INCREASING LAND AND FORAGE UTILIZATION BY MISSOURI COW/CALF OPERATIONS USING SILVOPASTURE PRACTICES

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ABSTRACT

Although rotational grazing has improved pasture management significantly in recent years, the need continues to exist for beef producers to increase land utilization and maintain a high level of forage production during the entire growing season. Two experiments were conducted primarily focusing on methods which allow producers to improve the number of animal grazing days on their operations by implementing silvopastoral systems and increasing forage quality of pastures by applying legumes and warm season grasses.

A silvopastoral system was placed under a two-year rotational grazing experiment to determine whether it would support grazing pressure in a shaded environment. Mature pregnant cows were rotated onto five one hectare pastures four times during the two-year period. It was determined that a silvopasture practice can in fact be productive under grazing pressure if managed correctly.

Samples of cool season grasses, warm season grasses, and legumes were collected at similar maturities from multiple years and different locations across the state of Missouri. An in depth analysis was done on the forages to determine changes in nutritive value throughout the growing season. It was determined that wet chemistry analysis is a poor indicator of digestibility in some forage types, and in-vitro digestibility is a better indicator of cell wall digestibility.

Chapter I

Review of Literature

Introduction

In 1972, the Forest Service projected that the demand for animal unit months of forage would need to increase 50% by the year 2000 to meet the future needs of the number of grazing cattle in the U.S. (Forest Range Task Force, 1972). Walker (1995) predicted that for grazing management to be successful in the future, three objectives must be accomplished: 1) control what animals graze, 2) control where they graze, and 3) monitor the impact on both the environment and the animal.

For this reason, many producers today have adopted the method of rotational grazing to optimize the amount of available forage in their pastures. The carrying capacity, or stocking density, of pastures has been shown to improve through the utilization of forage management practices. These practices allow animals to graze pastures for a specified period and then removing them, thus granting plants rest from grazing pressure (i.e., rotational grazing). A rotational grazing system prevents the more nutritious plants from becoming overgrazed, and thereby aids in maintaining pasture or range quality (Garrett et al., 2004). Managed grazing systems can benefit producers due to the fact that forage production is increased, allowing for greater animal stocking densities per unit of land and increasing the potential for greater profitability. Cattle

producers can further improve land utilization by increasing the diversity of their operation through agroforestry practices.

Even with rotational grazing, a problem continues to exist in the Central United States to maintain a high level of forage production during the entire growing season. Tall fescue is predominately found in the transition zone between the northern and southern regions of the eastern United States (Paterson et al., 1995). Tall fescue, as well as other cool season grasses, typically produces large amounts of high quality forage in spring, early summer, and fall, but growth rates slow considerably during the hot, dry summer months. Utilizing alternative forage species, such as warm season grasses and legumes, provides the potential to increase stocking densities of pastures by enhancing forage quality and season-long productivity.

Forages are typically analyzed in a consistent manner across species. Neutral detergent fiber and acid detergent fiber analysis are the two components primarily used in determining the quality of a forage. However, because cell wall constituents differ between cool season grasses, warm season grasses, and legumes, it is believed that nutrient quality analysis and forage digestibility measures should be analyzed with a different approach. The purpose of this review is to discuss the benefits which a silvopastoral system can have on a managed grazing system. The effects of utilizing different forage species in a pasture environment will be reported, along with varying methods for determining nutrient quality and digestibility of these forages.

Silvopasture Management

Agroforestry is defined by Lin et al. (1999) as any land use system that intentionally integrates trees with traditional crops. Agroforestry practices provide the ability to add an element of biological diversity to agronomic systems, and encourage sustainable, protective, and productive land use (Lin et al., 1999). The need for research on the possibility of combining livestock and wood production on the same unit of land is expressed by Adams (1975). For such research to be successful, it must be conducted by the agricultural scientist and the forester working in cooperation. Silvopasture is defined by the University of Missouri Center for Agroforestry as the intentional combination of trees, forage and livestock managed as a single integrated practice (UMCA, 2006).

The potential for implementing silvopastoral systems in the Central United States is overwhelming. At the present time, there is an estimated 34 million ha of forest within the Central Hardwood Region (Michigan, Wisconsin, Minnesota, Missouri, Ohio, Indiana, Illinois and Iowa), with 6.6 million ha of this land occurring on farms. Approximately 35% (2.3 million) of the 6.6 million ha is being pastured without the benefit of intensive management (Garrett et al., 2004).

Despite the fact that silvopastoral systems have been researched for many years, livestock producers in Central United States have been hesitant to adopt such practices (Dagang and Nair, 2003). The cause of this is likely due to the fact that silvopastoral practices call for increased land management. However, previous research has shown that these systems have the potential to generate benefits for producers (Lundgren et al., 1983; Standiford and Howitt, 1993). Silvopastoral systems are unique in their ability to increase

land utilization by combining three separate enterprises: 1) tree production, 2) livestock production and 3) forage production, which can equally complement one another if managed correctly.

Silvopastures can be initiated by introducing trees into open pastures or by selectively thinning existing forests and establishing forages. Seedlings can be successfully incorporated into open pastures provided they are given adequate protection from livestock (Lehmkuhler et al., 2003). However, financial returns on this type of system can be futuristic. Selectively thinning existing hardwood forests can provide more rapid returns than planting trees into open pastures, if placed under proper management.

Besides timber sales, other major benefits are provided by a silvopastoral system. Environmental factors can play a major role in influencing cattle performance. Cattle originating from temperate climates have been reported to show signs of heat stress at only 85°F (Cartwright, 1955). Research data has shown that cattle grazing under natural shade showed decreased signs of heat stress compared to cattle without shade. An increase in average daily gain of Hereford steers was present in cattle that were placed in a shaded environment compared to those that were not (McIlvain and Shoop, 1971). These cattle also grazed in a more uniform fashion, and were less likely to overuse or underuse forages at different locations in the pasture. McDaniel and Roark (1956) studied the effects of shade on animal performance and behavior using four treatments: abundant natural shade, scanty natural shade, artificial shade, and no shade. Cows grazing under abundant shade and scanty shade treatments showed greater gains than cows either without shade or with artificial shade treatments. Furthermore, time spent grazing was greatest for cows under abundant shade conditions, and decreased as the level of shade

decreased. Kelly et al. (1950) agreed that trees are potentially a more effective source of shade than artificial shade.

Shade can also have a positive influence on forage quality. Many cool season forages have the ability to perform as well or better in a 50% shaded environment as they do in open sunlight. Holechek et al. (1981) found that forages grown under a forest canopy contained higher levels of crude protein than those grown in open grasslands in early and late summer. *In vitro* organic matter digestibility of these forages was found to be lower on grasslands than on forest pasture during the periods of early and late summer. Similar findings were reported by Lin and others (2001), suggesting that crude protein content increased with most cool season forages grown under shade.

Amount of shade has also been shown to influence forage yield. Although it has been suggested that C4 (warm season) grasses need at least 85% sunlight to achieve maximum photosynthesis, only 50% sunlight is required for C3 (cool season) grasses (Gardner et al., 1985). Frost and McDougald (1989) studied the effects of overstory on seasonal as well as annual forage production in California. They found that the majority of herbaceous growth in oak woodlands occurs during the months of March, April, and May. They further concluded that a significant increase was present in herbaceous production under an oak canopy compared to open grasslands, especially early in the growing season. Data reported by Lin et al. (1999) showed a slight decrease in forage production under conditions of 80% shade, but no significant reduction in dry weight yield of cool season grasses at 50% shade. When several grass species were analyzed under shade stress, an increase in production of cool season grasses, as well as nitrogen and fiber digestibility, was found at 45% sunlight (Huck et al., 2001). Ehrenrich and

Crosby (1960) suggest that although forage species differ in their ability to adapt to shade stress, an increase in forage production was noted when hardwood crown cover was reduced to 50%.

The primary emphasis placed on grazing cattle in forests is that it must be controlled (Adams, 1975). Due to the fact that forage production and forage quality in a silvopastoral setting seem to be equally dependent on season, resource managers would likely gain the most benefit by utilizing management intensive grazing, and thereby rotating cattle from forested to open pastures depending on forage availability. Lundgren, et al., (1984) proposes that returns for grazing cattle on forested land may be further improved by implementing a rotational grazing system. Holecheck et al. (1981) agree that the most efficient grazing system would mix grazing under a forest canopy along with open pastures at different periods during the grazing season.

Structure of the Plant Cell Wall

Ruminants are unique in their ability to digest plant structural carbohydrates and use them for energy. Therefore, carbohydrate composition has long been of interest as a factor in determining forage quality. Forage carbohydrates can be divided into two groups: nonstructural carbohydrates and structural carbohydrates. The nonstructural carbohydrates consist primarily of monosaccharides, oligosaccharides, fructosans and starches, while the structural carbohydrates are made up of pectic substances, hemicellulose, cellulose and glycoproteins (Theander and Åman, 1980).

The plant cell wall is a primary area of concern in ruminant nutrition because it contains the indigestible component of the plant. Understanding the structure of the plant cell wall is crucial in considering why digestibilities of different types of plants vary. Furthermore, knowledge of plant physiology is important in determining why the nutritional value of plants tends to decrease as the plant matures.

The plant cell wall is a unique structure whose composition and properties are constantly changing due to growth, stage of differentiation, and the environment of the cell (Northcote, 1972). The cell wall is the structural component of the plant that surrounds the protoplast and provides structure to the plant. Individual plant cells are encircled by a cell wall which encloses meristematic tissues (Theander and Westerlund, 1993). A tough "exoskeleton" is formed by the wall, allowing for high turgor pressure (water pressure) to build inside the cell providing the plant with the ability to maintain an upright position. Furthermore, the cell wall acts as a barrier for pathogens entering the cell (Stacey, 2005).

The plant cell wall is composed of a primary and secondary cell wall. During cell division, each daughter cell deposits a new primary cell wall which is present throughout the life of the cell, and extends as the cell enlarges (Theander and Westerlund, 1993). The primary cell wall is composed of cellulose microfibrils in a matrix. The components of the primary cell wall are cellulose, hemicellulose, pectins, structural proteins, and non-structural proteins (Stacey, 2005). A diverse type of branched and linear sugars called polysaccharides make up these components. Polysaccharides have the ability to form different linkages through different carbons, and can be substituted in a variety of ways, making them versatile building materials. The most abundant polymer found in the cell

wall is cellulose, the most abundant naturally occurring organic substance on the planet (Stacey, 2005). Microfibrils are made up of cellulose. Cellulose is characterized by long chains of β (1→4) linked glucose residues [consisting of 8,000 to 12,000 units] (Northcote, 1972). Cellulose fibers typically consist of more than 500,000 glucose residues held together by hydrogen bonds. These fibers can contain approximately 2.5 billion hydrogen bonds and are the basis for the high tensile strength of cellulose (Stacey, 2005). Throughout the beginning stages of cell growth, the matrix of the wall is not rigid and it is suggested that the microfibrils may be grouped in bands within the matrix (Northcote, 1972).

Hemicellulose, or cross linking glycans, are unlike cellulose microfibrils in that they are flexible polysaccharides which are responsible for binding cellulose microfibrils together into a network. The bulk of the hemicellulose fraction is made up of xylans, which are laid down throughout the growth of the wall (Northcote, 1972). Pectin is also found in the cell wall and is responsible for cell-to-cell adhesions. Pectins form a hydrated gel phase in which the cellulose-hemicellulose network is embedded. These act as a hydrophilic filler and prevent collapse of the microfibril network. Pectins are the most soluble component of the cell wall, and are highly branched as well as easily extracted. Hemicellulose and pectin form a highly hydrated network which makes up the cell wall matrix (Stacey, 2005).

Compounds responsible for the formation of bridges between the polymers of the fibers and the matrix, although present in relatively small amounts, can have a major influence upon the properties of the material (Northcote, 1972). These compounds are the primary components affecting digestibility. A secondary cell wall is laid down inside the

primary cell wall as some cell types reach maturity. This wall is thicker than the primary wall and is hydrated to a much lesser degree. Cellulose is the major component of the secondary wall with other associated polysaccharides containing lower levels of polymerization, such as the phenolic polymer lignin (Theander and Westerlund, 1993**).** The secondary wall is formed by microfibrils that are more closely packed, lie parallel to one another, and are oriented with a smaller angle to the long axis of the cell (Northcote, 1972).

Secondary cell walls specialize in structure and composition and are formed after cell enlargement has stopped. Lignin is a major element in the secondary cell wall, and has the primary function of reinforcing the secondary cell wall (Stacey, 2005). Lignin appears to be almost indigestible, and may hinder carbohydrate digestion. This factor causes lignin to be a primary point of interest (Theander and Åman, 1980). Lignin is an aromatic polymer synthesized from the amino acid phenylalanine to make phenolic units (Stacey, 2005). It is laid down during secondary thickening only and penetrates the cell wall from the outside inwards at an early stage of secondary thickening. It allows the cell wall to become thicker as it replaces water within the wall and finally encrusts the microfibrils and the matrix polysaccharides, bonding tightly to cellulose and preventing it from moving. Because water is replaced, strong hydrogen bonds can occur between the polysaccharides both at the microfibrillar-matrix interface and between the components of the matrix. The possibility also exists for the formation of covalent bonds between the carbohydrates and the lignin, causing the linear polysaccharide polymers to become enclosed in a cross-linked polymer cage. The binding of cellulose and non-cellulose polysaccharides by lignin provides mechanical strength and hydrophobicity to the cell

wall. This binding decreases the accessibility of these polysaccharides to enzyme degrading microorganisms found in the rumen (Theander and Westerlund, 1993). Xylem cells are an example of secondary cell walls reinforced by lignin (Stacey, 2005).

Water plays an extremely important role in the composition of the cell wall. The amount of water in the cell wall is an inconsistent variable which can be controlled by polysaccharide filler material deposition, forming close intermolecular associations and gel-like structures, or by a nonwettable filler such as lignin. During later stages of development, the space occupied by the water in the wall becomes gradually replaced by lignin. This preserves the tensile strength of the microfibrils and makes a rigid matrix phase (Northcote, 1972).

Other structural constituents of the plant cell wall are proteins, which may be covalently linked to polysaccharides (Theander and Westerlund, 1993). Hydroxyproline-rich glycoproteins, known as extensins, are found in the primary cell wall of many dicots, as well as some monocots (Iiuama et al., 1993). The formation of isodityrosine, which has been identified in extensin, causes cell wall proteins to become cross-linked. These proteins are suggested to be rod-like molecules that are positioned perpendicular to the cell wall surface. The linkage of these molecules to cell wall microfibrils, located parallel to the wall surface, results in the formation of an interpenetrating polymer system (Hatfeild, 1993). Adjacent extensin molecules become cross-linked, and interact with cellulose microfibrils to cause the physical entrapment of polysaccharides in a stabilized network. The resistance of some pectic polysaccharides to solubilization from cell wall matrices could be explained by these interactions. Most of these proteins are highly glycosylated and difficult to extract from the cell wall (Hatfeild, 1993).

Intake and Digestion of Forages by Ruminants

Forages are the single most significant feed component of ruminant animal production (Jung and Allen, 1995). The primary sources of energy for ruminant diets are carbohydrates from forages (Moore and Hatfield, 1994). For ruminants to utilize polysaccharides for energy, they must first be degraded to simple sugars, which are then fermented by rumen microbes to yield volatile fatty acids (VFAs). These VFAs are then absorbed into the bloodstream through the rumen wall. Nonstructural polysaccharides, such as starch and fructans, can be rapidly and almost completely broken down by rumen microorganisms. However, structural polysaccharides vary considerably in their degradability. Pectins are quickly and almost completely broken down in the rumen, while cellulose and hemicellulose components are more slowly fermented and incompletely degraded. The digestibility of the cellulolytic polysaccharides can vary from 25 to 90%, with hemicellulose degradability ranging from 45 to 90% (Moore and Hatfield, 1994).

The plant cell wall comprises the major fraction of forage dry matter and is correlated with both forage intake and digestibility, causing it to be regarded as the primary factor affecting forage utilization (Paterson et al., 1994). Differences in intake can account for 60 to 90% of the variation in digestible dry matter or digestible energy, whereas differences in digestibility relate to only 10 to 14% of the variation. High correlations are present between dry matter intake and animal performance when cattle are fed a forage diet (Mertens, 1994). Measuring forage digestibility has been an area of much research, but digestibility can be accurately measured with relative ease compared

to dry matter intake. Although intake is described to be more important than digestibility in determining forage quality, little progress has been made in understanding and accurately measuring the factors that affect intake.

Ruminants consuming high fiber diets containing large quantities of cell wall content are unable to eat sufficient amounts of feed to meet their energy demands. Fiber has been related to fill because it passes through the reticulo-rumen at a slower rate than non-fiber constituents, due to a slower rate of fermentation (Jung and Allen, 1995). One system used to predict intake is the INRA (Institue National de la Recherche Agronomique) system, which defines fill unit (FU) based upon a reference forage fed to reference sheep (SFU), reference cattle (CFU), and reference lactating cows (LFU). The relationship between SFU and neutral detergent fiber (NDF) values of forages fed to sheep are not as linear as expected, suggesting that characteristics are present in the FU system which are not readily apparent (Mertens, 1994). If a linear relationship were observed between NDF and filling effect, one might suggest that NDF from diverse species is alike in producing fill and that intake is not affected by other factors. However, this is not the case.

Neutral detergen fiber analysis describes the amount of cell wall present in a particular forage, and therefore has been used by many researchers as a function of intake. Van Soest (1965) demonstrated that NDF could be used to predict intake in some forages, but concluded that relationships are not conclusive for all forage types. Reid and others (1988) found that relationships between dry matter digestibility, dry matter intake, and fiber fractions differ between forage classes. Although NDF content of C4 grasses

was much higher than that of C3 grasses, there was no difference in dry matter intake between the forage types, as might be expected.

Although voluntary dry matter intake has been correlated to NDF, data suggests that differences in the chemical nature of NDF in different feeds cause it to incompletely describe fill (Jung and Allen, 1995). This could be due to the fact that NDF does not distinguish between digestible and indigestible fiber, but rather is a more simplistic descriptor of the plant cell wall (Felton and Kerley, 2002).

Felton and Kerley (2002) determined that the indigestible fraction of fiber (INDF) accounts for more variation in dry matter intake than NDF alone. These researchers indicate that INDF may have a more direct effect on bulk fill than the entire plant cell wall. This is due to the fact that its exit from the rumen is dependent on particle size rather than rate of digestion. Although NDF and INDF are considered to have a parallel function in cool season grasses, this is likely not the case for warm season grasses. This indicates that INDF should be a more accurate predictor of forage intake across plant species.

Because digestibility is not constant among or within forages, reference data on forage digestibility are of limited value for diet formulation. Several biological and chemical methods have been developed to estimate forage. For many years *in vitro* techniques have been utilized to calculate dry matter digestibility (IVDMD). Since 1919 these techniques have been improved upon by scientists to search for the development of a more precise method which would improve the efficiency of estimating forage digestibility (Weiss, 1994). Research conducted by Vogel et al. (1999) found that forage analysis results obtained with filter bag IVDMD procedures (Daisy II) were similar and

consistent with results obtained from conventional procedures, suggesting that this could be an efficient and accurate method of determining INDF.

A primary indigestible component of the plant cell wall is lignin. Varying reports are present in the literature concerning the correlation of lignin concentration on fiber digestion (Jung and Allen, 1995; Fukushima et al., 1991; Merchen and Bourquin, 1994). These reports seem to be dependent on the type of forage material analyzed. A strong negative relationship exists between lignin content and forage digestibility when total herbage samples are analyzed across multiple levels of maturity. However, no correlation was found between lignin and cell wall digestibility from the analysis of individual forage species sampled from a single stage of maturity (Jung and Allen, 1995). These data agree with the fact that lignin is primarily found in stem tissue and as forage maturity increases, the leaf to stem ratio decreases.

A non-digestible protein-carbohydrate complex was discovered in forages in the late 1980s. While searching for a lignin-carbohydrate complex in the cell-free rumen fluid of steers fed a high-quality diet of alfalfa hay and coastal Bermuda grass hay, researchers instead isolated a complex which contained amino acids. The amino acid complex found to be present in the cell wall of plants is now referred to as extensin (Windham et al., 1989). Little research has been conducted concerning extensin, but it is believed to play a role in the inhibition of plant cell wall degradation by rumen microbes.

Various equations have been developed by researchers to predict forage INDF primarily based on lignin concentration (Traxler et al., 1998). Lignin content has been shown to have a greater effect on digestibility in grasses than in legumes, but this may be a reflection of the fact that the acid detergent lignin method typically used to determine

lignin deposition greatly underestimates lignin in grasses (Jung and Allen, 1995). Little work has been done analyzing the effect of lignin on an organic matter basis and a percentage of extensin on the digestibility of various forages at similar levels of maturity throughout the growing season.

Forage Types

Quality and production of forage types differ throughout the growing season. To accomplish an increase in forage availability throughout the growing season, one must take into consideration the environmental conditions for which different forage types are best suited to perform. Increasing stocking densities of pastures has been an area of primary interest in recent years. Improvements in pasture management have been made which allow producers to more effectively utilize their land resources. However, there continues to be a challenge in maintaining the presence of high quality forages during the entire year. Perennial cool season grasses typically make up the majority of the forage population in Missouri pastures. These are of relatively high nutritive value during the spring and early fall.

Late winter or early spring is a period when there is a void in forage availability. However, utilizing ryegrass (*Lolium multiflorum*) as a forage source can provide a high quality feed during a time when hay resources are depleted and spring growth of many grasses has yet to occur. Ryegrass is one of the most predominantly grown cool season grasses in the world (Aganga et al., 2004). Annual ryegrass has the ability to provide added benefit to cattle operations in the Southeastern United States, making it one of the

most widely used sources of forage during the winter grazing season. A period of low forage availability can occur between the transition from grazing summer perennials to grazing winter annuals. Grazing winter annuals early in the season can decrease the need for supplemental feeding at this time (Venuto et al., 2004). Annual ryegrass grazed in spring and early summer was reported to result in a faster rate of gain and cheaper cost of gain in cattle when compared to grazing only tall fescue or a tall fescue and caucasian bluestem mix (Paterson et al., 1994).

However, production as well as quality, of cool-season forage types tends to decrease dramatically during the mid-summer months. Often cattle must be supplemented or given access to hay during these periods of low forage production to supply them with the proper nutrient and energy requirements. The utilization of warm season grasses in conjunction with cool season grasses has proven to be a successful method of maintaining high levels of forages in pastures during mid-summer. Indiangrass and Caucasian bluestem have been reported to grow well on infertile soil found in the Ozarks, with Caucasian bluestem outperforming Indiangrass during the late summer (Brejda et al., 1995). However, Caucasian bluestem production has been found to have considerable variation from year to year, likely to be dependent upon precipitation (Brejda et al., 1995). Further research has shown that although quality of warm season grasses tends to decline during the summer months compared to cool season grasses, warm season pastures required less land then cool season pastures to carry the same number of cattle during this time of year (Moore et al., 2004). Therefore, adding warm season grasses into a grazing system could be advantageous in situations where land availability was limited

Warm season grasses have the ability to produce approximately 70% of their total yield during mid-summer, and have been reported to provide 212 cow grazing days ha^{-1}, or 60 % of the annual grazing time (Jung et al., 1978). Allowing cattle to graze these grasses so when they are in a vegetative state can prevent animal performance from suffering during the summer when quality of cool season grasses typically declines (Paterson et al., 1994).

Another method of increasing the quality of available forages is to add legumes into the grazing system. Legumes are known to have higher protein content when compared to grasses. Legumes can also increase overall pasture productivity due to their nitrogen fixation capabilities (Stacey, 2005). They characteristically have lower cell wall concentrations but greater lignin content than grasses at similar maturities. Futhermore, legumes have been described to contain hemicelluloses as a smaller percentage of total cell wall than grasses. The higher levels of lignin found in legumes relate to the fact that microbial degradability of legume cell walls is usually lower than that of grass cell walls. However, literature suggests that lignin protects similar amounts of cell wall polysaccharides from digestion in both grasses and legumes (Merchen and Bourquin, 1994). As maturity levels of legumes increased, Cassida and others (2000) found an increase in NDF and ADF concentrations, along with a decrease in crude protein levels and in situ dry matter digestibility. However, Broderick et al. (1992) did not find a seasonal trend in protein degradability of alfalfa, and suggests that maturity did not appear to influence rate of degradation.

Chapter II

Grazing Cattle on a Silvopastoral System

Abstract

The purpose of this study was to determine forage production and quality in a hardwood silvopastoral system under intensive grazing management. The two-year project began in 2004. A silvopastoral system was established in a hardwood timber stand located in Crawford County of South-Central Missouri. Following forage establishment, the pastures where placed under a two-year rotational grazing experiment to determine whether they would support grazing pressure in a shaded environment. Cattle were rotated onto five one hectare pastures a total of four times during the two-year period. The pastures produced 618 grazing cow days from May 2005 to July 2006, and were grazed at an average utilization rate of 58%. The average forage quality of the pastures over the four grazing periods was 11.6% crude protein, 63.1% NDF, and 34.8% ADF. Following a two-year acclimation period of forages seeded in a hardwood silvopastoral setting, it was determined that a silvopasture practice consisting of fescue and legumes can in fact be productive under grazing pressure if managed correctly.

Materials and Methods

Establishment

A silvopastoral system was incorporated into hardwood forests on the Wurdack Farm, a University of Missouri experiment station located near Cook Station, MO (Crawford County, Section 36, Township 36N, Range 5W). Five different locations on the farm, each consisting of 1 ha, were selected to be used in the silvopastoral system. Each of the five plots selected for silvopastures were located on the north or north-east facing slope. The pastures were 132.9 meters on the contour of the slope and 70.1 meters from the base of the slope. Trees were selectively harvested from each site in 2001. The forests were thinned to produce an environment that was approximately 50% shaded. Soil tests were collected from each site in the fall of 2002, and lime was applied to adjust the soil pH to 6.0 to 6.5 range. At this time all treatments received 154 kg of 0-150-75 fertilizer per hectare. Forages were sown on the pastures in April of 2003. Kentucky 31 Tall Fescue (*Festuca arundinacea* Schreb.) was sown at a rate of 36 kg of pure live seed (PLS) per hectare. Red clover (*Trifolium pretense* L.) was sown at a rate of 4.5 kg of PLS per hectare and Marion Lespedeza (*Kummerowia striata* Thunb.) was sown at the rate of 9 kg of PLS per hectare.

The primary goal for the first two years following the development of the silvopasture practice in unimproved timber was to establish a healthy stand of fescue interseeded with legumes. The next step will be to determine the productivity of these forages in the silvopastoral environment. Although some lespedeza and clover existed in

the pastures prior to 2005, the pastures were overseeded with legumes during the last week of February, 2005, to enhance overall forage quality. The seed was sown at a rate of 7.0 kg PLS/ha Marion lespedeza, 3.5 kg PLS/ha red clover, 0.9 kg PLS/ha Ladino clover. Soil cores were also taken at this time for evaluation of soil fertility, and determined to be adequate for forage production.

Forage Collection and Grazing

By May 10, 2005, the average mass of forage for all pastures was at the desired level to be grazed (423 ± 56 kg dry matter/ha). Forage samples were mechanically harvested with a flail chopper prior to turning cattle into the pastures, and again after the cattle were removed. Forage samples were harvested from 10 random locations in each one hectare pasture. Samples were taken from a strip which was 0.81 meters wide and 4.75 meters long. The total weight of each strip was recorded. A sub-sample was collected from each of the 10 individual strips. All sub-samples from a single pasture were pooled into a paper bag and dried in a 55°C forced air oven for a minimum of 72 hours. All tree leaves and fine material were removed from the sample, leaving only a pure sample of forage as the remainder. Fine material was determined as small particles that were undistinguishable components of the sample and did not exceed 20% of the sample weight. Weights were recorded for the amount of tree leaves, fines, and forage present in each sample. Material considered as tree leaf or fine was then disposed and not included in forage yield calculations. The forage samples were ground with a Wiley Mill to pass through a 2 mm screen and a quality analysis was performed to determine percent

crude protein (% CP), percent neutral detergent fiber (% NDF), percent acid detergent fiber (% ADF), and percent dry matter (% DM). The Ankom 200 Fiber Analyzer (Ankom Technololy, Fairport, NY) was used for NDF and ADF extraction. Nitrogen (N) was determined by placing samples of ground forage weighing between 0.5 to 1.0 g into a foil pouch and analyzing using a LECO Model FP-248 Nitrogen Determinator. Percent crude protein was calculated as percent nitrogen x 6.25. Samples were dried at 105°C, and 100% DM was determined as 55°DM x 105°DM.

Available forage and utilization rate were also calculated from these forage samples. The pastures were grazed with mature pregnant cows for approximately 4.5 days at a stocking rate determined by the amount of forage available for each individual pasture. Due to an extended period of time throughout the summer with an insufficient amount of rainfall, the pastures were not grazed again until August 19, 2005. At this time, forage samples were harvested and cattle were allowed to graze the pastures for three days. The cattle used for both grazing periods were mature pregnant cows and came from the same herd.

Because the pastures had not been fertilized since their establishment 2.5 years earlier, approximately 76.6 kg of urea per hectare was applied to the pastures on September 15, 2005. The pastures did not have enough accumulated growth during the late summer and fall of 2005 to warrant winter grazing. Therefore, the pastures where left idle until the spring of 2006. Forage samples were again mechanically harvested from each pasture on May 8, 2006 and cows were turned in at this time. Stocking rates were once again determined by the amount of available dry matter per pasture. The cows were allocated a five-day grazing period, and forage samples were once again harvested after

the cattle were removed to calculate utilization. After a two-month rest period the pastures were grazed on July 13 to 16 by the same methods previously mentioned.

Statistical Analysis

The general linear model procedure of SAS (SAS Inst. Inc., Cary, NC) was used to determine the effect of year and grazing period on amount of available forage, residual forage, and utilization rate. The experimental design was completely randomized (Kap and Lamberson, 2004). Type III Sum of Squares values were reported as significant if $P < 0.05$. Significant effects of year and grazing period were noted from the SAS output. Mean values and standard errors were also observed using the GLM procedure. A T-test comparison was utilized to analyze differences in mean values between years, grazing periods, and within each individual year.

Results and Discussion

During the first year, the average crude protein level of the forage prior to grazing was 11.6% for May and 11.0% for August (Table 1). The average NDF prior to grazing was 58.3% for samples taken in May and 64.9% for those harvested in August. The average amount of ADF found in the pre-grazed samples was 30.7% for May and 37.1% for August. For the second year of grazing, average CP levels for pre-grazed pastures were 12.9% for May and 10.9% for July. Neutral detergent fiber and ADF

values for pastures prior to early summer grazing were 65.9 and 36.1%, respectively. July pastures recorded an average NDF value of 63.2% and an ADF value of 35.5%.

Crude protein levels for pastures after grazing were lower for each grazing period. Furthermore, NDF and ADF values were higher, implying that cows selected the higher quality forage. The quality of the pastures did decline from early summer to late summer, as expected, during the first year of the experiment. However, second year data shows slightly lower NDF and ADF values for pre-grazed July pastures compared to pre-grazed May pastures. This could be due to the fact that the pastures were at an older age of maturity when they were grazed in May than in July.

There was no difference in available forage, residual forage, or utilization rate of the pastures between years 1 and 2 (Table 2). A difference was present in residual forage and utilization rate between grazing periods 1 and 2 (Table 3). The goal of an approximate 70% utilization rate was reached during the May grazing periods for both years, but was closer to 50% for the second grazing period, suggesting that the pastures could have been grazed longer than 3 days during the second grazing period for both years. A difference was also present in residual forage between grazing periods within year 1 (Table 4), and in both residual forage and utilization rate between grazing periods within year 2 (Table 5). However, there was no difference in available forage between grazing periods within year 1 or year 2.

Cow grazing days can be calculated by multiplying the number of cows used in each grazing period with the number of grazing days in each grazing period. Total cow grazing days is the sum of the number of cow grazing days for each grazing period. The silvopastoral system produced a total of 618 cow grazing days from mid May 2005 to

mid July 2006, a period of 432 days (Table 6). The average overall utilization rate for the four grazing periods was approximately 59%. Concluded from yield data of the pastures was that optimum utilization rates of the forages were not reached during the later grazing periods, and therefore, it is possible that the pastures could have produced more total grazing days than were calculated in this study.

Total rainfall for the Wurdack farm from January 2005 to the end of the experiment was 143.7 cm. Rainfall from the end of the first grazing period to the beginning of the second grazing period in 2005 was 22.9 cm. The amount of precipitation between grazing periods for the second year was 10.7 cm, less than half of that in the first year. It is believed that the pastures produced nearly as much forage dry matter in the second year during a shorter amount of time with less rainfall for two reasons. The first reason is that the forage stand was better established, and therefore more productive, during the second year of the experiment. The second reason is that the soil still contained some nitrogen from fertilization in the fall of 2005.

Table 1. Quality analysis of forages harvested before and after grazing a silvopastoral system

	Date	%CP	%DM	%NDF	%ADF
Year 1	5/11	11.6^{b}	33.9^{cd}	58.3^{e}	30.7^{e}
		± 0.26	± 2.08	± 0.59	± 0.44
	5/15	10.0^{d}	42.8^{a}	61.9^{d}	33.2^{d}
		± 0.26	± 2.08	± 0.59	± 0.44
Year 1	8/19	11.0^{b}	35.5^{bcd}	64.9^{bc}	37.1^{ab}
		± 0.26	± 2.08	± 0.59	± 0.44
	8/22	9.1^{e}	40.4^{ab}	66.8^{a}	37.8^{a}
		± 0.26	± 2.08	± 0.59	± 0.44
Year 2	5/8	12.9^{a}	30.8^{d}	65.9^{ab}	36.1^{bc}
		± 0.26	± 2.08	± 0.59	± 0.44
	5/13	10.2^{cd}	38.5^{abc}	66.2^{ab}	36.5^{bc}
		± 0.26	± 2.08	± 0.59	± 0.44
Year 2	7/13	10.9^{bc}	34.4^{bcd}	63.2^{cd}	35.5^{c}
		± 0.26	± 2.08	± 0.59	± 0.44
	7/16	10.0^{d}	44.5^{a}	65.9^{ab}	36.1^{bc}
		± 0.26	± 2.08	± 0.59	± 0.44

^{a,b,c,d,e} ls means within a column with unlike superscripts are significantly different ($P < 0.05$)

%CP = Percent Crude Protein; %DM = Percent Dry Matter; %NDF = Percent Neutral Detergent Fiber; %ADF = Percent Acid Detergent Fiber

Table 2. Effect of year on available forage, residual forage, and utilization rate of forages grazed in a silvopastoral system

	Year 1	Year 2	*P*
Available Forage (kg/ha)	511.1	509.0	0.7
	± 25.5	± 16.7	
Residual Forage (kg/ha)	214.6	213.1	0.2
	± 8.5	± 5.5	
% Utilization Rate	60.2	57.6	1.0
	± 3.4	± 2.2	

ls means are different within a row if $P < 0.05$

Table 3. Effect of grazing period on available forage, residual forage, and utilization rate of forages grazed in a silvopastoral system

Grazing Period	1	2	*P*
Available Forage (kg/ha)	499.5	522.9	0.6
	± 35.1	± 53.6	
Residual Forage (kg/ha)	162.4	278.0	0.002
	± 8.5	± 12.9	
Utilization Rate	68.4%	46.7%	0.01
	± 2.7	± 4.1	

ls means are different within a row if $P < 0.05$

Table 4. Year 1 yield data of available forage, residual forage, and utilization rate of forages grazed in a silvopastoral system

Grazing Period	1	2	*P*
Available Forage (kg/ha)	422.9	658.1	0.1
	± 55.9	± 85.4	
Residual Forage (kg/ha)	137.8	342.7	0.007
	± 8.4	± 12.9	
Utilization Rate	67.7%	47.7%	0.2
	± 3.8	± 5.9	

ls means are different within a row if $P < 0.05$

Table 5. Year 2 yield data of available forage, residual forage, and utilization rate of forages grazed in a silvopastoral system

Grazing Period	1	2	*P*
Available Forage (kg/ha)	576.1	441.8	0.05
	± 34.3	± 34.3	
Residual Forage (kg/ha)	187.0	239.2	0.03
	± 11.8	± 11.8	
Utilization Rate	69.1%	46.0%	0.01
	± 3.5	± 3.5	

ls means are different within a row if $P < 0.05$

Table 6. Stocking rate and number of cow days supplied by the silvopastoral system over a two year period

Year	Grazing Period	# cows	# days	# cow grazing days
1	1	32	4.5	144
1	1	42	3	126
2	2	45	5	225
2	2	41	3	123
			Total	**618**

Chapter III

Analysis of Seasonal Nutrient Content and Digestibility of Different Forages

Abstract

The purpose of this study was to develop a grazing system that integrates the seasonal change in nutritive value of different forage species utilized in Missouri grazing systems. Samples of cool season grasses, warm season grasses, and legumes were collected from multiple years at locations in Northern, Central, and Southern Missouri. All samples were harvested at similar maturities throughout the grazing season and analyzed for neutral detergent fiber, acid detergent fiber, crude protein, organic matter, lignin, extensin, indigestible neutral detergent fiber, and neutral detergent fiber digestibility as a percentage of neutral detergent fiber. Comparisons were made evaluating seasonal and yearly changes in forage quality and digestibility among forage species. Also, correlations were calculated that examined the relationships between NDF and ADF levels with actual NDF digestibility. It was determined that although correlations between ADF and *in vitro* digestibility are present in some forage species, they do not appear to be consistent across all forage types. Furthermore, little consistency is present in NDF and INDF relationships, suggesting that measurement of cell wall content incompletely describes intake and digestibility of most forages, and rather that INDF values may be better determinants of these variables.

Materials and Methods

Eight forage types were analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin (LIG), crude protein (CP), extensin (EXT), organic matter (OM), and *in vitro* digestibility. The forages analyzed were annual ryegrass (ARG), perennial ryegrass (PRG), Kentucky 31 tall fescue, stockpiled tall fescue, bermudagrass (BMG), Caucasian bluestem (CB), alfalfa (ALF), and birdsfoot trefoil (BFT). Scientific names of all forage species are presented in Table 7. Samples of forage were collected from studies conducted by the MU Division of Plant Sciences at three university research stations across the state of Missouri: Forage Systems Research Center (Linneus, MO; 39° 51' N, 93° 6' W), Bradford Research and Extension Center (Columbia, MO; 38° 53' N, 92° 12' W), and Southwest Research Center (Mt. Vernon, MO; 37° 10', 93° 38' W).

Samples were mechanically harvested at a cutting height of 10 cm when average height of the forage reached approximately 20 to 25 cm. This method of forage harvesting would closely simulate that of a rotational grazing situation for all forages studied The ARG samples were collected from four different pastures for two consecutive years at Bradford Research and Extension Center (BREC) and for one year at Southwest Research Center (SWC). The CB samples were taken from four replicated pastures over a period of four consecutive years at SWC. Because this particular forage has been found to have considerable variation from year to year (Brejda et al., 1995), it was determined that a four-year period would best be utilized to determine seasonal deviation in average quality of CB. Alfalfa samples were harvested for two consecutive years from four different locations at both FSRC and SWC, supplying a total of four

years worth of data. All other samples used were taken from two consecutive years. The PRG and tall fescue samples were each harvested from four pastures at BREC. Likewise, samples used for stockpiled tall fescue analysis were taken from four replicated treatments at Forage Systems Research Center (FSRC). Stockpiled tall fescue and tall fescue data were compiled into one dataset which is referred to as TF. The BMG samples were collected from SWC and BFT samples from BREC. Each of these forages were sampled from three replicated treatments.

Samples were air dried in a 55°C forced air oven and ground to pass through a one mm screen. All samples were analyzed in duplicate for organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF). Samples were ashed in a muffle furnace, and residue weight was subtracted from sample weight to determine percent OM. The Ankom 200 Fiber Analyzer (Ankom Technololy, Fairport, NY) was used for NDF and ADF extraction as described by Goering and Van Soest (1970). Samples were dried at 105°C, and dry matter corrections were performed. Nitrogen (N) was determined by placing samples of ground forage weighing between 0.5 to 1.0 g into a foil pouch and analyzing using a LECO Model FP-248 Nitrogen Determinator.

Following ADF extraction, one of the duplicated samples was then analyzed for lignin content while the other was used to determine the amount of extensin. Lignin content was determined by submerging samples in a 72% sulfuric acid solution for 3 hours, agitating the bags every 30 minutes. The filter bags were thoroughly rinsed with near boiling water and dried at 55°C. Weights were recorded for each dried filter bag, along with its lignin content. The filter bags were then placed in an individual pan which

was ashed in a muffle furnace. Percent lignin was calculated as grams of lignin (DM) minus grams of silica present following the ashing process, divided by the initial sample weight. Extensin was determined by removing the forage residue from the Ankom filter bag following ADF extraction. A sample of the residue was then cut into fine pieces and prepared for Nitrogen analysis using the LECO method.

An *in vitro* digestibility study was conducted with the DAISY^{II} incubator (ANKOM Technology) to analyze samples for indigestible neutral detergent fiber on a dry matter basis (INDFdm), as well as for digestible neutral detergent fiber on an NDF basis (NDFdig). Forages were analyzed in duplicate. Ground samples were placed in ANKOM filter bags previously rinsed with acetone. The filters were then incubated in rumen fluid and buffer solution for a period of 48 hours. Following incubation, filter bags were rinsed with water and placed in the Ankom for NDF extraction.

Statistical Analysis

A completely randomized design with unequal replication (minimum of three replications; maximum of five) was used. Analysis of variance was conducted on forage species (main plots), harvests within year (sub-plots), and years (sub-sub-plots) and all possible interactions using the model outlined by Steel and Torrie (1980). The Proc GLM function of SAS (version 8) was used for statistical analyses (SAS Institute, Cary, NC). Main effects and all interactions were considered significant when $P<0.05$. When the F test was significant ($P<0.05$), means were separated using Fisher's protected LSD (alpha=0.05).

Results and Discussion

Cool Season Grasses

Annual ryegrass data were analyzed for the months of April, May, and June for a period of three consecutive years. A significant date effect occurred for NDF, ADF, EXT, and OM in ARG (Table 8). There was also a significant year x date interaction effect for LIG, CP, INDFdm, and NDFdig (Table 9). Total cell wall content increased from April to June. Although values are different across year, cell wall digestibility, as well as CP levels, consistently decreased during this time, suggesting that there is an decrease in the leaf to stem ratio toward the middle of summer. The rise in lignin levels during the month of June agrees with this statement. However, the level of extensin is significantly lower during the middle of the spring growing season for ARG than the beginning or the end. Year 1 and 2 samples for ARG were collected from BREC in 2002 and 2003, while year 3 samples were harvested from SWC in 2004. A noticeable increase in lignin is present in samples collected from BREC in 2003, compared to those taken in 2002. However, little difference is present in precipitation or temperature of this location during the growing season of these two years, implying that other factors must be involved.

Two years of data are present for PRG from May, June, and September. A significant effect of date is present for the variables NDF, LIG, INDFdm, NDFdig, and OM (Table 10), while a year x date interaction is observed for ADF, CP, and EXT (Table 11). Cell wall digestibility decreased over time, while lignin increased linearly throughout the growing season. However, no change occurred in NDF from June to

September. The PRG samples were taken from BREC in 2002 and 2003. Differences in ADF and CP values between years could be explained that in 2002, the months of June and September each had approximately one-third the amount of rainfall as these months did the following year (June = 5.8 cm vs 16.8 cm: September = 8.1 cm vs 24.1 cm).

A year x date interaction in tall fescue is present for all variables except lignin, which was affected by date alone (Table 12). Lignin content was significantly higher during March because these samples were the result of the end of a stockpiled experiment, and not taken from a pasture with new spring growth. Tall fescue lignin remained consistently low throughout the summer, and an increase was not observed until late fall. Although some variation was observed in NDF and ADF values from forage samples harvested in the summer compared to those taken during late fall and winter months, a much greater difference appeared when comparing digestibility of tall fescue across seasons (Table 13a and 13b). Once again, differences are present between year of summer tall fescue samples collected from BREC in 2002 and 2003. The amount of rainfall varied 14.4 cm from April to September between these two years, which could partially explain the effect of year on forage quality.

Warm Season Grasses

Bermudagrass data collected throughout the summer for two consecutive years displayed a year x date interaction for ADF, CP, and EXT (Table 15). Year 1 data suggested that cell wall digestibility was greatest during the month of June and the lowest during July, while second year data had the exact opposite scenario. As a whole, crude

protein values were significantly lower for second year BMG samples, which could be related to 17.7 cm more rainfall between the months of July and September than the first year. Although a significant difference is not reported (P = 0.06), cell wall digestibility tended to be better during early and mid summer than in late summer for this particular forage species (Table 14).

Caucasian bluestem had a significant year x date interaction for LIG, CP, EXT, INDFdm, and NDFdig (Tables 16a and 16b). Although not significant (P = 0.15), there was a trend in both NDF and ADF values to increase as the growing season progressed. Although values were different between years, Caucasian bluestem crude protein levels consistently decreased from early to late summer. Extensin levels of Caucasian bluestem stayed constant throughout the four years with the exception of three different sampling periods. The month of May for the first year showed extensin to be three times higher than the average levels. However, third year May data, along with second year July data, indicated bound crude protein levels to be half of that normally observed. Interestingly, the digestible fraction of neutral detergent fiber for year one shows a significant increase from early summer to mid and late summer. Conversely, a significant decrease was observed in cell wall digestibility from May to September in second year data. Once again, rainfall appears to play a role in variability between years of this forage species. Year one had consistent amounts of rainfall throughout the growing season, with each month averaging from 8.2 to 16.8 cm. However, June of year 2 had only 2.6 cm of rainfall, while September had 1.5 cm which could decrease the quality, digestibility, and productivity of the forage. As a whole, no change was observed in digestibility of

Caucasian bluestem samples from the third and fourth year, with the exception of increased digestibility in May of the third year.

Legumes

Alfalfa samples labeled as year 1 and 2 were collected from FSRC in 2003 and 2004, while year 3 and 4 samples came from SWC in 1997 and 1998. A significant year x date interaction occurred for all variables in the analysis of alfalfa (Tables 17a and 17b). Trends in year one data are opposite of those observed in year 2, 3, and 4 data. May NDF and ADF values begin at similar levels each year. Furthermore, little difference is present inn NDF digestibility when samples were initially harvested. However, as the growing season progressed into late summer (i.e. July to September), year 1 data decreased in NDF and ADF levels, as well as increased in NDF digestibility. Maximum crude protein levels also occurred in September of year 1. On the contrary, year 2, 3, and 4 data increased cell wall content and a decreased cell wall digestibility as the growing season advanced. Rainfall values for year 1 are much lower than that for years 2, 3, and 4. For the months of July, August, and September year 1 had 16.8 cm of rainfall while precipitation for year 2 was 34.7 cm, year 3 was 22.1 cm, and year 4 was 39.8 cm. Although forage harvests took place at similar maturities, rainfall and temperature differences in year 1 likely led to a higher leaf to stem ratio for Alfalfa samples displaying increased NDF digestibility late in the first year.

Birdsfoot trefoil samples were available for only two months during the growing season. However, a significant effect of date was observed in NDF and extensin from

samples collected in May compared to those harvested in June (Table 18). Both NDF and extensin increased between May and June. Although not signicant (P = 0.07), a numerical difference occurred in lignin content between the two months, with June having the higher values. Cell wall digestibility correlated to these data, showing a trend of decreasing digestibility as the season progressed (INDFdm P = 0.06, NDFdig P = 0.075).

As expected, legumes contained the highest percentages of lignin and extensin when compared to cool and warm season grasses. This was due to these forages containing the greatest percentage of cell wall. Actual available crude protein levels of legumes could be 1.2 to 2% lower than expected due to presence of extensin.

Correlations

To determine the level at which NDF and ADF were related to digestibility across forage species, correlations between parameters were calculated. Correlations were made between NDF and INDFdm, ADF and INDFdm, NDF and NDFdig, ADF and NDFdig, lignin and NDFdig, and extensin and NDFdig. Correlation values are presented in Table 19. Cool season grasses displayed variable results when comparing fiber analysis with digestibility. The strongest correlation between cell wall content and cell wall digestibility occurs in annual ryegrass. Tall fescue showed a relatively strong relationship between NDF and INDFdm (0.85) and ADF and INDFdm (0.84). However, when comparing chemical analysis with actual NDF digestibility as a percent of NDF, a much lower correlation occurred (NDF vs NDFdig = 0.66, ADF vs NDFdig = 0.68). Perennial

ryegrass had a stronger correlation between ADF and fiber digestibility than NDF and fiber digestibility.

Legumes showed results similar to cool season grasses when comparing relationships between wet chemical analysis and actual fiber digestibility. Birdsfoot trefoil NDF and ADF had a high correlation with NDF digestion on a dry matter basis. Alfalfa also showed a link between fiber content and actual dry matter fiber digestibility. However, when comparing NDF and ADF values with NDF digestion on an NDF percentage basis, the relationships tended to decrease for both legumes.

Little relationship was found between the NDF and ADF fraction of warm season grasses and digestibility data. Caucasian bluestem showed a 0.72 correlation between ADF and INDFdm, but this decreased to only 0.37 when comparing ADF with NDFdig. Furthermore, Bermudagrass showed no relationship between either NDF or ADF values and cell wall digestibility, with ADF and NDFdig correlations being only 0.16. A correlation was present between cell wall content and cell wall digestibility in some forage species. However, correlations were not consistent among similar forage types or across forage types. Dry matter digestibility of cool season grasses and legumes have been correlated to ADF values in research reports (Undersander, 2003). These correlations are present in annual ryegrass and birdsfoot trefoil, but are less evident in perennial ryegrass, tall fescue, and alfalfa. When comparing NDF digestibility with ADF in warm season grasses, a much lower correlation was observed, suggesting that ADF should not be used consistently to measure cell wall digestibility across forage species. As previous literature suggested, warm season grasses displayed much lower correlations between fiber content and digestibility data. This relationship suggests that NDF and

ADF analysis are in fact poor procedures for estimating digestibility of warm season forages.

Although negative correlation existed between lignin content and forage digestibility when total herbage samples were analyzed across multiple levels of maturity, Jung and Allen (1995) found no correlation between lignin and cell wall digestibility for individual forage species sampled at a single maturity stage. Lignin values in this experiment were correlated with digestible NDF values to determine the correlation between lignin and cell wall digestibility of these forages harvested at similar stages of maturity. A negative relationship did occur between lignin and digestibility, although it was not strong. With the exception of BMG, all forage species evaluated had negative correlations ranging between -0.50 and -0.80 for lignin and NDF digestibility. No correlation was found between extensin and digestibility in any of the forage species.

Table 7. Forage species used to study the effect of seasonal change on nutritive quality and digestibility

Common Name	Scientific Name	Forage Type
Annual Ryegrass	*Lolium multiflorum* L.	C_3 grass
Perennial Ryegrass	*Lolium perenne* L.	C_3 grass
Kentucky 31 Tall Fescue	*Festuca arundinacea* Schreb.	C_3 grass
Alfalfa	*Medicago sativa* L.	Legume
Birdsfoot Trefoil	*Lotus corniculatus* L.	Legume
Bermuda Grass	*Cynodon dactylon* (L.) Pers.	C_4 grass
Caucasian Bluestem	*Bothriochloa baldhii* Retz.	C_4 grass

Table 8. Effect of date on the percentage (%) of NDF, ADF, EXT, and OM in Annual Ryegrass

Annual Ryegrass			
	Month		
	April	May	June
NDF	43.61[c]	47.97[b]	57.62[a]
	±0.99	±1.08	±1.08
ADF	22.72[c]	25.87[b]	31.64[a]
	±0.57	±0.62	±0.62
EXT	0.40[a]	0.28[b]	0.44[a]
	±0.04	±0.04	±0.04
OM	89.21[b]	90.13[a]	89.74[a]
	±0.17	±0.19	±0.19

[a,b,c] ls means within a row with unlike superscripts are significantly different ($P < 0.05$)
NDF = neutral detergent fiber; ADF = acid detergent fiber; EXT = extensin; OM = organic matter

Table 9. Effect of year x date interaction on the percentage (%) of LIG, CP, INDFdm, and NDFdig in Annual Ryegrass

Annual Ryegrass									
	Year 1			Year 2			Year 3		
	April	May	June	April	May	June	April	May	June
LIG	0.83^{e}	1.03^{de}	1.88^{a}	1.44^{bc}	1.24^{cd}	1.58^{ab}	0.89^{e}	1.12^{de}	1.82^{a}
	±0.11	±0.11	±0.11	±0.11	±0.11	±0.11	±0.08	±0.11	±0.11
CP	16.92^{bc}	11.66^{d}	11.81^{d}	18.30^{b}	12.03^{d}	10.50^{d}	22.35^{a}	13.60^{d}	15.12^{c}
	±0.62	±0.62	±0.62	±0.62	±0.62	±0.62	±0.44	±0.62	±0.62
INDFdm	7.57^{d}	9.07^{d}	18.36^{a}	7.60^{d}	11.19^{b}	17.73^{a}	5.14^{e}	12.81^{b}	17.54^{a}
	±0.56	±0.56	±0.56	±0.56	±0.56	±0.56	±0.40	±0.56	±0.56
NDFdig	83.73^{b}	80.07^{c}	68.75^{e}	82.12^{bc}	76.12^{d}	68.51^{e}	87.90^{a}	75.15^{d}	69.63^{e}
	±0.82	±0.82	±0.82	±0.82	±0.82	±0.82	±0.59	±0.82	±0.82

^{a,b,c,d,e} ls means within a row with unlike superscripts are significantly different ($P < 0.05$)

LIG = lignin; CP = crude protein; INDFdm = indigestible neutral detergent fiber as a percent of dry matter;
NDFdig = digestible neutral detergent fiber as a percent of neutral detergent fiber

Table 10. Effect of date on the percentage (%) of NDF, LIG, INDFdm, NDFdig, and OM in Perennial Ryegrass

Perennial Ryegrass			
	Month		
	May	June	Sept.
NDF	49.64[b]	52.78[a]	52.70[a]
	±0.73	±0.76	±0.88
LIG	1.19[b]	1.31[b]	1.96[a]
	±0.13	±0.14	±0.16
INDFdm	8.77[b]	10.11[b]	18.55[a]
	±0.68	±0.71	±0.82
NDFdig	82.34[a]	80.94[a]	64.90[b]
	±1.19	±1.25	±1.44
OM	89.32[b]	89.54[b]	91.78[a]
	±0.20	±0.21	±0.25

[a,b] ls means within a row with unlike superscripts are significantly different ($P < 0.05$)

NDF = neutral detergent fiber; LIG = lignin; INDFdm = indigestible neutral detergent fiber as a percent of dry matter; NDFdig = digestible neutral detergent fiber as a percent of neutral detergent fiber; OM = organic matter;

Table 11. Effect of year x date interaction on the percentage (%) of ADF, CP, and EXT in Perennial Ryegrass

Perennial Ryegrass						
	Year 1			Year 2		
	May	June	Sept.	May	June	Sept.
ADF	25.74[c]	27.40[b]	29.33[a]	25.02[c]	24.74[c]	25.49[c]
	±0.63	±0.44	±0.63	±0.38	±0.63	±0.63
CP	15.00[c]	20.36[b]	10.84[c]	24.89[a]	22.76[ab]	20.54[b]
	±1.54	±1.09	±1.54	±1.09	±1.54	±1.54
EXT	0.38[b]	0.65[a]	0.78[a]	0.69[a]	0.60[a]	0.61[a]
	±0.06	±0.04	±0.06	±0.04	±0.06	±0.06

[a,b,c] ls means within a row with unlike superscripts are significantly different ($P < 0.05$)
ADF = acid detergent fiber; CP = crude protein; EXT = extensin;

Table 12. Effect of date on percentage (%) of LIG in Tall Fescue

Tall Fescue								
	Month							
	Jan.	Feb.	March	May	June	Sept.	Nov.	Dec.
Lignin	2.24[b]	2.44[b]	3.12[a]	1.42[c]	1.53[c]	1.62[c]	2.59[b]	2.53[b]
	±0.18	±0.18	±0.18	±0.15	±0.15	±0.21	±0.18	±0.18

[a,b,c] ls means within a row with unlike superscripts are significantly different ($P < 0.05$)
LIG = lignin

Table 13a. Effect of year x date interaction on percentage (%) of NDF, ADF, CP, EXT, INDFdm, NDFdig, and OM in Tall Fescue

Tall Fescue								
	Year 1							
	Jan.	Feb.	March	May	June	Sept.	Nov.	Dec.
NDF	59.98^{bcd}	67.32^{a}	69.12^{a}	56.96^{ce}	53.48^{eg}	60.27^{bcd}	57.18^{ce}	61.82^{b}
	±1.52	±1.52	±1.52	±1.52	±1.08	±1.52	±1.52	±1.52
ADF	31.62^{d}	36.29^{ab}	37.95^{a}	28.51^{ef}	27.23^{f}	30.42^{de}	31.67^{d}	34.43^{bc}
	±0.83	±0.83	±0.83	±0.83	±0.59	±0.83	±0.83	±0.83
CP	11.20^{de}	11.65^{de}	12.15^{cde}	15.02^{bcd}	20.12^{a}	10.69^{de}	12.22^{cde}	12.18^{cde}
	±1.50	±1.50	±1.50	±1.50	±1.06	±1.50	±1.50	±1.50
EXT	0.53^{fg}	0.76^{bc}	1.02^{a}	0.57^{cg}	0.52^{g}	0.56^{dfg}	0.63^{cg}	0.86^{ab}
	±0.07	±0.07	±0.07	±0.07	±0.06	±0.07	±0.07	±0.07
INDFdm	22.16^{cde}	29.24^{ab}	30.66^{a}	14.25^{g}	14.45^{g}	23.01^{cde}	21.20^{de}	24.92^{cb}
	±1.28	±1.28	±1.28	±1.28	±0.91	±1.28	±1.28	±1.28
NDFdig	63.10^{bce}	56.59^{fh}	55.70^{h}	75.02^{a}	73.15^{a}	61.85^{ceg}	62.86^{ce}	59.74^{ceh}
	±1.74	±1.74	±1.74	±1.74	±1.23	±1.74	±1.74	±1.74
OM	90.96^{cd}	89.72^{df}	91.9^{cd}	90.52^{cde}	88.71^{cfg}	90.86^{cd}	88.28^{g}	88.48^{fg}
	±0.48	±0.48	±0.48	±0.48	±0.34	±0.48	±0.48	±0.48

^{a,b,c,d,e,f,g,h} ls means within a row in Table 11a and Table 11b with unlike superscripts are significantly different ($P < 0.05$)

NDF = neutral detergent fiber; ADF = acid detergent fiber; CP = crude protein; EXT = extensin; INDFdm = indigestible neutral detergent fiber as a percent of dry matter; NDFdig = digestible neutral detergent fiber as a percent of neutral detergent fiber; OM = organic matter;

Table 13b. Effect of year x date interaction on percentage (%) of NDF, ADF, CP, EXT, INDFdm, NDFdig, and OM in Tall Fescue

Tall Fescue								
	Year 2							
	Jan.	Feb.	March	May	June	Sept.	Nov.	Dec.
NDF	57.25^{ce}	61.30^{bc}	66.66^{a}	53.06^{g}	56.64^{deg}	55.69^{deg}	57.71^{bcdf}	54.90^{efg}
	±1.52	±1.52	±1.52	±1.08	±1.52	±2.01	±1.52	±1.52
ADF	30.13^{deg}	32.19^{cd}	34.62^{b}	28.19^{fg}	29.18^{ef}	27.54^{fg}	29.79^{deg}	28.59^{ef}
	±0.83	±0.83	±0.83	±0.59	±0.83	±1.10	±0.83	±0.83
CP	10.42^{e}	11.24^{de}	12.57^{cde}	21.50^{a}	16.01^{bc}	19.32^{ab}	11.29^{de}	10.76^{de}
	±1.50	±1.50	±1.50	±1.06	±1.50	±1.98	±1.50	±1.50
EXT	0.74^{bc}	0.57^{cg}	0.72^{bce}	0.76^{b}	0.76^{bcd}	0.65^{bg}	0.62^{ceg}	0.44^{g}
	±0.07	±0.07	±0.07	±0.05	±0.07	±0.09	±0.07	±0.07
INDFdm	23.82^{cde}	24.85^{cd}	25.65^{bc}	15.24^{g}	18.16^{eg}	19.75^{be}	24.89^{cd}	21.90^{bd}
	±1.28	±1.28	±1.28	±0.91	±1.28	±1.70	±1.28	±1.28
NDFdig	58.36^{eh}	59.44^{ceh}	61.55^{cef}	71.49^{ab}	68.00^{bc}	64.51^{cd}	56.99^{gh}	60.20^{deh}
	±1.74	±1.74	±1.74	±1.23	±1.74	±2.31	±1.74	±1.74
OM	93.09^{ab}	94.03^{a}	94.27^{a}	90.27^{cde}	89.32^{efg}	91.42^{bc}	92.62^{b}	92.54^{b}
	±0.48	±0.48	±0.48	±0.34	±0.48	±0.63	±0.48	±0.48

^{a,b,c,d,e,f,g,h} ls means within a row in Table 11a and Table 11b with unlike superscripts are significantly different ($P < 0.05$)

NDF = neutral detergent fiber; ADF = acid detergent fiber; CP = crude protein; EXT = extensin; INDFdm = indigestible neutral detergent fiber as a percent of dry matter; NDFdig = digestible neutral detergent fiber as a percent of neutral detergent fiber; OM = organic matter;

Table 14. Effect of date on percentage (%) of NDF, LIG, INDFdm, NDFdig, and OM in Bermuda Grass

Bermuda Grass					
	Month				
	June	July	August	September	P-value
NDF	64.30	66.36	64.93	65.17	0.50
	±0.91	±0.91	±0.91	±0.91	
LIG	2.16	2.16	2.30	2.32	0.09
	±0.09	±0.09	±0.09	±0.09	
INDFdm	23.57	23.21	22.63	25.62	0.08
	±0.77	±0.77	±0.77	±0.77	
NDFdig	63.34	65.06	65.17	60.74	0.06
	±0.99	±0.99	±0.99	±0.99	
OM	92.01	92.74	92.36	91.00	0.12
	±0.34	±0.34	±0.34	±0.34	

NDF = neutral detergent fiber; LIG = lignin; INDFdm = indigestible neutral detergent fiber as a percent of dry matter; NDFdig = digestible neutral detergent fiber as a percent of neutral detergent fiber; OM = organic matter;

Table 15. Effect of year x date interaction on percentage (%) of ADF, CP, and EXT in Bermuda Grass

Bermuda Grass								
	Year 1				Year 2			
	June	July	Aug.	Sept.	June	July	Aug.	Sept.
ADF	25.32^{d}	30.17^{a}	28.54^{bc}	29.23^{abc}	29.59^{ab}	27.69^{c}	29.34^{ab}	28.15^{bc}
	±0.44	±0.44	±0.44	±0.44	±0.44	±0.44	±0.44	±0.44
CP	22.09^{a}	19.48^{b}	20.71^{ab}	17.16^{cd}	12.51^{d}	18.61^{bcd}	19.06^{bc}	16.68^{d}
	±0.66	±0.66	±0.66	±0.66	±0.66	±0.66	±0.66	±0.66
EXT	1.11^{a}	0.83^{c}	0.97^{ac}	0.90^{bc}	0.97^{ac}	1.04^{ab}	1.00^{ab}	0.92^{bc}
	±0.05	±0.05	±0.05	±0.05	±0.05	±0.05	±0.05	±0.05

^{a,b,c,d} ls means within a row with unlike superscripts are significantly different ($P < 0.05$)

ADF = acid detergent fiber; CP = crude protein; EXT = extensin;

Table 16a. Effect of year x date interaction on percentage (%) of NDF, ADF, LIG, CP, EXT, INDFdm, NDFdig, and OM in Caucasian Bluestem

Caucasian Bluestem										
	Year 1					Year 2				
	April	May	June	Aug.	Sept.	May	June	July	Sept.	P-value
NDF	49.33	49.60	63.14	64.82	66.88	59.61	64.32	66.70	68.85	0.15
	±1.58	±2.05	±1.58	±1.58	±1.58	±1.58	±1.58	±1.58	±2.05	
ADF	30.83	31.39	36.69	36.46	37.88	30.95	35.27	37.47	37.41	0.18
	±1.01	±1.30	±1.01	±1.01	±1.01	±1.01	±1.01	±1.01	±1.31	
LIG	2.80^{bc}	6.36^{a}	2.89^{b}	2.08^{def}	2.40^{bf}	1.80^{fg}	2.08^{deg}	2.00^{efg}	2.42^{bg}	<0.05
	±0.19	±0.25	±0.19	±0.19	±0.19	±0.19	±0.19	±0.19	±0.25	
CP	10.34^{eh}	11.74^{df}	10.43^{fh}	9.44^{h}	11.88^{de}	12.37^{d}	12.70^{cd}	10.65^{fg}	9.76^{gh}	<0.05
	±0.39	±0.50	±0.39	±0.39	±0.39	±0.39	±0.39	±0.39	±0.50	
EXT	0.59^{b}	1.82^{a}	0.66^{b}	0.57^{b}	0.54^{bc}	0.59^{b}	0.61^{b}	0.35^{cd}	0.50^{bd}	<0.05
	±0.07	±0.09	±0.07	±0.07	±0.07	±0.07	±0.07	±0.07	±0.09	
INDFdm	22.12^{be}	24.77^{bc}	22.71^{bcd}	22.04^{be}	24.96^{b}	15.27^{gh}	18.87^{e}	30.78^{a}	33.13^{a}	<0.05
	±1.27	±1.64	±1.27	±1.27	±1.27	±1.27	±1.27	±1.27	±1.65	
NDFdig	55.36^{d}	50.12^{d}	63.77^{c}	65.99^{bc}	62.58^{c}	74.39^{a}	70.68^{ab}	53.97^{d}	51.70^{d}	<0.05
	±1.87	±2.40	±1.87	±1.87	±1.87	±1.87	±1.87	±1.87	±2.43	
OM	91.51	90.28	93.19	94.76	93.42	92.35	94.01	95.67	95.72	0.51
	±0.35	±0.45	±0.35	±0.35	±0.35	±0.35	±0.35	±0.35	±0.47	

^{a,b,c,d,e,f,g,h} ls means within a row in Table 14a and Table 14b with unlike superscripts are significantly different ($P < 0.05$)

NDF = neutral detergent fiber; ADF = acid detergent fiber; LIG = lignin; CP = crude protein; EXT = extensin; INDFdm = indigestible neutral detergent fiber as a percent of dry matter; NDFdig = digestible neutral detergent fiber as a percent of neutral detergent fiber; OM = organic matter;

Table 16b. Effect of year x date interaction on percentage (%) of NDF, ADF, LIG, CP, EXT, INDFdm, NDFdig, and OM in Caucasian Bluestem

Caucasian Bluestem									
	Year 3					Year 4			
	April	May	June	July	Aug.	June	July	Sept.	P-value
NDF	51.80	50.16	62.77	64.02	62.12	63.06	66.08	67.76	0.15
	±1.58	±1.58	±1.58	±1.58	±1.58	±1.58	±1.58	±1.58	
ADF	28.07	25.45	35.09	36.22	33.67	33.36	36.66	37.96	0.18
	±1.01	±1.01	±1.01	±1.01	±1.01	±1.01	±1.01	±1.01	
LIG	2.47^{be}	1.46^{g}	2.36^{bef}	2.28^{cef}	2.13^{def}	2.27^{cef}	2.65^{bcd}	1.89^{fg}	<0.05
	±0.19	±0.19	±0.19	±0.19	±0.19	±0.19	±0.19	±0.19	
CP	16.43^{b}	19.96^{a}	16.19^{b}	12.89^{cd}	12.78^{cd}	13.73^{c}	12.03^{d}	10.76^{efg}	<0.05
	±0.39	±0.39	±0.39	±0.39	±0.39	±0.39	±0.39	±0.39	
EXT	0.56^{b}	0.32^{d}	0.68^{b}	0.57^{b}	0.66^{b}	0.63^{b}	0.59^{b}	0.52^{bd}	<0.05
	±0.07	±0.07	±0.07	±0.07	±0.07	±0.07	±0.07	±0.07	
INDFdm	16.62^{gh}	13.34^{h}	21.07^{cef}	24.01^{bcd}	20.40^{de}	20.69^{ce}	23.56^{be}	24.58^{bf}	<0.05
	±1.27	±1.27	±1.27	±1.27	±1.27	±1.27	±1.27	±1.27	
NDFdig	67.73^{bc}	73.88^{a}	66.38^{bc}	62.51^{c}	67.15^{bc}	67.15^{bc}	64.35^{c}	63.72^{c}	<0.05
	±1.87	±1.87	±1.87	±1.87	±1.87	±1.87	±1.87	±1.87	
OM	91.72	91.29	92.90	94.22	94.61	94.02	94.79	94.51	0.51
	±0.35	±0.35	±0.35	±0.35	±0.35	±0.35	±0.35	±0.35	

^{a,b,c,d,e,f,g} ls means within a row in Table 14a and Table 14b with unlike superscripts are significantly different ($P < 0.05$)

NDF = neutral detergent fiber; ADF = acid detergent fiber; LIG = lignin; CP = crude protein; EXT = extensin; INDFdm = indigestible neutral detergent fiber as a percent of dry matter; NDFdig = digestible neutral detergent fiber as a percent of neutral detergent fiber; OM = organic matter;

Table 17a. Effect of year x date interaction on percentage (%) of NDF, ADF, LIG, CP, EXT, INDFdm, NDFdig, and OM in Alfalfa

Alfalfa								
	Year 1				Year 2			
	May	June	July	Sept.	May	June	July	Sept.
NDF	35.68^{fg}	41.01^{cf}	27.87^{h}	24.56^{h}	34.95^{g}	40.56^{cfg}	41.95^{bcde}	44.65^{ac}
	±1.99	±1.99	±1.99	±1.99	±1.99	±1.99	±1.99	±1.99
ADF	26.05^{def}	30.06^{bc}	17.75^{gh}	16.48^{h}	21.02^{g}	25.56^{e}	29.31^{ce}	29.91^{bcdf}
	±1.33	±1.33	±1.33	±1.33	±1.33	±1.33	±1.33	±1.33
LIG	7.03^{ac}	5.54^{ce}	3.85^{e}	4.16^{e}	5.25^{de}	6.64^{acd}	6.85^{acd}	6.09^{acd}
	±0.60	±0.60	±0.60	±0.60	±0.60	±0.60	±0.60	±0.60
CP	25.83^{c}	22.57^{de}	25.85^{c}	38.52^{a}	28.31^{b}	25.95^{c}	22.25^{def}	25.13^{cd}
	±0.53	±0.53	±0.53	±0.53	±0.53	±0.53	±0.53	±0.53
EXT	1.94^{ab}	1.21^{gi}	1.03^{i}	1.50^{bg}	1.31^{fgi}	1.73^{abc}	1.20^{gi}	2.07^{a}
	±0.12	±0.12	±0.12	±0.12	±0.12	±0.12	±0.12	±0.12
INDFdm	20.69^{de}	18.84^{ef}	11.34^{ij}	5.56^{k}	10.86^{j}	15.89^{g}	20.88^{de}	21.67^{cd}
	±0.74	±0.74	±0.74	±0.74	±0.74	±0.74	±0.74	±0.74
NDFdig	49.72^{eg}	54.07^{def}	59.19^{cd}	77.39^{a}	69.13^{b}	60.71^{cd}	50.16^{eg}	51.33^{eg}
	±2.41	±2.41	±2.41	±2.41	±2.41	±2.41	±2.41	±2.41
OM	89.54^{g}	92.00^{be}	91.92^{bc}	90.54^{d}	92.42^{ab}	91.68^{bc}	92.98^{a}	92.57^{ab}
	±0.32	±0.32	±0.32	±0.32	±0.32	±0.32	±0.32	±0.32

^{a,b,c,d,e,f,g,h,i,j,k} ls means within a row in Table 15a and Table 15b with unlike superscripts are significantly different ($P < 0.05$)

NDF = neutral detergent fiber; ADF = acid detergent fiber; LIG = lignin; CP = crude protein; EXT = extensin; INDFdm = indigestible neutral detergent fiber as a percent of dry matter; NDFdig = digestible neutral detergent fiber as a percent of neutral detergent fiber; OM = organic matter

Table 17b. Effect of year x date interaction on percentage (%) of NDF, ADF, LIG, CP, EXT, INDFdm, NDFdig, and OM in Alfalfa

Alfalfa										
	Year 3					Year 4				
	May	June	July	Aug	Sept	May	June	July	Aug	Sept
NDF	38.67^{efg}	38.76^{cfg}	42.73^{acde}	45.52^{acg}	38.71^{df}	39.31^{dfg}	48.11^{a}	46.95^{ab}	47.74^{ab}	47.46^{ab}
	±1.99	±1.99	±1.99	±1.99	±1.99	±2.49	±1.99	±1.99	±1.99	±1.99
ADF	25.63^{de}	27.68^{cde}	31.08^{abc}	31.4^{abc}	26.40^{de}	27.35^{ce}	33.30^{ab}	34.17^{a}	34.69^{a}	30.31^{b}
	±1.33	±1.33	±1.33	±1.33	±1.33	±1.67	±1.33	±1.33	±1.33	±1.33
LIG	5.44^{ce}	6.29^{acd}	6.97^{acd}	6.93^{acd}	6.39^{acd}	6.59^{acd}	7.01^{ac}	7.23^{ab}	7.41^{a}	5.62^{bcd}
	±0.60	±0.60	±0.60	±0.60	±0.60	±0.75	±0.60	±0.60	±0.60	±0.60
CP	28.04^{b}	21.42^{deg}	21.18^{degh}	19.93^{gh}	21.96^{def}	23.64^{d}	19.70^{h}	20.19^{gh}	20.03^{gh}	20.76^{fgh}
	±0.53	±0.53	±0.53	±0.53	±0.53	±0.66	±0.53	±0.53	±0.53	±0.53
EXT	1.69^{bcd}	1.10^{ci}	1.40^{ceg}	1.70^{bde}	1.40^{ceg}	1.23^{fgi}	1.48^{dg}	1.18^{gi}	1.63^{bdef}	1.72^{abde}
	±0.12	±0.12	±0.12	±0.12	±0.12	±0.12	±0.12	±0.12	±0.12	±0.12
INDFdm	13.44^{hi}	17.92^{fg}	22.00^{bd}	23.95^{ab}	20.02^{de}	15.25^{gh}	23.45^{abc}	23.55^{abc}	24.94^{a}	21.53^{cd}
	±0.74	±0.74	±0.74	±0.74	±0.74	±0.93	±0.74	±0.74	±0.74	±0.74
NDFdig	65.69^{bc}	55.16^{de}	48.65^{eg}	46.86^{g}	46.45^{g}	60.80^{cd}	51.25^{eg}	49.89^{eg}	47.77^{fg}	54.10^{def}
	±2.41	±2.41	±2.41	±2.41	±2.41	±3.02	±2.41	±2.41	±2.41	±2.41
OM	88.27^{h}	91.06^{c}	90.33^{dg}	90.50^{df}	89.58^{fg}	90.97^{cde}	91.06^{cd}	92.12^{ab}	91.72^{bc}	91.65^{bc}
	±0.32	±0.32	±0.32	±0.32	±0.32	±0.41	±0.32	±0.32	±0.32	±0.32

^{a,b,c,d,e,f,g,h,i,j,k} ls means within a row in Table 15a and Table 15b with unlike superscripts are significantly different ($P < 0.05$)

NDF = neutral detergent fiber; ADF = acid detergent fiber; LIG = lignin; CP = crude protein; EXT = extensin; INDFdm = indigestible neutral detergent fiber as a percent of dry matter; NDFdig = digestible neutral detergent fiber as a percent of neutral detergent fiber; OM = organic matter

Table 18. Effect of date on percentage (%) of NDF, ADF, LIG, CP, EXT, INDFdm, NDFdig, and OM in Birdsfoot Trefoil

Birdsfoot Trefoil			
	Month		
	May	June	P-Value
NDF	37.46	43.40	0.04
	±0.90	±0.90	
ADF	28.04	33.16	0.13
	±1.43	±1.43	
LIG	6.05	7.81	0.07
	±0.35	±0.35	
CP	19.85	19.51	0.32
	±0.85	±0.85	
EXT	1.62	1.97	0.02
	±0.04	±0.04	
INDFdm	18.79	25.00	0.06
	±1.12	±1.12	
NDFdig	50.34	42.71	0.08
	±1.57	±1.57	
OM	92.55	92.47	0.95
	±0.70	±0.70	

ls means within a row are significantly different if $P < 0.05$

NDF = neutral detergent fiber; ADF = acid detergent fiber; LIG = lignin; CP = crude protein; EXT = extensin; INDFdm = percent indigestible neutral detergent fiber as a percent of dry matter; NDFdig = digestible neutral detergent fiber as a percent of neutral detergent fiber; OM = organic matter

Table 19: Correlations between wet chemical analysis of cell wall content versus extent of cell wall digestibility as a percent of dry matter and as a percent of neutral detergent fiber in different forage species

Forage Species	NDF vs INDFdm	ADF vs INDFdm	NDF vs NDFdig	ADF vs NDFdig
Annual Ryegrass	0.95	0.97	0.91	0.94
Perennial Ryegrass	0.49	0.73	0.34	0.61
Tall Fescue	0.85	0.84	0.66	0.68
Bermuda Grass	0.58	0.20	0.24	0.16
Caucasian Bluestem	0.55	0.72	0.08	0.37
Alfalfa	0.79	20.86	0.47	0.62
Birdsfoot Trefoil	0.95	0.98	0.73	0.82

NDF = neutral detergent fiber; ADF = acid detergent fiber; INDFdm = indigestible neutral detergent fiber as a percent of dry matter; NDFdig = digestible neutral detergent fiber as a percent of neutral detergent fiber

CHAPTER IV

Conclusion

A managed silvopastoral system is viable when incorporated into a grazing scheme to increase land utilization. Grazing systems which utilize grassland pasture along with forest pasture would be most productive. Previous research data suggests that livestock performance could be enhanced by correct timing of grazing different vegetative types (Holechek et al., 1981). Integrated warm season grasses and legumes into open pastures can greatly enhance pasture quality and improve pasture yield during different times of the year.

Research presented here shows that NDF incompletely describes the fiber fraction of some forages. This research agrees with previous data presented by Felton and Kerley (2002), which shows that INDF would be a better predictor of rumen fill than NDF alone. Furthermore, ADF was proven to be a poor indicator of forage digestibility in warm season grasses. Up to two percent of the crude protein levels found in legumes can be bound by extensin. This suggests that bound protein can play a key role in cell wall degradability of some forage species, and should be analyzed along with lignin when determining the composition of INDF.

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