browse species within the reach of the goats. The vegetative stratum utilized by goats ranges from the soil surface up to two meters (Garcia and Gall, 1981). Defoliation level, however, will vary between different species of goats. Information on stocking rates for goats is lacking, not only in Cross Timbers, but also in many parts of the world.

Briggs and Beall (1946) suggested a stocking rate of 2 to 5 goats per acre for brush suppression in rangelands and pastures of central Oklahoma. However, Briggs and Briggs (1980) reported that 4 Angora goats per acre were not sufficient to "brushoff" an area of rather heavy growth, but 6 goats per acre did a satisfactory job over a period of three years.

One goat per 2 to 3 acres on a yearlong basis and 5 to 8 goats per acre on short-term grazing were recommended for brush management in Texas (Scifres, 1980). Hanselka and Paschal (1992), working in the south Texas brush complex, reported a complete removal of all leaf material below 5 feet on an experimental pasture stocked at 2 goats per acre for 5 months. In order to have a greater impact on the brush, stocking rates of 2 to 4 goats per acre were recommended for short periods. Hanselka and Paschal (1992) noted heavy grazing of the desirable browse species.

Wilson et al. (1980) evaluated the carrying capacity of tropical savannah stocked with goats at 4 different levels. In this study, performance was not uniform due to the apparent understocking and overstocking of the pastures. Carrying capacity of 2.3 and 7.5 breeding does per hectare for unimproved and improved pastures, respectively, was recommended.

Severson and Debano (1991) evaluated the effect of 4-goat stocking levels in a short duration grazing system in Arizona chaparral. At the end of this trial, brush cover was lower on paddocks stocked at 1.4, 2.4, and 4.2 Spanish goats per hectare, compared to unstocked controls. Mechanical brush crushing increased the effectiveness of goats with respect to the preferred species at all stocking levels. But, no differences were noted in cover of the shrubs least preferred by goats. Shrubs preferred by the goats were also preferred by mule deer and white-tailed deer. Therefore, overstocking was tantamount to nutritional stress for both animal species.

Summary

Rangelands support a wide variety of forage resources suitable for browsing and grazing herbivores. However, suppression of the woody species has been a common practice in most grazing areas. Optimum animal production can only be attained by encouraging the desirable woody species and maintaining a proper balance with the other forage groups. Woody plants are preferred by many species of herbivores and complement grasses in the seasonal spectrum of forage availability and quality.

Information on utilization and the chemical nature of browse species in Cross Timbers rangelands is scarce. The primary objective of this study was to assess: (1) the effect of stocking rate on forage utilization and plane of nutrition of Angora goats, and (2) seasonal changes in the chemical composition of the browse species.

CHAPTER III

MATERIALS AND METHODS

Study Area

The research was conducted adjacent to the Cross Timbers Experimental Range located 11 km southwest of Stillwater, Oklahoma. Mean annual temperature is 15.5^{o} C--the January mean is 2.3^{o} C, and the July mean is 27.6^{o} C. Annual precipitation averages 831 mm with the majority falling from April to October (Myers, 1982). The most reliable rainfall occurs from April to June. During 1992, rainfall exceeded the mean annual precipitation, especially in June and August (unpublished data) (Figure 2).

Soils of the area are generally sandy and low in fertility. The landscape is dominated by shallow savannah (Stephenville-Darnell soil complex, 1 to 8 % slopes) and sandy savannah (Harrah-Pulaski soil complex, 0 to 8% slopes) range sites (Ewing et al., 1984). The vegetation is a mosaic of plant communities, including tallgrass prairie and upland forests dominated by *Quercus stellata* (post oak) and *Quercus marilandica* (blackjack oak), and bottomland forests, which include the upland species mixed with *Ulmus americana* (American elm) and *Celtis spp.* (hackberry). The understory vegetation can include *Juniperus virginiana* (eastern redcedar), *Cornus drummondii* (rough-leaf dogwood), *Cercis canandensis* (redbud), *Symphoricarpos orbiculatus* (coralberry or Buckbrush), *Vitis spp.* (grape), and

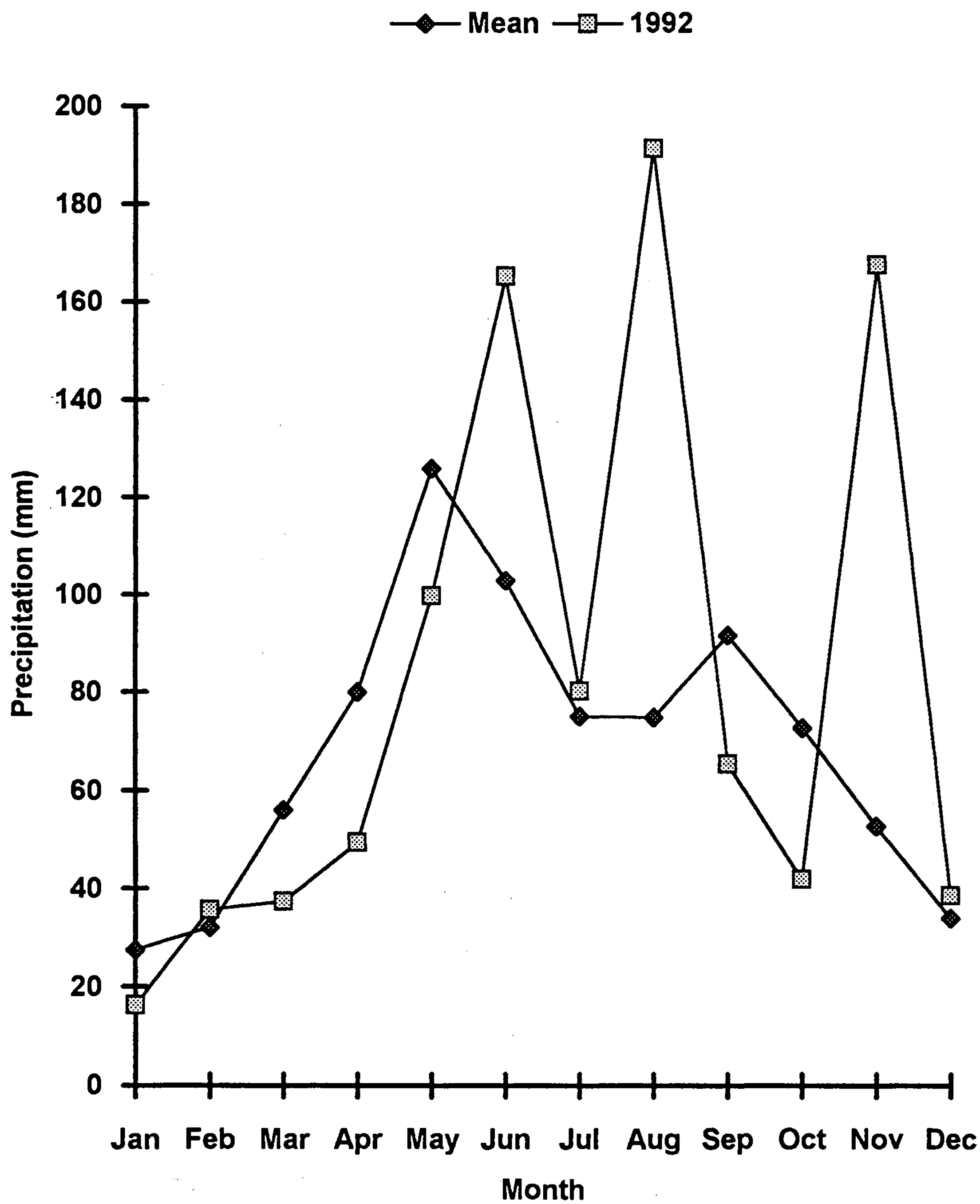

Figure. 2. Long Term Mean Precipitation (1894-1984) and 1992 Rainfall at Stillwater, Oklahoma (Myers, 1982, and Unpublished Data)

Rhus radicans (poison ivy) (Ewing et al., 1984). Additional species include *Bumelia lanuginosa* (chittamwood), *Rhus glabra* (smooth sumac), and *Rhus copallina* (winged sumac).

Frequency of occurence of woody plants ranged between 1 and 53% (Table 1). Although woody species dominated the vegetation cover, herbaceous species were abundant in all the grazing paddocks. *Symphoricarpos orbiculatus* (coralberry), *Quercus stellata* (post oak), *Juniperus virginiana* (eastern redcedar), and *Celtis sp.* (hackberry) were the most common woody species. Botanical composition data are consistent with the studies reported by Ewing et al. (1984).

The entire area was grazed by cattle at a moderate stocking rate prior to 1991. In 1991, the four hectare study site was grazed by mutton goats at stocking rate of 4 goats/hectare from mid-May to October. Between 1987 and 1989, some harvesting of *Q. marilandica* (blackjack oak) and *Q. stellata* (post oak) had occurred. There is no known herbicide application or use of fire in recent history.

TABLE I

FREQUENCY (%) OF OCCURENCE OF PLANTS ON THE CROSS TIMBERS RANGELANDS[1]

Plant Species	Pasture 1	2	3	4	Mean
Bumelia lanuginosa (chittamwood)	2	2	7	10	5
Cercis canadensis (redbud)	1	1	2	2	2
Celtis sp. (hackberry)	7	13	12	17	12
Cornus drummondii (rough-leaf dogwood)	1	1	1	1	1
Juniperus virginiana (eastern redcedar)	20	12	16	11	15
Prunus mexicana (Mexican plum)	1	1	2	2	2
Quercus marilandica (blackjack oak)	3	11	4	13	8
Quercus muehlenbergii (chinquapin oak)	0	2	0	3	3
Quercus stellata (post oak)	7	23	29	42	25
Rhus copallina (winged sumac)	2	2	3	14	5
Rhus glabra (smooth sumac)	1	2	1	8	3
Rhus radicans (poison ivy)	0	5	1	2	3
Smilax bona-nox (saw greenbriar)	1	2	7	16	7
Symphoricarpos orbiculatus (coralberry)	30	53	20	20	31
Ulmus americana (American elm)	5	1	0	1	2
Vitis spp. (grape)	1	3	0	1	2
Herbaceous	77	60	52	46	59
% Brush cover	52	80	64	94	
Stocking rate (head/hectare)	4	9	4	9	

[1] Frequency (%) of occurence in 100, 0.1m^2 quardrat determined by a modified step-point method.

Field Methods for Forage Utilization Study

Treatments

A 4 hectare study site was fenced in 1990 and divided into 4, 1-hectare paddocks. Two stocking rates were evaluated. Either 4 or 9 head of Angora muttons grazed the paddocks continuously during the 119-day period from May until early October, resulting in a range of less than 100 goat days/hectare for the first month of grazing on the light stocking rate to almost 1100 days/hectare for the season on the heavily stocked paddocks.

Vegetation

A vegetation inventory of each pasture was conducted in May, 1992, using a modified step point method (Evans and Love, 1957). Frequency of occurence of woody species were recorded at sampling points along seventeen transects located in each pasture. Sampling points, spaced at eight paces, were established by lowering a 1.5-meter bar vertically into the sward. Herbaceous vegetation intercepting the metal bar and the woody species with plant parts within a 0.10 m^2 of the bar were recorded at 100 points in each paddock. Woody plants were identified by species and the herbaceous component (forbs and grasses) as a group.

Utilization of woody species and the herbaceous layer was visually rated by two observers every 30 days. A scoring system of 1 to 5 (1=0% use, 2=25% use, 3=50% use, 4=75% use, and 5=100% use) was used to describe the defoliation of available vegetation below 1.5 meters. On the final date, utilization of eastern redcedar was evaluated by scoring different height classes of trees (0-0.75 meters, 0.75-1.50 meters and 1.50 meters or taller).

Standing residue of the herbaceous layer was measured at the end of the season. Twenty 0.10 m^2 (20 x 50 cm) quadrats were located in each pasture. The herbaceous component was clipped to ground level in each plot, bagged, and oven-dried at 100^o C to a constant weight.

Livestock

Ruminal, fecal, and blood samples were collected in June (6-9 to 6-12), July (7-7 to 7-10), August (8-11 to 8-14), and September (9-15 to 9-18) to monitor plane of nutrition of the goats. Ruminal and fecal samples were collected on four consecutive days between 9 and 11 a.m. and 4 and 6 p.m. Blood samples were obtained in the morning of the final day of each sampling.

Twelve rumen-fistulated wether goats (3 head/pasture) were used for obtaining ruminal samples. At each sampling period, whole rumen contents were separated by straining through cheesecloth. The fluid portion was acidified with 2 ml of 20% sulfuric acid (H_2SO_4) and placed in a whirlpark. An additional sample of whole rumen contents was placed in a whirlpark and chilled on ice until placed in frozen storage. In the laboratory, samples of total rumen contents and rumen fluid were composited within goat and time of day.

Fecal samples were collected from 16 wether goats (4 head/pasture). The samples were placed in plastic bags and refrigerated. These samples were composited within goat and across days and time of the day.

Blood samples were obtained from 4 goats in each pasture. Samples were collected from the jugular vein into vacuum tubes and immediately placed on ice. After clotting, the samples were centrifuged for 30 minutes. Serum aliquots were frozen for later analysis.

Laboratory Analysis

Samples of total rumen contents and feces were lyophilized and ground to pass a 2 mm screen (Wiley mill). Dry matter and ash were determined by oven-drying the ground samples at 100° C for 24 hours, and then combusting them in a muffle furnace at 500° C for 4 hours (AOAC, 1991). Nitrogen content of the samples was estimated by the micro-kjeldahl procedure (AOAC, 1991). The Prussian Blue Test, using spectrophotometric determination of color intensity, was used to analyze condensed tannins (Price and Butler, 1977). This test was chosen because of its accuracy and convenience. The vanillin test (Burns, 1971) is a commonly used method of quantitative analysis of tannins, but it requires an overnight extraction. The Prussian Blue Test needs about 20 minutes for analysis. Results were expressed as "catechin equivalents" (mg of catechin/100 gm sample) required to give the observed absorbance. Standard curves were prepared daily for the analysis.

Whole ruminal contents were further analyzed for ammonia nitrogen (NH3-N) by magnesium oxide distillation (AOAC, 1991) NDF, and ADF (Goering and Van Soest, 1970). Rumen fluid was thawed, centrifuged at 10,000 x g for 10 minutes, and the supernatant analyzed for NH3-N (Broderick and Kang, 1980). Blood serum samples were analyzed for total protein, blood urea nitrogen, creatinine, albumin, and glucose on an autoanalyzer.

Data Analysis

Data on utilization (UTIL), total rumen content (TRC), and blood indices (BI) were analyzed as a split-plot (Steel and Torrie, 1980) with repeated measurements using GLM procedures as described in SAS/STAT User's Guide

(SAS Institute, 1990). The model included stocking rate (H), sampling date (D), and the interaction term (HxD) as shown below:

$$Y_{ijk}=u+H_i+(PxH)_{ij}+D_j+(HxD)_{ij}+e_{ijk}$$

where

Y_{ijk}=j^{th} observation (UTIL,TRC,and BI) in the k^{th} pasture for i^{th} stocking rate

u=overall mean

H_i=i^{th} stocking rate effect (whole unit effect)

D_j=j^{th} sampling date effect (sub-unit effect)

$(HxD)_{ij}$=effect of interaction between j^{th} stocking rate and i^{th} sampling date

$(PxH)_{ik}$="error a", pasture within stocking rate

e_{ijk}=random error effects (residual error)

The stocking rate main effect was tested with the "error a" term. Sampling date and the stocking rate interactions were tested with the residual error. If sampling date *x* stocking rate interaction was significant, data were analyzed within sampling periods using *t*-tests. Vegetation data were analyzed by plant species. When the sampling date x stocking rate (HxD) interaction was significant for dominant, problem brush species and the herbaceous layer, regression models were developed to describe the relationship between utilization and stocking rate.

Field Methods for Browse Species Study

Browse samples were collected from four pastures on the Cross Timbers Experimental Range to assess nutrient composition. On each pasture, samples of current year's growth were obtained from *Ulmus americana* (American elm), *Quercus stellata* (post oak), *Quercus marilandica* (blackjack oak), *Smilax bona-nox* (saw greenbriar), *Symphoricarpos orbiculatus* (coralberry or Buckbrush), *Cornus drummondii* (rough-leaf dogwood), *Rhus copallina* (winged sumac), *Cercis canandensis* (redbud), *Vitis sp.*(grapevine), *Juniperus virginiana* (eastern redcedar), and *Celtis sp.*(hackberry) in June (6-6-90), August (8-6-90), and September (9-6-90) of 1990. Forage samples were placed on ice in the field and then frozen until the time of analysis.

Laboratory Analysis

Samples were lyophilized and ground to pass through 2 mm screen (Wiley mill). Dry matter and ash were determined by oven-drying the samples for 24 hours and ashing them for 4 hours (AOAC, 1991). A micro-kjeldahl procedure (AOAC, 1991) was used for nitrogen analysis. Acid detergent fiber was determined using the method described by Goering and Van Soest (1970).

Statistical Analysis

Data on nitrogen (N), acid detergent fiber (ADF), and ash (A) were analyzed as a split-plot (Steel and Torrie, 1980) using the GLM procedure described in SAS/STAT User's Guide (SAS Institute, 1990). The GLM included pasture (P), browse species (S), sampling period (D), and the interaction term (sampling period x browse species) as shown below:

$$Y_{ijk}=u + P_i + S_j + (PxS)_{ij} + D_k + (SxD)_{ij} + e_{ijk}$$

where

Y_{ijk}=k^{th} observation (N, ADF, and A) on the j^{th} species, in the i^{th} pasture

u=overall mean

P_i=i^{th} pasture effect

S_j=jth species effect (whole unit effect)

D_k=kth sampling period effect (sub unit effect)

$(SxD)_{ij}$interaction effect between jth species and kth sampling period

$(PxS)_{ij}$="error a", pasture x species interaction

e_{ijk}=random error effects (residual error)

The browse species main effect was tested with the "error a" term. The sampling period *x* species interaction term was tested with the residual error. If interaction between browse species and sampling period was significant, period means were compared using *t*-tests.

CHAPTER IV

RESULTS AND DISCUSSION

Forage Utilization

A wide range of plant species was utilized by the goats (Table II), but the level of utilization varied among forage species/classes and period of use. Based on the level of utilization woody species in Cross Timbers rangelands can be initially ranked into highly preferred species, moderately preferred species, and less preferred species. It is realized that the methods utilized in this study do not reflect preference as measured by quantitative removal of available material. Instead, preference is used in the context of level of defoliation required for suppression or maintenance of plant species or group. Highly preferred browse species are those that were heavily utilized throughout the grazing period irrespective of the stocking rate. Less preferred species experienced less than 30% defoliation, regardless of stocking rate. Moderately preferred species were less utilized early in the season but heavily browsed during the last half of the grazing period and experienced both period and stocking rate differences. Utilization data are consistent with the views of Van Dyne et al. (1980) who pointed out that the preference of plant species by grazing animals is not static, but conditioned by the season and the species composition of the vegetation. Factors responsible for these differences are not

TABLE II

PERCENTAGE UTILIZATION BY SAMPLING PERIOD
FOR SEVERAL BROWSE SPECIES

	Sampling Date				
	June	July	August	September	SE
Bumelia lanuginosa (chittamwood)	85.8	91.8	93.5	91.8	3.1
Cercis canadensis (redbud)	94.7	96.8	96.2	98.4	3.0
Celtis sp. (hackberry)	95.0	97.7	94.8	96.2	1.0
Cornus drummondii (rough-leaf dogwood)	99.0	95.6	98.7	97.8	1.7
Juniperus virginiana (eastern redcedar)	4.5	9.3	7.1	7.8	2.3
Prunus mexicana (Mexican plum)	82.3^{a}	95.6^{b}	93.5^{b}	97.7^{b}	3.2
Quercus marilandica (blackjack oak)	15.8^{a1}	51.6^{b1}	72.7^{bc1}	82.1^{c1}	7.0
Quercus muehlenbergii (chinquapin oak)	95.6	80.1	94.3	94.3	7.0
Quercus stellata (post oak)	19.8^{a1}	29.8^{a1}	47.8^{bc1}	61.0^{c1}	5.1
Rhus copallina (winged sumac)	48.3^{a}	94.8^{b}	84.8^{c}	100.0^{d}	12.2
Rhus glabra (smooth sumac)	61.7^{a}	97.0^{b}	97.8^{b}	96.8^{b}	4.7
Smilax bona-nox (saw greenbriar)	99.3	100.0	98.2	99.9	1.0
Symphoricarpos orbiculatus (coralberry)	2.5^{a1}	4.8^{a1}	13.6^{b1}	56.2^{c1}	1.4
Ulmus americana (American elm)	93.2	93.8	95.0	94.3	2.6
Vitis sp.(grape)	99.7	100.0	100.0	100.0	0.3
Herbaceous species	16.8^{a1}	29.5^{ab1}	34.9^{bc1}	50.0^{c1}	4.7

^{a,b} Period means are different (P<0.05).

^{1} Main effects; period x stocking rate interaction (P<0.05).

well documented, but can be partly attributed to the morphological and chemical characteristics of the available forage species.

Highly preferred woody species included *Bumelia lanuginosa* (chittamwood), *Cercis canadensis* (redbud), *Celtis sp.* (hackberry), *Cornus drummondii* (rough-leaf dogwood), *Prunus mexicana* (Mexican plum), *Quercus muehlenbergii* (chinquapin oak), *Rhus copallina* (winged sumac), *Rhus glabra* (smooth sumac), *Smilax bona-nox* (saw greenbriar), *Ulmus americana* (American elm), and *Vitis spp.* (grape) (Table II). It is important to note these species were not dominant based on frequency (Table 1). Utilization of highly palatable species remained high throughout the grazing period (May - October) and stocking level differences were not significant. Similar results were reported by Severson and Debano (1991) who evaluated the effect of 4-goat stocking rates in a short duration grazing system in Arizona chaparral. High defoliation of the preferred species was observed, regardless of the stocking rates.

Although *Prunus mexicana* (Mexican plum) experienced period differences, it was highly defoliated throughout the grazing period. Selectivity for *Smilax bona-nox* (saw greenbriar) was high and consistent throughout the grazing period. Similar results were reported by Lopes and Stuth (1984) for Spanish goats grazing in the Post Oak Savannah of central Texas, and by Gray (1959) for Angora goats grazing in the Edwards Plateau of Texas. *Rhus copallina* (winged sumac) and *Rhus glabra* (smooth sumac) were highly browsed, debarked, and eventually killed. Preference for and the subsequent suppression of sumacs by Angora goats was also reported by Gray (1959).

Moderately preferred species became increasingly important as summer advanced. These species included *Quercus marilandica* (blackjack oak) and *Quercus stellata* (post oak) (Figure 3 and 4). Oak species were among the dominant woody plants (Table I), but the availability of more preferred species curtailed their utilization early in the season. Oak utilization ranged from 16% to 82% and 20% to 61% for blackjack oak and post oak, respectively (Table II). Similarly, blackjack oak utilization ranged between 44% and 67% while post oak utilization ranged from 27% to 53% in lightly and heavily stocked pastures respectively (Table III).

Regression models to describe the relationship between percentage utilization (Y) and stocking rates (X), expressed as goat grazing days per hectare of brush cover, were developed for *Quercus marilandica* (blackjack oak) (Figure 3) and *Quercus stellata* (post oak) (Figure 4).

The linear model for *Q. Marilandica* accounted for 79% of total variation, while the quadratic model explained 85% of the total variation. The quadratic effect ($P<0.0001$) suggests that utilization of blackjack oak (Figure 3) relative to stocking rates was not consistent over the entire grazing period. Lack of linear relationship could possibly be attributed to the frequent occurrence of regrowth of preferred browse species and the chemical change in blackjack oak that reduced the palatability as the season progressed. Utilization of *Q. stellata* had a positive linear relationship with stocking rate (Figure 4) with 70% of total variation explained by the model.

Heavy browsing on oaks was realized during the last half of the grazing period. Therefore, stocking rate and period of use differences ($P<0.05$) were both realized, in contrast to the highly palatable browse species that experienced only minor period differences. Villena and Pfister (1990) reported similar trends on the diets selected by Angora and Spanish goats grazing on sand shinnery oak (*Quercus havardii*) range in west Texas. Shinnery oak dominated the available forage, just as oaks dominate browse species in Cross Timbers rangelands, and became increasingly important dietary component as summer advanced.

TABLE III

PERCENTAGE UTILIZATION BY STOCKING RATES
FOR SEVERAL BROWSE SPECIES

	Stocking Rate		
	Low	High	SE
Bumelia lanuginosa (chittamwood)	85.2	96.2	5.1
Cercis canadensis (redbud)	93.9	99.1	2.1
Celtis sp.(Hackberry)	93.4	98.5	2.8
Cornus drummondii (rough-leaf dogwood)	96.8	98.7	1.9
Juniperus virginiana (eastern redcedar)	5.8	8.5	3.4
Prunus mexicana (Mexican plum)	88.4	96.1	5.1
Quercus marilandica (blackjack oak)	43.7[a]	67.3[b]	8.1
Quercus muehlenbergii (chinquapin oak)	91.4	90.8	5.6
Quercus stellata (post oak)	26.6[a1]	52.7[b1]	15.8
Rhus copallina (winged sumac)	77.2	87.1	12.0
Rhus glabra (smooth sumac)	86.4	90.2	7.3
Smilax bona-nox (saw greenbriar)	99.4	100.0	1.1
Symphoricarpos orbiculatus (coralberry)	8.9[a1]	29.6[b1]	2.3
Ulmus americana (American elm)	93.4	94.8	4.0
Vitis spp.(grape)	100.0	100.0	0.0
Herbaceous species	7.5[a1]	58.1[b1]	3.9

a,b Stocking rate effects are different ($P<0.05$).

1 Main effects; period x stocking rate interaction ($P<0.05$).

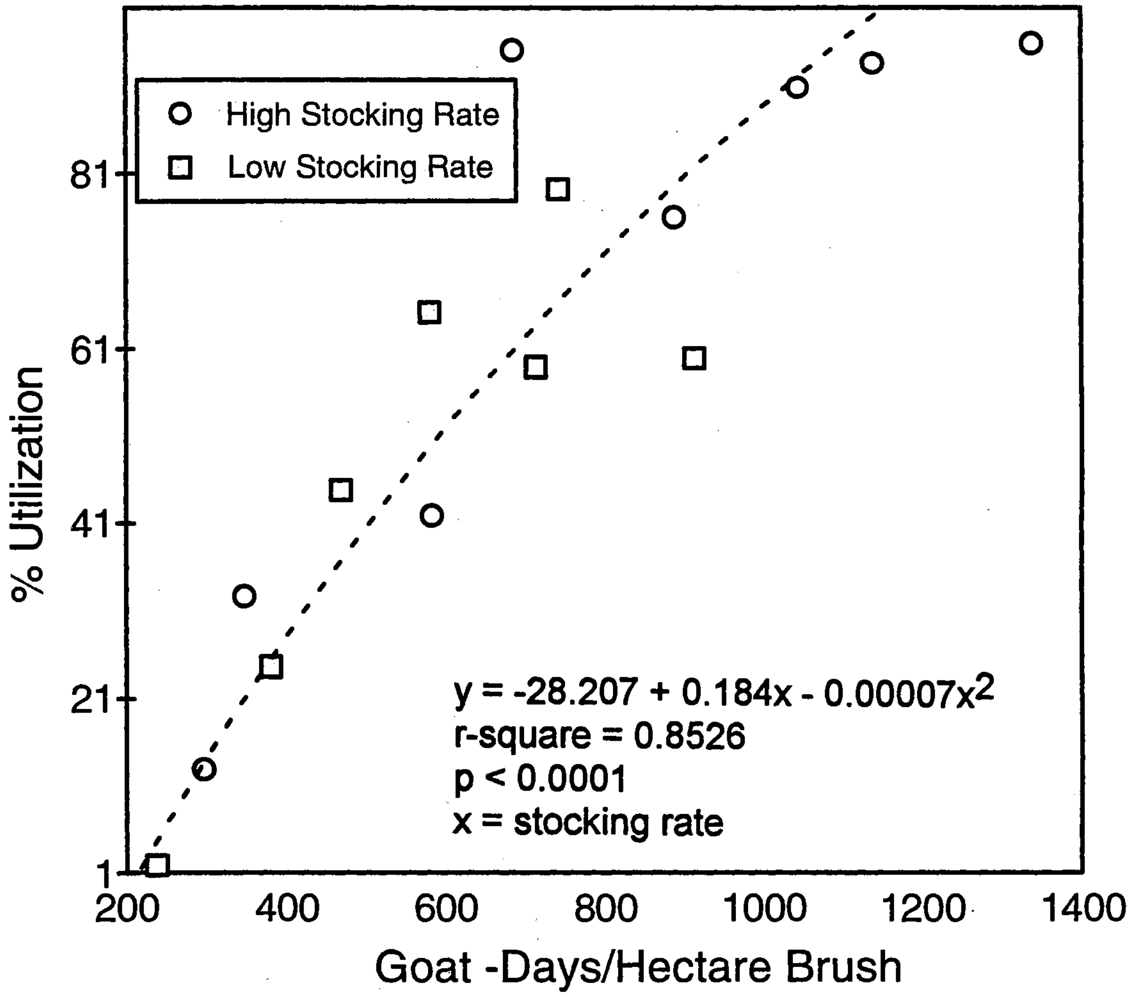

Figure 3. Relationship of Stocking Rate and Utilization of *Quercus marilandica* (blackjack oak) by Angora Goats

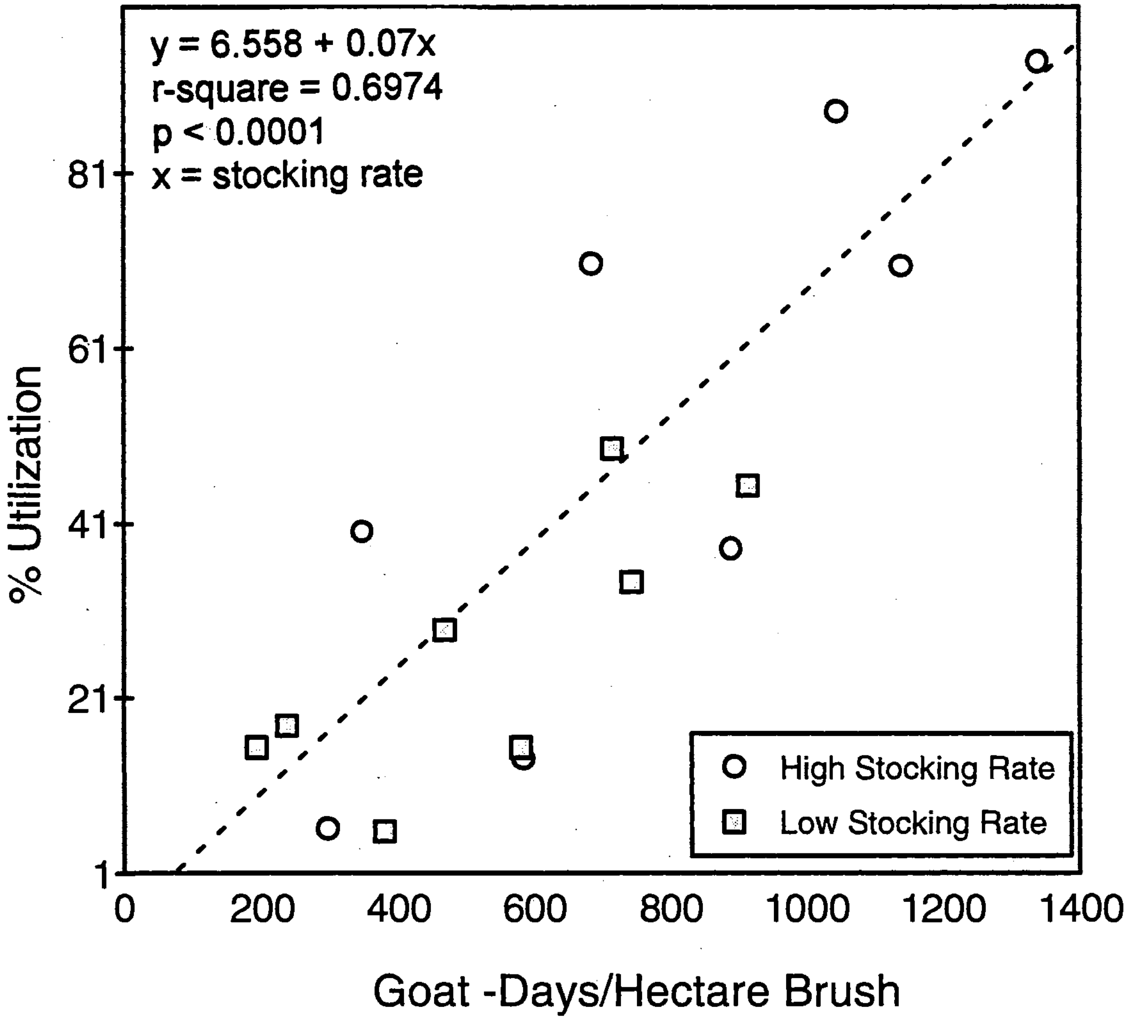

Figure 4. Relationship of Stocking Rate and Utilization of *Quercus stellata* (post oak) by Angora Goats

The relationships between brush utilization and goat stocking rate, expressed as goat grazing days per hectare of brush cover, may be useful in the management of woody species in Cross Timbers rangelands. Suppose that the management objective requires 50% post oak utilization in cattle grazing pastures. The predicted goat stocking rate required to achieve this level of utilization would be 621 goat-days/hectare of brush cover. Based on this stocking rate, the herbaceous layer would be reduced by about 30% depending on percentage frequency of occurrence (Figure 6). This impact on the herbaceous layer suggests that moderate goat stocking would possibly be compatible with cattle grazing.

Juniperus virginiana (eastern redcedar; Table II) and *Symphoricarpos orbiculatus* (coralberry or buckbrush; Figure 5) were among the least preferred browse species. In general, frequency of less preferred browse species was high (Table I), but utilization was generally less than 30%. A regression model relating percentage utilization (Y) of coralberry to the stocking rate and percentage frequency of occurrence (X) was developed and is presented in Figure 5.

Change in coralberry utilization per unit change in stocking rate had a significant ($P<0.01$) quadratic relationship with an R-square of 0.86. Utilization of coralberry remained very low (less than 30%) until September when significant differences ($P<0.05$) were realized among stocking rates. Abrupt shifts of the Angora goats' preference for coralberry may be explained by (1) reduced availability of more palatable browse species during the last part of the grazing period, or (2) fruit production late in the season. Regression analysis suggested that different stocking rates may have affected utilization of coralberry However, percentage frequency of occurrence had a significant effect ($P<0.05$) on defoliation of coralberry (Appendix C). Utilization was lower as frequency of

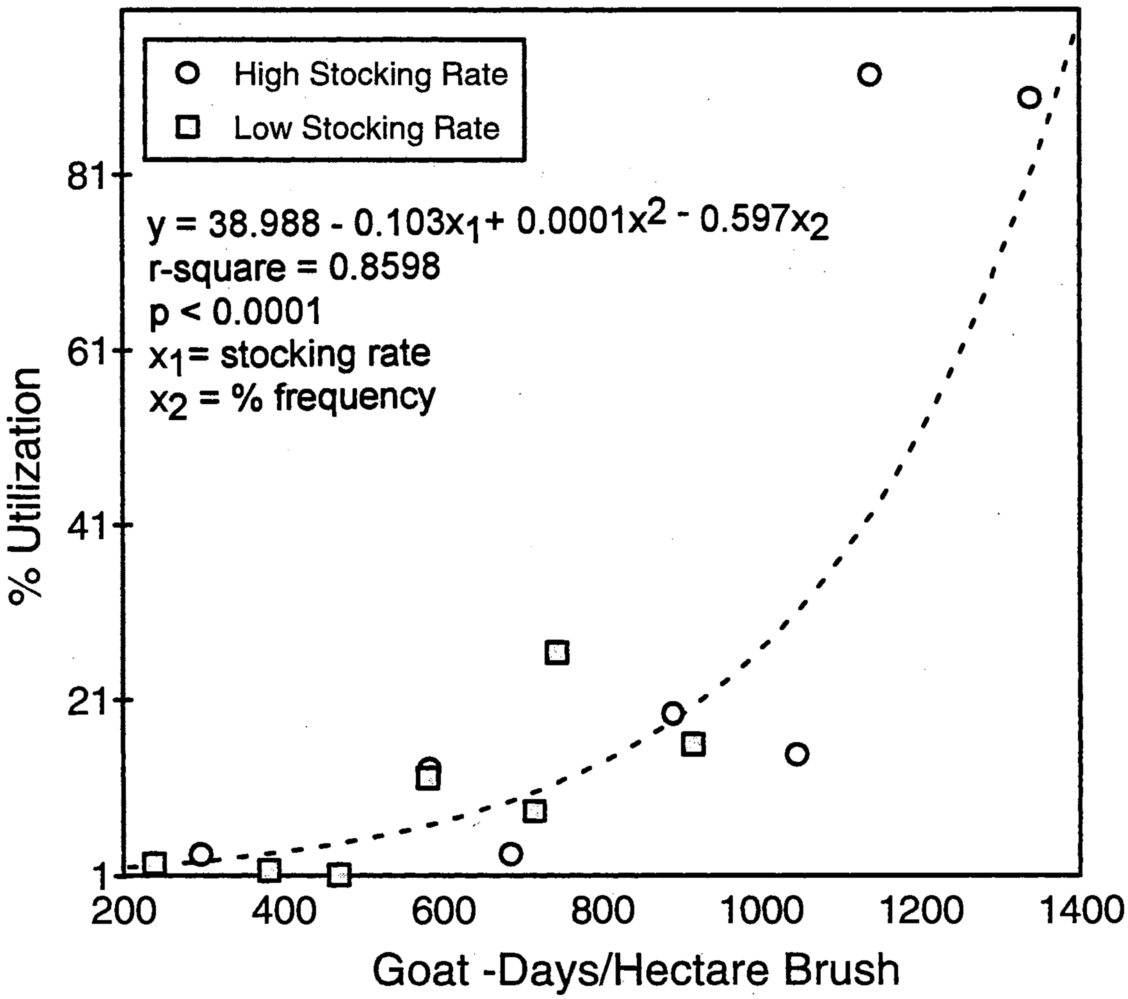

Figure 5. Relationship of Stocking Rate and Utilization of *Symphoricarpos orbiculatus* (coralberry) by Angora Goats

coralberry increased. These data compare well with the botanical composition of the diets selected by Spanish goats grazing Texas Post Oak Savannah (Lopes and Stuth, 1984). In this study, for example, coralberry was among the least preferred browse species and comprised less than 10% of the goat diets.

Eastern redcedar is a common understory woody species (Table I), but has a minimal input toward livestock feed. Although cedar in general was poorly utilized by Angora goats, small, young, growing plants were readily utilized. Utilization of cedar ranged between 17% in lightly stocked pastures and 45% in heavily stocked pastures (Table IV). Of particular interest was the size class and stocking rate interaction ($P<0.05$). In the lightly stocked pastures, utilization appeared to be limited to those plants below the height of 0.75 meters. In heavily stocked pastures, browsing gradually declined with height of the cedar plants. Heavy defoliation and debarking of the young cedar trees was a common phenomena in all pastures, regardless of the stocking levels and period of use. Consumption of eastern redcedar has often been associated with fall and winter, when little or no other green feed is available (Gray, 1959), or at times when palatable browse species have been fully utilized (Merrill, 1975).

The herbaceous layer was readily utilized by the goats (Table II). Utilization was between 2% and 15% in lightly stocked pastures, with an average residual dry matter of 2,105 kg per hectare (Table, V). In heavily stocked pastures, utilization ranged between 31% and 88%, with the mean residual dry matter of 255 kg per hectare (Table V). The regression model describing the relationship between utilization (Y) and goat grazing days per hectare of brush cover (X) accounted for 65% of the variation (Figure 6).

A second regression model was developed to describe the relationship between the average residual herbaceous dry matter (Y) and (1) stocking rates (X) expressed as goat grazing days per hectare:

TABLE IV

PERCENTAGE UTILIZATION OF EASTERN REDCEDAR
BY HEIGHT CLASS AND STOCKING RATE

	Height Class				
Stocking Rate[f]	<0.75m	0.75-1.50m	>1.50m	SE	Mean
Low	42.4[a]	7.3[b]	1.5[b]	3.2	17.0[d]
High	90.4[a]	40.1[b]	4.7[c]	6.9	45.0[e]
Mean	66.4[a]	23.7[b]	3.1[c]	4.5	31.0

a,b,c Row means are different ($P<0.05$).

d,e Column means are different ($P<0.05$).

[f] Stocking rate x height class ($P<0.05$).

TABLE V

END OF SEASON HERBACEOUS STANDING CROP

	Stocking rate			
	Low		High	
Pasture	1	3	2	4
Standing crop (Kg/ha)	2963±2460	1248±2177	217±383	293±497
Mean standing crop (Kg/ha)	2105±1213		255±54	

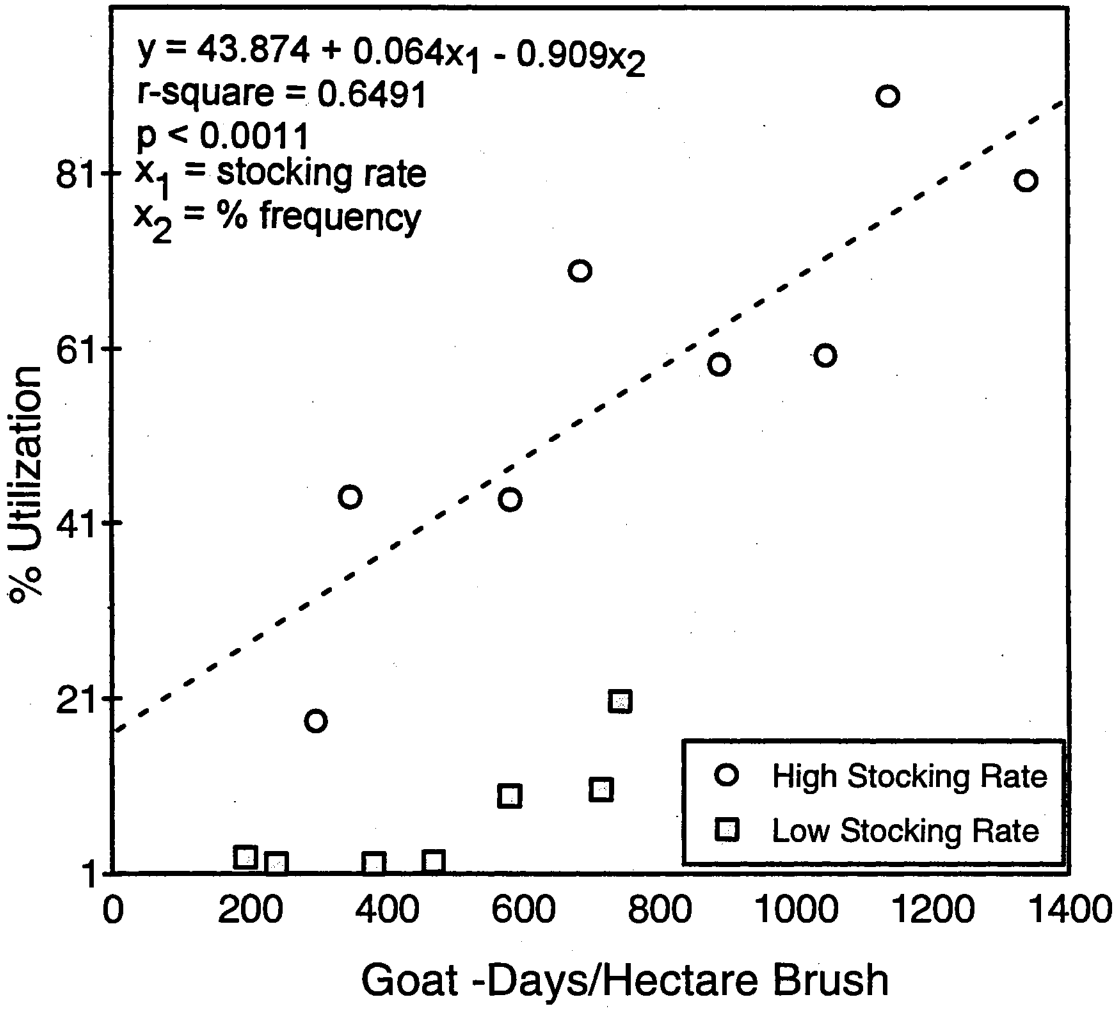

Figure 6. Relationship of Stocking Rate and Utilization of Herbaceous Layer by Angora Goats

$$Y=3586.02 - 3.1099X \qquad R^2=0.70 \qquad P<0.16$$

and (2) stocking rate (X) expressed as goat grazing days per hectare of brush cover:

$$Y=4340.97 - 3.0556X \qquad R^2=0.38 \qquad P<0.38$$

The linear relationship for goat grazing days per hectare explained more total variation in herbaceous utilization than did stocking rate expressed as goat grazing days per hectare of brush cover. Translation of these data clearly indicates that goats make use of herbaceous vegetation and the intensity of utilization is linearly related to the stocking rates and length of use.

It is difficult to generalize on the feeding habits of goats, but several studies have classified them as browsers (Sidahmed et al., 1981; Warren et al., 1984). Others have categorized them as intermediate feeders (Migongo-Bake and Hansen, 1987) or opportunistic generalists with a tendency to consume the most palatable vegetation available (Coblentz, 1977; Villena and Pfister, 1990). Results from the current study suggest that goats are best classified as opportunists in the Cross Timbers environment.

Plane of Goat Nutrition

Chemical composition of the TRC was not significantly affected by stocking rates. Statistical analysis on the basis of time relative to morning and afternoon sampling showed no differences. Results did not correspond to the expected higher quality diets in the afternoon sampling. The tendency for goats to consume the most palatable vegetation available (Coblentz, 1977; Villena and Pfister, 1990) may partly explain why no differences were realized. Information on diets selected by different livestock species in respect to the time of the day is scarce. Langlands (1965) reported significant differences in the nitrogen content of the diets selected by sheep at different times of the day. The lowest selectivity was realized at dawn, but gradually improved with time. The relationship between dietary nitrogen and time was quadratic, with a tendency to level off somewhere between 11 and 17 hours.

Nutritive value of total rumen contents differed ($P<0.05$) among sampling periods. Nitrogen concentration in the ruminal contents was high throughout the grazing period (Table VI), but differed among sampling periods. These data were consistent with the studies reported by Pfister and Malechek (1986). The authors observed a decline in goat dietary crude protein as the season advanced into the dry period. In the current study, utilization of browse species (Table II) high in nitrogen content (Table IX) explains the high level of ruminal nitrogen. These findings compare well with studies reported by Ramirez et al. (1990, 1991), where goats were reported to select browse species high in crude protein, even though grasses represented a significant proportion of plant cover in the study area.

Ammonia-N and fecal-N followed a pattern similar to TRC nitrogen concentration, with the highest values corresponding to the availability of new growth in June and July (Table VI). However TRC ammonia-N differed ($P<0.05$) among stocking rates (Table VII). Fecal-N gradually declined as the summer advanced into the dry period, but remained reasonably high as compared to the values reported for cattle grazing the same area Fecal-N values corresponding to 6, 8, and 10% crude protein in cattle diets were 1.42, 1.83, and 2.23%, respectively (McCollum, 1990). Fecal-N is an index of diet quality and has been shown to be positively correlated with dietary protein (Arman et al., 1975; Holloway et al., 1981; Holechek et al., 1982; Leslie and Starkey, 1985;

TABLE VI

CHEMICAL COMPOSITION OF TOTAL RUMEN CONTENT AND FECES OFANGORA GOATS GRAZING CROSS TIMBERS RANGELANDS

	Utilization Date				
Parameters	June	July	August	September	SE
Total rumen-N (g N/100 g OM)	3.4^{ab}	3.7^{a}	3.2^{a}	2.8^{b}	0.1
Total rumen ammonia-N (g/100 g OM)	0.06^{a}	0.09^{b}	0.07^{ab}	0.06^{ac}	0.005
Total rumen tannins (mg CE/100 mg OM)	0.07	0.06	0.07	0.05	0.01
Total rumen content NDF (g/100 g OM)	60.3	56.0	56.6	60.2	1.64
Total rumen content ADF (g/100 g OM)	37.8^{b}	33.7^{c}	36.4^{bc}	41.4^{a}	1.75
Rumen fluid ammonia (mg/100 ml)	9.4^{a1}	8.7^{ab1}	7.8^{b1}	7.9^{b1}	0.43
Fecal N (g/100g OM)	2.6^{ab}	2.7^{a}	2.4^{b}	2.1^{c}	0.06
Fecal tannins (mg CE/100 mg OM)	0.03	0.03	0.03	0.03	0.002

[a,b,c] Period means are different ($P \leq 0.05$).

[1] Main effects; period x stocking rate interaction ($P<0.05$).

TABLE VII

CHEMICAL COMPOSITION OF TOTAL RUMEN CONTENTS BY STOCKING RATE

	Stocking Rate		
Parameters	Low	High	SE
Ammonia-N (g/100 g OM)	0.07[a]	0.06[b]	0.001
ADF (g/100 g OM)	35.9[c]	38.6[d]	1.77

[a,b] Effect of stocking rate is different ($P<0.05$).

[c,d] Effect of stocking rate is different ($P<0.16$).

Shaabani et al., 1986; Hakkila et al., 1988; Leite and Stuth, 1990; and McCollum, 1990). However, the general application of the prediction equation (Leslie and Starkey, 1987) or extrapolation beyond the data used in the relationship (McCollum, 1990) is not recommended.

Rumen fluid ammonia-N was the only parameter with sampling date x stocking rate interaction. The highest concentration (9.4 mg/100 mls) was realized early in the season (Table VI). There was stocking rate effect ($P<0.05$) in June and July but no differences occurred during the final two sampling periods. The effect of low stocking rate remained reasonably constant throughout the grazing period (Appendix E). The microbial requirement for ammonia-N varies among diets, but these relationships are poorly understood (Orskov, 1982). Rumen ammonia-N in excess of 5 mg/100 ml of rumen fluid has no beneficial effect on microbial protein synthesis (Satter and Roffler, 1975; Orskov, 1982). Therefore, concentration of ammonia was within the range to adequately support microbial fermentation.

Ruminal tannin content did not differ among sampling periods (Table VI). Samples collected in June and August had the highest numerical tannin values (0.07 mg CE/100 OM). Tannins are present in many woody species and often interact with dietary proteins, salivary proteins, and digestive enzymes to form a complex unlikely to undergo normal metabolism (Haslam, 1979). However, goat rumen microflora are capable of adapting to the tannin diets (Bederski et al., 1992). In the current study, tannins were within the acceptable levels. Fecal-tannins did not differ among the sampling periods. Fecal tannins remained constant (0.03 mg CE/100 mg OM) throughout the grazing period. The presence of tannins in woody species (McLeod, 1974; Kumar and Singh, 1984) elevates the concentration of fecal-N (Hakkila et al.,1988) and reduces the accuracy of diet quality predictions (Hobbs, 1987) using the fecal-N as an index. Fecal-tannin concentration, when added to the regression models, improves the ability for predicting diet protein (Leite and Stuth, 1990). The ratio between fecal-tannins and fecal-N remained reasonably constant throughout the grazing period, suggesting that dietary tannins were proportional to the nitrogen concentration in the feces.

The average neutral detergent fiber (NDF) of TRC was 58.3% and remained reasonably constant throughout the grazing period. Acid detergent fiber (ADF) differed ($P<0.05$) among sampling periods, with the highest values late in the season (Table VI). A significant reduction in ADF ($P<0.05$) during the month of July was unusual from the standpoint of plant maturity. Occurrence of regrowth during this period might have provided more nutritious and less fibrous forage. Acid detergent fiber of the TRC differed ($P<0.16$) among stocking rates (Table VII) and may be attributed to the effect of stocking rate on forage availability and diet selection.

Neutral detergent fiber and ADF are good indicators of feed quality. In general, fiber components increase while soluble components decrease with maturity. Cell wall components are negatively related to the nutritive value of the feed. However, dietary fiber is essential for normal body metabolism, but increased fiber intake often decreases digestibility and rumen turnover rate. The efficiency by which fiber can be utilized by grazing ruminants depends on the adequate nutrition of the microbial populations (Van Soest, 1987). Based on the ruminal ammonia nitrogen (NH_3-N), adequate nitrogen was available for microbial fermentation throughout the season on all paddocks.

Changes in the NDF and ADF of ruminal contents were in concert with the changes in ruminal N, ruminal ammonia N, fecal N, and fecal tannins. The lowest ruminal fiber content, for example, coincided with the highest level of ruminal N, ruminal ammonia N, fecal N, and fecal-tannins. In general, no single indicator is adequate to describe the nutritional status of grazing herbivores.

Blood Indices

Serum concentration of total protein, albumin, glucose, urea nitrogen, and creatinine were within the normal range and not influenced by stocking rate (Table VIII). Serum proteins and glucose are sensitive to nutritional influences and can be used to assess protein and energy status. Urea nitrogen was within the normal range, but differed ($P<0.05$) among sampling periods. Serum urea nitrogen increases as dietary nitrogen increases (Sykes and Field, 1973; Richardson, 1984; Sawadogo et al., 1991; Sahlu et al., 1992) partly due to the increased rumen ammonia absorption and deamination of the absorbed amino acids. Reduced energy intake can also result in elevated blood urea-N. Increased urea-N in the blood can also result from kidney failure. Decreased serum urea-N not only results from the decreased dietary protein, but also increased dry (energy) matter intake (Richardson, 1984). Increased dry matter intake increases protein retention (Orskov, 1982) with subsequent decrease in the amount of urea entering the plasma pool. Increased organic matter fermentation in the rumen may also increase the amount of urea-N transfer from the plasma pool to the rumen (Kennedy, 1980). Therefore, the magnitude of serum urea-N is dependent on the protein and energy balance in the diets. High serum urea-N may result from high protein/low energy or low protein/low energy intake, while low serum-N may be due to high protein/high energy or low protein/high energy diets. In the current study, low serum-N early in the season may be attributed to the high protein/high energy diets, while high serum-N late in the season may be due to high protein/low energy intake resulting from plant maturation and reduced intake of forage due to stocking rate.

Serum albumin did not differ among the first three sampling periods (Table VIII). Richardson (1984) reported that plasma albumin is unaffected by protein intake. However, serum albumin is sensitive to severe protein deficiency (Sykes and Field, 1973). Although blood glucose differed ($P \leq 0.05$) among sampling periods, variations were not consistent over the grazing period. Richardson (1984) reported that plasma glucose varies with both protein and dry matter intake, but the effects of diets are not always consistent. Variations among sampling periods could therefore be attributed to the changes in the environmental factors common under grazing conditions. Rainfall pattern (Fig. 2) may be a dominant factor attributable to some of the unexplained variations among the sampling periods. Serum glucose has been used as an indicator of energy status in beef cows (Russel and Wright, 1983) and in diagnosis of metabolic disorders in dairy cows (Blowey et al., 1973).

TABLE VIII

BLOOD SERUM COMPOSITION OF ANGORA GOATS GRAZING CROSS TIMBERS RANGELANDS

	Collection Date				
Blood constituents	June	July	August	September	SE
Albumin (g/dl)	2.9^{b}	2.9^{b}	3.0^{b}	3.2^{a}	0.05
Creatinine (mg/dl)	0.82	0.79	0.83	0.93	0.042
Glucose (mg/d/)	61.3^{ab}	54.9^{b}	62.7^{ab}	68.1^{a}	2.39
Total protein (g/dl)	6.8	6.8	6.8	6.9	0.14
Urea nitrogen (mg/dl)	8.0^{bc}	7.3^{c}	12.6^{a}	11.1^{ab}	0.96

^{a,b,c} Period means are different ($P \leq 0.05$)

Chemical Composition of Browse Species

Nitrogen content of the browse species ranged from 1.5% to 3.4% early in the season and 1.3% to 2.1% late in the season (Table IX). Browse species with nitrogen content above 2% (NRC, 1981) early in the season include *Cercis canadensis* (redbud), *Celtis sp.* (hackberry), *Cornus drummondii* (rough-leaf dogwood), *Quercus stellata* (post oak), *Rhus copallina* (winged sumac), *Smilax bona-nox* (saw greenbriar), *Ulmus americana* (American elm), and *Vitis spp.* (grape). *Quercus marilandica* (blackjack oak) and *Symphoricarpos orbiculatus* (coralberry) had N content of 2.0%. *Juniperus virginiana* (eastern redcedar) had the lowest N concentration of 1.5%. There were significant differences ($P<0.05$) in N content among sampling periods in all the browse species, except eastern redcedar and post oak. Nitrogen concentration gradually declined from June to July and remained relatively constant for the remaining part of the season.

Nitrogen is among the most limiting nutrients to range animal productivity (Holechek et al., 1989) and is generally higher in current annual growth than the more mature woody material (Van Soest, 1987). The data presented (Table IX) indicate higher nitrogen in most browse species early in the season followed by a gradual decline as the forage matured. In spite of the decreasing nitrogen levels with age, most of the browse species maintained at least the minimum ruminant requirement of 2% N (NRC, 1981) throughout the season. These data compare well with previous studies (Bogle et al., 1989).

Ash is a measure of the total mineral content, but its value in nutrition may give an erroneous impression because of high levels of silica and other non-nutritious elements (Dietz, 1972; Van Soest, 1987). Ash content was nearly constant in all species throughout the season, except *Cercis canadensis*

TABLE IX

SEASONAL NITROGEN CONTENT (%) OF BROWSE SPECIES ON CROSS TIMBERS RANGELANDS

Browse species	June	July	September	SE
Cercis canadensis (redbud)	2.9[a]	2.1[b]	2.1[b]	0.1
Celtis sp. (hackberry)	2.5[a]	2.2[ab]	1.9[b]	0.1
Cornus drummondii (rough-leaf dogwood)	2.2[a]	1.6[b]	1.4[bc]	0.1
Juniperus virginiana (eastern redcedar)	1.5	1.4	1.4	0.1
Quercus marilandica (blackjack oak)	2.0[a]	1.9[ab]	1.5[b]	0.1
Quercus stellata (post oak)	2.2	2.0	1.8	0.1
Rhus copallina (winged sumac)	2.4[a]	1.5[bc]	1.3[c]	0.1
Smilax bona-nox (saw greenbriar)	2.9[a]	2.2[bc]	2.0[c]	0.1
Symphoricarpos orbiculatus (coralberry or Buckbrush)	2.0[a]	1.5[bc]	1.3[c]	0.1
Ulmus americana (American elm)	3.4[a]	2.3[bc]	2.0[c]	0.1
Vitis sp. (grape)	2.5[a]	2.0[bc]	1.8[c]	0.1

[a,b,c] Period means are different ($P \leq 0.05$).

(redbud), *Celtis sp.* (hackberry), and *Ulmus americana* (American elm) (Table X). Differences among sampling periods were not consistent within the three browse species. In redbud, for example, ash content increased significantly ($P<0.05$) between June and July, but remained reasonably constant from July to September. In coralberry, the differences in ash content were realized between July and September. Hackberry had the highest ash content, ranging from 13.94% in June to 22.15% in September. Most of the other browse species had less than 10% ash, with blackjack oak and winged sumac falling below 5%. It is interesting to note that most of the highly preferred browse species (Table II) had the highest ash content (Table X), while low preferred species had the lowest ash values. The amount of ash in each individual species may affect the taste.

Acid detergent fiber (ADF) is a measure of the fibrous component of the forage and consists of insoluble protein, cellulose, lignin, bound nitrogen, and silica (Goering and Van Soest, 1970; Van Soest, 1987). ADF is a negative index of forage quality and often substitutes for "crude fiber" as an estimate of fiber content in feeds (Van Soest, 1987). ADF content differed ($P<0.05$) among sampling periods in most browse species, except *Quercus stellata* (post oak), *Rhus copallina* (winged sumac), and *Ulmus americana* (American elm) (Table XI). ADF content gradually increased between June and July and remained almost constant for the remaining part of the growing season.

At comparable stages of maturity, grasses a have higher fiber concentration than woody species (Nelson et al., 1970; Van Soest, 1987). In general, ADF content of grasses ranges between 40 and 60%. In the current study, however, ADF content of the browse species ranged between 17 and 40%, suggesting quality differences between grasses and browse species.

TABLE X

SEASONAL ASH CONTENT (%) OF BROWSE SPECIES ON CROSS TIMBERS RANGELANDS

	Collection Dates			
Browse species	June	July	September	SE
Cercis canadensis (redbud)	5.5[a]	7.1[bc]	7.6[c]	0.5
Celtis sp. (hackberry)	13.9[a]	18.6[b]	22.1[c]	0.5
Cornus drummondii (*rough-leaf dogwood*)	10.3	9.3	9.1	0.5
Juniperus virginiana (eastern redcedar)	5.2	5.8	5.8	0.5
Quercus marilandica (blackjack oak)	4.0	4.3	4.5	0.5
Quercus stellata (post oak)	5.3	5.7	6.0	0.5
Rhus copallina (winged sumac)	4.7	3.6	4.5	0.5
Smilax bona-nox (saw greenbriar)	7.1	6.9	7.1	0.5
Symphoricarpos orbiculatus (coralberry or Buckbrush)	5.2	5.6	6.0	0.5
Ulmus americana (American elm)	12.2[a]	12.2[a]	14.3[b]	0.5
Vitis sp. (grape)	7.3	8.5	8.6	0.5

[a,b,c] Period means are different ($P \leq 0.05$).

TABLE XI

SEASONAL ACID DETERGENT FIBER CONTENT (%) OF BROWSE SPECIES ON CROSS TIMBERS RANGELANDS

	Collection Date			
Browse species	June	July	September	SE
Cercis canadensis (redbud)	18.4[a]	25.6[b]	23.4[ab]	0.7
Celtis sp. (hackberry)	27.6[a]	34.9[b]	26.2[a]	0.7
Cornus drummondii (rough-leaf dogwood)	19.1[a]	24.6[b]	22.7[ab]	0.8
Juniperus virginiana (eastern redcedar)	34.2[a]	39.8[b]	37.5[ab]	0.7
Quercus marilandica (blackjack oak)	29.0[a]	34.2[b]	33.7[ab]	0.7
Quercus stellata (post oak)	32.9	35.7	33.9	0.8
Rhus copallina (winged sumac)	17.4	16.8	17.6	0.8
Smilax bona-nox (saw greenbriar)	28.7[a]	33.4[ab]	35.2[b]	0.7
Symphoricarpos orbiculatus (coralberry or buckbrush)	25.5[a]	37.5[bc]	32.9[c]	0.7
Ulmus americana (American elm)	22.4	24.9	24.2	0.7
Vitis sp. (grape)	20.0[a]	25.9[b]	21.7[ab]	0.7

[a,b,c] Period means are different ($P \leq 0.05$).

CHAPTER V

IMPLICATIONS

Angora goats should be effective in suppressing secondary brush species on Cross Timbers rangelands. However, mechanical treatments will be necessary for reducing the canopy height to within the reach of the goats.

The presence of a high proportion of the most preferred browse species will have a negative impact on utilization of oak species. Heavy stocking (more than 4 goats per hectare) will be necessary to suppress *Quercus marilandica* (blackjack oak) and *Quercus stellata* (post oak). Lighter stocking rates may be effective in upland areas which typically support a less diverse community with fewer woody species and a higher proportion of post oak and blackjack oak. Stocking at the lighter rate would be compatible with cattle grazing, but will take longer to impact oak species. However, heavy stocking may not be compatible with concurrent cattle grazing due to the heavy use of the herbaceous layer.

Goats will utilize *Juniperus virginiana* (eastern redcedar) but heavy use appears limited to small-size classes. Therefore, goats may be more effective for eastern redcedar management if incorporated with other conventional methods of brush management such as burning. A common problem in the Cross Timbers is cedar encroachment following oak suppression. Grazing savannahs with goats prior to chemical application may reduce this problem.

Goats prefer browse and will directly compete with white-tailed deer (*Odocoileus virginianus*). Therefore, stocking plans incorporating goats should also consider wildlife habitat.

Nutritional indices suggest no impact of stocking rate on goat well-being. However, an adequate assessment of energy status was not available.

Browse species have high nitrogen and low fiber content and may be used to complement grasses for optimum livestock production in Cross Timber rangelands.

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APPENDICES

APPENDIX A

MEAN UTILIZATION SCORE BY PASTURE AND SAMPLING DATE

APPENDIX A

MEAN UTILIZATION SCORE BY PASTURE AND SAMPLING DATE

	Sampling Date															
	June				July				August				September			
Pasture	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Bumelia lanuginosa (chittamwood)	3.7	4.8	4.6	4.5	4.2	5.0	4.6	4.9	4.5	5.0	4.4	5.0	4.1	5.0	5.0	5.0
Cercis canadensis (redbud)	4.4	4.9	4.9	4.8	4.9	5.0	4.6	4.9	4.4	—	5.0	4.9	4.8	4.9	4.9	5.0
Celtis sp. (hackberry)	4.7	4.7	4.9	4.9	4.7	5.0	4.9	4.9	4.4	4.9	4.8	5.0	4.5	5.0	4.9	5.0
Cornus drummondii (rough-leaf dogwood)	—	—	5.0	5.0	4.6	—	4.9	4.9	4.9	4.9	4.9	5.0	—	4.9	4.9	5.0
Juniperus virginiana (eastern redcedar)	1.0	1.2	1.2	1.3	1.1	1.9	1.3	1.1	1.2	1.4	1.3	1.1	1.1	1.4	1.5	1.2
Prunus mexicana (Mexican plum)	3.7	4.8	4.4	4.1	4.7	4.9	4.7	4.8	4.1	4.9	4.9	5.0	4.5	5.0	5.0	5.0
Quercus marilandica (blackjack oak)	1.0	2.3	1.6	1.5	2.8	4.8	2.0	2.6	3.3	4.6	3.6	4.0	3.4	4.8	4.1	4.7
Quercus muehlenbergii (chinquapin oak)	—	4.5	4.8	4.7	4.6	2.9	4.2	4.9	4.5	4.9	4.6	4.9	4.9	4.9	4.2	4.9
Quercus stellata (post oak)	1.7	2.6	1.6	1.2	2.1	3.8	1.2	1.5	3.0	4.5	1.6	2.5	2.8	4.7	2.3	3.8
Rhus copallina (winged sumac)	1.2	5.0	3.7	1.7	5.0	5.0	5.0	4.1	3.3	5.0	4.2	4.9	5.0	5.0	5.0	5.0
Rhus glabra (smooth sumac)	3.0	5.0	2.7	3.1	5.0	5.0	5.0	4.4	4.8	5.0	5.0	4.7	5.0	5.0	5.0	4.4
Smilax bona-nox (saw greenbriar)	5.0	5.0	4.9	4.9	—	5.0	5.0	5.0	5.0	4.9	4.7	5.0	5.0	5.0	4.9	4.9
Symphoricarpos orbiculatus (coralberry)	1.1	1.0	1.1	1.1	1.0	1.1	1.0	1.5	1.3	1.6	1.5	1.7	1.6	4.6	2.0	4.7
Ulmus americana (American elm)	4.5	4.9	4.8	—	4.7	4.9	4.7	4.6	4.7	4.9	4.8	—	4.5	4.9	4.9	—
Vitis sp. (grape)	5.0	5.0	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Herbaceous species	1.1	2.7	1.1	1.7	1.1	3.8	1.1	2.7	1.4	3.4	1.4	3.3	1.3	4.2	1.8	4.6

APPENDIX B

MEAN UTILIZATION SCORE BY SAMPLING PERIOD FOR SEVERAL BROWSE SPECIES

APPENDIX B

MEAN UTILIZATION SCORE BY SAMPLING PERIOD FOR SEVERAL BROWSE SPECIES

Plant Species	Sampling Date June	July	August	September
Bumelia lanuginosa (chittamwood)	4.4	4.7	4.7	4.7
Cercis canadensis (redbud)	4.8	4.9	4.8	4.9
Celtis sp. (Hackberry)	4.8	4.9	4.8	4.8
Cornus drummondii (rough-leaf dogwood)	4.9	4.8	4.9	4.9
Juniperus virginiana (eastern redcedar)	1.2	1.4	1.3	1.3
Prunus mexicana (Mexican plum)	4.3[a]	4.8[b]	4.7[b]	4.9[b]
Quercus marilandica (blackjack oak)	1.6[a1]	3.0[bc1]	3.9[cd1]	4.3[d1]
Quercus muehlenbergii (chinquapin oak)	4.8	4.2	4.8	4.8
Quercus stellata (post oak)	1.8[a1]	2.17[a1]	2.89[b1]	3.41[c1]
Rhus copallina (winged sumac)	2.9	4.8	4.7	4.5
Rhus glabra (smooth sumac)	3.4	4.9	5.0	5.0
Smilax bona-nox (saw greenbriar)	4.9	5.0	4.9	5.0
Symphoricarpos orbiculatus (coralberry)	1.1[a1]	1.2[a1]	1.5[b1]	3.2[c1]
Ulmus americana (American elm)	4.7	4.7	4.8	4.8
Vitis sp (grape)	5.0	5.0	5.0	5.0
Herbaceous species	1.7[a1]	2.2[ab1]	2.4[b1]	3.0[c1]

[a,b] Period means are different ($P \leq 0.05$).

[1] Main effects; period x stocking rate interaction ($P<0.05$).

APPENDIX C

MULTIPLE REGRESSION ANALYSIS FOR *SYMPHORICARPOS ORBICULATUS* (CORALBERRY)

APPENDIX C

MULTIPLE REGRESSION ANALYSIS FOR UTILIZATION FOR

SYMPHORICARPOS ORBICULATUS (CORALBERRY)

Variable	Parameter Estimate	Standard Error	Prob >| T |
Intercept	16.74895	24.85802	0.5174
Goat -days /ha brush	-0.00088	0.09933	0.9931
Goat-days/ha brush^2	0.00003	0.00009	0.7665
% Frequency of occurence	-0.66954	0.27084	0.0354*
Dummy	41.59727	34.53739	0.2591
Dummy (Goat-days/ha brush)[1]	-0.14355	0.12162	0.2681
Dummy (Goat-days/ha brush)^2	0.00012	0.00010	0.2667

[1] Dummy=0 for low stocking rate

Dummy=1 for high stocking rate

* Significant differences ($P<0.05$)

APPENDIX D

CHEMICAL COMPOSITION OF TOTAL RUMEN CONTENTS AND FECAL SAMPLES BY PASTURE AND SAMPLING DATE

APPENDIX D

CHEMICAL COMPOSITION OF TOTAL RUMEN CONTENTS AND FECES BY PASTURE AND SAMPLING DATE

	Sampling Date															
	June				July				August				September			
Pasture	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Total rumen-N (%)	3.3	4.0	3.3	3.2	3.3	4.3	3.7	3.4	3.1	3.4	3.4	3.0	2.2	3.3	2.8	2.9
Total rumen ammonia-N (%)	.06	.07	.06	.06	.11	.09	.07	.08	.08	.07	.07	.05	.04	.06	.06	.06
Total rumen tannins (*mg CE/100 mg sample*)	.07	.08	.08	.06	.02	.09	.03	.10	.03	.08	.08	.08	.03	.04	.07	.06
Total rumen-NDF (*% OM*)	59	60	58	63	61	50	59	54	60	53	56	56	66	58	58	58
Total rumen-ADF (*% OM*)	36	35	40	39	33	31	36	35	35	35	36	40	44	38	41	42
Rumen fluid ammonia N (*mg/100 ml*)	5.4	9.3	13	9.8	7.0	8.5	11	8.4	7.3	9.1	8.2	6.7	5.2	9.6	9.1	7.6
Fecal-N (*% OM*)	2.5	2.7	2.5	2.7	2.6	3.0	2.7	2.7	2.2	2.4	2.7	2.3	1.9	2.1	2.2	2.3
Fecal tannins (*mg CE/100 mg OM*)	.03	.03	.02	.03	.03	.04	.03	.03	.03	.03	.03	.03	.02	.02	.02	.03

APPENDIX E

CHEMICAL COMPOSITION OF TOTAL RUMEN CONTENTS AND FECES BY SAMPLING DATE AND STOCKING RATE

APPENDIX E

CHEMICAL COMPOSITION OF TOTAL RUMEN CONTENTS AND FECAL SAMPLES BY PASTURE AND SAMPLING DATE

	Sampling Date								
	June		July		August		September		
Stocking rate	Low	High	Low	High	Low	High	Low	High	SE
Total rumen-N (g N/100 g OM)	3.6^{ab}	3.2^{a}	3.8^{ab}	3.5^{ab}	3.2^{a}	3.2^{a}	2.7^{c}	2.9^{c}	0.14
Total rumen ammonia-N (g/100 g OM))	0.06^{a}	0.06^{a}	0.10^{b}	0.08^{a}	0.08^{a}	0.06^{a}	0.05^{a}	0.05^{a}	0.007
Total rumen-tannins (mg CE/100 mg OM)	0.07	0.07	0.06	0.07	0.06	0.08	0.04	0.06	0.016
Total rumen-NDF (g/100 g OM)	59.9	60.7	55.6	56.4	57.0	56.2	62.0	58.4	2.32
Rumen ADF (g/100 g OM)	35.8^{b}	39.7^{b}	32.1^{c}	35.2^{c}	34.9^{cb}	37.8^{b}	40.9^{a}	41.8^{a}	2.48
Rumen fluid ammonia-N[1] (mg/100ml)	7.4^{a}	11.4^{c}	7.7^{a}	9.7^{cd}	8.2^{ad}	7.4^{a}	7.4^{a}	8.3^{ad}	0.60
Fecal-N (g/100 g OM)	2.6^{ab}	2.6^{ab}	2.8^{a}	2.7^{a}	2.3^{bc}	2.5^{ab}	2.0^{c}	2.3^{c}	0.09
Fecal tannins (mg CE/100 mg OM)	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.003

a,b,c Row means are different (P<0.05).

1 Sampling date x stocking rate interaction (P<0.05).

APPENDIX F

BLOOD SERUM COMPOSITION BY PASTURE
AND SAMPLING DATE

APPENDIX F

BLOOD SERUM COMPOSITION BY PASTURE AND SAMPLING DATE

	Collection Date															
	June				July				August				September			
Pasture	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Albumin (g/dl)	2.9	2.8	2.9	3.0	2.9	2.9	2.7	3.0	3.0	2.8	3.0	3.3	3.2	3.2	3.0	3.5
Creatinine (mg/dl)	.82	.67	.90	.87	.82	.80	.87	.67	.75	.87	.80	.90	.92	.90	.92	.95
Glucose (mg/dl)	63	61	59	61	60	52	53	54	65	68	56	62	59	64	66	82
Total protein (g/dl)	7.1	6.6	6.9	6.7	6.8	6.6	6.8	7.0	6.6	6.7	6.7	7.2	7.3	6.2	6.8	7.2
Urea nitrogen (mg/dl)	8.0	6.7	8.0	9.5	11	4.0	8.0	6.2	17	11	13	9.0	10	8.5	12	13

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VITA

Sabinyano Mbae Bauni

Candidate for the Degree of

Doctor of Philosophy

Thesis: UTILIZATION OF CROSS TIMBERS RANGELANDS BY ANGORA GOATS

Major Field: Animal Nutrition

Biographical:

Personal Data: Born in Meru, Kenya, June 3, 1953, the son of Pankrasio Bauni and Juanina Ithiru. Married to Margaret Jepchumba Mbae, June 8, 1985. Children: Isaac David Mutwiri Mbae, Moses Peter Munene Mbae, and John Paul Mwiti Mbae.

Education: Graduated from Kenyatta High School, Mwatate, Taita-Taveta, Kenya, in December, 1974; received Bachelor of Science Degree from Nairobi University, Nairobi, Kenya, in November, 1978; received Master of Science Degree in Range Science from Colorado State University, Fort Collins, Colorado, in May, 1983; completed requirements for the degree of Doctor of Philosophy at Oklahoma State University in December, 1993.

Professional Experience: Research Officer, Plant Genetic Resources Conservation and Evaluation for Animal Production, National Agricultural Research Center, Kitale, Kenya, 1978-1983; Center Director of Regional Research Center, Garissa, Kenya, 1984-1988; Deployed in Livestock-Pasture Research at the National Dryland Farming Research Center, Katumani, Machakos, Kenya, 1988-Date.

Professional organizations: American Society of Animal Science and Society for Range Management.