Management Strategies for
Sustainable Cattle Production
in Southern Pastures

Edited by **Monte Rouquette, Jr. PAS** and **Glen E. Aiken**

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Foreword

Forage-based livestock production is challenged to enhance sustainability of pastures and cattle production, and to maintain economic stability in the presence of changes in market prices of cattle, fertilizer, feed, and other requirements. Management strategies that meet production goals while maintaining soil and ecosystem health and with minimal impact on the environment require a basic understanding of how: (1) the intensity, rate, and duration of stocking will impact cattle performance and production; (2) grazing systems can be used to maintain sustainable, productive pastures; (3) innovations in feeding and watering systems can be used to minimize negative impacts on water and soil health; (4) management of soil nutrients, which are components of nutrient cycling, can be effective in minimizing environmental impacts and controlling input costs; (5) control of noxious weeds is needed to maintain forage composition, pasture condition, and ecosystem stability; and (6) forage systems can accommodate wildlife habitat and diet requirements.

This book addresses concerns and questions of cattle producers when using grazing systems for different forages and environments, stocking rates, or stocking methods to meet sustainable production goals. Cattle genotype $\times$ environment interactions, economical fertilization programs, and integrated wildlife management strategies are discussed. Emphasis has been placed on issues that are presented to livestock producers such as improved soil health, water quality, and animal well-being. Different cattle marketing channels discussed includes cow-calf, stocker (pasture backgrounding), pasture finishing, and seed stock production. Subject matter is presented with a thorough description of the biology and ecological components of pastures and principles of sustainable grazing and forage management.

Chapters in this book expand existing information sources such as "Forages" and "Southern Forages," and incorporate research-based databases into management strategies that can be applicable for 365-day pasture—animal systems. Management strategy options are presented that may be used by: (1) small-sized operators with 20—35 cows; (2) medium-sized operators with 50—200 cows; (3) operators who want a "least input approach with respect to fertilization"; or (4) operators who may want to be more aggressive (intensive), and seek to increase stocking rate and perhaps incorporate retained ownership until calves reach the feeder stage. Information presented in the chapters relate to Environmental-Plant Hardiness Zones, soils and fertility status, adapted forage species (introduced and native if applicable), forage dry matter and nutritive value during season of growth and as conserved forage, animal performance, sustainability of pastures, integrated forage-wildlife ecosystems, and economic implications. Management strategies in 13 Southern and 6 adjoining upper Southern states affect sustainable pasture-cattle production for nearly 60% of the US beef cows. Cattle production from both the warm- and cool-season perennial grass-based pastures has a major impact on quantity and quality of beef for consumers in the United States and for export marketing. Implementation of many of these management strategies will influence short term and strategic objectives for sustainability of cattle production on Southern pastures.

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Acknowledgments

The hypotheses, experiments, and summarizing of management strategies for sustainable soil-forage-animal-environmental relationships has been the long-term product of numerous, multidiscipline teams of scientists. A vast number of "early" and current scientists who deserve acknowledgment were part of disciplines that included plant breeding, plant physiology, soil-fertility, soil microbiology, animal nutrition, reproductive physiology, agricultural engineering, agricultural economics, wildlife, water quality, statistics, etc., who were seeking enhanced biological efficiencies of soil-forage-animal systems with potential sustainable and economic implications for stakeholders. In addition to "pioneer scientists" evaluating forages that could improve cattle performance, pasture stocking rates, and gains per acre, other scientists were devoted to developing techniques for design and measurement; whereas, others concentrated on the defining of cause-and-effect of soil-forage-animal relationships. These scientists were stimulated, encouraged and included in the "International Scientific Community" who investigated perennial and annual forages adapted from tropical to temperate environments under humid and arid conditions. The formation of scientific journals and international symposia-meetings provided incentives and opportunities for professional and personal relationships among scientists who were committed to sharing ideas and discoveries. Ideas became discoveries with the assistance and efforts of numerous research associates, technicians, undergraduate and graduate students, and secretarial staff who were involved in the planning and executing of an array of laboratory, greenhouse, and field projects that included "sweat and dedication" in collecting, documenting, and analyzing soil, forage, and animal data to provide the baseline information for management strategies.

The authors of each chapter in this book are leading scientists in their disciplines and professional societies, and recognized by their peers. Sincere appreciation is extended to each of these authors who "bought in" to the philosophy of documenting relevant publications and incorporating scientific facts into collective strategies. They shared and endorsed the opportunities to transcend component-based databases into management strategies to enhance sustainable pastures and beef cattle production in the Southern Region of the United States for scientists, students, and stakeholders.

Acknowledgments and thanks are extended to representatives and project managers of Elsevier who provided professional guidance and patience in many areas of the publication processes. A special acknowledgment is warranted for Ms. Jennifer Santos who provided numerous versions of the text and references for the book. In addition, acknowledgment and endorsement for extra effort is extended to Ms. Kelli Norman for her attention to details and assistance in editing the chapter text, and for her dedication, expertise, and creativity in formatting numerous figures and tables that exceeded author expectations.

A very special "Heart-Felt" thanks are given to our wives, Sharlot and Mary, who provided support, patience, "listened to our discussions on approaching deadlines," and who never asked, "Are you finished, yet?"

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CHAPTER 1

Introduction: Management strategies for sustainable cattle production in Southern Pastures

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Sustainability of forages and cattle production

Management strategies provide guidance and set expectations and objectives for the overall property–pasture–cattle production goals. Sustainable beef has been defined by the Global Roundtable for Sustainable Beef (GRSB) [1] to be a product that is socially responsible, environmentally sound, and economically viable. The GRSB also emphasized that beef production should be attentive to natural resources, efficiency and innovation, people and the community, animal health and welfare, and end product to generate income. As pointed out by Rouquette [2], the natural resource principles of the GRSB serve as the primary factors of sustainable pasture–livestock systems. These natural resource principles encourage management to (1) practice environmental stewardship with adaptive management; (2) adopt practices to improve air quality and minimize net greenhouse gas emissions; (3) protect grasslands, native ecosystems, and valuable conservation areas from land conversion and degradation; (4) implement land management practices that conserve and enhance ecosystem health; (5) incorporate efficient management practices to maintain or improve soil health; (6) enhance native plants and animal biological diversity; and (7) implement management practices for sustainable-product feed sources.

Management strategies that integrate the socially responsible management, environmentally sound principles, and economically viable components of sustainability of forage–pasture–cattle production are shown in Fig. 1.1 [2]. Within a specific vegetation zone, pasture ecosystem, management inputs, and stocking strategies are the principal factors that influence sustainability of pastures and livestock production. The level or extent of aggressiveness, intensity, or stocking rate–animal performance goals of the operation are manager or ownership specific. Beef production and the value of product are controlled by biological and economic risk, and the stewardship–property legacy objectives. The economic effect and viability of

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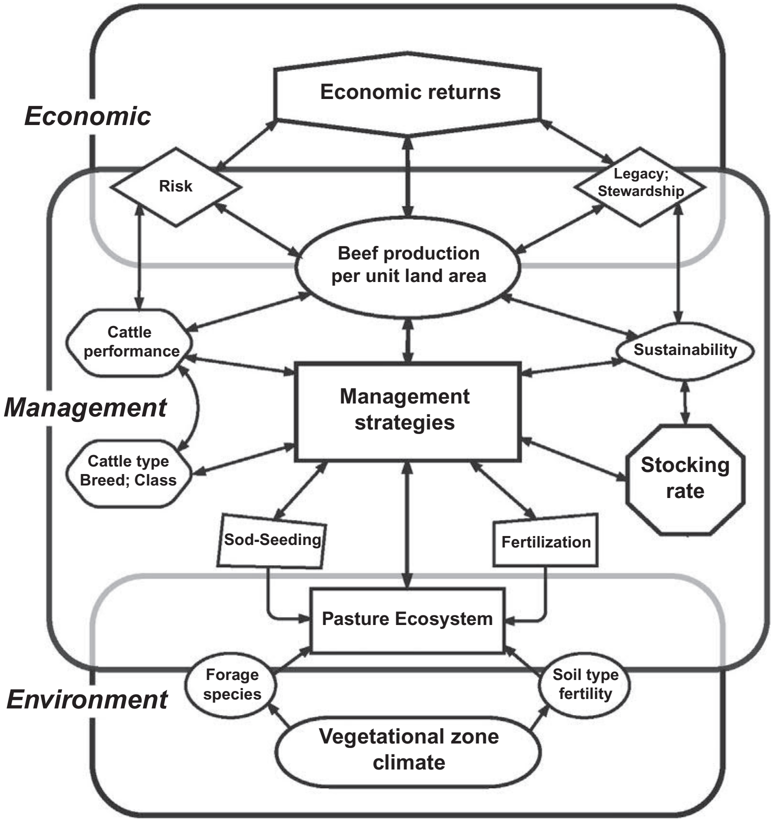

Figure 1.1 Sustainability of pasture—cattle production systems guided by environment, management, and economic considerations. *Adapted from F.M. Rouquette, Jr., Management strategies for intensive, sustainable cow-calf production systems in the southeastern United States: Bermudagrass pastures overseeded with cool-season annual grasses and legumes, Prof. Anim. Sci. 33 (2017) 297—309. https://doi.org/10.15232/pas.2016-01591.*

the pasture—beef system are influenced by production per animal and per unit land area. These aspects of pasture management and cattle production are influenced primarily by stocking rate and secondarily by stocking method. Various stocking strategies will be discussed in the following chapters to implement forage—pasture utilization approaches that seek to optimize animal gains without destruction of the forage resource.

Stocking strategies

The assessment and identification of forage and cattle production constraints related to climatic conditions, soil fertility, ecosystem diversity, and persistent-adapted forages set the general boundaries for management inputs and output opportunities.

Components of stocking strategies are the primary factors that affect the decisions for management (Fig. 1.2) [3]. The primary factors controlling a viable, sustainable operation involves selecting and utilizing adapted forage species for a specific "zip code" location within a vegetational hardiness zone. Management strategies that have the greatest opportunities to meet personal goals, sustainable production objectives, and

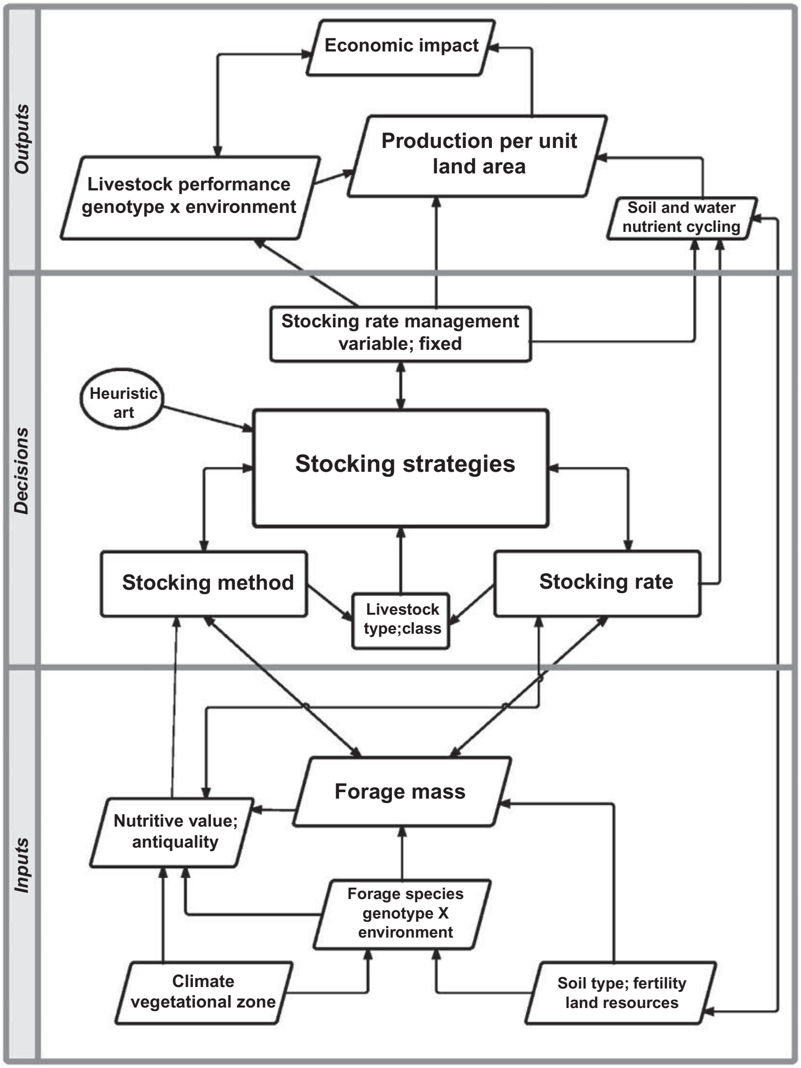

Figure 1.2 Inputs and outputs of forage–animal production systems as affected and directed by stocking strategy decisions. *Adapted from F.M. Rouquette, Jr., Grazing systems research and impact of stocking strategies on pasture-animal production efficiencies, Crop Sci. 55 (2015) 2513–2530. https://doi.org/10.2135/cropsci2015.01.0062.*

economic rewards are based on comparative facts and data for forage production and utilization. Successful managers should be familiar with cause—effect relationships of pasture—animal performance, and the short-term, seasonal, and yearlong climatic conditions related to rainfall and temperature. Thus, within a specific vegetational zone, managers must combine on-site, visual assessment, and management of efficient, sustainable forage use for desired pasture—animal production. Management must be aware of the competitive challenges of climatic conditions and the current and strategic rainfall—temperature related issues. Using appropriate inputs (Fig. 1.2), managers can make decisions and stocking strategies that stimulate forage production, utilization, and nutritive value for desired animal performance. Some of the most valuable factors to consider to optimize system outputs include: (1) an understanding and expectation of forage growth and regrowth; (2) experience with animals and animal husbandry; (3) the ability to assume biological and economic risks associated with stocking outcomes; (4) a constant awareness of vegetation, land, and water resources; (5) an alternative or escape plan for animals and pastures in the event of extreme climatic conditions; and (6) an intuitive application of decisions for inputs and output [3].

Stocking strategies are uniquely linked and integrated with decisions on forage production, grazing pressure, stocking rates, stocking methods, deferment of pastures, and mechanically harvested forages. A stocking strategy is a daily and seasonal approach to forage utilization using stocking rates and stocking methods [3]. Changes in stocking rates and deferment may be made according to various classes, age, and weight of livestock to achieve the primary objectives of optimum forage use for desired optimum or maximum animal performance [3]. Stocking strategies and management decisions used to optimize forage utilization and animal performance lead managers to incorporate the concept of flexible grazing management [4]. Blaser et al. [5] introduced the use of flexible grazing systems by adjusting stocking methods and forage utilization strategies on visual—quantity bases and not a calendar-basis to optimize gain per animal and/or gain per acre.

Plant Hardiness Zones and Southern Pastures

The Southern Pasture areas that are discussed throughout the following chapters are the same states and general locations shown and discussed in Southern Forages [6]. This overall southern region comprises the core states that were part of the original 13 member states of the Southern Pasture and Forage Crop Improvement Association that was founded in 1940 at Tifton, GA [7]. These 13 states include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. These states are included in one or more of six of the USDA Plant Hardiness Zones (Figs. 1.3 and 1.4) [8]. These Southern Pastures are bounded on the west by Texas and Oklahoma, and

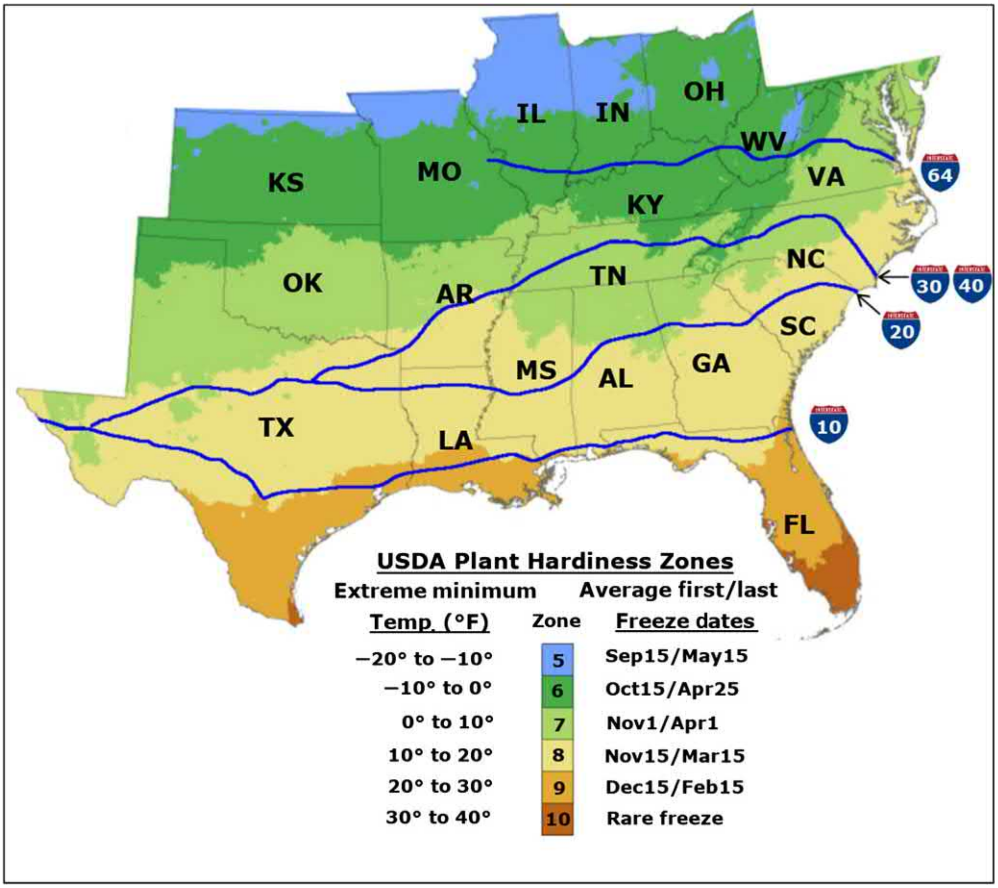

Figure 1.3 Extreme minimum temperatures and average first-last freeze dates in southern region. *Adapted from USDA/ARS, Plant Hardiness Zones. <http://planthardiness.ars.usda.gov>, 1990 (accessed 07.03.18).*

include all those states bordering the Gulf of Mexico. This geographical area includes the Atlantic seaboard states of Georgia, South Carolina, North Carolina, and Virginia, and the land-locked states of Arkansas, Tennessee, and Kentucky. Management strategies will be presented within the Hardiness Zones and subdivided as follows: (1) Lower South: Interstate 10 Corridor; (2) Middle South: Interstate 20 Corridor; and (3) The Upper South: Interstate 30, Interstate 40, and Interstate 64 Corridors. The forage base of the Lower and Middle South is primarily warm-season perennial grasses such as bermudagrass and bahiagrass (Fig. 1.5) [9,10]. The primary pastures in the Upper South include cool-season perennial grasses such as tall fescue with some mixed bermudagrass pastures (Fig. 1.6) [11]. In all Hardiness Zones, cool-season annual grasses and legumes may be used to extend the active forage growing and grazing season for

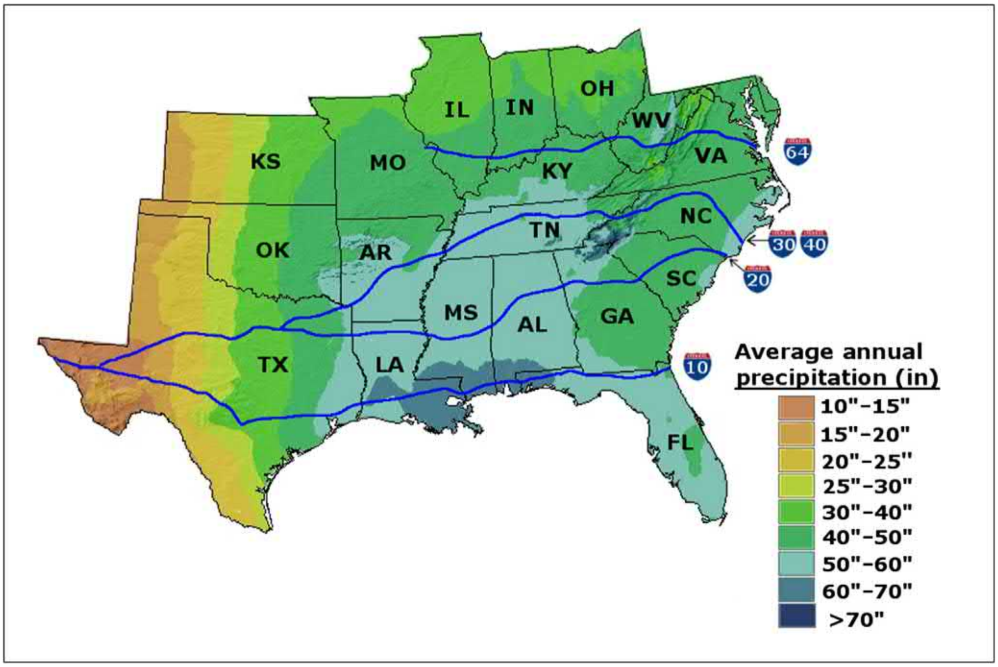

Figure 1.4 A 30-year average annual precipitation in the southern region, 1981–2010. *Adapted from USDA/ARS, Plant Hardiness Zones. <http://planthardiness.ars.usda.gov>, 1990 (accessed 07.03.18).*

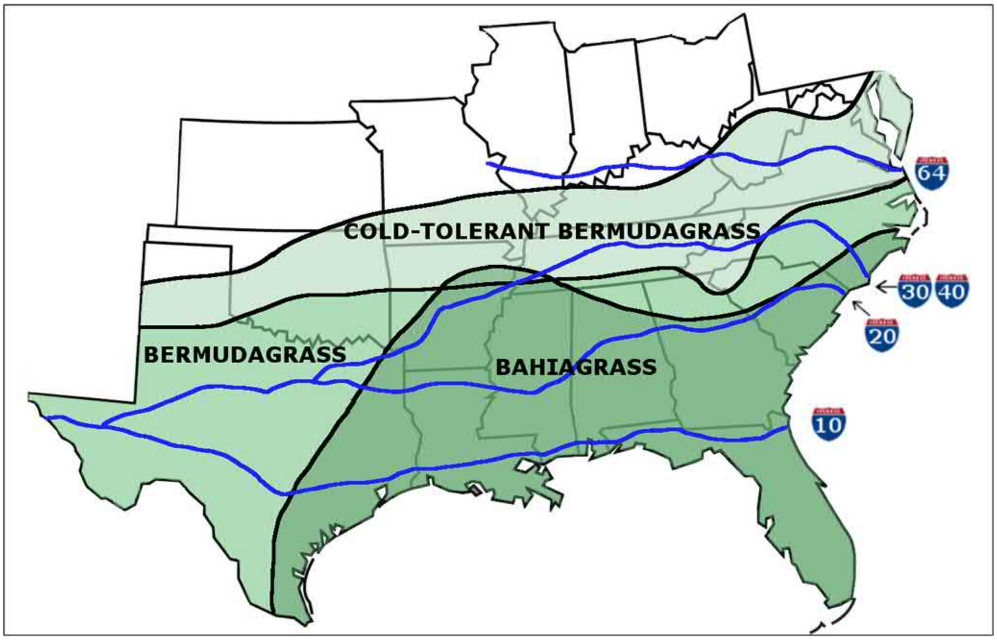

Figure 1.5 Warm-season perennial grasses, bermudagrass and bahiagrass, adaptation area in the southern region. *Adapted from G.W. Burton, W.W. Hanna, Bermudagrass, in: M.E. Heath, R.F. Barnes, D.S. Metcalfe (Eds.), Forages: The Science of Grassland Agriculture, fourth ed., Iowa State Univ. Press, 1985, pp. 247–254; V.H. Watson, B.L. Burson, Bahiagrass, carpetgrass, and dallisgrass, in: M.E. Heath, R.F. Barnes, D.S. Metcalfe (Eds.), Forages: The Science of Grassland Agriculture, fourth ed., Iowa State Univ. Press, 1985, pp. 255–262.*

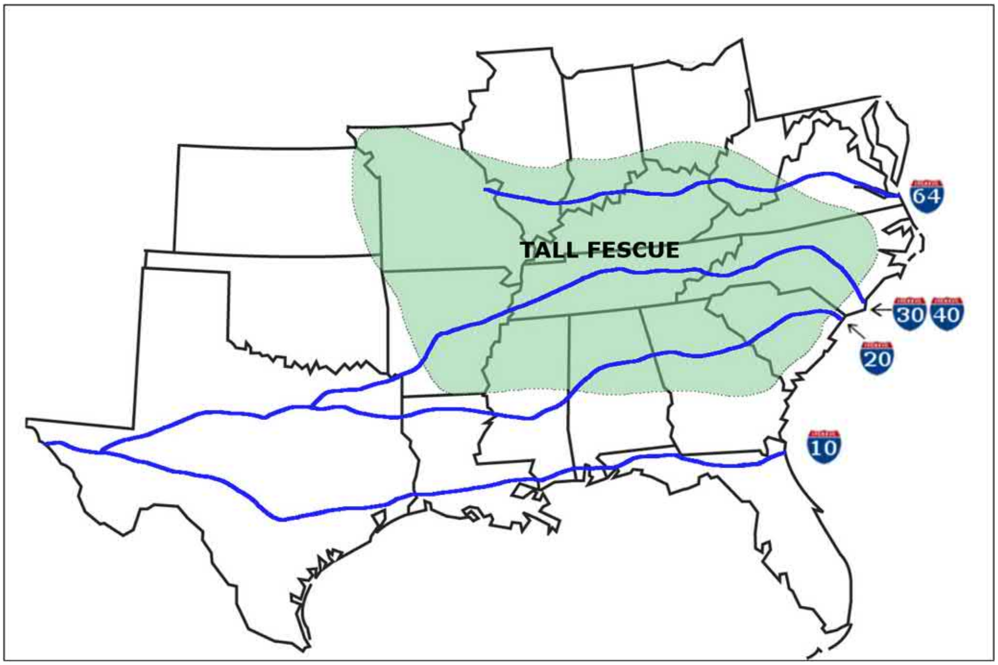

Figure 1.6 Primary use area for tall fescue in the southern region. *Adapted from R.C. Buckner, The fescues, in: M.E. Heath, R.F. Barnes, D.S. Metcalfe (Eds.), Forages: The Science of Grassland Agriculture, fourth ed., Iowa State Univ. Press, 1985, pp. 233−240.*

300−365 days [12]. These annual forages provide the greatest nutritive value of any class of forages, and are important for reproduction and animal gain. The success of seasonal or yearlong pastures and grazing systems are dependent on adapted forages to the "zip code"-specific Hardiness Zones. Management strategies that promote and stabilize sustainable pastures can be implemented. Management success is challenged by climatic conditions and soil fertility that affects monthly, seasonal, and total forage production. By integrating these controlling factors, decisions can be made for pasture utilization strategies. Stocking rate and flexible rotation adjustments among pastures can fulfill utilization strategies for desired animal performance and economic rewards. Adjustments in stocking rates and utilization strategies may involve harvested forage as hay or baleage from pastures.

The 13 core states are "home" to about 44% (13.6 M) of the beef cows in the United States [13]. There are six other states that adjoin the Upper South and are located in the Fescue Belt. These states include Kansas, Missouri, Illinois, Indiana, Ohio, and West Virginia, and are in similar Hardiness Zones to those states of the Interstate 64 Corridor. By combining these 6 states and the core 13 states, there are about 59% (18.6 M) of the US beef cows located in this southern and eastern region [13].

Thus, management strategies of sustainable pasture—cattle production on Southern Pastures have a major effect on the total US cow numbers, total calves weaned, weight of cattle entering feedlot, and overall beef quality.

Beef cattle production practices on Southern Pastures

As a component of the US Beef Sustainability Program, a characterization of regional beef production practices was conducted for the northeast and southeast United States. Information obtained by surveys and on-site visits suggested that 80% of the producers maintained less than 100 cows. The characterization of the cow-calf industry in the southeastern United States showed that about 60% of operations were cow-calf only, and 23% were both cow-calf and stocker [14]. In another overview [15] it was reported that 70% of the operations weaned calves at 6—8 months of age; 68% sold all calves at weaning except for replacements; 23% retained calves for preconditioning prior to sales; about 10% retained calves through the stocker phase; about 75% of operations sold calves at local auctions; and about 15% were stocker only operations.

Breed types of cows in the I-10 Corridor are predominately *Bos indicus* purebred and crossbred with *Bos taurus*. The preferences for the Brahman-influenced cows have been well-established with longevity, persistence, adaptation to the environment—climatic conditions, and overall productivity with respect to percent weaning and weaning weights. In the I-20 Corridor, both Brahman-influenced breed types and non-Brahman cows are the primary breed types used. In the Upper South, the predominant breed types of cows are non-Brahman and include both English and Continental sires. In the 2008 survey [14] Angus cattle were reported as the dominant breed type on about 70% of the operations, and Hereford cattle were the next preferred breed type.

Results of the US Beef Sustainability survey [14] showed that operators used a bull for 21 cows, had an average stocking rate of about one cow-calf pair per 2.5—3.0 acres, and stocking rates ranged from 1 to 20 acres per pair. From the pasture fertility perspective, 65% used nitrogen fertilizer at about 100 lbs/acre; 45% used phosphate (P_2O_5) at about 70 lbs/acre; 50% used potash (K_2O) at about 70 lbs/acre; and nearly 80% applied limestone to buffer soil pH. These survey data revealed that about 65% of the operators harvested pasture for conserved forage, and primarily as hay. Cattle born in the southeastern United States are most often shipped to feedlots and finished in Western Regions that are closer to feed grain (corn) sources.

Management questions for sustainability

Input information that managers need may arise from some of the following questions: (1) What forage(s) do I have, and which forages are best adapted to my property?

(2) What is the level of soil fertility in pastures, and fertilizer required for desired forage production? (3) What is the best stocking rate for my operation, and what visual or measured "indicators" show an optimum stocking rate strategy for sustainable cattle production? (4) Should I produce or purchase hay, and how do I know if a supplemental protein or energy may be needed? (5) What breed types of cattle are best adapted to my vegetational zone, and what season(s) should they calve? and (6) How do I plan my forage—cattle operational system which includes a sustainable ecosystem that encourages wildlife food and habitat? These and many more questions may be asked by both the novice landowner and experienced manager. The management strategies addressed in the following chapters have been structured to provide detailed information on soil—forage—animal—environment relationships for management successes.

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CHAPTER 2

Cattle grazing effects on the environment: Greenhouse gas emissions and carbon footprint

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Introduction

The Southeastern United States is characterized by relatively warm and wet conditions. Variations occur throughout the region and from year to year, but in general, precipitation is abundant throughout the year and temperature is hot in the summer and mild in the winter (Fig. 2.1). Such environmental conditions are important features that affect soil and water resources, which together ultimately affect agricultural production and environmental quality characteristics of the region.

Soils in the Southeastern United States are generally characterized as relatively poor in fertility due to a low level of base cations, low pH, low organic matter, and coarse texture. According to USDA Natural Resources Conservation Service, the Southeastern United States is categorized into land resource regions defined by soil and landscape features along with historical management. Regions include (N) east and central farming and forest region; (O) Mississippi delta cotton and feed grains region; (P) south Atlantic and gulf slope cash crops, forest, and livestock region; (T) Atlantic and gulf coast lowland forest and crop region; and (U) Florida subtropical fruit, truck crop, and range region [1]. Major land resource areas are more specific categorization that separates unique soil and landscape characteristics. Soil orders in the region include:

- Ultisols—Highly weathered soils that have been leached of cations, such as calcium and magnesium, and are acidic.
- Alfisols—Moderately weathered soils, slightly acidic, and having enriched clay content below the surface.
- Inceptisols—Moderate degree of soil development and lacking clay accumulation in the subsoil.
- Entisols—Little to no soil development typically in flood plains and sand dunes.
- Mollisols—Deep, fertile, dark-colored surface rich in base cations.
- Histisols—Highly enriched organic soils from historical water submersion.

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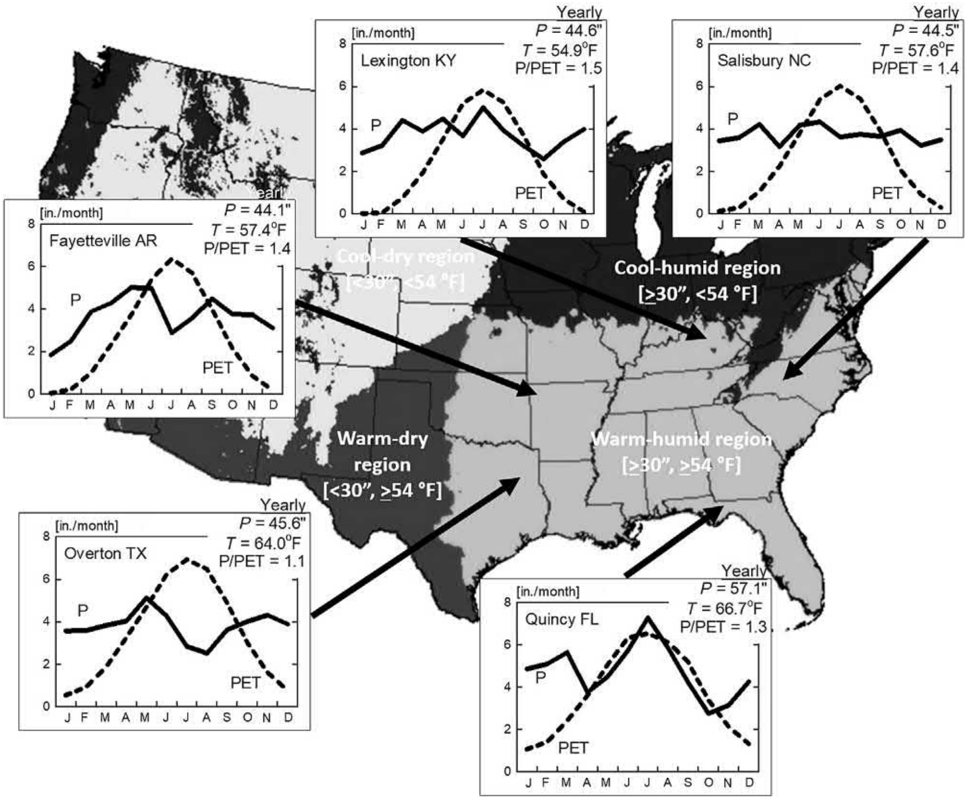

Figure 2.1 Climate characteristics of locations in the Southeastern United States. *P*, precipitation (inches); *T*, temperature (°F); *PET*, potential evapotranspiration (in.).

Differences in soil types are likely to have impacts on site-specific greenhouse gas emissions, particularly with regard to soil organic carbon (C) sequestration potential and soil nitrous oxide (N_2O) emissions. Enteric methane (CH_4) emissions in the region are not likely to be vastly different than in other regions if ruminants are fed a similar diet in confinement but could be different when raised on pasture forages. The botanical composition may affect intake and nutritive value, as well as the timing of grazing with respect to environmental conditions, all of which could affect rumen microbiota. Secondary metabolites in various forages may alter rumen microbiota as well.

The Southeastern United States is mostly an undulating landscape with significant forestlands, but also contains important corridors of rapidly expanding human population and associated transportation and industrial developments. These features are important to characterize the relatively small and variable nature of pastures throughout the region. Fig. 2.2 is an example of landscape cross-sections to show broad undulations in landscape across the Appalachian Mountains, Piedmont, and Coastal Plain regions.

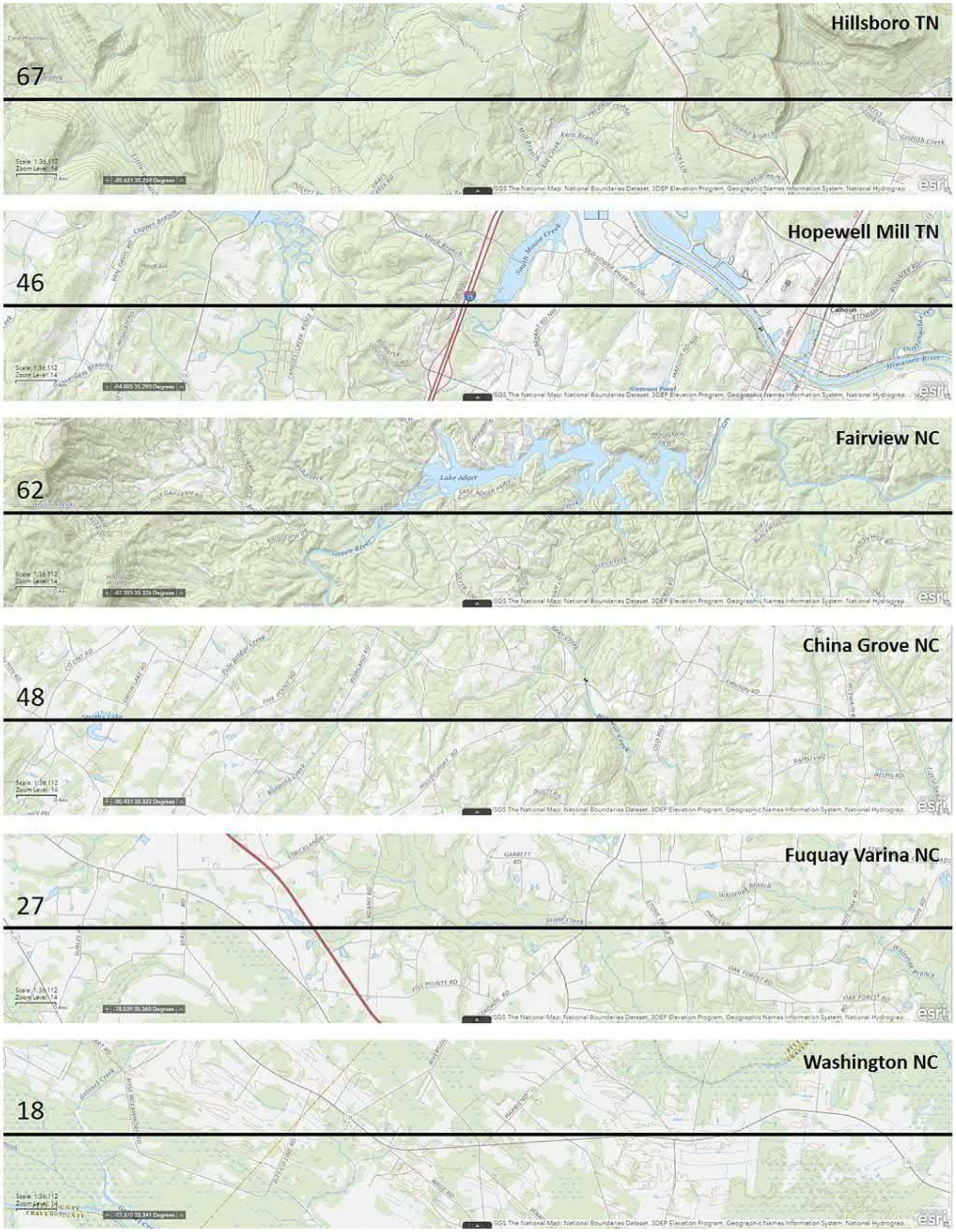

Figure 2.2 Cross-section maps every 100 miles across the Southeastern United States at ∼35°N latitude. Value at left in each panel indicates the number of times a 100′ elevation isoline is intersected in each image.

Carbon cycle and greenhouse gas emissions

The global C cycle can be partitioned into five major pools based on quantity of C stored ($Pg = 10^{15}$ g; 984 million English tons): oceanic (38,000 Pg), geologic (5000 Pg), pedologic (2500 Pg; composed of 1550 Pg in organic form and 950 Pg in carbonate form), atmospheric (760 Pg), and biotic (560 Pg) [2]. Soil organic C contains, therefore, 2−3 times the C as biotic and atmospheric pools. Soil organic C is the dominant storage pool in cropland and grasslands.

The terrestrial C cycle is dominated by two important fluxes: photosynthesis (net ecosystem uptake of carbon dioxide from the atmosphere) and respiration (release of C back to the atmosphere via plant, animal, and soil microbial respiration). Biochemical transformations occur at numerous stages in the C cycle, for example, simple sugars in plants are converted into complex C-containing compounds, animals consuming plants create bioactive proteins, and exposure of plant and animal residues to soil microorganisms and various environmental conditions creates humified soil organic matter complexes. Human intervention often results in the harvest of enormous quantities of C as food, fiber, fodder, and energy products. Additionally, unintended consequences of management can result in significant erosion of soil and leaching of nutrients.

Although carbon dioxide (CO_2) is the dominant greenhouse gas (due to its relatively high concentration in the atmosphere and magnitude of additional CO_2 being emitted to the atmosphere from land-use change and burning of fossil fuels), agriculture also emits two other important greenhouse gases, CH_4 and N_2O. Each of these three greenhouse gases has significant relevance for pasture-based livestock production systems in the Southeastern United States. In the United States, CO_2 in agriculture is accounted primarily as land-use change through its impact on soil organic C. Fossil fuels consumed in operating agricultural equipment are typically accounted in the energy and transportation sectors. Significant CO_2 sequestration (i.e., negative emissions) can occur as a result of plant uptake (i.e., photosynthesis) and storage of dead biomass in the soil as organic C. Ruminant livestock production is a very important contributor to CH_4 emissions. Agricultural soils (both croplands and grazing lands) are important contributors to N_2O emissions. All three greenhouse gases have been increasing during the past century, as a result of greater production and reliance on mechanization in agriculture (Fig. 2.3). As a sector, agriculture accounts for $\sim$9% of all greenhouse gas emissions in the United States (Fig. 2.4).

Sources of greenhouse gas emissions are often combined in calculations of C footprint or global warming potential in terms of CO_2 equivalence. These equivalencies are based on the reactivity of each gas over a specified time, most often during a 100-year period. Carbon dioxide is considered the reference gas because it is the most abundant greenhouse gas and has the lowest reactivity. One unit of CH_4 is equivalent

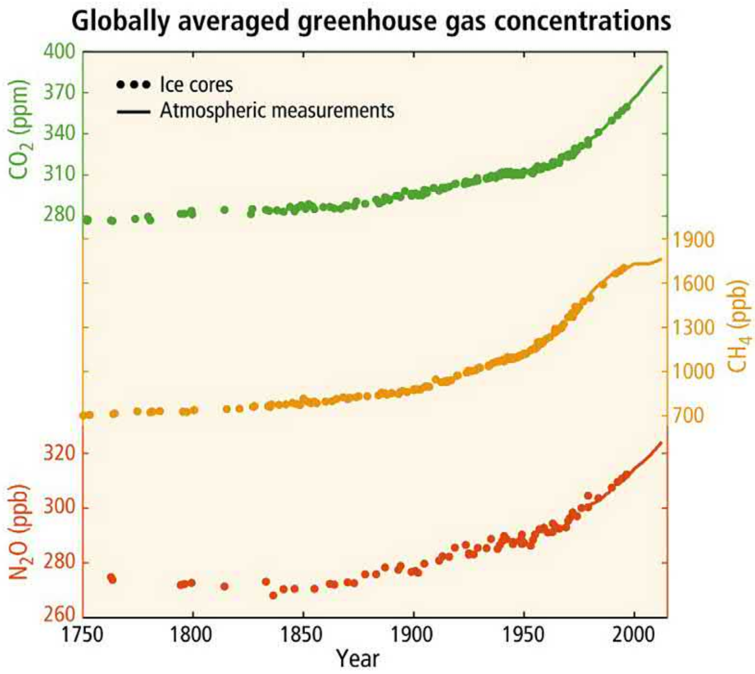

Figure 2.3 Atmospheric concentrations over time of three greenhouse gases of relevance in agriculture: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) [3].

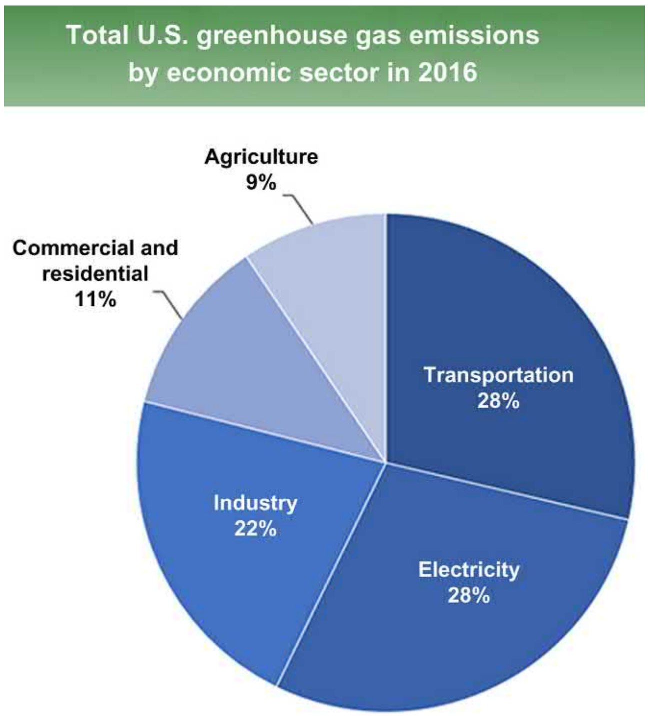

Figure 2.4 Sectoral contributions to total greenhouse gas emissions in the United States [4].

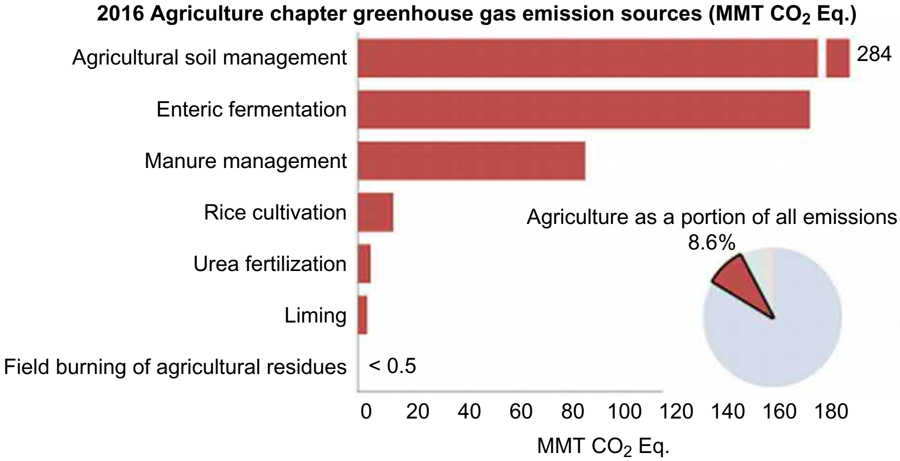

Figure 2.5 Sources of greenhouse gas emissions in US agriculture [4]. *Note*: 1 MMT CO_2 Eq. = 0.27 million English tons of CO_2-C equivalence.

to 25 units of CO_2. One unit of N_2O is equivalent to 298 units of CO_2 [5]. In the United States, agricultural greenhouse gas emissions of relative importance and their sources of emission are shown in Fig. 2.5.

Enteric methane emission

Globally, CH_4 emission contributes about 20% of the estimated human-induced greenhouse gas emissions, second behind CO_2 emission at 60% [6]. In 2011, the atmospheric concentration of CH_4 was 1803 ppb (parts per billion) [7], which was more than double the concentration of ~700 ppb in 1700 AD [8]. Global sources of CH_4 emission are livestock production, rice farming, waste decomposition (animal waste, crop residues, and landfills), and fossil fuel mining. Livestock sources of CH_4 emission (enteric and manure) account for 20%–34% of all global emissions of CH_4 [9,10] (Fig. 2.6).

Enteric CH_4 from livestock and emission of N_2O associated with N fertilizer application in agriculture are the largest contributors to agricultural greenhouse gas emissions (Fig. 2.5). Enteric CH_4 emission is a natural by-product from the activity of rumen microbiota that breaks down cellulose in forages. Variation in CH_4 emission from ruminant livestock (cattle, buffalo, sheep, goats, and camels) is controlled largely by feed intake and quality. Greater feed intake and/or lower feed quality leads to greater CH_4 emission. Larger animals generally have greater feed intake requirements. For average conditions in the United States, feed dry matter intake was estimated as 8.4 lb/day for calves (<500 lb live weight), 19.8–22.0 lb/day for growing steers and heifers (>500 lb live weight), 24.3 lb/day for mature beef cows, and 48.5 lb/day for

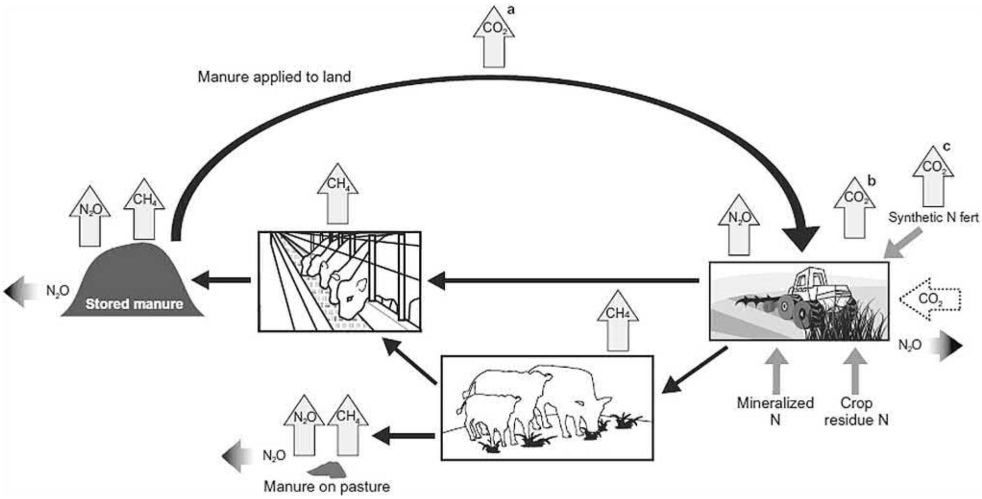

Figure 2.6 Components of the life-cycle assessment for beef production in southern Alberta. *From K.A. Beauchemin, H.H. Janzen, S.M. Little, T. McAllister, S.M. McGinn, Life cycle assessment of greenhouse gas emissions from beef production in western Canada: a case study, Agric. Syst. 103 (2010) 371–379.*

lactating dairy cows [11]. CH_4 production rates can be generalized as 0.008–0.013 lb CH_4/lb dry matter intake (0.055–0.089 lb CO_2-C_{equiv}/lb feed intake) for cattle on feed and 0.02 lb CH_4/lb dry matter intake (0.136 lb CO_2-C_{equiv}/lb feed intake) for pastured grazing conditions. In addition, consideration has to be given to growth rate of young livestock, as well as life stage and/or activity (e.g., lactation, wool growth of sheep, pregnancy, or workload). Enteric CH_4 emission from agriculture in the United States (102 billion lb CO_2-C_{equiv}) is dominated by beef production (71%), while dairy contributes 25% and swine (nonruminant CH_4 produced in the large intestine) contributes $<2\%$ [4].

A life-cycle assessment of beef production in western Canada has given some insights as to the relative proportion of greenhouse gas emissions derived from the cow–calf suckling/grazing period (typical stage of many operations in the Southeastern United States) to the growing phase on a high-grain diet in the feedlot [12]. The simulation was for a 120-head beef cow herd (1323 lb) with four bulls and calves fattened on the same farm in southern Alberta over an 8-year period. Cropland was available for producing grain, and native pasture was used for grazing. Suckling calves nursed and fed on either mixed hay or pasture when available. Calving rate was 85%, with birth in February-March and weaning in September. Weaned calves (530 lb) were fed a high-forage diet for 110 days [60% barley (*Hordeum vulgare* L.) silage and 40% barley grain] with an average daily gain of 2.2 lb/day. On reaching 770 lb, the diet was switched to 90% barley grain and 10% barley silage for 170 days to achieve an average daily gain of 3.2 lb/day. Slaughter occurred when cattle reached 1334 lb at 16 months of age. Greenhouse gas emission was 262 lb CO_2-C_{equiv}/brood cow/year. This equated to 3.6 lb CO_2-C_{equiv}/lb live weight and 5.9 lb CO_2-C_{equiv}/lb carcass weight. The cow–calf system accounted for 80% of total greenhouse gas emissions, and the feedlot system was 20%, which comprised 8% from backgrounding and 12% from finishing stages. Enteric CH_4 was 63% and N_2O from soil and manure was 27% of total greenhouse gas emissions. Of the enteric CH_4 emissions, 79% came from brood cows, 9% from finishers, 7% from backgrounders, 3% from bulls, and 2% from calves. The authors of this study suggested CH_4 emission reduction in the cow–calf component of production be targeted through dietary supplementation with oilseeds [13] and grains [14], greater use of grain-based forages [15] and forage legumes [16], and use of tannin-containing legumes [17]. Other mitigation options might be improving the reproductive performance of cows, reducing death loss of calves, and improving feed conversion efficiencies. The Canadian evaluation considered summer pasture at steady-state with respect to soil organic C, but significant soil organic C sequestration could significantly reduce net greenhouse gas emissions from cow–calf operations in the Southeastern United States [18].

In another study in southern Alberta, Canada, a spring-calving herd of 350 beef cows, 15 breeding bulls, 60 replacement heifers, and 112 steers were the basis for a comparison of whole-farm greenhouse emissions between calf-fed and yearling-fed production with and without growth implants [19]. Greenhouse gas emission intensity was 6.2 lb CO_2-C_{equiv}/lb carcass weight for calf-feeders (11–14 months of age) without growth implants and 5.8 lb CO_2-C_{equiv}/lb carcass weight with growth implants. Greenhouse gas emission intensity was 10.7 and 10.1 lb CO_2-C_{equiv}/lb carcass weight without and with growth implants, respectively, for yearling feeders (19–23 months of age). Other estimates of greenhouse gas emission intensity vary from 4.4 to 7.4 lb CO_2-C_{equiv}/lb carcass weight in Europe [20,21] and 12.0 lb CO_2-C_{equiv}/lb carcass weight in Brazil [22].

Greenhouse gas emissions estimate from a life-cycle assessment of beef production in the United States was generally the same as those evaluations in Canada at 5.9 lb CO_2-C_{equiv}/lb carcass weight [23]. In the United States simulation, cows weighed 1102 lb, and weaned calves backgrounded on forage for 5 months before entering the feedlot.

Greenhouse gas emissions from three different beef production strategies in the Midwestern USA were evaluated with a life-cycle assessment approach using 100 cows and three bulls with 90% calving rate and 15 replacement heifers [24]. After calf weaning, systems evaluated were: (1) direct placement into feedlot for finishing, (2) shipment to out-of-state wheat (*Triticum aestivum* L.) pasture backgrounding prior to the feedlot, and (3) backgrounding and finishing on pasture and hay on a farm. Total greenhouse gas emissions were 1575 lb CO_2-C_{equiv}/brood cow/year for the direct feedlot system, 2044 lb CO_2-C_{equiv}/brood cow/year for the wheat backgrounding system, and 1954 lb CO_2-C_{equiv}/brood cow/year for the pasture-finished system. Scaled to a finished calf, greenhouse gas emission was 4.0 lb CO_2-C_{equiv}/lb live weight for the direct feedlot system, 4.4 lb CO_2-C_{equiv}/lb live weight for the wheat backgrounding system, and 5.2 lb CO_2-C_{equiv}/lb live weight for the pasture-finished system. When significant soil organic C sequestration (357 lb C/acre/year) was factored into the pasture-finished system, greenhouse gas emission was reduced to 3.0 lb CO_2-C_{equiv}/lb live weight.

A life-cycle analysis of beef cattle production in Brazil illustrates the complexity of factors involved with system modifications [25]. Authors clearly state several limitations of assumptions, but the process of listing each line item in the analysis is informative. Rationalizing the assessment along a gradient of intensification allows stakeholders to find a suitable entry point. Table 2.1 outlines key inputs and outputs of significance in this analysis of beef production in Brazil. A similar gradient of management systems could, and should, be prepared for the United States, particularly for the Southeastern United States. Important points in this analysis are for reducing land area required to make better use of natural resources, improving the efficiency of feedstuff utilization to reduce enteric CH_4 emission, and limiting energy-intensive N fertilizers to reduce CO_2 and N_2O emissions and other water quality and landscape diversity problems.

Soil nitrous oxide emission

Global atmospheric N_2O concentration was 324 ppb in 2011, a value 20% greater than preindustrial concentration [7]. N_2O emission from agricultural soils is a function of soil inorganic N availability, which varies as a function of decomposition of soil organic matter, contributions of biological N fixation from legumes, and application of inorganic fertilizers and animal manures. Generally, soils with greater concentration of available nitrate have higher emission of N_2O due to denitrification (i.e., the utilization of nitrate by anaerobic bacteria as an energy source). The process of nitrification (i.e., conversion of ammonium to nitrate) during soil organic matter decomposition or transformation of ammonium fertilizers to nitrate in the soil can also lead to N_2O emission. Because agriculture is a large portion of the land area in the United States and because N fertilizers are often applied to agricultural lands, higher emission from agricultural soils occurs relative to nonagricultural lands. In addition, livestock manure management can affect emissions of CH_4 and N_2O. Concentrated manure generally leads to greater emissions than distributed manure systems. Animal manure is estimated to contribute 15% to the total agricultural greenhouse gas emission portfolio in the United States [4].

Table 2.1 Characteristics of five beef production scenarios along with a gradient of degradation improvement in Brazil [25].

Variable	**Degraded pasture**	**Moderate pasture**	**Improved pasture—continuous stocking, no TMR**	**Improved pasture—rotational stocking, no TMR**	**Improved pasture—rotational stocking, TMR finish**
Forage	*Urochloa* sp.	*Urochloa brizantha*	Mixed grass–legume (*U. brizantha*, *Stylosanthes*, *Arachis*)	Guinea grass (*Panicum maximum* cv. Tanzania)	Guinea grass (*Panicum maximum* cv. Tanzania)
Pasture management	Natural, no lime–fertilizer	Reseeded every 10 year, lime every 10 year, no fertilizer	Reseeded every 5 year, lime every 5 year, fertilized with P and K	Reseeded every 5 year, lime every 5 year, fertilized with N, P, and K	Reseeded every 5 year, lime every 5 year, fertilized with N, P, and K
Cattle breed	Undefined—mostly *Bos indicus*, some *B. taurus*	Mixed—Nellore with Gir, Guzerat, Holstein, Curraleiro, others	Nellore cross	Nellore cross	Nellore cross
Stocking rate	0.2 head/acre	0.4 head/acre	0.7 head/acre	1.0 head/acre	1.1 head/acre
Breed characteristics	Late first calf, high mortality, slaughtered 3–4 years of age	First calf at 3 years, more calves per cow, less mortality, finished earlier	First calf at 2 years, more calves per cow, less mortality, finished earlier	First calf at 2 years, more calves per cow, less mortality, finished earlier	First calf at 2 years, more calves per cow, less mortality, finished earlier
Diet at calving	Pasture only	Pasture with occasional supplement	Pasture with mineral supplement	Pasture with mineral supplement	Pasture with mineral supplement

Diet at rearing	Pasture only	Pasture with occasional supplement	Pasture with mineral supplement	Rotational grazing, pasture with mineral supplement	Rotational grazing, pasture with mineral supplement
Diet at finishing	Pasture only	Pasture with occasional supplement	Pasture with mineral and energy supplements	Rotational grazing, pasture with mineral, protein, and energy supplements	Confinement with total mixed ration feed
Animal management	Minimal, random breeding, compulsory vaccinations	Basic, random breeding, compulsory vaccinations	Breeding season, controlled weaning, parasite controls	Breeding season, controlled weaning, parasite controls	Breeding season, controlled weaning, parasite controls
Performance documentation	Minimal	Management indicators	Individual ID, calving number and date, gain recorded	Individual ID, calving number and date, gain recorded	Individual ID, calving number and date, gain related to specific grazing area
Diet digestibility	49%	56%	60%	63%	63%–70%
Pregnancy rate	60%	65%	75%	75%	75%
Carcass weight	441–507 lb	463–529 lb	485–551 lb	485–551 lb	518–584 lb
Weaning weight	309–353 lb	342–375 lb	375–408 lb	375–408 lb	375–408 lb
Finishing gain	0.7–0.9 lb/day	1.1–1.3 lb/day	1.3–1.7 lb/day	1.6–2.0 lb/day	2.6–3.3 lb/day
Carcass yield	28 lb/acre	67 lb/acre	125 lb/acre	180 lb/acre	198 lb/acre
CH_4 emission (lb CO_2-C_{equiv}/lb carcass)	15.3	10.2	6.8	5.7	5.0
N_2O emission (lb CO_2-C_{equiv}/lb carcass)	0.7	0.9	1.1	2.6	2.4
C footprint (lb CO_2-C_{equiv}/lb carcass)	15.9	11.2	8.1	8.8	8.1

Land use has a significant effect on soil N_2O emissions. In a review of N_2O emissions from agricultural systems in North America, annual emissions were 3−7 lb N_2O-N/acre/year [26]. Grassland systems generally had lower N_2O emission (0.5 ± 1.3 lb N_2O-N/acre/year) than cropland systems (3.4 ± 7.2 lb N_2O-N/acre/year) in the northwestern USA, and the agricultural systems had similar differences in the northeastern USA (1.1 ± 1.3 lb N_2O-N/acre/year in grasslands and 3.3 ± 5.4 lb N_2O-N/acre/year in croplands). In a review of studies in eastern Canada, soil N_2O emission averaged 1.4 ± 0.9 lb N_2O-N/acre/year in cropland without N fertilizer applied, 4.5 ± 7.0 lb N_2O-N/acre/year in cropland with N fertilizer application, 0.1 ± 0.2 lb N_2O-N/acre/year in perennial grass without N fertilizer applied, and 0.6 ± 1.0 lb N_2O-N/acre/year in perennial grass with N fertilizer application [27]. In this same review, soil N_2O emission from alfalfa (*Medicago sativa* L.) forage stands was 2.1 ± 1.0 lb N_2O-N/acre/year as compared with 1.9 ± 1.1 lb N_2O-N/acre/year when cropped to soybean [*Glycine max* (L.) Merr.].

From a temperate site in northern Japan (47°F mean annual temperature and 49″ mean annual precipitation), soil N_2O emission from a >30-year-old grassland [reed canary grass (*Phalaris arundinacea*), meadow foxtail (*Alopecurus pratensis*), and timothy (*Phleum pretense*)] averaged 0.5 ± 0.1 lb N_2O-N/acre/year without N fertilization [28]. When the grassland was converted to corn (*Zea mays* L.) production for 3 years, soil N_2O emission was 4.0 ± 1.1 lb N_2O-N/acre/year when unfertilized, 11.3 ± 4.7 lb N_2O-N/acre/year when fertilized inorganically, and 13.4 ± 6.8 lb N_2O-N/acre/year when fertilized with a combination of inorganic and manure fertilizers. During a third phase when new grassland was re-established, soil N_2O emission was 2.9 ± 2.1 lb N_2O-N/acre/year without N fertilizer, 4.0 ± 2.5 lb N_2O-N/acre/year with inorganic N fertilizer, 5.0 ± 6.0 lb N_2O-N/acre/year with manure as fertilizer, and 4.9 ± 4.4 lb N_2O-N/acre/year with a combination of inorganic and manure fertilizer application. This study illustrated that long-term pastures can reduce N_2O emissions and that if N fertilizer inputs can be kept reasonably low to only stimulate forage growth and not lead to accumulation of excess N, then periodic rejuvenation of pastures with cropping and re-establishment of desirable species will mitigate against N_2O emissions. Prediction of soil N availability when a pasture is rejuvenated would be particularly helpful to reduce soil N_2O emission, and there is potential for achieving this with a simple test of soil biological activity [29].

Results from other regions clearly show that grass and forage lands generally have reduced levels of N_2O emission compared with croplands, but the magnitude of the effect is dependent on the extent of N supplied to the grassland system. We do not know if the warm/humid climate and/or soil type and management characteristics of the Southeastern United States might offer other unique opportunities to either further reduce N_2O emission or even enhance N_2O emission. Therefore additional field research is needed in the region to characterize how the diversity of pasture conditions might contribute to N_2O emissions.

Grazing impacts

> ***Improved grazing management is needed to maintain pasture at the highest forage quality possible under the existing environmental constraints and convert it into saleable animal product. Beef pasture systems research is needed to identify problem areas, develop efficient year-around systems and predict future opportunities.***
>
> **Carl S. Hoveland (1986)**

Grazing livestock have a key role in greenhouse gas emissions from pastures because livestock defoliate vegetation, return excreta to the soil, and cause mechanical disturbance of the pasture sward. Ruminants emit CO_2 from their metabolic activity and CH_4 from enteric fermentation [30]. Unfortunately, very few greenhouse gas emission data are specifically available from the Southeastern United States to fully determine the impacts of pastureland grazing in the region on this important environmental topic. We must rely on greenhouse gas emission data from other regions to infer generalities. Grazing management in the region varies from continuous stocking of pastures with cow—calf pairs to different levels of intensity of rotational stocking during the primary growing seasons of spring-summer-fall to strip grazing of stockpiled forage in the winter. Botanical composition of pastures will determine how intensively pastures can be grazed and how frequently stock are moved. All of these livestock management decisions might affect the balance of greenhouse gas emissions on a particular soil type within a landscape.

At an upland semi-natural grassland site on a silt loam soil in France (45° 38′ N, 2° 44′ E, 3466′ elevation), a 16-acre field that received 47″ of precipitation per year was divided in half to determine the impacts of intensive grazing management (inorganic N fertilizer applied at 128 ± 49 lb N/acre, grazed to 2″ height, 0.4—0.5 head/acre) compared with extensive grazing management (no N fertilizer, 0.2 head/acre) [31]. In this 3-year study, cows weighing 1012 ± 130 lb gained 226 ± 7 lb in the intensively managed pasture and gained 234 ± 61 lb in the extensively managed pasture. Net ecosystem exchange of CO_2 (the net flux of CO_2 from the soil—plant ecosystem to the atmosphere) was always negative during the growing season, reflecting the strong uptake of CO_2 from the atmosphere to the accumulating plant biomass. However, during the winter period net CO_2 was released to the atmosphere. Gross primary productivity (i.e., plant CO_2 uptake) was $14,232 \pm 1043$ lb CO_2-C/acre/year under intensively managed pasture and $13,521 \pm 1397$ lb CO_2-C/acre/year under extensively managed pasture, while total ecosystem respiration (i.e., plant and soil CO_2 release) was $13,351 \pm 1382$ lb CO_2-C/acre/year under intensively managed pasture and 12,854 ± 1120 lb CO_2-C/acre/year. On balance over the years, net CO_2 sequestration occurred and was 881 ± 472 lb CO_2-C/acre/year under intensively managed pasture and 670 ± 294 lb CO_2-C/acre/year under extensively managed pasture. CH_4 emissions from ruminant enteric fermentation ranged from 0.36 to 0.52 lb CH_4/head/day in both systems, and because of the greater stocking density was greater in the intensively managed pasture (729 ± 76 lb CO_2-C_{equiv}/acre/year) than in the extensively managed pasture (376 ± 31 lb CO_2-C_{equiv}/acre/year). Soil CH_4 emission was negligible in both pastures but soil N_2O emission was greater in the intensively managed pasture (65 ± 29 lb CO_2-C_{equiv}/acre/year) than in the extensively managed pasture (15 ± 10 lb CO_2-C_{equiv}/acre/year). When summing all greenhouse gas emissions/sequestration components (net ecosystem exchange, enteric emission, and soil CH_4 and N_2O emissions), net C sequestration was 87 ± 435 lb CO_2-C_{equiv}/acre/year under intensively managed pasture and 278 ± 278 lb CO_2-C_{equiv}/acre/year under extensively managed pasture. Calculated per unit of cattle weight gain, net C sequestration was 0.1 ± 2.4 lb CO_2-C_{equiv}/lb live-weight gain/year under intensively managed pasture and 3.6 ± 4.3 lb CO_2-C_{equiv}/lb live-weight gain/year under extensively managed pasture. This study illustrated that grazing management systems can be C neutral or small sinks for atmospheric CO_2 if soil organic matter has not reached steady-state status. Therefore, a research focus on soil organic C changes with different pasture management approaches in the Southeastern United States is warranted to account for all significant offsets to enteric CH_4 emission from livestock.

Across a diversity of pasture types at nine locations throughout Europe, net ecosystem exchange of CO_2 from soil to the atmosphere was −2110 ± 1350 lb CO_2-C/acre/year [32]. Soil N_2O emission was 119 ± 181 lb CO_2-C_{equiv}/acre/year. Enteric CH_4 emission was 368 ± 220 lb CO_2-C_{equiv}/acre/year. Across sites, net C sequestration was calculated, but there was a large variation among sites and years (1795 ± 1448 lb CO_2-C_{equiv}/acre/year). Accounting for off-site CO_2 and CH_4 emissions from exported forage and imported manure in some systems, net C sequestration was reduced to 759 ± 1442 lb CO_2-C_{equiv}/acre/year.

On semi-natural pasture in France, enteric CH_4 emission was not different during either of 2 years between low (447 lb live weight/acre; 0.44 head/acre) and high (893 lb live weight/acre; 0.89 head/acre) stocking rate [33]. Enteric CH_4 emission was 3.3 ± 0.3 lb CO_2-C_{equiv}/day. CH_4 emission per unit of digestible organic matter intake was 1.2 ± 0.3 times greater with low than with high stocking rate. These data support an approach of estimating CH_4 emissions based on stocking density, although nutritive value could be a potentially important modifier.

Animal traffic on pastures during wet periods, particularly in the winter when pastures remain consistently wet and forage regrowth is slow or nil could cause significant poaching of the surface soil. This leads to compaction, poor water infiltration, saturated soil conditions, mixing of organic-rich surface residues and dung with mineral soil to create ideal conditions for excess N to undergo denitrification with available C, and subsequently high levels of N_2O emission [34]. Denitrification requires soluble C as the energy source, low O_2 levels (caused either by water saturation or consumption of O_2 by high microbial activity), and nitrate as electron acceptor. Enriched surface soil organic C under pastures may either build soil structure to keep the soil well aerated when animal traffic is optimized, or it could also contribute to denitrifying conditions when animal traffic is excessive during wet periods and soil can be molded. Therefore, stocking density and pasture management via N fertilization practices can have large roles to play in controlling N_2O emissions. To develop environmentally sound pasture management systems in the Southeastern United States region, we need more soil N_2O emission data under different grazing conditions from a diversity of pasture types.

Dung and urine deposition onto pastures by grazing cattle provide local hotspots of C and N that can stimulate both CH_4 and N_2O emissions. Large spatial variation in N_2O emission has been observed in pastures due to excrement deposition [35,36]. Emission of N_2O from dung and urine deposition was investigated on Russell River grass (*Paspalum paniculatum* L.) in subtropical Brazil [37]. Peaks of N_2O emission occurred 17 ± 9 days after deposition for both dung and urine, but the peak of soil ammonium occurred one day after urine deposition and 10−14 days after dung deposition. The peak of soil nitrate occurred 19−50 days after deposition of dung and 23−26 days after deposition of urine. Emission factor of dung was 0.1%−0.2% of applied N and emission factor of urine was 0.2%−0.3% of applied N, both of which are considerably lower than IPCC default value of 2%. These results suggest that warm−moist environments may not have as high of N_2O emission from livestock excreta as in colder−drier environments.

Fertilization impacts

Nutrient availability in pastures of the Southeastern United States can be greatly limited due to a variety of factors. Kaolinitic clays and poorly crystalline iron and aluminum oxides of many Ultisols in the region limit P availability. High overall precipitation, periods of drought due to low water-holding capacity of sandy soils, and intensive storms that cause runoff and leaching create frequent opportunities for nutrients (primarily N, but also base cations) to wash away if managed solely in inorganic form. However, a resilient feature of mature pastures can be the quantity and quality of organic matter that becomes stored in the surface 6″ of soil [18]. With 58% of soil organic matter composed of C as the main constituent, retention of other nutrients in this organic phase becomes highly dependent on the cycling of organic C in soil under pastures [38]. Soil organic C is maintained and increased in perennial pastures primarily through root and surface residue contributions, which ultimately are controlled by forage mass development and frequency of removal and/or cycling from plant to animal to soil via excretion.

N_2O emission from soil is highly variable in space and time, irrespective of the agricultural system [39,40]. The quantity of N applied at any one time and cumulative throughout the year, as well as the source of N and its time of application on pasture are likely to affect N_2O emissions. High nitrate availability in soil leads to high N_2O emissions. Saturated soil conditions can promote N_2O emissions, especially if soluble C is available during rapid decomposition conditions when the temperature is high. Soluble C and fast N mineralization following animal manure application (e.g., poultry litter and dairy or swine effluent) or deposition of dung and urine can lead to ephemeral, but intensive peaks in N_2O emission [41].

In a review of studies under ungrazed pasture conditions in Arkansas, Michigan, and Missouri, soil N_2O emission ranged from 0.0008 to 0.0069 lb N_2O-N/acre/day (extrapolated to 137−1175 lb CO_2-C_{equiv}/acre/year) [42]. Application of poultry manure to a bermudagrass (*Cynodon dactylon* L.) pasture in Arkansas caused a 45% increase in soil N_2O emission over an unfertilized pasture [43]. Over-seeding the bermudagrass pasture with ryegrass (*Lolium multiflorum* L.) in winter effectively took up the available nitrate from poultry manure application and reduced N_2O emission.

Soil N_2O emission was determined from a perennial ryegrass/white clover (*Trifolium repens* L.) grassland in Scotland (33.5″, mean monthly temperature of 39°F in January and 56°F in July) when different sources of N were applied [44]. Fertilization with different sources of inorganic and organic N was applied at 0 and 134 lb available N/acre during April and again in June for two successive years. As a percent of applied N, N_2O emission factor was 1.4 and 0.1 with ammonium nitrate fertilizer in Year 1 and Year 2, respectively. Values were 0.4 and 0.1 with urea, 4.3 and 1.3 with sewage sludge pellets, 0.5 and 0.2 with cattle slurry, and 2.6 and 0.5 with poultry manure. On average, N_2O emission factor was 1.1%, nearly the same as a standard IPCC emission factor of 1.25% for N fertilizers, although considerable variation occurred among sources and years. Dry matter yield of forage was 2.1 ± 0.3 times greater with inorganic N fertilizer sources than without N fertilizer, and organic sources of N were equally effective as inorganic sources. In the year following the last application of N fertilizer sources, dry matter yield when previous fertilized with inorganic N sources was only 0.9 ± 0.2 that of the unfertilized treatment. The organic sources of N had significant carryover to the year following fertilization with 1.3 ± 0.1 times greater dry matter yield than the unfertilized treatment. The effectiveness of the applied N fertilizer in this study resulted in 15 ± 4 lb forage dry matter per pound of N applied. It is very likely that N fertilizer applied at half the full rate in this study could have had nearly twice the effectiveness (e.g., 25 lb forage per pound N) without greatly affecting yield production. This greater efficiency could have also reduced the N_2O emission factor considerably, but such interpretation remains to be explored.

A new soil testing process is emerging that may offer farmers a quick and accurate estimation of the amount of N mineralized from soil organic matter [29]. Yield response to fall-applied N fertilizer was shown to be an inverse function of soil test biological activity, whereby soils with high biological activity (i.e., high net N mineralization supply) provide sufficient soil-derived N to growing forage.

On a temperate grassland in Japan, soil N_2O emission over 5 years of study was not different between inorganic N fertilizer only (1.9 ± 0.7 lb N_2O-N/acre/year) and when fertilized with a combination of inorganic N and animal manure (2.3 ± 1.5 lb N_2O-N/acre/year) [28]. Inorganic fertilizer was applied at 105 ± 47 lb N fertilizer/acre, and composted beef cattle manure was applied at 303 ± 80 lb N/acre (along with 51 ± 61 lb N fertilizer/acre). Both N addition treatments resulted in greater N_2O emission than from unfertilized grassland (0.5 ± 0.1 lb N_2O-N/acre/year).

Some data on greenhouse gas emissions are available in Kentucky with different fertilizer sources, and although applied to no-tillage corn, these data could serve as a guide to what might be expected in some pasture conditions in the region. Swine effluent at 5231−6704 gallons/acre to achieve 180 lb N/acre was applied for 2 years on a silt loam in Kentucky [45]. Soil N_2O emission from April to September was lowest without N fertilizer application (0.9 lb N_2O-N/acre) and was greatest in treatments receiving swine effluent (3.3 ± 0.4 lb N_2O-N/acre) and urea fertilizer to supply similar plant available N as with manure (3.0 lb N_2O-N/acre). Injection or aeration along with swine effluent had no major impact on soil N_2O emissions. In contrast, injection of the swine effluent greatly enhanced CH_4 emission (118 lb CO_2-C_{equiv}/acre) compared with aerating the soil surface following surface swine effluent application (33 lb CO_2-C_{equiv}/acre) and simply applying swine effluent without disturbance (16 lb CO_2-C_{equiv}/acre). In another 2-year study of different sources of N on no-tillage corn in Kentucky, unfertilized soil had the lowest soil N_2O emission (1.0 lb N_2O-N/acre) from April to September, and application of poultry litter had the highest (7.4 lb N_2O-N/acre) [46]. Various formulations of inorganic N fertilizer led to intermediate levels of emission of 2.8 ± 0.8 lb N_2O-N/acre, and urease inhibitors and polymer coatings tended to provide only a minor reduction in soil N_2O emission.

Silvopasture management impacts

Microclimate moderation in the summer with trees in pastures could significantly alleviate heat stress for grazing livestock [47]. Heat-stressed cattle can have reduced forage intake and poor performance. Few data are available to quantitatively estimate the impact of tree shade on livestock performance and subsequent enteric CH_4 emission. Shading of the soil surface could also impact soil N_2O emission, as well as alter the geospatial distribution of feces and urine in a pasture, which could affect emissions. In fact, cattle were more evenly distributed during the summer in a 20-year-old loblolly pine (*Pinus taeda* L.) silvopasture with bahiagrass (*Paspalum notatum* Fluegge) than in an adjacent open bahiagrass pasture in Florida [47]. Cattle excrement deposited under the canopy of trees, which are not typically fertilized, could help avoid oft-observed stimulation of N_2O emission with dung and urine deposition. Quantitative data are lacking to test this hypothesis for affecting system-level mitigation of greenhouse gases.

In a young silvopasture in Missouri, 30′ alleys between lines of trees [single-, double-, and triple-row lines of either pitch pine (*Pinus rigida* Mill.) × loblolly pine hybrids or black walnut (*Juglans nigra* L.)] were planted in the fall to a ryegrass/cereal rye (*Secale cereal* L.) mixture for livestock grazing in the spring [48]. Heifers (500 ± 50 lb) rotationally grazed the silvopasture and open pastures of the same forage mixture to 3—4″ stubble height from March to June in 2 years. Forage production was 21%—36% lower in the tree pasture than in the open pasture, likely due to differences in light penetration and warming of the canopy. Crude protein of forage in the tree pasture became progressively higher later in the spring than in the open pasture, which helped to overcome reduced forage production. Average daily gain was not different between pasture types (1.7 lb/day), but total gain tended to be lower in tree pasture (371 lb/acre) than in the open pasture (443 lb/acre), and animal grazing days were lower in tree pasture (226 head-days/acre) than in open pasture (266 head-days/acre). Although not measured, greater nutritive value may have reduced enteric CH_4 emission from cattle, but reduced gain may have counter-acted this effect.

In a silvopasture system in Brazil, dry matter intake of dairy cows did not vary between tree and open pastures (25 ± 2 lb/cow/day), but crude protein tended to be greater in tree pasture than in open pasture [49]. By reducing solar incidence by 21% in the silvopasture, cattle spent more idle time than in open pasture. Legume persistence was a key factor in creating favorable forage characteristics for this heat-stressful tropical environment. In another silvopasture system in Brazil, forage production was reduced by 22% with tree-legume silvopastures compared with open pastures [50]. However, the nutritive value of forage and cattle performance and gain per acre were unaffected whether forage was grown with or without trees.

In an alley-cropping system in the Coastal Plain of North Carolina, soil N_2O emission was greatly reduced under the canopy of trees [loblolly pine, longleaf pine (*Pinus palustris* Mill.), and cherrybark oak (*Quercus pagoda* Raf.)] compared with alleys of annual ryegrass [51]. This occurred partly due to fertilization of forage, but also likely due to reduced soil temperature and water conditions during much of the year under the canopy of trees. A strong soil textural effect was observed for N_2O emission, in which ryegrass grown on clayey parts of the landscape emitted far greater N_2O than forage grown on sandier sections of the landscape. Overall soil N_2O emission under annual forage production was of similar magnitude (1.1 ± 0.4 lb N_2O-N/acre/year) as from studies in other regions [27,42].

Pasture–crop rotation impacts

In many areas, integrated production of grain and oilseed crops with cattle from pastures may offer long-term benefits of reduced soil erosion and better watershed management, in addition to the sale of commodities.

Carl S. Hoveland (1986)

Rotation of pastureland with cropland is not currently a widespread management practice in the United States, but it has been historically practiced as a means to restore soil fertility and capture the benefits of diversity on the farm. Traditionally, 2- to 7-year-old pastures were plowed and land devoted to crop production for 2–7 years. In modern agricultural practice the land would not have to be physically plowed but could be sprayed or smothered to terminate perennial forages. Preservation of surface soil organic C without tillage would be recommended to maintain the integrity of soil pores and keep soil biologically diverse and active. However, the impact on greenhouse gas emissions of alternating low and high soil organic C with plow-tillage or of stabilized and increasing soil organic C with no-tillage has not received much attention. Recently, more research has focused on short-term pasture–crop rotations via cover cropping following annual cash crops, for example, grazing winter cover crops following corn or soybean.

In a tropical environment in Brazil, soil N_2O emission was greater in a corn–silage system with grazing of a fertilized cover crop (54 lb N/acre) than in a traditional system using unfertilized ryegrass as an ungrazed cover crop (3.8 vs 1.1 lb N_2O-N/acre/year) [52]. Application of N fertilizer to the grazed annual ryegrass contributed significantly, but N_2O emission was also greater immediately following N application to corn in the system with grazed cover crop than the system without grazing (0.039 vs 0.028 lb N_2O-N/acre/day). Authors estimated that 2.1 of the 3.8 lb N_2O/acre/year were derived from excreta. Calculated per ton of forage produced, greenhouse gas emission intensity was 7.8 and 4.9 lb CO_2-C_{equiv}/ton in the integrated crop–livestock system and grain only system, respectively.

In a tropical environment in Brazil, net C sequestration occurred in a 2-year soybean/oat (*Avena strigosa* Schreb.)-*Urochloa* pasture (353 lb CO_2-C_{equiv}/acre/year), while net C emission occurred in both a conventionally tilled soybean/oat system (60 lb CO_2-C_{equiv}/acre/year) and a no-till soybean/oat-turnip (*Brassica rapa* L.) cover-corn/wheat system (70 lb CO_2-C_{equiv}/acre/year) [53]. Soil N_2O emission was slightly lower in the integrated crop–livestock system than in the cropping only systems. Soil organic C accumulation in the integrated crop–livestock system was the dominant factor for net change in the greenhouse gas footprint.

In an analysis of farming systems in Brazil, degraded *Urochloa* pastures without inputs that supported <50 lb cattle gain/acre/year had cumulative greenhouse gas emissions of 195 lb CO_2-C_{equiv}/acre/year, while improved pastures with fertilizer inputs supporting 1.5−1.9 lb gain/day had emission of 2059 lb CO_2-C_{equiv}/acre/year, and an integrated crop−livestock−forestry system with Eucalyptus (*Eucalyptus globus* Labill.) had emission of 1571 lb CO_2-C_{equiv}/acre/year [54]. Scaled per unit of liveweight gained and all other C emissions/sequestration accounted, C footprint was 0.5 lb CO_2-C_{equiv}/acre/year for degraded pasture, 0.2 lb CO_2-C_{equiv}/acre/year for improved pasture, and −0.7 lb CO_2-C_{equiv}/acre/year for the integrated crop−livestock−forestry system. Net C uptake in the integrated system was due to C sequestration in *Eucalyptus* wood and soil organic matter.

Many environmental and production benefits can be harvested from integration of crops and livestock [55], but significant trade-offs from labor, management intensity, and government support programs may be hindering adoption. The lack of fundamental data to support or refute such systems is a serious limitation at this time. However, this is an area of much-needed research to formulate pathways toward greater sustainability with livestock production systems in the future.

Summary and recommendations

Pasture-based beef production systems in the Southeastern United States have significant greenhouse gas/C footprint implications. Although region-specific data are mostly lacking for many components of the production system, information from other parts of the country and world give some insights into the likely trajectories of greenhouse gas emissions that are dependent on management choices. Enteric CH_4 emission appears to be an unavoidable consequence of ruminant livestock production, but the magnitude of its emission can be controlled by feed intake and quality. Providing high nutritive value forages allows young livestock to mature at a faster pace, and this reduces carcass-specific CH_4 emission intensity. Maintaining a high conception rate and avoiding debilitating health issues in the brood herd is essential to increase efficiency of forage supply and its effect on greenhouse gas emissions. Offering forages with secondary metabolites to reduce CH4 emission may be a fruitful strategy, but more research is needed to understand its role in the region. Therefore new research into alternative forages is warranted.

Soil N_2O emission is typically a function of soil N availability, and therefore, application of the right amount of N fertilizer at the right time with the right source is key to reducing this potent greenhouse gas. Utilizing more on-farm N resources and understanding how to predict N availability will be important attributes of sustainable pasture management approaches. Grazing returns much of the N ingested in forages back to the land in animal excreta, so getting more uniform distribution on the landscape is critical to avoid nutrient accumulation zones that can lead to high N_2O emissions. We need more research on spatial distribution patterns in different grazing systems and landscape-specific conditions. Quantifying soil N supply to avoid over-fertilization and linking N supply to estimates of soil N_2O emission are needed for major physiographic zones in the region.

The relatively small size and the close proximity of pastures with neighboring woodlands and suburban developments present numerous opportunities for understanding landscape-specific effects on cattle behavior and their contribution to greenhouse gas emissions. Making effective utilization of locally sourced feedstuffs could reduce waste streams and create greater nutrient cycling. In addition, pastures have an inherent capacity to absorb nutrients from a wide spectrum of organic sources, so they can be viewed as filters for local communities. For example, many farmers utilize municipal solid waste on pastures, as well as poultry and swine waste from on-farm or neighboring farms. Accounting for greenhouse gas emissions in livestock production systems and documenting the positive and negative aspects of production system components could lead to stronger public support of this neo-agrarian lifestyle throughout the region. Good neighbors are to be appreciated!

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CHAPTER 3

Maintaining soil fertility and health for sustainable pastures

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Soil fertility programs for pastures

> ***The ultimate goal of a pasture fertility program is animal feed for the most economical production of meat or milk. It is unwise to try a maximum fertility program on a large scale until the grower has had sufficient experience to know that he/she can efficiently utilize the quantity and quality of feed produced.***
>
> **W.G. Blue**

Importance

Soil fertility management is one of the most important decisions that can affect pasture productivity and sustainability. Most pastures in the Southeastern United States are established on marginal areas usually associated with poor soil fertility conditions (i.e., low nutrient availability, acidic pH, limited nutrient, and water holding capacity). These soils often contain insufficient amounts of one or more essential plant nutrients which results in decreased forage production and overall pasture performance. Therefore, sustainability of productive perennial forage systems in the Southeastern United States depends, to a major extent, on well-planned, environmentally and economically sound soil fertility programs. Ideally, pasture fertilization strategies should be aimed at balancing production (including the amount and nutritive value of the forage produced) and nutritional requirement of ruminant animals. However, in most circumstances, fertilization represents the costliest input and it is often absent or limited to N application. This "minimum input" approach may not supply adequate amounts of nutrients to replace those removed with harvested forage, and consequently, may result in inadequate forage performance, stand degradation through loss of desirable species coverage, weed encroachment, an increase in bare area, and an overall reduction in soil health conditions.

The combination of low soil nutrient availability, efficient nutrient uptake by most forage species, and relatively high-yield potential create favorable conditions for obtaining positive responses to pasture fertilization. However, the fate of nutrients

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applied through pasture fertilization is extremely complex and is affected by several factors including application rate and timing, fertilizer source, and soil and environmental conditions. The key is to consider all the factors that affect fertilizer efficiency to achieve sustainable forage production while protecting the environment.

Environmental concerns associated with pasture fertilization

Pasture fertilization is a vital component of modern agriculture; however, it has the potential to induce eutrophication in surface waters. As nutrients accumulate in soils in response to excessive fertilizer, animal manure, or municipal waste application, nutrients (particularly N and P) may become susceptible to transport via surface runoff and subsurface leaching. Pasture fertilization continues to be a controversial and a topic of agronomic and environmental importance in various agricultural production systems. For decades, pasture fertility management was focused primarily on the agronomic aspects of crop and livestock production. However, because of growing concerns over accelerated water degradation through excessive nutrient input, current pasture fertilization strategies are generally aimed at balancing agronomic requirements, economic returns, and the risks of nutrient transport to surface water and groundwater.

Repeated application of fertilizers or organic amendments can result in excess nutrient input in the soil and subsequent transport to surface waters. In most freshwater systems, primary productivity is limited by inadequate levels of nutrients, primarily N and P. External nutrient inputs from surface runoff and groundwater discharge can dramatically increase N and P status of natural waters; thus, stimulating biological productivity and causing a general degradation of water quality. This phenomenon of nutrient enrichment in the aquatic system, also known as *eutrophication*, has been identified as the major cause of surface water impairment in the United States [1]. In addition to drinking water quality issues, eutrophication can also negatively affect algae, aquatic plant diversity and productivity, and water use for recreation and fisheries.

As livestock production continues to modernize and intensify, public concerns will increase the impacts of plant nutrients and organic contaminants on environmental quality. Best management practices that mandate reduced nutrient inputs will continue to be the main focus of water restoration programs and regulatory agencies in the Southeastern United States. Thus, cost-effective nutrient management strategies that optimize yields while protecting water quality are critical for the success of sustainable beef cattle operations in this region.

In addition to potential environmental problems, the increasing cost of commercial fertilizers has also prompted the need to reexamine optimum fertilizer application levels, sources, and methods of application that can sustain economic pasture productivity. In many regions, pasture fertilization represents the most expensive cost in beef cattle production and is often not a priority for beef cattle producers. However, lack of proper soil fertility management can reduce forage yields and have important economic implications for the profitability of livestock production operations [2]. Inadequate soil fertility management can, for instance, increase the cost associated with extra animal feed needed to overcome the unsatisfactory forage yields and nutritive value. Although the target or goals of production vary depending on a number of factors such as forage utilization (hay vs stocking), desired stocking rate, and animal category (cow—calf and/or stocker), the choice and selection of fertilizer source, application level, and frequency are often governed by availability and cost of product. Fertilization strategies are therefore driven mainly by production for a targeted dry matter response and by the need to sustain the pasture system.

Fertility management for harvested versus grazed pastures

Fertility management of warm-season grasses depends on the goals and objectives of production and costs of fertilizer. Harvested forages including hay, green chop, silage, and grain crop residue have similar fertility management as row crops. Because the majority of the crop residue is exported with the harvested forage, large nutrient removal rates occur in these systems, and relatively high fertilizer inputs are often necessary to maintain forage productivity. Nutrient removal rates vary considerably depending on the soil nutrient availability, crop species, stage of maturity, harvest procedure, and the number of harvests.

In grazing systems, a large proportion of nutrients is returned to the soil via animal excreta. Therefore, grazing management can have significant impacts on soil fertility status. Significant amounts of N, P, K, Ca, Mg, and micronutrients can be recycled to the soil via animal feces and urine deposition. An estimated 60%—99% of the P and K ingested returns to the soil through animal excreta [3,4]. Similarly, only 5%—30% of ingested N is used by livestock for meat and milk production [5]. Therefore, fertilizer requirements of grazed pastures can be considerably lower than in harvested forage systems. However, because grazing animals tend to defecate and urinate near water, shade, and feeding areas, excreted minerals are not evenly distributed across the landscape which imposes a major challenge. The unequal distribution of nutrients is not only undesirable in terms of forage management, but it may also result in environmental problems due to high concentration of nutrients in small areas.

Grazing management is important for improving nutrient distribution and availability in grazed pastures [4,6]. Rotational stocking with short grazing intervals often results in more uniform nutrient distribution than continuously stocked pastures [7—9]. Research has also shown that intensifying pasture use by increasing stocking rates significantly affects excreta distribution, nutrient cycling, and redistribution of nutrients in the soil [4,6,10,11]. Nutrients are mineralized at a greater rate from animal excreta than from plant material [12]; thus, nutrient recycling is often accelerated at high stocking rates where greater forage use results in less plant litter deposition. Grazing management that promotes more uniform distribution of nutrients via excreta can potentially reduce fertilizer requirements while also reducing risks associated with nutrient buildup in the soil when adequate stocking rates are used [3,13].

Factors such as daily temperature and animal type may also affect animal grazing behavior, and consequently, nutrient redistribution in pastures. For example, nutrient distribution in a pasture may change with livestock tolerance to solar radiation, particularly in warm climates. Cattle breed and coat color may interact with environmental conditions and can affect pasture utilization and nutrient redistribution patterns [14,15]. Because there is a positive relationship between time spent in a particular pasture area and the number of excretions [16], it is likely that the more time cattle spend under shade, the greater the nutrient concentration will be in that area, and less excreta will be deposited on other pasture areas. These graze and rest behavioral traits also correlate with increasing air temperature or the temperature—humidity index [17].

Another important pathway for nutrients to be recycled in grazed pastures is through the plant material. Grazing animals and plant litter are not a source, but rather a pathway by which nutrient recycling is redistributed into the system. Senescent above- and belowground plant material is returned to the soil, forming part of the soil organic matter. The relative contribution of plant litter versus animal excreta in terms of nutrient cycling will depend on the stocking rate. Under high stocking rates, more nutrients are recycled through animal excreta, while at low stocking rates, nutrient turnover through plant litter may be favored [12,18].

Nutrient returns from senescent litter are more uniformly distributed than returns from animal excreta. However, only minimal amounts of nutrients are expected to derive from litter recycling in intensively -managed pastures relative to that of urine and dung [19]. Because of the chemical characteristics of tropical grasses (including high lignin content), litter of tropical grass pastures decomposes more slowly than that of temperate grasses. A major factor that affects litter decomposition is the carbon to nitrogen (C:N) ratio. Because warm-season grasses normally exhibit low tissue nitrogen concentrations, their C:N ratios tend to be greater than those of cool-season (temperate) species. Under high C:N ratios ($>30:1$), the microorganisms decomposing the litter "compete" with pasture plants for soil nutrients. This process is known as nutrient immobilization, and it is often associated with N deficiency and subsequent pasture degradation through reduced forage production, nutritive value, and, ultimately, pasture persistence. Pasture management strategies that improve litter quality, such as N fertilization or the use of legumes, can promote litter decomposition and increase nutrient availability to the forage [12].

Soil and tissue testing

From both agronomic and environmental perspectives, it is critical to understand the amounts and forms of nutrients present in the soil. The primary objectives of evaluating soil fertility levels are to: (1) determine the nutrient needs of the plant, with management strategies that meet dry matter production goals for hay or grazing; and (2) provide opportunities for efficient use and recycling of nutrients for economic and sustainable pasture production. Soil testing is the best management tool for monitoring soil fertility levels [20] and providing baseline information for cost-effective fertilization programs that meet forage nutrient requirements and minimize production costs. Routine soil tests can identify nutrient deficiencies and inadequate soil pH conditions that may negatively affect forage production. Soil tests also indicate which nutrients are present at adequate levels in the soil which provides an opportunity to avoid unnecessary addition of soil amendments. Applying only the required fertilizers results in cost savings and can also minimize off-site losses of nutrients and associated environmental problems.

A major limitation associated with soil testing is that it typically accounts for the plant available nutrient pool present in the surface (0−4 or 6 in.) soil layer. However, the subsoil can be an important source of water and nutrients, particularly in perennial forage systems, in which plant root systems can explore deeper soil depths. In addition, some nutrients are highly mobile in the soil and can easily leach into the subsoil resulting in nutrient accumulation in deep soil depths.

Plant tissue analysis is widely used as a diagnostic tool for assessing the nutrient requirement of crops [21−23]. This procedure involves the determination of nutrient concentrations from a particular part or portion of a crop, at a specific time and/or stage of development. Unlike soil analyses which relate soil-extracted nutrients to plant response, plant analyses usually give an indication of nutrient availability to the crop. Because of its extensive root system, plant analyses are believed to better assess the overall nutrient status of perennial forages while also revealing imbalances among nutrients that may affect crop production.

The application of plant tissue analysis to plant nutrition revolves around the concept of a critical nutrient concentration in the plant determined from calibration curves. The critical tissue nutrient concentration of a particular crop has been defined as the nutrient concentration corresponding to 90% of maximum yield [24]. Plants with tissue nutrient concentration above the critical concentration are adequately supplied with nutrients; whereas those with nutrient concentrations lower than the critical level are considered deficient and prone to respond to fertilization.

Critical nutrient level is affected by a number of factors including forage crop species, plant part used for the analysis, physiological growth stage [23,25], harvest or grazing management, mobility of that particular nutrient in the plant, soil moisture, temperature [26,27], and seasonality [28,29]. Since various factors can influence crop tissue concentrations, tissue testing should be used with caution and in conjunction with a routine soil testing program.

Recent reports from Florida have shown that when plant tissue analysis is used in combination with soil testing, it has the potential to be a useful diagnostic tool for developing nutrient management programs that predict when crops need additional nutrients while avoiding unintended impacts of excess fertilization on the environment [30]. Plant tissue analysis is currently being used in Florida in association with soil testing to guide P fertilization of established bahiagrass (*Paspalum notatum* Flügge) pastures.

Liming and fertilization of warm-season forage crops

> ***Soil acidity and fertility management are critical for grasses and legumes production on Coastal Plain soils of the southern and southeastern US. Acidity must be counteracted by limestone treatment of the soil to improve the environment for bacterial growth and activity, increase nutrient use efficiency, and reduce toxic levels of soil Al and possibly Mn.***
>
> **Vince Haby**

Essential nutrients

A total of 17 elements are considered essential for plant growth. These include carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), boron (B), manganese (Mn), copper (Cu), zinc (Zn), molybdenum (Mo), iron (Fe), chlorine (Cl), and nickel (Ni). C, N, and O are obtained from the air and soil water, while the other 14 are supplied by the soil. N, P, and, K are considered primary nutrients because they are taken up by plants in the largest amounts. Ca, Mg, and S are considered secondary nutrients and are taken up in the next largest amounts. Fe, Mn, Zn, Cu, B, Mo, Cl, and Ni are required by the plants in very small amounts and are known as micronutrients. Regardless of the class to which they belong, all essential nutrients are equally important for plant growth.

Nitrogen is often a limiting nutrient in perennial pasture systems in the Southeastern United States. It can be supplied to pastures as commercial fertilizer, animal manure, or organic amendments. Biological fixation of atmospheric N by forage legumes can also provide adequate amounts of N to sustain forage and livestock production. P and K can be included in fertilizer blends and applied along with N. Sulfur is often associated with N and P fertilizers (i.e., ammonium sulfate and triple superphosphate), while Ca and Mg are usually supplied to forage crops through liming. Micronutrients are typically present in adequate amounts in the soil and are seldom applied to forage crops. However, under high soil pH conditions ($pH > 7$), Fe and Zn may become limiting [31]. Conversely, under acidic conditions (pH $<$ 4.5) some elements such as Al and Mn can become toxic to the plants.

Nutrients can be provided to pastures through different sources and application methods. This section of the chapter is intended to provide a brief summary overview of the most important aspects of soil fertilization management for perennial forage crops.

Managing soil acidity

Maintenance of adequate soil pH is an extremely important step in soil fertility programs for forage crops. Soil pH is one of the most important soil properties that controls nutrient availability to plants, root development, and fertilizer efficiency. Optimum soil pH promotes better root growth, which, in turn, results in more efficient fertilizer and water utilization by the plants [32,33].

> ***Coastal bermudagrass root weight per acre remained at a high level while nitrogen content of the roots and organic matter content of the soil increased slightly as fertilizer nitrogen rates increased from 0 to 1600 pounds per acre. Hay yields were greatly increased... from 1 to 11 tons per acre of dry forage... with the same treatments resulting in an 8-fold change in the root-top ratio.***
>
> **Ethan C. Holt and F. L. Fisher (1960)**

Coarse-textured Coastal Plain soils often exhibit low pH and are considered "acidic," and lime or limestone is frequently applied to raise soil pH. Lime also serves as a primary source of Ca and Mg to pastures. Forage yield decline in response to soil acidity is commonly associated with toxicity of Al and Mn and low availability of essential nutrients. By raising the soil pH (desirable range of 5.5−6.5), macronutrient (i.e., N, P, and K) availability can also increase [34]. Conversely, at high soil pH ($>$ 6.5) micronutrients become less available. With the exception of Mo, micronutrient availability decreases as soil pH increases [35,36]. Therefore, it is important that adequate amounts of lime are applied to the soil to increase the pH to a desirable range. Excessive lime application may cause nutrient imbalances and micronutrient deficiency. Excessively high or low soil pH can reduce root growth and crop ability to utilize nutrients and water, and consequently, impact forage production. Repeated applications of lime-containing soil amendments such as lime-stabilized biosolids can increase soil pH to excessively high levels that can reduce forage productivity.

Lime recommendations are based on soil test results and are specific to each soil type and forage species. For instance, cool-season legumes require higher soil pH levels than warm-season perennial grasses (Table 3.1). Forage grasses commonly cultivated in the Southeastern United States are relatively more tolerant of acidic soils than cool-season grasses. Recommended soil pH varies from 5.5 or greater for warm-season perennial grasses such as bahiagrass, bermudagrass, and limpograss [*Hemarthria altissima* (Poir.) Stapf & C.E. Hubbard] to 6.5 or greater for cool-season legumes or

Table 3.1 Target pH for different forage crops grown on mineral soils.

Crop category	Crops included	Target pH
Warm-season perennial grasses	Bahiagrass, bermudagrass, stargrass (*Cynodon nlemfuensis*), limpograss (Hemarthria *altissima*), Rhodes grass (*Chloris gayana*), and digit grass (*Digitaria eriantha*)	5.5
Warm-season annual grasses	Corn (*Zea mays*), sorghum (*Sorghum bicolor*), sorghum-sudans, and millets *(Pennisetum glaucum)*	6.0
Warm-season legumes or legume–grass mixtures	Perennial peanut (*Arachis glabrata*), stylo (*Stylosanthes guianensis*), desmodiums (*Desmodium spp.*), aeschynomene (*Aeschynomene virginica*), alyceclover (*Alysicarpus vaginalis*), hairy indigo (*Indigofera hirsute*), and other tropical legumes	6.0
Cool-season annual grasses	Small grains and ryegrass (*Lolium spp.*)	6.0
Cool-season legumes or legume–grass mixtures	All true clovers (*Trifolium* spp.) (white, red, arrowleaf, crimson, subterranean), vetches (*Vicia sativa*), lupines (*Lupinus sp.*), and sweet clover (*Melilotus officinalis*)	6.5
Alfalfa	Alfalfa (*Medicago sativa*)	7.0

Adapted from R.S. Mylavarapu, D. Wright, D.G. Kidder, UF/IFAS standardized fertilization recommendations for agronomic crops. Florida Cooperative Extension Service, IFAS, University of Florida, SL 129. <http://edis.ifas.ufl.edu/ss163/>, 2015 (accessed 22.06.18).

legume–grass mixtures (Table 3.1). Rye (*Secale cereale* L.) is generally more tolerant of soil acidity and associated Al toxicity when compared to other small grain species [37]. Multiple genes condition resistance to Al toxicity in rye through mechanisms that include the release of organic anions from the roots [38].

Forage responses to lime application can vary considerably. While several studies showed positive bermudagrass yield response to lime application in acidic soils [39–41], others reported no effect [42,43]. Similar contrasting results have also been observed for other forage species. In a 4-year field study, Adjei and Rechcigl [31] observed a 30% decrease in bahiagrass yield when forages were fertilized in the absence of lime. Additionally, these authors observed that repeated N fertilizer applications in the absence of lime decreased root/stolon mass and created favorable conditions for mole cricket and weed infestations. However, in an earlier study [44], bahiagrass did not respond to the addition of calcitic lime, even when the initial pH was as low as 4.5.

Recommended lime application rates are also affected by soil chemical and physical properties. Soils with high buffering capacity (high clay and organic matter concentration) require more lime to reach the target pH than soils of similar pH and low buffering capacity. In general, sandy soils have lower buffering capacities than loamy soils, and thus require less lime to increase the pH. However, soils with lower buffering capacities require more frequent lime applications to maintain pH. Most soil testing laboratories include some type of estimate on soil buffering capacity when making a ground limestone recommendation.

The most common liming materials are dolomitic and calcitic limestone, calcium and magnesium oxide, slag, sludge, and wood ashes. Since the solubility of these materials is often very limited, they are typically applied 3–6 months prior to seeding or fertilization for the targeted production goals [45]. The reactions that take place in the soil when lime is applied will only occur in the presence of water and acidity. If soil moisture is not adequate, the positive effects of lime in neutralizing soil acidity will be very limited.

The quality of the lime material is expressed in terms of effective calcium carbonate equivalent (ECCE). The ECCE of lime materials is affected by two main factors: (1) fineness of the material or particle size, and (2) chemical purity. The physical composition of liming materials is defined by the percentage of the materials that pass through 10-, 60-, and 100-mesh sieves. Finely ground materials normally neutralize soil acidity faster than coarse liming materials [45]. Materials that contain a range of particles may be desirable when soil pH is not required to be increased in the short term. The moisture content should also be considered when selecting liming materials. Liming materials with greater moisture content may be more difficult to apply in the field.

In addition to the fineness of the material, the chemical composition and percentage of impurities will also impact the effectiveness of liming materials. The purity of the liming material is measured by the calcium carbonate equivalence (CCE). A material with CCE of 100% is equivalent to pure calcium carbonate. Some examples of CCE of various liming materials are shown in Table 3.2.

Lime recommendations vary from laboratory to laboratory based upon assumptions regarding ECCE and state lime laws. If a recommendation is made based on lime material that has 100% ECCE, the rate should be adjusted by dividing the recommended rate by the actual ECCE of the material.

Table 3.2 Calcium carbonate equivalence (CCE) of various liming materials.

Material	CCE (%)
Pure calcium carbonate	100
Calcitic lime	75–100
Dolomitic lime	75–109
Hydrated lime	120–136
Burned lime	179
Wood ash	30–70

Nitrogen fertilization

> ***Increasing the nitrogen rate from 0 to 900 pounds per acre annually increased hay yield, protein percentage, protein yield, stem length, leaf length, internode length and internode number in Coastal Bermudagrass; but decreased leaf percentage, seed-head frequency, and percentage nitrogen recovery.***
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> **Gordon M. Prine and Glenn W. Burton (1956)**

Nitrogen is a key nutrient that affects forage production, nutritive value, and sustainability of forage-based systems. Nitrogen application rates vary considerably depending on the region, forage species, management, and economic return, and are generally calculated based on expected yields. Crop removal (e.g., hay crops) and stocking rate are important variables that should be considered when choosing N fertilization levels.

Early reports in the literature suggest that Coastal bermudagrass may respond to N application at rates up to 1000 lb N/acre per year [46], with a linear yield response to N up to ~550–620 lb N/acre per year [47]. In the early 1950s, research demonstrated that application of 400–800 lb N/acre per year resulted in Coastal bermudagrass yields of ~9.8 and 10.7 tons/acre, respectively [48]. Similarly, Wilkinson and Langdale [49] demonstrated that Pensacola bahiagrass responded to as much as 600 lb N/acre per year. Blue [50] showed that bahiagrass yield increased as N increased to 360 lb N/acre per year. Research in Florida reported stargrass yield responses to N application of 180–360 lb N/acre per year [51]. Although yields may increase at increased N rates, high levels of N application are neither economical nor environmentally sustainable in most forage-based animal production systems. At present, levels of ~60–80 lb N/acre are typically applied to established grass swards in Florida [52]. Higher N levels (up to 80 lb N/acre per harvest) are often associated with intensive hay production systems [53]. These high N rates do not take into consideration N recycling in pasture through animal excreta or litter decomposition.

Management of inorganic and organic nitrogen fertilizer sources

Ammonium nitrate has been the predominant N fertilizer source used on pastures in the United States. It typically contains between 33% and 34% N, and despite its relatively high solubility in water, is stable under adequate storage conditions. When applied at agronomic rates, ammonium nitrate does not produce as much acidity as other N fertilizer sources (i.e., ammonium sulfate). In addition, the salt index (a measure of the salt concentration that the fertilizer produces in the soil after its application) of ammonium nitrate is 2.99, indicating that there is limited probability of ammonium nitrate to cause burning problems in the pastures.

Ammonium sulfate is another common N fertilizer source used in pastures in the Southeastern United States. It contains between 20% and 21% N and approximately

24% sulfur. Repeated application of ammonium sulfate can significantly increase soil acidity [54]; therefore, it is important to monitor soil pH after repeated applications of ammonium sulfate. An advantage of ammonium sulfate is that in addition to providing N, this fertilizer can also provide adequate amounts of S, which is an essential nutrient for forage grasses. Ammonium sulfate has a salt index of 3.25, which may result in temporary forage damage due to burning when applied at extremely high rates. However, when applied at adequate rates, the potential of ammonium sulfate to cause injury in forages is negligible.

Urea has become a popular N source due to the high N concentration ($\sim$46%) and consequent lower cost associated with transport. Urea can be applied to pastures as a solid or as a solution via foliar spray. After application to the soil, urea first reacts with water and is converted to ammonium bicarbonate (NH_4HCO_3). In soils that exhibit high pH ($>$6.5), ammonium bicarbonate can be further converted to ammonia gas (NH_3). Under these circumstances, significant amounts of N can be lost via ammonia volatilization. Compared to ammonium nitrate and ammonium sulfate, urea produces less acidity and typically does not affect soil pH significantly.

While plants may benefit from soluble nutrients present in inorganic fertilizer sources, a significant fraction of these nutrients may be lost before the plants have a chance to utilize them. Most commercial inorganic fertilizers should be applied when the forage is actively growing, preferably at the beginning of the season (early spring). Mid-season or late fertilizer application normally occurs for stockpiled forage production. For the establishment of new plantings, fertilizer is not recommended to be applied until plants have emerged. In harvested foraged systems, N and K are typically applied after each cutting according to soil type and soil test recommendations.

Different fertilizer technologies have been developed recently to increase crop nutrient uptake. These include slow-release fertilizers and fertilizer materials that contain urease or nitrification inhibitors [55–57]. Slow-release N fertilizers can be classified into two categories: (1) chemical compounds with inherently slow rates of dissolution; and (2) N fertilizers provided with a coating that acts as a moisture barrier. Sulfur-coated urea, urea form, and polymer-coated fertilizers are examples of slow-release N fertilizers. Only a small proportion of the pastures in the Southeastern United States receive slow-release fertilizers; however, there has been an increasing interest in these fertilizer forms because of their potential to reduce the environmental impacts of N fertilization. Although slow-release N fertilizers are believed to increase the synchrony between N release from the fertilizer and crop requirements, limited science-based data on how forage crops respond to these N sources are currently available.

Organic fertilizer sources such as biosolids and animal manure represent important sources of N that can be used in pastures, but the majority of N present in organic sources is not readily available to plants. As the organic compounds mineralize, N and other essential nutrients become available. Therefore, time and rate of application are critical factors that can impact the effectiveness of organic sources for providing N to pastures. In addition, organic sources typically contain excessive P concentrations than is required by the forage when application is based on N due to the lesser ratio of N:P in the manure compared to crop demand [58]. In general most manures have an approximate N:P_2O_5 ratio of 1:1, while plants generally take up at least five times more N than P_2O_5. Therefore, supplying N to the plants via organic sources often results in excessive phosphorus application rates. While manure application based on crop P requirements may reduce excess P accumulation in the soil, it results in smaller manure application rates and larger land area required for manure disposal [59], as well as the need for supplemental N application via commercial fertilizer.

Total nitrogen is often a poor indicator of N availability from organic amendments. For example, nitrogen availability of beef cattle manure has been shown to be about 40% of the total manure N applied in the first year, compared to 90% for swine manure, 50% for dairy manure, and 75% for poultry manure [60]. These differences are often related to the amount of total N present as ammonium N, urea N, or organic N in the manure. In addition to nutrient availability, factors such as source, time and rate of application, and environmental conditions can impact the effectiveness of organic materials in providing N to pastures.

Management of organic fertilizer sources such as animal manure, broiler litter, or biosolids is more complex than that of inorganic fertilizers, primarily because the nutrient composition of organic sources is extremely variable, and not all nutrients are available immediately for plant uptake. Organic fertilizer strategies that synchronize rate of nutrient mineralization and crop demand result in greater manure utilization by plants and reduce losses of nutrients to the environment [61]. However, predicting and achieving this goal for organic fertilizer sources has proved elusive. Choice of fertilizer source will ultimately rely on goals in production, environmental and regulatory constraints, cost, and availability of materials.

Nitrogen inputs through forage legumes

While N fertilizer is a costly energy input and a potential source of environmental contamination when improperly managed, atmospheric N_2 may be efficiently fixed by legume species and may be a reasonable economic and environmental alternative for providing N to grass pastures [62]. In addition, while synthesis, storage, transfer, and application of N fertilizers result in considerable emissions of CO_2 primarily from fossil fuels, N derived from biological fixation is C neutral [63,64]. Nitrogen fixed by legumes can be efficiently transferred to companion or succeeding grasses through animal excreta and legume plant decomposition [65]. Nitrogen-fixing legumes provide adequate N supply for pasture growth [66–68], increase forage nutritive value [69,70], extend the stocking period [65], and enhance animal performance compared to grass monoculture [65,71,72]. Pasture systems using N-fixing legumes can also produce forage with high cumulative nutritive value and is often an economically viable management option to livestock producers in the United States [73,74]. Application of N fertilizer to swards containing over 50% legumes is rarely considered because of the cost and potentially detrimental impacts on legume persistence [75,76].

The amounts of legume N transferred to the forage grass and the predominant pathway of this transfer are variable (<18–180 lb N/acre per year) and depend on the species, cultivar, soil fertility conditions, and proportion of legume if cultivated with non-N-fixing species [65]. Dubeux et al. [77] reported that rhizoma peanut (*Arachis glabrata* Benth.) cultivars in monocultures fixed between 100 and 250 lb N/acre per year. When cultivated in mixtures with bahiagrass, Santos et al. [78] found that rhizoma peanut fixed an average of 12 lb N/acre per harvest (~36 lb N/acre per year) compared with 27 lb N/acre per harvest (~81 lb N/acre per year) in monoculture. Nyfeler et al. [79] reported that in legume (red clover [*Trifolium pratense* L. cv. Merviot] and white clover [*Trifolium repens* L. cv. Milo])–grass (perennial ryegrass [*Lolium perenne* L. cv. Lacerta] and orchardgrass [*Dactylis glomerata* L. cv. Accord]) mixtures fertilized with 45, 134, or 400 lb N/acre, N fixation activity was reduced when legume proportion was above 40% or at the higher N fertilization level. They also reported that the presence of grasses increased atmospheric N uptake through symbiosis in the legume, with N yields equal to that of legume monocultures when legume proportion was between 40% and 65% in mixtures with grasses. Evaluating similar treatments, Nyfeler et al. [80] also showed that forage mass in grass–legume mixtures with 50%–70% legumes was equivalent to that of grass monocultures fertilized with 450 lb N/acre. Nyfeler et al. [79] reported that perennial ryegrass and orchardgrass root density and N acquisition were greater in grass–legume mixtures compared with grass monocultures. The authors suggested the positive effects of the mixture were the result of mutual stimulatory effects on N acquisition of the grass and legume component of the mixture. Morris et al. [67] reported that active transfer from arrowleaf clover (*Trifolium vesiculosum* Savi.) to annual ryegrass was less than 5 lb N/acre as measured by isotope dilution using ^{15}N-depleted ammonium nitrate. In mixtures of alfalfa (*Medicago sativa* L.) and bermudagrass, the active transfer from legume to grass was about 16 lb N/acre [81].

The predominant pathways of N transfer from legumes to grasses are through decomposition of legume plant residue, excreta from grazing animals, and subsequent N mineralization. Decomposition of belowground biomass from legumes is a significant N input source. Dubach and Russelle [82] demonstrated that while decomposing nodules are the main source of belowground N transfer in birdsfoot trefoil (*Lotus corniculatus* L.), alfalfa inputs to soil N come mainly from fine root decomposition. In an experiment conducted in pots with stylosanthes (*Stylosanthes guianensis* cv. Mineirão) and brachiaria mixtures (*Brachiaria decumbens* cv. Basilisk), transfer of legume N from belowground biomass to grass was significant only after aboveground biomass was removed, but not while both plants were growing concomitantly [83].

Potassium and phosphorus fertilization

Potassium is an essential nutrient for forage production required by plants in greater amounts than any other nutrient except N. Despite its important roles, however, pasture K fertilization has received much less attention than N. In most forage production systems in the Southeastern United States, K is not supplied at adequate levels to replace that which is removed with harvested forage. Intensively managed hay production systems are particularly prone to K deficiency because of the relatively high amount of K removed with harvested forage. Several studies reported significant bermudagrass yield increases in response to K fertilization. For instance, Slaton et al. [84] observed a ~20% bermudagrass yield increase in response to K application (at annual levels of 89 lb K_2O/acre) compared to control (no K application) treatments. In a 4-year study in Texas, Haby et al. [85] observed a 22% bermudagrass yield increase when K was applied at 134 lb K_2O/acre compared to zero K application. Nelson et al. [86] observed a 50% yield increase of bermudagrass when K was annually applied at 170 lb K_2O/acre on a fine sandy loam soil in east Texas. Similarly, Snyder and Kretschmer [87] demonstrated that limpograss and bermudagrass forage accumulation decreased linearly as K fertilization level decreased. In addition to yield increases, many studies have demonstrated that adequate levels of soil K reduce bermudagrass winter injury and increase survival after freezing temperatures [88,89].

In addition to the negative impacts on forage production, K deficiency has also been linked to reductions in stand integrity and increases in pest and disease incidences [90,91]. Several studies have demonstrated the important role of K fertilization on rhizome production, root development, stand persistence, and plant resistance to disease and pest injury [92–94]. These reports suggested that first visual signs of stand decline due to K limitation were more frequently observed in the initial spring regrowth.

Because of the sandy nature and low cation exchange capacity of most coastal soils of the Southern and Southeastern United States, these soils often exhibit limited ability to retain K even after receiving K fertilization. Therefore, the repeated application of K is often required to meet plant requirements. Potassium application rate, frequency, and time of application are important considerations for pasture production in the Southeastern United States. Soil test along with tissue analysis can provide a good estimate of K status. Reports in the early 1970s suggested that Coastal bermudagrass required between 200 and 400 lb K_2O/acre per year. Corroborating these early studies, Robinson et al. [95] observed maximum bermudagrass yields at the 300 lb K_2O/acre rate. However, despite the positive impacts on bermudagrass production, these relatively high K application rates are likely not economical in many production systems. Similarly, maintaining soil test K at medium or higher levels can be expensive and difficult to achieve in coastal plain soils in the Southeastern United States. On the other hand, extremely low K supply may also represent an economic risk, and efforts should be focused on replacing K removed with harvested forage.

Although forage response to P fertilization is typically less than that of N and K because of the lower crop P requirement as compared to the other primary macronutrients [96], adequate supply of P is critical for establishment and maintenance of productive warm-season grass stands. Reduction in forage accumulation due to low P supply has been documented in several previous studies. For instance, Adjei et al. [97] reported a linear decrease in limpograss herbage accumulation as P fertilization levels decreased. However, the extent of warm-season grass responses to P fertilization varies considerably depending on the forage species, soil type, and management history [97]. Because N fertilization has the greatest potential to increase herbage accumulation, greater levels of N fertilization can also increase P requirements of forage crops [96,98]. As soil P reserves become more depleted, marginal crop responses to added N (or any other nutrient) are expected to occur [96]. Similarly, although P fertilization is not expected to have direct impacts on forage nutritive value, reduced N use efficiency due to P deficiency may, in turn, decrease forage nutritive value.

Organic fertilizers such as animal manure and biosolids can be used to provide P and K to forages. Immediately after application, N availability in organic fertilizers is between 40% and 90% of total N. The remaining N requires a mineralization process to become available to plants; however, K and P are typically more readily available for plant uptake at the time of application. The P availability is about 82% of the total P in applied beef cattle manure [60], and this relatively high availability is due to a large portion of total P (60%–90%) being in the inorganic form [99]. Availability of K is close to 100% for manure of several animal species [60] and similar to that of K fertilizer because K is rarely tied up as inorganic or organic compounds in the plant cells. Similar to N fertilization, the concentration and availability of P and K present in the amendment should be taken into consideration when planning organic fertilizer application to maximize nutrient use efficiency by plants as well to avoid detrimental effects to the environment.

Managing soil health for pasture sustainability

Definition

In the past 50 years, significant scientific effort toward improving crop productivity was directed to soil and nutrient management based on standardized soil testing procedures to predict the availability of essential nutrients to the plants. Routine soil testing, for instance, was designed to estimate plant nutrient availability for optimal forage production, and to diagnose potential nutrient deficiencies and suboptimal soil pH conditions that may negatively affect crop production. Soil testing was also intended to determine nutrients that were present at adequate levels in the soil; thus, providing an opportunity to eliminate unnecessary soil amendment applications. For decades, soil test reports have been used to predict the likelihood of obtaining a positive crop response from the application of the nutrients tested. However, recent evidence suggests that in certain circumstances, a standard predictive soil test alone may be a poor predictor of nutrient requirements and particularly for perennial pasture systems where the root system can extend beyond the top 4–6 in. of soil that are typically tested. Similarly, assessment based on routine soil test indices often poorly reflects the impact of grazing and nutrient management on soil properties.

Maintaining a healthy and productive soil is the foundation of sustainable agriculture. To address the concerns and limitations associated with routine soil testing, scientists and land managers in recent years have looked for new tools that can provide an overall assessment of soil's ability to sustain crop production. In this context, the concept of "soil health" was developed to provide a more holistic view of soil management. The term soil health refers to the ability of soils to support specific functions such as nutrient cycling, regulating water, filtering and buffering potential pollutants, and so forth. According to the USDA Natural Resource and Conservation Service, soil health is defined as "the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans." Soil health has also been defined as the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental health, and promote plant and animal health [100].

Soil health also influences crop resilience to extreme climatic events, and it can directly impact local jobs and the economic stability of rural communities. Soils can also support other important functions such as environmental protection, biodiversity habitat, water relations, and waste recycling. Additionally, soils mediate many ecological processes that can have important and direct impacts on the global water cycle and climate. Although economic factors may limit the extent to which soil health concepts can be adopted at a farm scale, there is a growing recognition that agriculture, and more specifically soil management, can provide much more than food, fuel, and fiber. Critically important ecosystem services offer a potential for society to recognize farmers and land managers for the true value they provide.

Soil health indicators

Indicators of soil health provide information about how the soil is functioning with respect to a particular management goal or ecological role. Since a specific soil function may involve several processes, and each process may be associated with a combination of soil chemical, physical, and biological properties, the exact number of properties measured to assess soil health may, therefore, vary considerably. Similarly, because many soil properties that contribute to soil health are interrelated, no single soil attribute can be used as a measure of soil health.

Significant efforts are currently being placed on identifying soil properties for the determination of soil health. Researchers have developed a wide range of soil health assessment methodologies. These often include a combination of physical, chemical, and biological properties such as soil organic matter, texture, water holding capacity, and extractable essential nutrient concentrations. Ideal soil health indicators should: (1) be easy to measure; (2) measure changes in soil functions; (3) encompass chemical, biological, and physical properties; (4) be accessible to many users and applicable to field conditions; and (5) be sensitive to variations in climate and management.

Universal calibration of soil health indicators is not possible; therefore, interpretation of soil health assessments must rely on comparative data. Similarly, soil health indicators will vary depending on the soil type, management goal, region, and cropping system; therefore it is critical that soil health indicators be developed at a local/regional scale so that they are relevant to the area of interest. Likewise it is expected that soil health indicators for perennial pastures will likely be different than those commonly used for grain crops in the Midwestern United States. In addition, the coarse texture of most coastal plain soils and their intrinsic limited nutrient holding capacity associated with low organic matter levels suggest that sensitive soil attributes that can distinguish differences in soil health under different pasture management scenarios will likely be unique to the Southeastern United States. Research is needed to develop and validate a soil quality framework for guiding pasture management decisions and monitoring their outcomes.

Soil organic matter

A number of soil properties may serve as indicators of soil health. Some of these properties are descriptive and can be measured directly in the field. Others must be measured using laboratory analyses. Because some properties such as soil texture and depth are inherent of a particular soil type, they are not affected by soil management. Others, however, can be reversed and/or improved through the adoption of proper soil management strategies. Soil organic matter has been long recognized as an important indicator of soil productivity and ecosystem sustainability. Soil organic matter is essential to diverse soil functions and ecosystem services and plays an important role in improving soil physical, chemical, and biological properties. Maintenance of adequate levels of organic matter in the soil have been linked to reductions in soil degradation [101] and overall improved soil health conditions [102]. Likewise, soil organic matter has been suggested as the single best integrator of inherent soil productivity and a useful indicator of soil health. Although there is no threshold level of soil organic matter below which crop productivity can be negatively impacted, soil organic matter loss is of concern because it may also adversely affect other important soil properties.

Until recently, the importance of maintaining (or preferably increasing) soil organic matter in pastures was underestimated compared with the use of fertilizers and lime. Therefore, knowledge of soil organic matter levels in perennial pasture systems and the impacts of management on soil organic carbon dynamics is limited. Although pasture management strategies (e.g., fertilization strategy and grazing management) are generally aimed at increasing forage production to match animal stocking rates or forage demand for hay, a significant body of the literature demonstrated that pasture management can also promote soil organic matter accumulation [103–106]. In fact, most techniques used to improve forage production promote carbon inputs to the soil and increase soil organic matter accumulation. For instance, fertilization, irrigation, grazing management, fire regimen, introduction of legumes, and use of improved grass species can boost plant productivity while promoting soil carbon sequestration. Studies have shown that when low-fertility soils receive fertilizer or lime, forage productivity and soil carbon levels generally increase [105,107]. Research also shows that grazing intensity can have major impacts on soil carbon accumulation. Although overgrazing is often associated with reductions in soil carbon concentrations, proper grazing management can result in greater soil carbon concentrations than nongrazed systems. Well-managed grazing lands generally maintain or even increase soil carbon accumulation compared with native ecosystems. Also, livestock benefit from well-managed lands because the grass usually has higher nutrient concentrations due to proper fertilization. Opportunities for increasing soil organic matter accumulation in response to management practices vary in intensity and are specific to each ecosystem.

Conclusion

The sustainability of productive perennial forage systems in the Southeastern United States depends, to a major extent, on well-planned, environmentally and economically sound soil fertility programs. Soil pH controls nutrient availability to plants, root development, and fertilizer efficiency; thus, maintenance of adequate soil pH should be the first strategy to improve soil fertility conditions. Fertilizer recommendations vary considerably depending on the production system, forage species, soil type, and climatic conditions. The choice of fertilizer application rate and source should be based on both the production goals and routine soil and tissue testing.

The recycling of nutrients and harvest management can have significant impacts on soil fertility status. Mechanically harvested forage systems including hay, green chop, silage, and grain crop residue have similar fertility management as row crops; however, because a large proportion of nutrients in grazing systems is returned to the soil via animal excreta, the use of fertilizer can be reduced. Grazing management that promotes more uniform distribution of nutrients via excreta can potentially reduce fertilizer requirements while also reducing risks associated with nutrient buildup in the soil.

In addition to increasing forage herbage accumulation and nutritive value, soil fertility strategies can also affect soil chemical, physical, and biological properties; therefore, pasture fertilization decisions should include both production and conservation goals. Currently new technologies and assessment tools are being developed to identify soil properties that affect pasture productivity and resilience as well as to guide pasture management strategies and monitor their outcomes.

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CHAPTER 4

Nutrient cycling in grazed pastures

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Definition and importance of nutrient cycling

What are nutrients and nutrient cycling? Nutrients are elements essential for plant and livestock growth. They are found naturally in "nutrient pools" that can include soil minerals, soil organic matter (SOM), plant and animal tissue, senescent plant material, animal excreta, and the atmosphere. Nutrients do not remain in a single pool indefinitely; instead, they cycle among pools, undergoing biochemical processes that change their chemical structure and biological availability (Fig. 4.1).

Consider the nutrient cycle for nitrogen. If we start with nitrogen as a component of soil, it can be taken up by living organisms, including soil biota, plants, and livestock. For example, plants take up nitrates from the soil and transform them into amino acids and proteins. After livestock consumes forages, rumen microorganisms ferment plant proteins and other plant compounds, such as carbohydrates, to form volatile fatty acids, ammonia, and other by-products of fermentation. Protein that escapes ruminal fermentation can be digested in the abomasum and absorbed in the small intestine to become part of the animal tissue or of an animal product such as milk. Alternatively, protein can pass through the digestive tract undigested and returned to the soil via excreta. Livestock also eliminates excess N via urinary excretion. Nitrogen in livestock excreta has several fates. Soil microorganisms decompose proteins in dung with the resulting mineralized N taking different pathways, including immobilization by soil microbes, plant uptake, volatilization, denitrification, leaching, and runoff. Urinary N is mainly in an inorganic form and does not require microbial activity to be plant available. Its chemical form allows it to function much like a fertilizer nutrient source, but it also suffers greater losses to the environment, especially in warm climate regions, via ammonia volatilization. These nitrogen pathways and transformations are an example of a nutrient cycle in a grassland ecosystem, where nutrients move among different pools while undergoing chemical changes (Fig. 4.2). While this example addresses N cycling, all other nutrients pass through similar processes, with unique biochemical reactions for each nutrient.

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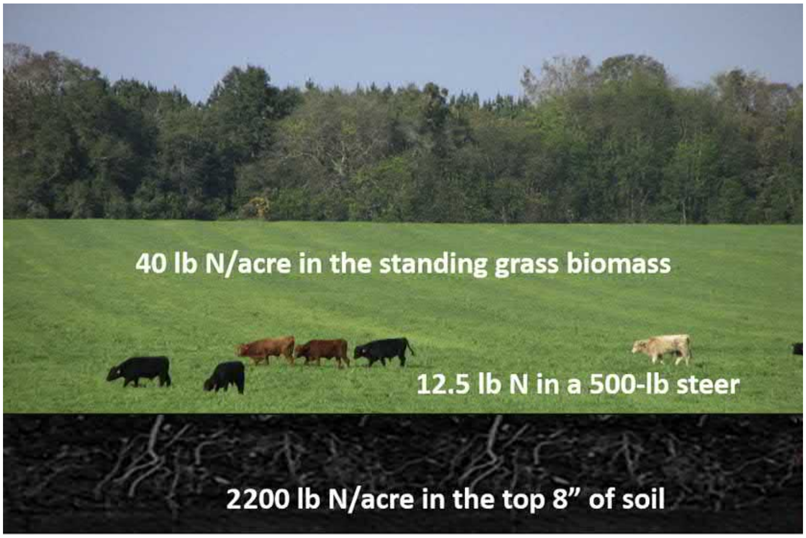

Figure 4.1 Relative N pools in a grassland ecosystem. Assuming (1) herbage mass of 2000 lb DM/acre and 2% N; (2) 2.5% N in steer body mass; (3) 2% soil organic matter (SOM), 57% C in the SOM, C:N ratio of 12:1. *Photo credit: Jose Dubeux.*

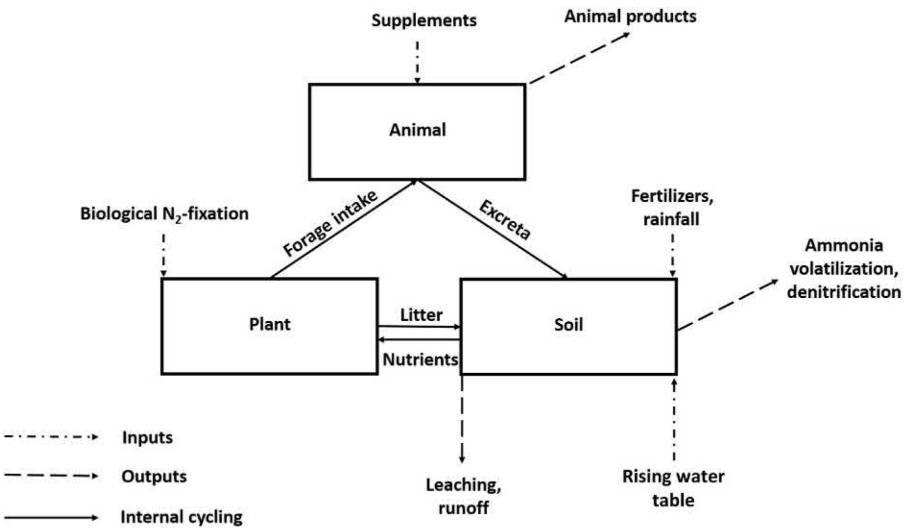

Figure 4.2 Nitrogen cycling in grassland ecosystems.

Nutrient cycling is essential in grassland ecosystems because it replenishes soil nutrients and sustains plant growth. The faster these nutrients cycle and the smaller the losses, the more efficient the process of nutrient cycling. In this chapter, we will explore ways to enhance the efficiency of nutrient cycling in grazed grassland ecosystems.

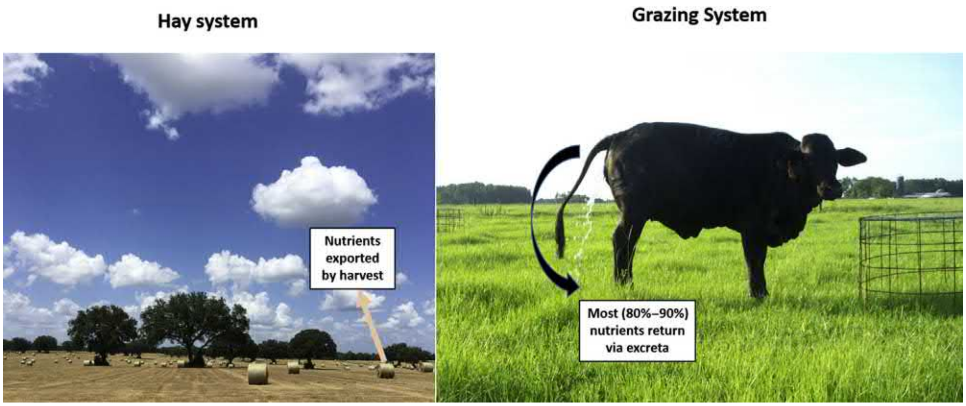

Figure 4.3 Contrasting nutrient cycling in hay versus grazing systems. *Photo credit: Jose Dubeux.*

Nutrient budgets for grazed pastures

> ***Where animals go, nutrients flow.***
>
> **D.M. Ball, G.D. Lacefield, V.G. Allen, C.S. Hoveland, and J.H. Bouton (2014)**

Nutrient budgets in the grassland ecosystems are important to define fertilization requirements when the nutrient balance is negative, and strategies to reduce nutrient losses to the environment when the balance is positive. Nutrient budgets include inputs, outputs, and transformations that nutrients undergo across ecosystem nutrient pools. The balance between inputs, outputs, and transformations will affect the sustainability of the system in the long term. Positive nutrient balances are typical in confined animal feeding operations (CAFO). Negative nutrient balances are common in low-input systems with limited use of fertilizers, or in systems where nutrients are exported via harvested forages (e.g., hay production). Grazing animals return most of the nutrients they eat back to the pasture via excreta (Fig. 4.3), but the return is not uniform and is concentrated around shade, water, and feeding points.

Inputs

Fertilizers

Fertilizers are an important source of nutrients for grazed pastures. Deficiencies of macro and/or micronutrients often limit the growth of forages, especially in highly weathered soils. Forages are not all the same, with some species requiring greater soil fertility than others. Alfalfa (*Medicago sativa* L.) is an example of a species with a large nutrient requirement, while other species, such as bahiagrass (*Paspalum notatum* Flügge) and bermudagrass [*Cynodon dactylon* (L.) Pers.], are able to persist and produce in low-input systems. In some regions or production systems, nutrient inputs to grazed pastures via fertilizer are limited because of economic constraints. One of the approaches to overcome this limitation is to use forage crops adapted to low soil fertility. In contrast to these nutrient-scarce environments, grazing systems using excessive fertilization and pastures associated with CAFO often have a surplus of nutrients with a positive nutrient balance. This may lead to environmental contamination because of nutrient losses.

Legumes are an alternative to N fertilizer to increase the amount of N in grazed pastures. Forage legumes are able to overcome soil N limitations by associating with soil microorganisms to transform atmospheric N_2 into N compounds that plants can use. However, biological N_2-fixation (BNF) requires other essential nutrients that are often deficient in soils, such as P, K, S, B, Mo, and in some cases, Fe. Thus, even in grass–legume mixtures, fertilization is necessary to obtain the full benefit from BNF.

Biological N_2-fixation

BNF is an important N input in terrestrial ecosystems. Forage legumes associate with soil bacteria to convert atmospheric N_2 to ammonia [1]. Some grasses associate with BNF microorganisms (diazotrophs) that are able to fix atmospheric N_2 [2], but the amount fixed is highly variable and is usually much less than BNF from legumes. These N inputs from legume BNF bring a variety of benefits to grasslands and land-managers, and these include reduced cost due to less N fertilizer, enhanced nutrient cycling, greater pasture productivity, and improved forage nutritive value.

In the Southeastern United States there are many forage legume options, including the perennial legumes rhizoma perennial peanut (*Arachis glabrata* Benth.); short-lived perennials such as alfalfa, red clover (*Trifolium pratense* L.), white clover (*Trifolium repens* L.), and pigeon pea (*Cajanus cajan* L.); warm-season annuals such as cowpea (*Vigna unguiculata* L.), sunn hemp (*Crotalaria juncea* L.) and aeschynomene (*Aeschynomene americana* L.); and cool-season annuals such as crimson (*Trifolium incarnatum* L.), and ball (*Trifolium nigrescens* L.) clovers. Poor persistence of perennial forage legumes in mixed grass–legume pastures is often a problem, although grazing-tolerant types of some species have been identified [3]. Managing annual legumes to reseed can be a challenge, but it is possible with proper timing and intensity of grazing [4].

Amount of fixed N in grass–legume mixtures depends on the proportion of legume in the mixture, overall legume forage production, N concentration of the legume, and proportion of N that is derived from the atmosphere versus that from the soil. Typically, it is necessary to have at least 30% legume in the total forage mass to measure significant contributions of BNF [5].

Atmospheric deposition

Nutrient deposition from the atmosphere is also an input to the pasture nutrient budget. Annual atmospheric N deposition is typically lower than 10–15 lb N/acre.

Although this amount might be considered low for cultivated forage crops and pastures, it is significant for rangelands and extensive livestock systems. Nitrogen is the main nutrient deposited. The average deposition has been increasing since the mid-1990s and could more than double by 2050 [6]; however, other nutrients including sulfur are also deposited [7].

Feeds and supplements

Supplements fed to grazing animals are another nutrient input to grazed pastures. Supplementation, in this case, encompasses mineral mixtures, creep feeding, or supplementation to adult livestock using concentrates or roughages (e.g., hay or baleage). Supplementation amount, type of supplement, and supplement chemical composition are the main factors of importance for this source of nutrients in the overall pasture nutrient budget. To avoid large deposition of nutrients from livestock excreta around supplement or mineral feeding stations on pastures, it is important to move feeders and periodically distribute hay bales to different locations.

Outputs and losses

Nutrients can exit the grassland ecosystem in different ways, including exportation via animal products such as beef, milk, and wool, or through losses via different processes, including ammonia volatilization, denitrification, leaching, and runoff. Maximizing exportation via animal products with reduced nutrient losses is the goal of the land manager.

Nutrient losses

Ammonia volatilization

Ammonia volatilization is a major pathway of N loss and is more important in warm-climate regions and during periods when rainfall is plentiful. Ammonia volatilization is affected by several environmental factors, and the amount of volatilization is difficult to predict. Conditions that favor ammonia volatilization include large amounts of plant litter residue, warm temperatures ($>55°F$), a drying soil surface (water vapor loss from surface), neutral or alkaline soil pH, and soil with a low cation exchange capacity [8]. Based on these conditions, urine spots from grazing animals are "hotspots" for ammonia volatilization. The moisture from the urine coupled with the urea present in the urine and the high pH favor the ammonia volatilization process. Losses from urine patches vary with environmental factors, and in some cases can be as high as 25% of the N returned in a particular spot [9].

Denitrification

Denitrification is the chemical reduction of soil nitrates or nitrites by denitrifying bacteria leading to gaseous N losses. When oxygen is limited, some bacteria use nitrate to support respiration. Thus, denitrification occurs in anaerobic conditions with the presence of denitrifying microorganisms, soluble C compounds, and oxidized forms of N (e.g., nitrates or nitrites). In addition to N losses, denitrification end-products, such as nitrous oxide (N_2O), are powerful greenhouse gases. N_2O has a global warming potential 298 times greater than carbon dioxide for a 100-year timescale [10].

Based on the conditions for denitrification to occur, management strategies that enhance uniformity of nutrient spatial distribution across the pasture will reduce N losses via this pathway. When selecting sites for locating grazing systems with greater N inputs, poorly drained soils should be avoided. These poorly drained areas may be used for more extensive systems, that is, with reduced fertilization and off-farm nutrient inputs, and/or to establish natural reserves. Preventing nitrification can potentially reduce denitrification losses. Some plants produce nitrification inhibitors and release them into the area around the roots (i.e., rhizosphere), reducing nitrate formation, and thereby reducing denitrification losses [11].

Leaching

Leaching occurs when nutrients move with water beyond the root zone. Plants are no longer able to take up these nutrients and they move into the groundwater. This problem is important because nutrients are valuable, but it is particularly critical because of potential environmental contamination of groundwater, lakes, and streams. Excessive nutrient concentration impairs the use of water for humans and promotes algea growth (i.e., eutrophication), which can result in reduction of oxygen levels in the water and thereby affect fish and other aquatic organisms.

Movement of water beyond the root zone occurs when water input from rainfall or irrigation is greater than the soil water storage capacity for the soil layers where most roots are located. Nutrient concentration in the water will also drive nutrient leaching. Soil texture affects soil water storage capacity, with clay soils storing more water than sandy soils. Management practices that strengthen and develop the root system while establishing conditions for deeper rooting will reduce leaching and nutrient losses. One important example of such practices is the proper adjustment of stocking rate. Plants that are overgrazed have less root mass and shallower roots; thus, they are not well-suited for efficient nutrient uptake. Avoiding pasture fertilization when the soil is already wet and additional rainfall is predicted will also reduce nutrient leaching.

Runoff

Runoff is the water discharged into surface water bodies. When rainfall is greater than soil infiltration rate, surface runoff occurs. Factors affecting runoff include rainfall intensity, slope, soil water storage capacity, and infiltration rate [12]. Nutrients contained in the runoff water will be lost from the system and deposited elsewhere. When added to lakes and streams, these nutrients can cause eutrophication, especially when soil fertility is high, as typically found around CAFO. Reducing soil nutrient concentration in these areas is essential, and manure management is very important.

Animal products

Nutrient output via animal products is one of the major goals of livestock production; therefore, we do not consider it a nutrient loss. However, as the nutrients move out of the natural cycle in the grassland ecosystem, this output must be considered in the overall nutrient budget. Nutrient export via animal products varies with the animal physiological status (e.g., lactation, growth), level of production, and the type and composition of the product exported. In general, ruminants return most (80%–90%) of the nutrients they consume to the system in excreta [13], but a small portion is retained in the animal body and another portion is exported via products such as milk and wool.

Transformations

In addition to inputs and outputs, there are transformations that may occur, which render nutrients unavailable for certain periods of time. For example, very low or very high pH can result in the formation of insoluble compounds. These nutrients might return to the nutrient cycle, but whenever they are unavailable, nutrient use-efficiency in the overall system is reduced.

Nutrient immobilization

Soil microbes use nutrients from the soil to grow, and they compete for nutrients directly with plants. When microbes outcompete plants for nutrients and retain these nutrients, this is referred to as immobilization, and the nutrients become unavailable for plant uptake. Certain conditions increase nutrient immobilization by soil microbes, for example, the presence of a large amount of dead plant material (i.e., plant litter) that is low in N and has a high C:N ratio. Litter C:N ratio of C_4 grasses might reach 50–100:1 while the C:N ratio of average soil microbes is 8:1. Therefore more N (and other nutrients) is needed in order for microbes to grow [14]. These nutrients come from the soil solution, which is the same pool from which plants are taking up nutrients. Immobilization is not permanent because soil microbes will die and decay over time, with nutrients being released and returned to the soil. A strategy to improve litter quality, minimize nitrogen immobilization, and enhance the efficiency of nutrient cycling is that of integrating legumes into livestock systems [15]. Another approach is to apply nutrients via fertilizer to reduce nutrient immobilization.

Nutrient movement across soil layers

Nutrients can move vertically in either direction across soil layers and will become available or unavailable for plants. Some nutrients are readily soluble in water and move by mass flow of water across soil pore space. This is the main mechanism of nutrient transport over longer distances. Therefore, factors affecting the movement of water in the soil profile will also affect the movement of nutrients. Leaching is the main downward movement of water, and it was explained in a previous section. Upward nutrient movement might occur in soils with a high water table during periods of high rainfall, with nutrients that were formerly lower in the soil profile rising to surface soil layers [16].

Nutrient availability

Nutrients undergo chemical changes in the soil profile by converting from available to unavailable forms. Phosphorus has complex chemistry in the soil. Plants take up P as phosphates and orthophosphate. Phosphorus also forms insoluble complexes with Fe and Al that make it unavailable for plant uptake. Soil pH is a major driver of these chemical transformations, which are reversible upon pH change. Other nutrients may bind to soil colloids (e.g., 2:1 layered clay) and become temporarily unavailable for plant uptake. These chemical changes are different than soil microbial immobilization described previously. Liming is an important agronomic practice to correct soil pH, and to increase nutrient availability because it can change the chemical form in which a nutrient appears in the soil.

Excreta and plant litter: links between above- and below-ground

Once nutrients are taken up by grassland plants, they have two pathways of return to soil: litter or excreta. Forages grazed by cattle will result in nutrients returning via excreta. Ungrazed, senescent forages will return via litter. The proportion of nutrient returned through either pathway depends on the grazing pressure. Increasing stocking rate and grazing pressure results in greater nutrient flow via excreta. Low stocking rates and reduced grazing pressure shifts the return from excreta to litter deposition. In both pathways, there are advantages and disadvantages. We will discuss them in the following sections.

Nutrient return through excreta

Dung

Most of the nutrients ingested by cattle (often 80% or more) return through excreta [17]. Nutrient partitioning to dung and urine varies with several factors which include animal developmental stage, forage chemical composition, and production level. In general, most of the P and Ca (nearly 100%) and the majority of Mg (70%–90%) return via dung. Other nutrients such as Na (30%–40%) and K (10%–30%) return in

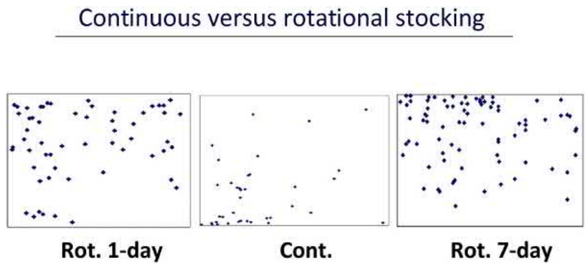

Figure 4.4 Dung spatial distribution as affected by stocking method [32]. *Rot. 1-day*, rotational stocking with a 1-day residence period; *Rot. 7-day*, rotational stocking with a 7-day residence period; *Cont.*, continuous stocking.

lower proportion through dung, with the majority excreted via urine. Nitrogen and S proportion depends on their concentration in the diet. Greater N and S concentrations in the diet increase their proportion in the urine [18].

Uneven spatial distribution of dung often occurs in grazing systems. Cattle spend more time under the shade and around mineral troughs and water sources [13]. These are considered nutrient "hotspots" because of their greater concentration of soil nutrients that derive from animal excreta. Stocking methods and managing the location of shade and water can improve the spatial distribution of nutrient return from dung. Rotational stocking with short grazing periods and high stocking rate often results in more uniform dung distribution [19]. Moving shade and mineral-feeding troughs, and if possible, the water troughs, are management practices that can improve dung spatial distribution (Fig. 4.4).

Urine

Urine is an important pathway of nutrient return to pastures. A single urine deposit by beef cattle grazing pasture may provide the equivalent of 180 lb N/acre and even larger amounts of K to the small area affected [20]. Bahiagrass forage accumulation in urine-affected areas increased 31%–58% on pastures fertilized with 53 lb N/acre per year [21]. Increases in forage accumulation were still measurable 84 days after the urine deposit, and extended up to 1 ft. beyond the edge of the actual urine application [21].

Because nutrients from urine are concentrated in relatively small areas, amounts can far exceed what plants can take up. As a result, losses occur. Nitrogen losses from urine occur mainly via ammonia volatilization, especially in warm-climate regions during the rainy season. Nitrogen losses via denitrification are also likely to occur [22]. Potassium is another important essential macronutrient that returns mainly via urine. Potassium can be lost via leaching, especially in soils with lower cation exchange capacity (e.g., sandy soils) that lack the ability to hold nutrient cations. In general, recommendations for more uniform dung spatial distribution will also be effective for urine distribution.

Forages with high N concentration, such as N-fertilized cool-season grasses, will result in a greater proportion of N returning via urine [23]. Forages with low N concentration results in a greater proportion excreted via feces [24]. One possible alternative to reduce urinary-N losses when animals consume N-rich forages is feeding low-protein, high-energy supplements, with the potential to reduce N excretion in the urine by 50% [25].

Nutrient return through plant litter

Litter quality

Above- and below-ground litter are important pathways of nutrient return to the soil. Amount of litter return will vary with grazing pressure, with greater litter deposition occurring when grazing pressure is less. Nutrient return will be a function of the amount of litter deposited, litter chemical composition, and decay rates. Several factors play a role in litter quality, including plant species, soil fertility, maturity stage, and fertilization.

Litter quality can be defined as the chemical composition and nature of chemical compounds affecting the litter decomposition process. Plants have different compounds, and some of them are more readily available for decomposition, including sugars, proteins, amino acids, and lipids. Other compounds are more resistant to decay, such as lignin, polyphenols, and structural carbohydrates. The combination of these compounds and their ratios have been used to qualify the ability of litter to decay. One of the most common indexes of litter quality is the C:N ratio. Compounds with greater C:N ratio (>30) immobilize nutrients and decay slowly, while compounds with lower C:N ratio decompose faster. Litter C:N ratio is a reliable indicator to assess potential decomposition for recently deposited residues. Long-term decomposition responses may be better explained by other indexes, such as lignin:N or lignin:ADIN (acid detergent insoluble N; considered nearly unavailable) ratio. One possible way to improve litter quality is to add plant species with greater N concentration, such as forage legumes. Because C concentration does not vary widely in plants, increasing N concentration will reduce C:N ratio leading to faster decay rates [15]. Nitrogen fertilization generally reduces litter C:N ratio and may lead to faster decay rates [26,27].

Litter decomposition and nutrient release

Litter decomposition supplies nutrients to the soil solution, which renders them available for plant and soil microbial uptake. In addition to litter quality, other factors affect decomposition including moisture, temperature, soil nutrient availability, and particle size. Faster decay rates may result in more efficient nutrient cycling; thus, more plant biomass is produced per unit of nutrient. This is particularly true when losses after decomposition are limited. Litter decay rates vary, but typically 40%–60% of warm-season grass litter decays per year [27]. Combining litter deposition, nutrient

Poor-quality litter

Assuming:

- 4,000 lb DM/acre of litter deposition
- 1% N in litter
- C:N ratio of 42
- 1/3 microbial C use efficiency and C:N ratio of 8:1 in microbial biomass

We would have:

- 40 lb N/acre deposited via litter
- 1680 lb C/acre
- We would need 70 lb N/acre to decompose the litter
- As a result, we would have a **negative balance** of 30 lb N/acre, which would come from N immobilization

- **Result:** reduced plant growth and pasture degradation

Good-quality litter

Assuming:

- 4,000 lb DM/acre of litter deposition
- 2% N in litter
- C:N ratio of 21
- 1/3 microbial C use efficiency and C:N ratio of 8:1 in microbial biomass

We would have:

- 80 lb N/acre deposited via litter
- 1680 lb C/acre
- We would need 70 lb N/acre to decompose the litter
- The N provided would give a **positive balance**, enough to decompose the litter input with a surplus of 10 lb N/acre

- **Result:** improved plant growth and pasture productivity

Figure 4.5 Effects of litter quality on nutrient cycling and pasture productivity.

concentration, and decay rates allow for the estimation of litter nutrient release [28]. It is important to account for both above- and below-ground litter when estimating litter nutrient contribution, but understanding processes involving below-ground litter presents significant challenges.

Nutrient release from decomposing litter is important, but in some cases, the timing of nutrient release may not match crop nutrient demand. In semiarid regions, litter deposited during the dry season accumulates until the beginning of the following rainy season because limited moisture during the dry season prohibits decomposition. Likewise, regions with cold temperatures during the winter have reduced litter decomposition. As a result, a flush of decomposition occurs at the beginning of the rainy, warm season with a surplus of nutrients. Often, during this time of the year the forages are in the early stages of regrowth after the prolonged dry (or cold) season. Many times the shortage of forage during this period forces land managers to stock pastures to take advantage of this fresh regrowth. This will result in nutrient losses via excreta and reduced regrowth due to overgrazing. From a nutrient management perspective, an efficient practice is to allow the forages more time to regrow by utilizing efficiently the nutrient surplus from litter that occurs at the beginning of the season (Fig. 4.5).

Excreta, plant litter, and soil organic matter

Excreta and plant litter supply C to support the formation of SOM. Initial decomposition of dung and litter will release more soluble C compounds, while more stable (i.e., recalcitrant) compounds remain. Soil microbes that use the labile (more soluble) compounds in the initial phase of decomposition will also decay over time and form stable compounds by binding with clay particles [29]. At the end of this decomposition process, a matrix composed of stable microbial products and persistent (hard-to-decay) compounds will be the building blocks of the SOM. Soils with greater SOM are able to supply more nutrients over time. This results in greater net primary productivity, which will translate into greater stocking rates and livestock productivity, with less nutrient inputs from fertilizers. Therefore, the ultimate goal is to manage SOM in such a way that it increases or at least is maintained.

SOM concentration is a function of residue deposition and decomposition. Greater residue inputs with reduced decomposition will result in greater SOM. The first step to increase residue deposition is to increase plant productivity. This will result in greater litter and excreta return to the soil. This can be achieved through diversification of plant species and plant functional groups, fertilization, irrigation, and combinations of these practices. Maintaining existing SOM is affected by land disturbance. Minimum tillage or no-tillage reduces SOM decomposition compared with soil-disturbing techniques such as plowing, disking, or tilling the soil.

Stocking rate and stocking method: how they affect nutrient cycling

Stocking rate and stocking method affect the pathway of nutrient return and its spatial distribution. Because these grazing practices can be controlled by land managers, they are powerful tools for affecting nutrient cycling in grasslands.

Stocking rate

Shifting between litter and excreta

Stocking rate directly affects the proportion of forage harvested by livestock, which in turn, affects the proportion of nutrients returning to the pasture as plant litter or animal excreta. The proportion in excreta increases with increasing stocking rate. Nutrients returned in plant litter are more evenly distributed across the pasture surface compared with those returned via excreta. Nutrient losses are less when they are returned via litter compared with urine or dung. Therefore, overgrazing might lead to increasing nutrient losses, especially N. This is of concern in low-input C_4 (i.e., warm season) grass-based pastures because it can result in loss of productivity and pasture sustainability over time [14]. Litter accumulation in undergrazed pastures is also not desirable, especially with poor-quality litter. Accumulation of poor quality litter is associated with nutrient immobilization, and thereby reduces soil nutrient availability for plant growth. Excess litter will also reduce tillering by the plants because it limits the amount of light reaching the base of the canopy. Adjustment of stocking rate is the most powerful grazing management tool to balance nutrient return between litter and excreta which is a condition that favors the pasture's ability to persist and produce over time.

Impacts on soil characteristics and nutrient cycling

Stocking rate may also affect soil characteristics which include physical and chemical properties. Cattle hooves exert pressure on soil and may cause soil compaction [30]. Therefore, it is expected that high stocking rates may lead to greater soil compaction, particularly in soils containing considerable amounts of clay. This effect, however, occurs mainly in the shallower soil layers and does not affect deeper layers. Within shallower layers, roots play a major role in stabilizing the soil, thereby increasing SOM and soil aggregates. A strong and developed root system, therefore, counteracts the compaction exerted by cattle hooves and reduces the extent of the problem. Litter cover on the soil surface also helps to reduce hoof pressure and soil compaction.

It is important to differentiate between high stocking rate and overgrazing. Productive pastures may support high stocking rates without signs of overgrazing (i.e., they maintain adequate soil cover, proper canopy height, developed root system), and with no significant soil compaction. Conversely, degraded pastures with reduced herbage mass and soil cover and a limited root system will suffer severely from high stocking rate, and soil compaction is more likely to occur.

Stocking rate will also affect soil nutrient spatial distribution and nutrient losses as it will shift the balance between litter and excreta, as explained previously. Stocking rate exerts a major effect on the root system, especially in overgrazing conditions. Overgrazing leads to a depleted root system, reducing nutrient uptake as a result. Therefore, overgrazing will not only increase nutrient losses by shifting the balance toward excreta return, but it will also reduce the plant's ability to take up nutrients because of a weakened root system.

Stocking method

Nutrient spatial distribution

Stocking method is a defined procedure or technique to manipulate animals in space and time to achieve specific objectives [31]. Continuous and rotational stocking are the most commonly discussed methods in the literature, however, there are variations of rotational stocking which differ in how animals are manipulated. One important feature of rotational stocking is the ability to congregate animals in smaller areas for shorter periods of time. This may lead to improved excreta spatial distribution compared with continuous stocking [19]. Camping sites are areas where cattle repeatedly lounge, and they usually have a greater density of excreta deposition [19]. Moving animals daily or within 1–3-day periods reduces the number of days they camp at the same site and can improve nutrient distribution. Other features related to stocking methods, such as positions of shade and water, will be discussed next.

Shade and water

Cattle spend proportionally more time in shaded areas of the pasture and near water sources which transfers nutrients from other pasture areas to these "hotspots" [19]. This will increase soil nutrient concentrations near shade and water points [33], and may result in greater nutrient losses to the environment. Because rotationally stocked pastures are subdivided into smaller paddock units, livestock are forced to utilize different camping sites across the pasture which results in better spatial distribution of nutrient deposition. One possible alternative to improve nutrient distribution in a continuous stocking system is to have portable shades, watering points, and mineral and feeding stations.

Management practices to improve the efficiency of nutrient cycling

Soil testing and fertilization

Nutrient cycling efficiency can be defined as the amount of desired product (or environmental service) delivered per unit of nutrient cycled in the system. Therefore, the faster nutrients cycle and the smaller the losses, the more efficient the overall nutrient cycling. The balance of all essential nutrients for plant and livestock growth is essential to maximize the use of all nutrients. The first step is to take a representative soil sample. Based on previous information, it is important to sample separately the soil near shade, water, and camping sites, since they will overestimate the status of soil fertility in the pasture. Soil test results will indicate liming requirements as well as needs for macro and micronutrients. Fertilization is often essential to balance soil nutrients. Grass–legume mixtures may need the addition of lime, P, K, and other macronutrients. Nitrogen application to mixtures can be reduced when considering the ability of forage legumes to associate with N-fixing bacteria. Once soil nutrients are adequate, it is important to supplement livestock with minerals, since some elements that are essential for livestock may not be present in sufficient quantities in the plants they consume [34].

Pasture design (e.g., shape, water, and shade placement)

Pasture design may improve nutrient distribution. Major features of design include location of shade and water, and managing animals to utilize different camping sites. Silvopasture systems can enhance nutrient spatial distribution since shade is available across the pasture. Smaller paddocks with short grazing periods using rotational stocking also tend to improve nutrient spatial distribution [19]. Another feature of paddock design is to reduce the number of neighboring paddocks with resident

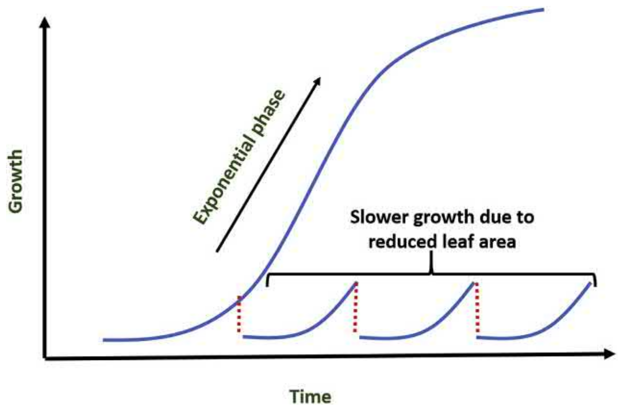

Figure 4.6 Growth curve of forage crops.

livestock. This limits the amount of fence line shared between 2 paddocks, which in turn limits congregation of livestock near a fence line [19].

Grazing management

Grazing management strategies include the adjustment of stocking rate, stocking method, and whatever other method is available to manage defoliation. Grazing frequency, intensity, and timing are the major aspects of defoliation affecting plant regrowth. Maximizing plant growth, forage quality, and harvesting the forage efficiently with grazing animals are the ultimate goals of the grazing manager. It is also important to reach economic goals and to apply sustainable management practices. Sometimes greater plant or animal productivity may not be the best option to maximize economic and environmental benefits.

Rotational stocking often results in greater herbage accumulation [35], because these plant canopies have greater leaf percentage and younger average leafage than those in continuously stocked pastures. As a result, forage in rotationally stocked pastures spend a greater proportion of time in the linear phase of the forage growth curve (Fig. 4.6). Greater nutrient use efficiency is the result of more products and services being delivered per nutrient unit. However, it is important to optimize both herbage accumulation and forage nutritive value. This is a challenging task since forages often increase herbage accumulation with longer rest periods between grazing events, but forage nutritive value declines as plants mature.

Conclusions

Nutrient cycling is an important process contributing to grassland persistence and productivity. Efficient nutrient cycling will produce more forage with less nutrients; thus, economic and environmental benefits are enhanced. Management practices that affect the efficiency of nutrient cycling include adjustment of stocking rate, choice of stocking method, manipulating forage species diversity, and distribution of shade structures, supplement feeding stations, water troughs, and fertilization.

Reducing nutrient losses and improving nutrient turnover are key aspects to enhancing overall nutrient cycling. Several management practices can contribute to achieving these objectives, but the adjustment of stocking rate is the single most important tool in order to balance nutrient return between litter and excreta. Improving litter quality by integrating forage legumes, especially in warm-climate C_4-based grasslands, is also an efficient way to improve nutrient cycling and potential economic returns.

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CHAPTER 5

Managing grazing in forage−livestock systems

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The success of any forage-animal system depends on the grazier, a person with equal interest and expertise in managing the interplay of soils, plants, and animals.
Roy E. Blaser (1986)

Definition and importance of grazing management

Grasslands cover more than 40% of Earth's ice-free terrestrial surface [1]. Forage is the most consumed livestock feed in the world [2], and land grazed by livestock is the largest single land-use type [3]. Although grazing management is an important tool for grassland ecosystem maintenance and regulation, grazing has also been implicated in grassland degradation [4]. When considered together, these factors support an effort to optimize grazing management in forage−livestock production systems [5].

What is grazing management? Grazing management is simply "the manipulation of grazing in pursuit of a specific objective or set of objectives" [6]. Objectives may include optimizing forage production, efficient utilization of forage produced, maintaining pasture persistence, achieving specific goals for animal production and economic return, sustaining natural resources, and delivery of ecosystem services [5]. Achieving such a wide range of objectives is a formidable challenge for those implementing grazing management practices. However, the potential reward is great because when pasturelands are managed sustainably, they maintain the resource base of the ecosystem while providing human food in an economically viable manner that enhances the quality of life for both producers and consumers [7].

Grazing management tools

We have already described grazing management as manipulation of grazing. But what specifically are the components of grazing management that can be manipulated in

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order to achieve our objectives? These components, or grazing management tools, include grazing intensity, grazing frequency, which is related to stocking method, and timing of grazing.

Grazing intensity relates to the severity of grazing. Measures of grazing intensity can be animal-based, like stocking rate (animal units or lb of animal liveweight per acre), or pasture-based, like quantity of forage or plant height. These descriptions of grazing intensity are limited to an extent because they refer only to one component of the system, i.e., either the plant or the animal, and do not integrate both components. For example, one animal unit per acre may be a high grazing intensity for pastures of relatively low productivity, but it is likely a low grazing intensity for a very productive pasture. Thus, there is value in describing grazing intensity as forage allowance (amount of forage per unit of animal liveweight) or grazing pressure (relationship between animal liveweight and amount of forage), which contain both pasture- and animal-based aspects [6,8].

Stocking method is another grazing management component or tool. Stocking method is the manner in which animals are allocated to pastures during the grazing season, and choice of stocking method affects grazing frequency. Many stocking methods have been described [6], but typically they are either continuous stocking or some form of rotational stocking.

The last grazing management tool we will discuss is the timing of grazing. It relates to the plant growth stage or season of the year when grazing occurs. This tool is important because a particular management practice may be effective at certain times of the year or under certain conditions but not others [9]. These three tools, grazing intensity, stocking method, and timing of grazing are the focus of the sections that follow.

Grazing intensity (stocking rate)—where it all begins

In determining the appropriate pasture stocking rate, a useful starting point is to consider the carrying capacity of the pasture. In a specific grazing system, carrying capacity is the maximum stocking rate that will achieve a target level of animal performance without deterioration of the grazing land [6]. Carrying capacity is a useful concept when based on adequate historical data and experience, but it is site-specific and varies from season to season and year to year. There also are multifunctional uses of grazing lands, and carrying capacity can differ depending on the function that is of greatest priority.

The selection of grazing intensity (e.g., forage allowance, stocking rate, and pasture height) is more important than any other grazing management decision [10]. Grazing intensity plays a major role in determining subsequent forage plant productivity and persistence [5], animal performance and profitability of the grazing operation [11], and environmental impact and delivery of ecosystem services [12]. Understanding the relationship of grazing intensity (subsequently used interchangeably with the term stocking rate) to pasture and animal performance is crucial for the long-term success of the forage–livestock enterprise.

Factors that affect choice of stocking rate

There are a number of factors to consider when choosing the stocking rate. As a starting point pasture carrying capacity (affected by plant species, species and class of animals, soil characteristics, climate, etc.) should be assessed based on the particular land-use objective. It is also important to think about stocking rate within two contexts, the entire farm or ranch versus an individual pasture. We revisit this issue several times throughout the chapter, so let us highlight a few important distinctions. In the absence of weather extremes or major changes in overall farm/ranch management, many producers maintain approximately the same number of animals per unit land area on their entire farm or ranch over periods of years. In contrast, stocking rate of individual pastures may change annually, due to variable weather conditions, or even several times per year in order to match stocking rate with seasonal differences in forage production. Entire farm or ranch stocking rate decisions must consider climate (i.e., long-term averages of weather) effects on seasonality of forage production on their property. If entire-farm stocking rate is based on forage production during the season when it is greatest, the amount of conserved or purchased feeds required during the season of forage shortfall increases dramatically. Costs of these supplementary feeds negatively affect farm profitability. Thus, entire-farm stocking rate decisions must take into account the amount of forage produced during the season of shortfall (cold or dry season) and the availability and cost of conserved forage or purchased feeds relative to the price received for the animal product.

Other factors that influence the choice of stocking rate are the species and class of animal on the farm and the producer's goal for animal production (e.g., weight gain or milk production). Additionally, stocking rate is an important determinant of overall pasture persistence, and in pastures with a mixture of several forages the stocking rate can affect the survival of these species differently. Choice of stocking rate in pastures also affects the likelihood of soil erosion, amount of sediment and nutrient runoff to surface water and nutrient leaching to groundwater, soil organic matter levels, and quality of wildlife habitat. More detail about stocking rate effects on these factors follows.

Impact of stocking rate on the forage–livestock system

Animal performance

Starting with an overgrazed condition (i.e., high stocking rate), as stocking rate decreases (i.e., herbage allowance increases) individual animal performance increases (Fig. 5.1). This occurs initially because forage quantity becomes less limiting and

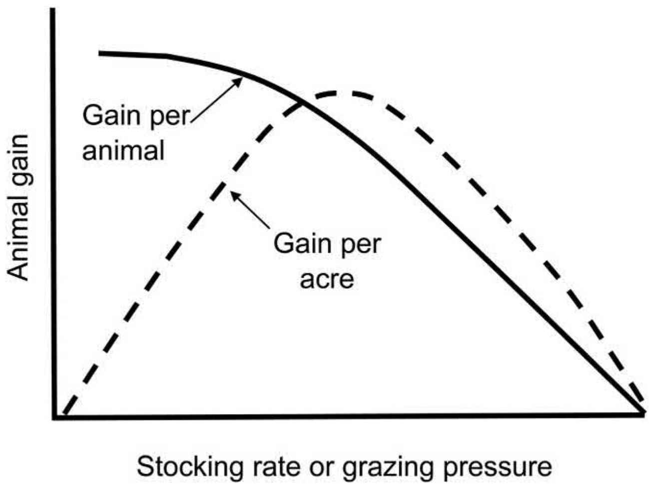

Figure 5.1 The relationship of gain per animal and gain per acre with stocking rate or grazing pressure. *Adapted from G.O. Mott, J.E. Moore, Evaluating forage production. in: R.F Barnes et al. (Eds.), Forages: The Science of Grassland Agriculture, Iowa State University Press, Ames, IA, 1985, pp. 97–110 [78].*

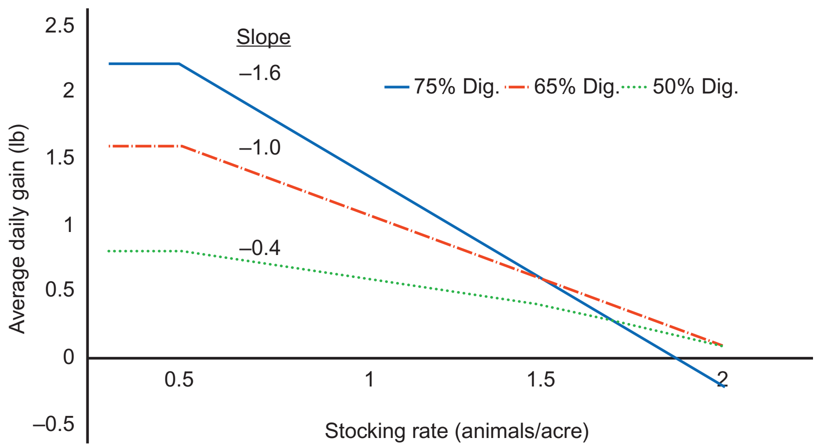

Figure 5.2 The expected relationship of grazing livestock average daily gain with stocking rate for forages of different digestibility. Note that slope of the linear portion of the curve typically is more negative as forage digestibility increases. *Based on concepts described by L.E. Sollenberger, E.S. Vanzant, Interrelationships among forage nutritive value and quantity and individual animal performance. Crop Sci. 51 (2011) 420–432 [13].*

eventually because of greater opportunity for diet selection by the animal. The rate of the increase (i.e., slope) in individual animal performance with decreasing stocking rate is related to forage nutritive value; and the greater the nutritive value of the forage the faster animal performance increases as stocking rate is reduced (Fig. 5.2) [13]. Total animal production per unit area of pasture responds differently than individual animal production (Fig. 5.1). Starting from an overstocked condition, as stocking rate decreases production per acre increases. This continues up to some maximum, after which further decreases in stocking rate cause a decline in production per acre because the forage is underutilized (Fig. 5.1).

It is important to understand that both individual animal performance and animal production per acre cannot be maximized using the same stocking rate. Maximum individual animal production will nearly always occur at a lower stocking rate than maximum production per acre (Fig. 5.1). In light of this, what is the best choice? This depends on a number of factors, in particular, the product that is being marketed. For example, a producer who sells breeding stock, which is priced based on their individual weight gain on pasture, will want to use a relatively lower stocking rate to maximize individual animal performance. In contrast, a producer who grazes stocker cattle on a fixed area of pastureland and is paid based on total amount of weight that the entire group of stockers gains, will want to choose a stocking rate that maximizes gain per acre, knowing that they are sacrificing some individual animal gain.

Plant productivity, nutritive value, and persistence

Increasing stocking rate or grazing to shorter canopy heights decreases pasture forage mass [14,15] and forage allowance [16,17], leading to decreasing individual animal performance with increasing stocking rate (Fig. 5.1). The effect on forage plant productivity (referred to as forage accumulation) is less clear cut. In a review of published research, nearly half of the studies showed that greater forage accumulation occurred as grazing intensity decreased. However, forage accumulation was not affected by grazing intensity in one quarter of studies, and actually increased with increasing grazing intensity in one quarter of studies [5]. Forage species that showed greater forage accumulation as grazing intensity increased were typically grazing-tolerant plants, for example, tall fescue [*Lolium arundinaceum* (Schreb.) Darbysh.] [18], a perennial ryegrass (*Lolium perenne* L.) white clover (*Trifolium repens* L.) mixture [19], and a decumbent type of rhizoma peanut (*Arachis glabrata* Benth.) adapted to close grazing [20]. In contrast, forage accumulation decreased with increased grazing intensity for forages including stargrass (*Cynodon nlemfuenis* Vanderyst) [21], bermudagrass [*Cynodon dactylon* (L.) Pers.] [22], and orchardgrass (*Dactylis glomerata* L.) [23]. For orchardgrass, this response was attributed to its upright growth habit and lack of tolerance for heavy grazing. Thus, we can conclude that for most forage species, forage accumulation decreases as grazing intensity increases; but this expected outcome may be different for some forages that are particularly grazing tolerant, or can adapt their growth habit to heavy grazing.

About two-thirds of published experiments show that nutritive value of the forage presented to the animal generally increases with increasing grazing intensity [5],

Table 5.1 Stargrass forage crude protein, in vitro digestibility, and neutral detergent fiber when grazed by weanling bulls that were rotationally stocked at three stocking rates during 300 days/year in each of 2 years.

Stocking rate (head/acre)	Crude protein (%)	In vitro digestion (%)	Neutral detergent fiber (%)
1	13.4	58.6	77.4
2	14.0	59.3	76.2
3	15.1	59.9	74.9
Polynomial contrast	Linear	Linear	Linear

Data from A. Hernández Garay, L.E. Sollenberger, D.C. McDonald, G.J. Ruegsegger, R.S. Kalmbacher, P. Mislevy, Nitrogen fertilization and stocking rate affect stargrass pasture and cattle performance, Crop Sci. 44 (2004) 1348−1354 [21].

although greater grazing intensity does reduce the opportunity for diet selection by the animal. A good example of this is the effect of stocking rate on stargrass nutritive value (Table 5.1) [21]. Crude protein and digestibility of stargrass forage increased, and neutral detergent fiber concentration decreased as stocking rate became greater. Why did this happen? When pastures are continuously stocked and grazed closely (i.e., high stocking rate) for an extended period, there is a relatively small amount of forage present for animals to consume. As a result, the animals visit and revisit specific pasture locations more frequently. Frequent visits mean less mature forage which results in greater forage nutritive value. Under rotational stocking the situation is somewhat different because the manager, and not the grazing animal, controls the frequency of grazing. In this case when stocking rate is high, the forage is grazed closely by the time the cows are moved to the next paddock. This closely grazed forage often regrows more slowly. The rate at which it matures is also slower; thus, the forage in the heavily grazed pasture is greater in nutritive value when the animals return to that paddock the next time. Note that this discussion relates to the nutritive value of the forage present in the pasture, not necessarily to the diet consumed by the animal. At low stocking rates, there is greater opportunity for diet selection by the animal, and this can result in the nutritive value of the diet being considerably greater than that of the forage present.

> ***Management of forages must be associated with the morphology of species in order to maintain production and persistence.***
>
> **Roy E. Blaser (1986)**

Long-term pasture survival is a goal for most pasture-based livestock systems because pasture establishment is a major input cost. How is persistence affected by grazing intensity? Stocking rate is an important determinant of pasture survival, so it is critical to avoid overgrazing that can lead to subsequent loss of stand. Forages differ in their level of grazing tolerance, so it is important to know how the plant species present in a particular pasture respond to grazing in order to determine the most appropriate stocking rate. Generally, plants that have rhizomes or stolons and a more decumbent growth habit can tolerate greater stocking rates than upright-growing legumes or bunch grasses. However, each plant within a population has some ability to adapt to stress from defoliation by changing the way it orients and positions its stems and leaves, an attribute termed phenotypic plasticity [24]. Phenotypic plasticity includes changes in size, structure, and spatial positioning of stems and leaves in response to defoliation [20,25]. Phenotypic plasticity is related to grazing tolerance, and the degree to which it occurs varies among forage species [26], even among cultivars within the same species [27]. Plants that exhibit phenotypic plasticity may shorten the length of internodes or change the angle of stem growth resulting in a shorter canopy that is arranged in a way that leaves and growing points are less easily accessed by grazing animals. Even for plants capable of these adaptations, phenotypic plasticity has limits, and if defoliation is too severe it may exceed the ability of the plant to adjust, and plant death may occur [28].

Ecosystem services

Ecosystem services are benefits an ecosystem provides to society including effects on soil, water, and atmosphere. Delivery of ecosystem services by pastureland is affected by grazing intensity. Excessive stocking rate leads to increased soil erosion, soil compaction, and a decline in soil quality [5]. Pastures grazed too closely are associated with greater amounts of soil sediment and nutrients flowing into surface water and negatively affecting water quality [29]. For example, three stocking rates (0.6, 0.8, and 1.2 animal units/acre) were studied in Texas rangeland composed of several mid-grass and short-grass species and forbs, and highest stocking rate led to the greatest amount of sediment loss (nearly 1340 lb/acre) and lesser rates of water infiltration into soil [30]. Likewise, the amount of phosphorus in runoff was approximately three times greater for a smooth bromegrass (*Bromus inermis* Leyss.) pasture grazed to a 2- versus a 4-in. stubble under rotational stocking [31]. Overgrazed pastures have diminished root or rhizome mass [32] which can increase the likelihood of soil erosion, limit nutrient uptake, and increase nutrient leaching to groundwater.

Organic matter is a critical component of soil because it increases water-holding capacity, supply of nutrients, and nutrient cation (e.g., potassium and magnesium) retention. Organic matter accumulation in soil is favored by greater amounts of below-ground plant biomass, aboveground senescent material, and deposition of animal excreta. After 20 years of management, grazed bermudagrass pastures had 23% greater soil organic carbon (top 8 in. of soil) than fields that were hayed [33], but the effect of grazing on soil carbon and soil organic matter accumulation depends on the intensity of grazing. For example, 'Coastal' bermudagrass was either unharvested, hayed monthly, or grazed at low or high stocking rates during 12 years [34].

The annual rate of increase in soil organic carbon (depth of 0–35 in.) was approximately twice as great for the low stocking rate as for unharvested areas and the high stocking rate, and approximately five times as great for the low stocking rate as for hayed areas [34]. In another study with bermudagrass, a low stocking rate resulted in greater increases in soil carbon and nitrogen than a high stocking rate [35]. The soil carbon response to grazing intensity is climate dependent. In drier regions, low or moderate grazing intensities increased soil carbon under grasslands, but soil carbon decreased with greater intensities [36]. Adoption of sustainable management practices, including reducing stocking rate to an optimum level, contributed to the restoration of soil carbon levels in Canadian prairie grasslands over the past 70–80 years [37].

An important ecosystem service of pastureland is providing wildlife habitat and food supply. High grazing intensity is blamed for a reduction in abundance of pastureland birds due to loss of preferred habitat for nesting, destruction of nests due to trampling, and a reduction in invertebrate food sources [38]. Field vole abundance in pastureland is important because of their role as a food source for other wildlife species, and vole abundance was greater in plots with low versus high stocking rate of sheep plus cattle [39]. Low stocking rate favored voles because of greater food resources and greater cover to protect from avian predators. Not all species are favored by low stocking rate, however. Lightly grazed pastures were less preferred by brown hares (*Lepus europaeus*) compared with moderately grazed ones because grazing reduced herbage height and density, allowing hares to see approaching predators [40]. The spur-thighed tortoise (*Testudo graeca*) also selected areas with intermediate annual grass cover and rejected areas with low and high cover [41]. Thus, high stocking rates are rarely favorable to wildlife, but moderate grazing may improve habitat for some species versus a nongrazed condition.

Pollinators benefit 35% of global crop-based food production [42], and insects, particularly bees, are the primary pollinators of most agricultural crops. Populations of wild and domesticated pollinators are declining, and this is considered a threat to global food security [43]. Grazing intensity affects pollinator populations, and managing grazing intensity to avoid overgrazing and to increase the number of flowering plants (e.g., many legumes) is beneficial for both cattle and pollinators [44].

Should stocking rate be constant or variable throughout the year?

There have been many arguments about this question. Two conflicting points of view can be summarized as follows. Advocates for use of a variable stocking rate, where stocking rate changes throughout the growing season, argue that strong seasonality of forage production requires adjustment of animal numbers on pasture to avoid under- or over-grazing. Advocates for use of a constant (or fixed) stocking rate, that is, one that does not change seasonally, argue that producers cannot simply buy or sell animals throughout the year to account for variation in seasonal forage production.

As is the case with many arguments, there are strengths and weaknesses in both positions. Part of the difference in perspective relates to the issue discussed earlier of total farm versus individual pasture stocking rates. Individual pasture stocking rates can be varied by moving animals from one pasture on a ranch to another more productive pasture on the same ranch to better utilize the forage currently present. Similarly, during a time of rapid forage growth a producer may increase stocking rate on a pasture simply by closing off to livestock a portion of the pasture and subsequently cutting hay from the fenced area or allowing forage to stockpile. These are both examples of varying stocking rates of individual pastures but keeping total farm stocking rate constant.

Another issue that adds confusion to this discussion is different perspectives regarding what constitutes variable stocking. As noted earlier, advocates of a fixed stocking rate argue that producers cannot adjust their total farm stocking rate by regularly buying or selling cattle when forage production indicates that they need to raise or lower stocking rate. This is a valid point, but it fails to take into account the true definition of stocking rate. Stocking rate is determined by a number of animals *and* amount of land area. The amount of land area refers to *all* land that is used to produce feed for the animals on that farm or ranch. When feed grown off the farm or ranch is purchased, the producer has effectively reduced their stocking rate because they have increased the amount of land used to feed the same number of livestock. Of course there are some farms or ranches that bring in no feed from elsewhere, but that is relatively rare. Thus, the argument of fixed versus variable stocking rate may not be terribly relevant to the production environment because most farms and ranches vary stocking rate by some means, even if it is only by buying feed from off the property.

Stocking methods (frequency)—fine-tuning the system

Stocking method is "a defined procedure or technique to manipulate animals in space and time to achieve a specific objective" [6]. Producer and popular press conversations about grazing management often focus on stocking method more than grazing intensity. It is important to recognize that errors in selection of grazing intensity cannot be fully compensated by the choice of stocking method. Thus, grazing intensity is the most important grazing management decision, and the choice of stocking method is used to fine tune grazing management to improve sustainability of the grazing system [5].

We need to distinguish between the terms stocking method and grazing system because they are often used interchangeably despite having different meanings.

Grazing system is "a defined, integrated combination of soil, plant, animal, social and economic features, stocking method(s), and management objectives designed to achieve specific results or goals" [6]. Looking at the definitions, we can see that the stocking method is one of many components of the overarching grazing system.

In this discussion we will consider stocking method to be the manner in which animals are stocked or are given access to pastures and paddocks (pasture subdivisions, if present) during the grazing season. Note that the choice of stocking method is independent from the choice of grazing intensity, with a particular stocking method potentially being used across a wide range of intensities. Many stocking methods have been described [6], but each is derived from continuous or some form of rotational stocking. Continuous stocking is "a method of grazing livestock on a specific unit of land where animals have unrestricted and uninterrupted access throughout the time when grazing is allowed" [6]. In contrast, rotational stocking "utilizes recurring periods of grazing and rest among three or more paddocks in a grazing management unit throughout the time when grazing is allowed" [6].

Factors affecting choice of stocking method

> ***With continuous stocking, pastures should be stocked so the sod residue maintains an adequate leaf area to generate new growth.***
>
> **Roy E. Blaser (1986)**

Long-term pasture persistence is an important objective in most grazing systems, and some species may require rotational stocking to persist, or they may perform better under rotational than continuous stocking [45]. Alternatively, if pastures are planted to bahiagrass, Kentucky bluegrass (*Poa pratensis* L.), or endophyte-infected tall fescue, species that persist well under continuous stocking if stocking rate is not excessive, the producer may not wish to assume the additional cost of fencing and waterlines to facilitate rotational stocking. Another reason to consider rotational stocking is the potential to increase pasture carrying capacity because of less spot grazing and faster average forage accumulation rate on rotationally than continuously stocked pastures [5]. Moving animals from paddock to paddock under rotational stocking can increase uniformity of distribution of animal excreta and increase the efficiency of nutrient cycling relative to continuous stocking [46,47]. Rotational stocking also makes it easier to utilize techniques like first-second grazer and forward creep grazing. Both allow first access to new paddocks to animals with greatest nutrient requirements, and they are designed to more closely match the nutrient requirements of the animal with the nutritive value of the forage in the portion of the canopy that is grazed. In addition to less capital outlay, advantages for continuous stocking include greater opportunity for diet selection (if the pasture is not over-stocked), less variation in day-to-day forage intake and digestibility, fewer decisions required of management (e.g., when to begin and end grazing on a new paddock), and somewhat less labor.

Impact of stocking method on the forage–livestock system

The relative advantages of different stocking methods are often a subject of vigorous debate, not all of which is based on data and experimentation [10]. In this section we will attempt to clarify the effects of various stocking methods based on a consensus of published research.

Animal performance

The ways that we describe animal performance include individual animal production (e.g., liveweight gain or milk production per day) and production per acre (e.g., liveweight gain or milk produced per acre of pasture), where production per acre is determined by individual animal performance and the number of animals grazing the pasture (i.e., average stocking rate or carrying capacity). Therefore, in order to determine if stocking methods affect animal performance differently, we need to consider their effects on individual animal production, average pasture stocking rate, and animal production per acre.

When looking at many published studies, about two-thirds of the comparisons of continuous and rotational stocking show no difference in daily individual animal production [5]. About one quarter of published studies show an advantage of continuous over rotational stocking, and only slightly more than 10% show an advantage of rotational over continuous stocking. This is surprising for some, particularly for those whose image of a continuously stocked pasture is one that is overgrazed. If that image is what you see, keep in mind that an overgrazed pasture occurs because grazing intensity (i.e., stocking rate) is too high, not because of the stocking method used. In order to draw accurate conclusions about the effect of stocking method, we must consider only those comparisons of stocking methods where grazing intensity was the same. That was the approach in the summary described earlier, so we conclude from the literature that in the majority of situations there will not be a measurable difference in individual animal production between rotational and continuous stocking methods.

Why is this the case? Does it make sense biologically? Let us think about it. Individual animal performance is affected by both quantity of forage and forage nutritive value (i.e., chemical composition and digestibility), however, if forage quantity is not limiting then nutritive value explains a large proportion of the individual animal performance response. The following studies provide support of this statement. When cattle were grazing pearl millet and quantity was not limiting, forage in vitro digestibility explained 74% of the variation in individual animal performance [48]. In an experiment with bermudagrass pastures, the proportion of the variation in individual animal performance explained by nutritive value was 56% when quantity was not limiting [49]. We can conclude from these studies that forage nutritive value explains from about one-half to three-quarters of the variation in individual animal performance if the amount of forage is not limiting. It follows then that if stocking method affects individual animal performance, it will be because stocking method affects forage nutritive value. So the question is, does stocking method affect forage nutritive value? What does the published literature tell us? This will be discussed more thoroughly later, but over 70% of papers reviewed regarding this question showed no effect of stocking method on nutritive value. Thus, it stands to reason that nearly the same percentage of papers found no effect of stocking method on individual animal performance.

Does stocking method affect the average stocking rate or carrying capacity of the pasture? In the review of previous studies, 85% reported an advantage in forage quantity or carrying capacity for rotationally versus continuously stocked pastures [5]. The average increase for rotational versus continuous stocking was 30%, meaning that if there is a *well-managed* pasture that is continuously stocked, and the manager switches to well-managed rotational stocking, we expect that stocking rate could be increased approximately 30%. There are several possible reasons for this. One is more uniform forage utilization across the pasture, improving the efficiency of grazing [50]. Rotational stocking generally increases utilization by 5%—15% in research studies, but this number may be greater in larger pastures that are common on farms [51].

Lastly, we want to know if stocking method affects animal production per acre. We already know production per acre is a function of two factors, individual animal production and average stocking rate. And we know that in most cases stocking method does not affect individual animal performance, however, rotationally stocked pastures can often support a 30% greater stocking rate than continuously stocked pastures. Based on experiments in which stocking rate was adjusted occasionally based on the amount of forage in the pasture, there was no difference in gain per acre due to stocking method 50% of the time, but rotationally stocked pastures had greater gain per acre than continuously stocked pastures 45% of the time.

So, what do we know about how the choice of stocking method affects animal production? Generally, individual animal production (daily gain or daily milk production) will not differ between continuous and rotational stocking. However, average stocking rate can be greater on rotationally than continuously stocked pastures most of the time, and this results in greater animal gain per acre on rotationally stocked pastures in approximately half of the situations where it has been used.

Plant productivity, nutritive value, and persistence

It has been established that rotational stocking often allows greater average stocking rates (i.e., carrying capacity) than continuous stocking. In order for this to happen, rotationally stocked pastures must have either greater forage accumulation rate, more efficient utilization of existing forage mass, or both. More efficient utilization of existing forage was already confirmed to occur, and it likely contributes part of the forage quantity advantage observed for rotational stocking. What about greater forage accumulation rate? Does that occur, and if so, how?

Several observations are of interest in considering these questions. Canopy photosynthesis was greater in continuously (leaf area index = 1) than rotationally stocked (leaf area index = 0.5) perennial ryegrass pastures immediately following defoliation [52]. However, this soon reversed because the leaf area index and percentage of young leaves increased more rapidly in rotational pastures. As a result, long-term canopy photosynthesis rates of rotationally stocked pastures exceeded those of continuously stocked pastures even when defoliation was severe and regrowth periods were relatively short. Therefore, we can conclude that a greater average leaf area index and a younger average leaf age in rotationally stocked pastures contribute to their forage quantity advantage over continuously stocked pastures.

Before leaving this topic we should also consider that greater uniformity of grazing may contribute to greater average forage accumulation rate in addition to affecting efficiency of utilization. An example is the patch grazing that often occurs in continuously stocked pastures. The plants in these patches are grazed closely and frequently which causes plant growth to slow because leaf area is consistently limited. Rotational stocking allows the manager, instead of the grazing animal, to control the length of the regrowth period. As a result, even moderately overgrazed pastures may have time to recover and move into a more rapid growth phase if the regrowth period is long enough (Fig. 5.3). This means that especially when stocking rates are high or during times of feed deficit, rotational stocking should better control the average leaf area, leading to faster growth rates than continuous stocking. Of course, if stocking rates are extremely high, rotational stocking will not be able to compensate for this poor management.

There is limited information regarding the effect of stocking method on forage nutritive value. As noted earlier, most studies evaluating this response have found no measurable difference. Logically, we might conclude that if differences exist, they would be more likely to favor continuous stocking [53]. Let us think about that for a moment. Forage nutritive value is primarily affected by maturity, and nutritive value of the diet is affected by the opportunity for selection. If forage quantity is not limiting, greater nutritive value for continuous than rotational stocking could be associated with greater opportunity for selection and the tendency of animals to make frequent visits to the same grazing stations, which would result in the consumption of less mature forage [54].

The persistence (i.e., long-term survival) of some forage species is strongly favored by rotational stocking [45] while for others either rotational or continuous stocking can be used so long as grazing intensity is not too great. One of the challenges in

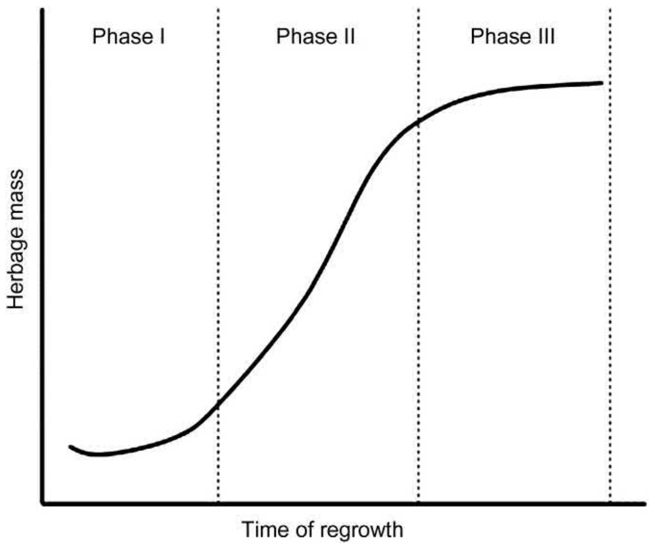

Figure 5.3 Accumulation of forage during a regrowth period follows this general pattern. The pasture starts at low forage mass (Phase I: Low accumulation rate), increases to intermediate forage mass (Phase II: High accumulation rate), and then to high forage mass (Phase III: Little or no net accumulation due to balance between new growth and death of aging plant tissue). *Adapted from G.R. Saul, D.F. Chapman, Grazing methods, productivity and sustainability for sheep and beef pastures in temperate Australia. Wool Technol. Sheep Breed. 50 (2002) 449–464 [51].*

assessing whether stocking method will eventually affect animal performance is most grazing experiments are too short to measure long-term survival. One example of this is a study comparing two cultivars of the legume rhizoma peanut under continuous stocking [55]. One cultivar was upright growing; the other was lower growing. During the first 2 years, the percentage of both cultivars in the pasture was greater than 80%, and there was no difference in average daily gain of grazing cattle. In year 3, the proportion of the more upright-growing plant decreased to 66%, and animal gain was greater for the lower growing plant that composed 87% of the pasture mass. Thus, some changes in persistence take time to occur, and conclusions about best management practices may not be obvious in the first year or two of an experiment.

Ecosystem services

Rotational stocking may provide environmental benefits, but limited research has been conducted to evaluate the effects of rotational versus continuous stocking. The majority of a relatively small number of studies indicate that rotational stocking is less detrimental to water quality, hydrology, and stream morphology than is continuous stocking [5]. Mean total phosphorus in runoff was 34% greater with continuous stocking to maintain a 2-in. canopy height than with rotational stocking leaving a 2-in. postgrazing stubble [31]. During the regrowth period, plants on the rotationally stocked pasture grew much taller than 2 in. This resulted in greater average forage coverage of the soil; therefore, the impact of raindrops on soil was reduced, and water runoff decreased from rotationally versus continuously stocked pastures. A review of the literature showed that average vegetation cover was greater using rotational than continuous stocking, which implied that choice of rotational stocking may have long-term positive implications for water quality [56]. Winter-feeding areas on pastures in Ohio have been associated with greater runoff, sediment, and phosphorus loads as compared with nonuse areas, and losses of total *N* were approximately twice as great with continuous as with rotational stocking [57]. In Minnesota, suspended sediment was greater in the stream and more streambank soil was exposed for continuously compared with rotationally stocked sites [58]; whereas in Wisconsin, lower amounts of streambank erosion and suspended sediment in stream water occurred where intensive rotational stocking was practiced, compared with continuous stocking [59]. Responses to stocking method are not always consistent, as monthly water runoff was greater with continuous than rotational stocking 75% of the time in Ohio [60], but in Georgia, there was no difference in annual surface runoff volume between pastures treated with broiler litter that was continuously or rotationally stocked year-round [61].

Uneven spatial distribution of nutrients occurs in grazing systems because cattle deposit more dung and urine where they spend more time, that is, under the shade and around mineral troughs and water sources [62]. Rotational stocking with short grazing periods and high stocking density often results in more uniform dung distribution [47]. However, this benefit of rotational stocking is likely to be less pronounced in warm climates or during hot weather in temperate climates. Under these conditions, animals spend more time under shade or near watering points, and the majority of dung and urine is deposited there regardless of stocking method [45].

Stocking method has had limited or no effect on wildlife responses [5]. Several examples follow. In southwestern Wisconsin, there were no differences between rotational and continuous stocking in population size of several grassland bird species [63]. Instead, bird density was related to vegetation structure with greater density found on nongrazed buffer strips with deeper plant litter. Loss of nests due to cattle trampling was directly proportional to stocking rate in Texas, and stocking method had little effect [64]. In Wisconsin stocking method had no effect on either the number of individuals or number of small mammal species present in continuously or rotationally stocked riparian areas [65]. Relative to populations of pollinators, the most important consideration is likely choice of a stocking method that maximizes persistence of legumes or flower-rich species. Thus, if persistence of these key forage species is better under rotational than continuous stocking, then benefits to pollinators would likely follow.

Overall, the literature suggests a role for rotational stocking in enhancing the uniformity of nutrient deposition in pastures and protecting water quantity and quality. The choice of stocking method, however, is likely to be less important from an environmental perspective than maintaining an appropriate stocking rate.

Number of paddocks and stocking density in rotational stocking

Number of paddocks in rotationally stocked pastures

If the decision to rotationally stock a pasture has been made, how many paddocks (pasture divisions) should be used? More paddocks cost more money in infrastructures like fencing and water lines, so costs must be balanced against potential benefits. What do previous studies tell us about potential benefits of increasing number of paddocks on pasture productivity and nutritive value? Relative to forage production, approximately half of studies cited in a recent review [5] reported advantages in forage quantity by increasing number of paddocks, and about half reported no effect. So, relative to forage production, the number of studies is small and inconclusive. Relative to forage nutritive value, six of eight relevant studies representing a wide range of forage species reported no difference in forage nutritive value due to a number of paddocks, that is, length of the grazing period on each paddock. Of the other two studies, one favored more paddocks and one favored fewer paddocks. Thus, based on the currently available research for rotationally stocked pastures, there is not a consistent advantage of a large number of paddocks versus a smaller, more typical number in terms of pasture productivity or nutritive value.

Stocking density and "Mob Grazing"

Stocking density is defined as the relationship between the number of animals and the specific unit area of land being grazed at any one time [6]. It is an instantaneous measurement of the animal-to-land area relationship in contrast with stocking rate which is the same relationship, but over an extended period of time. Under continuous stocking, stocking density is the same as stocking rate. On rotationally stocked pastures they are different. For example, if over a summer grazing season there are five animals grazing a 5-acre pasture that is divided into five 1-acre paddocks, the stocking rate is one animal per acre, but the stocking density at any instant is five animals per acre.

An understanding of stocking density is important because currently, some people advocate using rotational stocking with a very high stocking density. This stocking method can be referred to as mob stocking, which is a method of stocking at a high grazing pressure for a short time to remove forage rapidly [6]. By definition, mob stocking is simply rotational stocking with pastures divided into a large number of paddocks. In recent years, a variation of this long-defined method has emerged. Its proponents have used the term "mob grazing" to describe it. It is a form of high-density rotational stocking, but in addition, it uses long rest intervals (often 60 days or more) between grazing events. It is useful to note that the formal definition of mob stocking does not carry any reference to the length of the rest interval between grazing events; thus, it should not be confused with the informal term "mob grazing." Although "mob grazing" is practiced in various forms by growers, and the method is not specifically defined, it has been described as concentrating grazing livestock into small paddocks to achieve stocking densities of 200,000 lb or greater of animal liveweight per acre, moving animals through multiple paddocks per day, and grazing a paddock only once (or at least infrequently) per grazing season [66]. Practitioners of "mob grazing" claim numerous benefits including increased forage production and species diversity, improved distribution of livestock grazing, and superior soil function [67]. Some have suggested that achieving 60% trampling of the standing forage mass is the optimum level for increasing soil organic matter and nutrient concentration [68]. Data are currently lacking to substantiate these claims.

In perhaps the most comprehensive replicated research assessment of "mob grazing," a Nebraska sandhills meadow was grazed during 60—80 days in each of 5 years [66,69]. The grassland was dominated by cool-season grasses but also included various sedges, forbs, legumes, and warm-season grasses. Treatments were (1) a 120-paddock rotation with a stocking density of 200,000 lb of animal liveweight per acre in which each paddock was grazed once per grazing season and (2) a 4-paddock rotation with two grazing events per paddock each grazing season. Stocking rate was the same on both treatments (three animal unit months per acre). Over 5 years, daily gain of yearling steers averaged 1.49 lb/day for the 4-paddock system and 0.39 lb/day for the 120-paddock system (Fig. 5.4), and forage production was not different between the two treatments. Greater gains were attributed to greater forage nutritive value for the 4-paddock system that was grazed twice during the grazing season instead of once for the "mob grazing" system. Relative to the use of the 120-paddock system, it was concluded that the lack of increased aboveground production and the large reduction in animal performance do "not justify the increased cost in both labor and implementation of this grazing strategy" [69].

In Virginia, pastures dominated by tall fescue, orchardgrass, and Kentucky bluegrass were overseeded with white and red clovers (*Trifolium pratense* L.) [70]. Stocking rate was one animal unit (1000 lb) per 2 acres on pastures that were stocked continuously, rotationally (28—30 day rest periods; 3—4 day residence periods), or using "mob grazing" (64-day rest periods; 1-day residence periods; stocking density of 40,000 lb/acre). Cows on the "mob grazing" treatment weighed least at breeding and had the lowest body condition scores, while calves on the same treatment had the lowest weaning weights. One notable advantage of "mob grazing" was lesser congregation of cattle near water and loafing areas; this likely would result in more even distribution of nutrients from dung and urine across the pasture. The author "found little evidence to

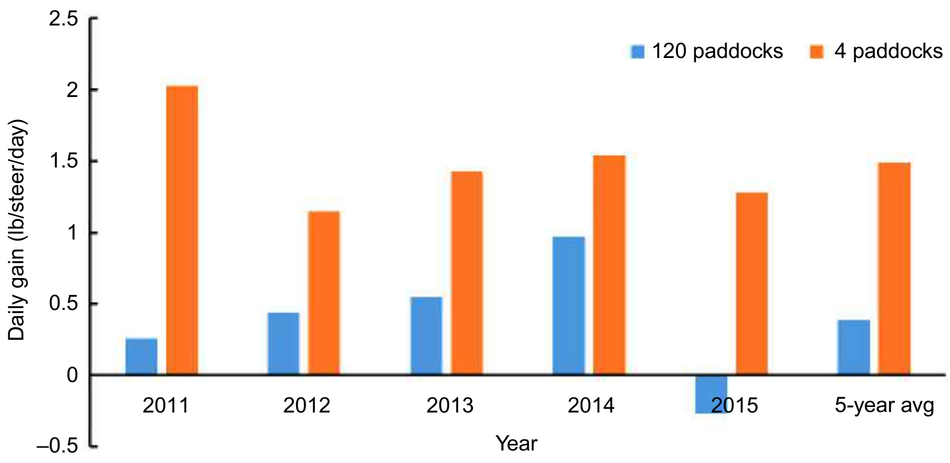

Figure 5.4 Average daily gain of yearling steers grazing Nebraska Sandhills meadow during 60–80 days in each of 5 years and the average of those 5 years. The grazing treatments were a 120-paddock rotation with a stocking density of 200,000 lb of animal liveweight per acre (each paddock grazed once per grazing season) and a 4-paddock rotation with two grazing events per paddock each grazing season. Stocking rate was three animal unit months per acre on both treatments. *Data from M.D. Redden, Grazing method effects on forage production, utilization, and animal performance on Nebraska Sandhills meadow (MS Thesis), University of Nebraska-Lincoln, 2014 [66] and T. Lindsey, Grazing method effects on forage production, utilization, animal performance and animal activity on Nebraska Sandhills meadow (MS Thesis), University of Nebraska-Lincoln, 2016 [69].*

support broad adoption of mob grazing in Virginia over standard rotational grazing practices," and he stated that "mob grazing appears to be better suited to specific, short-term management tasks (e.g., vegetation control) rather than year-round grazing" [70].

Testimonial versus data-driven decision-making

Bransby [71] stated "few topics in agriculture have been addressed with such charismatic language and such abandonment of scientific evidence and logic" as discussions of rotational and continuous stocking. Advocates of rotational stocking have often exaggerated its potential benefits or compared results from well-managed rotationally stocked pastures with continuously stocked pastures that were grossly overstocked or in general, poorly managed. Currently, so-called "mob grazing" is an example where advocates of practice rely largely on anecdotal evidence with little or no conclusive data to support their perspectives. Data from independent research is the best source of unbiased and reliable information from which sound decisions can be made. Researchers, however, must appreciate that their work needs to be relevant to production settings, and conducting experiments across sufficient time periods and spatial scales (pasture size) is important [72].

Timing of grazing

The third grazing management tool to be considered is timing of grazing. Timing can have significant impacts on plants and plant communities because implementing a particular management practice may be beneficial under some conditions but not others. For example, the extent to which plant reserves have been restored prior to the onset of winter or to a dry season can be greatly influenced by timing of defoliation prior to the period of stress. Appropriate timing of defoliation may also be affected by plant growth stage. For example, stand losses of smooth bromegrass (*Bromus inermis* Leyss.) and timothy (*Phleum pratense* L.) growing with alfalfa (*Medicago sativa* L.) have resulted when defoliation occurred during the critical period between grass stem elongation and inflorescence emergence [73]. Similarly, defoliation that removes the apical growing point of switchgrass (*Panicum virgatum* L.) often reduces tiller density, and if not followed by a long regrowth period, may compromise stand persistence [74].

Termination of grazing relative to the timing of flowering and seed set affects annual or short-lived perennial species that rely on natural reseeding for stand regeneration. In northeastern Texas, most cultivars of annual ryegrass (*Lolium multiflorum* Lam.) grazed until late April produced satisfactory volunteer stands the following autumn [75], but later grazing decreased volunteer annual ryegrass seedling density. Similarly, seed yield of the summer-annual legume aeschynomene (*Aeschynomene americana* L.) was greatly reduced if autumn grazing continued after first flower [76].

The timing of grazing may also take into account the diurnal variation in forage nutritive value. Nutritive value and animal preference can be greater in the afternoon compared with the morning because of the accumulation of nonstructural carbohydrates during the day associated with active photosynthesis [77]. In rotational–stocking systems where animals are rotated to a new paddock daily (e.g., lactating dairy cows), there may be advantages to moving them in the afternoon/early evening so that the larger meal that usually follows transition to a new grazing area is composed of forage of the greatest possible nutritive value [9]. This relationship requires further testing to be confirmed.

Role of producer preferences and operation characteristics in choice of grazing management

Choice of grazing management is definitely a decision where one size does not fit all. Intensification of management may well be profitable in some operations but not others. For example, a blanket recommendation of rotational stocking, and particularly rotational stocking with a large number of paddocks, may not be realistic economically nor fit the personality or situation of individual producers. Some producers are excited about management details, measuring everything they can, and keeping detailed, exacting records. Others may rather be fishing. It behooves scientists and extension specialists to account for this range in producer interests in developing research programs and outreach activities. Knowing the abilities, interests, and goals of individual producers is a very important first step in developing a relevant management program.

Conclusions

Because land grazed by livestock is the largest single land-use type, and forage is the most consumed livestock feed in the world, the global implications of grazing management are highly significant. Grazing management is the manipulation of grazing in pursuit of a specific objective or set of objectives, and the tools that we can use to manipulate grazing include grazing intensity, stocking method, and timing of grazing. Of these, grazing intensity (e.g., stocking rate or pasture height) is the most important and has overriding effects on forage production, pasture persistence, animal performance, and environmental impact of pasture-based livestock systems. Stocking method, i.e., the choice of rotational or continuous stocking, is important but less impactful than grazing intensity. In some situations there are measurable benefits of rotational stocking on pasture productivity, persistence of grazing-sensitive species, and sustaining plant cover to minimize runoff of water, sediment, and nutrients. In other situations, the species present, the cost of infrastructure, or the goals of the producer may favor continuous stocking. Within the community of grazing management practitioners, proponents of one approach or another may rely too heavily on anecdotes and too lightly on data. Before adopting a new grazing management approach, there is value in requesting data that support the recommendations being made. It is equally important that the source of the data be an independent organization without conflict of interest, and that the experiments be conducted on a time and size scale that provides relevant results to producers.

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CHAPTER 6

Management of forages and pastures in Lower-South: I-10 Corridor

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Description of the I-10 Corridor

The I-10 Corridor is the southernmost region in the United States, located at about 30°N latitude and between 80°W and 120°W longitude. It includes the state of Florida and the southern regions of Georgia, Alabama, Mississippi, Louisiana, Texas, New Mexico, and California. This chapter will focus on the southeastern production systems of the lower south from Florida to Texas.

According to the Koppen climate classification, the I-10 Corridor is predominantly a Cwa climate (humid subtropical). In the humid subtropical region, mean temperatures in the coldest months are between 32°F and 64°F, while mean temperatures in the warmest months are 72°F or higher. There is usually greater rainfall in the summer, especially when monsoon conditions develop in the Gulf of Mexico. Annual rainfall may vary from 30 to 50 in./year.

Although they vary across the region, soil orders in the I-10 Corridor have a significant presence of Spodosols (Florida), Ultisols (south Georgia, Alabama, Mississippi, Louisiana, and Texas), Alfisols (Louisiana and Texas) and Mollisols (Texas). Spodosols and Ultisols are generally sandy with decreased base saturation and low pH; whereas Alfisols and Mollisols have greater silt and clay concentration and base saturation. In south Florida the Spodosols are generally poorly drained which results in extended periods of flooding on grasslands.

Warm-season forages

Warm-season perennial grasses are the most widely used forages for livestock production in the I-10 Corridor. As a result of better water use and light conversion efficiency, warm-season grasses produce more forage than cool-season grasses in tropical and subtropical climates. Warm-season grasses tend to have less nutritive value

Management Strategies for Sustainable Cattle Production in Southern Pastures
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[crude protein (CP) and digestibility] than cool-season grasses, due in part to the parenchyma bundle sheath cells and a higher proportion of cell wall material. Although cell walls are potentially digestible, chemical barriers and anatomical structures decrease microbial attachment, degradation rate, and fermentation. The leaves of warm-season grasses have lower degradability in the rumen compared to leaves of cool-season grasses because of their greater proportions of vascular tissues, bundle sheath, and sclerenchyma.

Bermudagrass

Bermudagrass (*Cynodon dactylon*) is one of the most important species in the Southeastern United States with ~ 25–30 million acres planted for livestock grazing and hay. Many *Cynodons* have been used as herbage for livestock, but several are of minor value because of narrow distribution or characteristics limiting their adaptation. Some of the bermudagrass cultivars used for grazing, hay, or silage production include 'Coastal', 'Tifton 85', 'Alicia', Jiggs, 'Russell', 'Tifton 44', and others.

Hybrid bermudagrasses are commonly established by vegetative sprigs or mature tops. The sprigs may be harvested in early spring, which allows for establishment earlier in the year; whereas mature tops are commonly harvested and planted in early summer. Sprigs and mature tops are planted at the rate of 30 bushels/acre and 1200 lb/acre, respectively. There are commercial cultivars of bermudagrass propagated by seeds; however, they are not as widely used as hybrid cultivars due to limited herbage accumulation and nutritive value.

Bermudagrasses require relatively high soil nutrient availability to maintain good production performance. The major determinants of fertilizer response are climate, native soil nutrient status, source and rate of applied nutrients, season of application(s), cultivar, and defoliation regimen and method. Nitrogen (N) has the greatest influence on biomass yield and accordingly influences the amount of other nutrients required to sustain production at specific N levels. Prine and Burton [1] evaluated the effects of different N rates and harvest frequencies on Coastal bermudagrass biomass production and nutritive value. There was a curvilinear increase in herbage accumulation as N rate increased from 0 to 900 lb N/acre, with maximum DM accumulation of 16,400 lb/acre with a 6- to 8-week harvest interval. Bermudagrass showed the highest efficiency in production (lb DM per lb N/acre) at 300 lb N/acre. The forage CP concentration ranged from 9% to 19% with N fertilization rates from 0 to 900 lb/acre. Typically, increased CP concentrations have been reported with increasing N application. Silveira et al. [2] observed that potassium fertilization was crucial to maintain forage accumulation and persistence of bermudagrass hay fields. Crude protein at 12% and digestibility at 58% of bermudagrass can be expected at 28-day regrowth intervals.

Bahiagrass

Bahiagrass (*Paspalum notatum*) is a common and widely used grass in the I-10 Corridor, and is particularly important in the states of Florida and Louisiana. Bahiagrass is adapted to sandy soils and can tolerate low soil fertility, low pH, and periodic flooding. Bahiagrass has decreased production in early spring and autumn and decreased nutritive value during mid-late summer.

The most used cultivars of bahiagrass are 'Argentine' and 'Pensacola' however, recent selections of Pensacola have been released in Florida and Georgia. "Tifton 9" is a selection of Pensacola with greater herbage accumulation and, subsequently, "Tiftquik" was released as a selection of Tifton 9 with faster germination. In Florida, the cultivar "UF Riata" was released as a selection of Pensacola with extended growth in the autumn.

Bahiagrass is propagated by seed, and seeding rates of 20−30 lb/acre are recommended. Bahiagrass usually has a significant proportion of hard seed content and may take from 3 to 6 months to establish. It has been observed that bahiagrass does not have the greatest herbage accumulation among the most common warm-season grasses cultivated in tropical and subtropical regions, but it can have reasonable herbage accumulation during the growing season. Silveira et al. [3] tested herbage accumulation of 10 warm-season grass species in a 3-year study in Florida and observed that bahiagrass was among the species with the least herbage accumulation. Bahiagrass stands persisted under the frequent harvest regime (6-week interval) imposed in this trial, while the stand of some species decreased after 3 years.

Bahiagrass is routinely known as a warm-season forage with limited nutritive value; however, there are several management practices that may affect warm-season grass nutritive value. Vendramini et al. [4] harvested 'Tifton 9' bahiagrass at different regrowth intervals and observed that there was a decline in CP (from 12% to 7%) from 20 to 59 days of regrowth. There was no difference in in vitro true digestibility (mean = 59%). Cuomo et al. [5] observed that the nutritive value of Argentine, Pensacola, and Tifton 9 was CP = 11%, neutral detergent fiber (NDF) = 65%, acid detergent fiber (ADF) = 32%, and digestibility = 59%.

Dallisgrass

Common dallisgrass (*Paspalum dilatatum*) is widely used for grazing and hay production from Texas to North Carolina. It is best adapted to heavier-textured soils in areas with at least 37 in. annual rainfall, and it grows along streams and ditches in areas of low rainfall. It can tolerate poorly drained soils and temperatures below 32°F for short periods of time. In the I-10 Corridor, dallisgrass has the potential to extend the grazing season due to earlier growth in the spring and extended growth in the fall. Dallisgrass is generally used for grazing due to its tolerance to intense defoliation, and it is usually found in mixed swards with other forage species.

There has been limited breeding efforts conducted with dallisgrass, and the common biotype is still the most commonly used cultivar. Recommended seeding rate for dallisgrass ranges from 12 to 20 lb seed/acre. Robinson et al. [6] reported dallisgrass herbage accumulation from approximately 3000 to 11,000 lb DM/acre in different soil types and N fertilization levels. Venuto et al. [7] evaluated different entries of dallisgrass and observed CP concentration levels from 9.3% to 11.0% and digestibility from 63% to 71%.

The ergot (*Claviceps paspali*) contamination of dallisgrass seeds may decrease seed production and viability. Ergot appears with greater frequency in wet weather and has a dark gray color, which may turn orange as the spores mature. Producers should avoid grazing or feeding ergot-contaminated forage to livestock as individual animals have different tolerance to the toxins. There is no cure for ergot poisoning and the symptoms include staggering, walking sideways, arching of the back, and other conditions.

Limpograss

Limpograss (*Hemarthria altissima*) is a warm-season perennial grass widely cultivated in south Florida with limited use in the I-10 Corridor. It is well adapted to seasonal flooded soils, has superior herbage accumulation during the winter, and is resistant to most pests and diseases [8]. 'Floralta' is the most commonly used cultivar; however, 'Gibtuck' and 'Kenhy' are new hybrid cultivars released in 2014. These hybrids have shown greater herbage accumulation and nutritive value than Floralta. Limpograss is planted using vegetative mature plant tops with similar procedures to that described for bermudagrass.

It has been observed that limpograss has approximately 10% CP and 60% total digestible nutrient (TDN) concentrations at a 5-week regrowth interval. Limpograss usually has greater digestibility than other warm-season perennial grasses after long regrowth intervals. Conversely it has been observed that the CP levels decrease sharply during the growing season. According to Moore et al. [9], ruminants consuming forage with an IVDOM:CP ratio greater than 7:1 may respond positively to the use of protein supplementation. Limpograss plant parts vary widely in their nutritive value. Limpograss leaf sections usually have an IVDOM:CP ratio below 7; however, the stems tend to have an increased IVDOM:CP ratio. CP supplementation and fertilization are normal management strategies to overcome the CP deficiency of beef cattle grazing limpograss pastures.

Stargrass

Stargrass (*Cynodon* spp.), a member of the bermudagrass family, is also known as 'Giant' stargrass, or 'African' stargrass. The tropical nature of stargrasses limits their productivity in the I-10 Corridor; however, it is productive and persistent in south Florida, or where temperatures do not fall below 25°F. Stargrasses are well adapted to many soil types ranging from sands to clays. Stargrasses prefer moist, well drained, fertile soils. They will tolerate short periods (3 − 5 days) of surface water (1−2 in.) and perform well under these conditions. The current varieties include 'Florico,' 'Florona,' 'Ona,' and 'Okeechobee.' Stargrasses may be established vegetatively from mature (10- to 14-week old) stem sections. Stargrasses should be fertilized with nitrogen or complete fertilizer applied in three or four split applications for uniform seasonal production. If additional forage is not needed during the wet season, fertilizer application should be delayed until the end of the rainy season, thus extending forage production into the fall.

Herbage accumulation of stargrass may range from 5000 to 7000 lb DM/acre with 5-week regrowth, CP from 11% to 16%, and IVOMD from 55% to 60%. If the average rest period is shorter than 4 weeks, forage nutritive value increases, but persistence of the stand may decrease.

Rhizoma peanut

Rhizoma peanut (*Arachis glabrata*) is a warm-season perennial legume adapted to humid and tropical conditions, but it also tolerates drought and mild temperatures. Such characteristics make this plant well adapted to the US Gulf Coastal Plains. Rhizoma peanut, however, is not adapted to poorly drained soils and does not persist well in the Flatwoods of south Florida. It is primarily used for hay production and is valuable forage for grazing as pure stand or mixed with warm-season grasses.

The most common commercial genotypes of rhizoma peanut used for forage production include 'Arbrook,' 'Arblick,' 'UF Tito,' 'UF Peace,' 'Florigraze,' and 'Ecoturf'. These are propagated by sprigs, and planting recommendations are approximately 1000 lb rhizomes/acre. Rhizoma peanut has superior nutritive value, and CP concentration may range from 12% to 18% and digestibility from 55% to 70%. The overall annual herbage accumulation is approximately 10,000 lb DM/acre.

Annual grasses and legumes

Grasses

In general, warm-season annual grasses are commonly used for forage following a winter or spring crop. Rapid growth rates over a relatively short period make grazing management of warm-season annual grasses difficult. Therefore, methods of mechanical harvesting such as hay and baleage are recommended as best management practices for utilization of forage produced.

Pearl millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*) are warm-season annual forages with superior production and nutritive value during the growing season. They are upright growing, leafy, drought tolerant, and responsive to N fertilization. They can be harvested as hay, silage, greenchop, or grazed by livestock.

Sorghums may be classified into two types: (1) forage sorghums (mainly for forage or animal feed) and (2) grain sorghums (mainly for human consumption). The forage sorghums are further divided into four types: (1) hybrid forage sorghum, (2) sudangrass, (3) sorghum × sudan hybrids (also known as sudan hybrids), and (4) sweet sorghum. The latter is used mainly for molasses but more recently for biofuel production as well.

There are many sorghum cultivars available, and producers should seek cultivars adapted to their specific region. Seeding rates vary from 8 to 20 lb/acre. Nutritive value of different cultivars of sorghum is variable, and values from 53% to 70% digestibility and 9% to 18% CP have been observed. According to Fontaneli et al. [10] sorghum had CP and IVDOM concentrations of 15% and 68%, respectively, and they suggested seeding 3–6 weeks apart as a good management strategy. This seeding practice improves yield distribution and produces high nutritive value forage for nearly 5 months. Varieties that possess the brown midrib trait have brown vascular tissue as a result of reduced lignin concentration, and this improves digestibility. However, this trait may also increase the incidence of lodging in some varieties.

Pearl millet is a high nutritive-value summer-annual forage crop and popular among livestock producers for grazing, silage, hay, and greenchop. It is drought resistant and prefers well-drained soils. Seeding rates vary from 12 to 15 lb/acre when planted in drill rows to 30 – 40 lb/acre when broadcast. Lighter seeding rates are preferred for grazing because they result in more shoots per plant (12–15 per plant). Heavy seeding rates result in fewer tillers of finer stem, which is better for hay production. For more reliable stands it is recommended to seed pearl millet in a prepared seedbed.

Crabgrass (*Digitaria* sp.) is often considered a weedy species in the I-10 Corridor; however, it can be used as an annual forage crop. It is adapted to a wide range of soils and climatic conditions. The most common species found in the region are large crabgrass (*Digitaria sanguinalis*) and smooth crabgrass (*Digitaria ischaemum*). New growth of crabgrass in the spring originates from seeds from the previous growing season. 'Red River' is the most common improved cultivar of crabgrass, and seeding rates are 2 – 5 lb/acre. Crabgrass is responsive to N fertilization and can produce from 2000 to 10,000 lb DM/acre per year. It has superior nutritive value, but there is limited information available regarding digestibility and CP concentrations in the I-10 region.

Legumes

Aeschynomene is a warm-season annual legume adapted to the I-10 region, but it is mainly grown in south Florida. Seeds of two species are commercially available to producers: *Aeschynomene americana*, also known as common aeschynomene, joint vetch or deer vetch, and *Aeschynomene evenia*, which has no common name. Plants usually die after seed maturity, but the stand can be managed to re-seed and maintain itself in good production for several years after first establishment. *Aeschynomene* is usually overseeded into warm-season perennial grass pastures. Dehulled seed may be planted at 5–8 lb/acre or intact seeds at 20–25 lb/acre. Aeschynomene has high nutritive value with CP concentration ranging from 12% to 18% and digestibility from 55% to 70%. It has been used primarily for the cattle industry and wildlife.

Cool-season forages

Although warm-season grasses dominate most pastures in the I-10 Corridor, climatic conditions during the winter allow for use of cool-season forages. Due to high temperatures in the summer and mild winters, most of the cool-season forages in the I-10 Corridor are annuals. In general cool-season perennial forages have a shorter life span in tropical and subtropical vegetative zones than the same species in temperate areas.

Cool-season annual grasses

Cool-season annual forages, either sod-seeded or in prepared seedbeds, are important components of forage systems in the I-10 Corridor because they produce high-quality forage during a period of limited warm-season forage production. Reasons for use of cool-season annual grasses include extending the grazing period, high nutritive value, compatibility and ease of establishment in warm-season perennial grass pastures, and tolerance to different defoliation regimens and stocking rates.

Cool-season grasses are productive from late December to early May. The use of small grains such as oat (*Avena sativa*), wheat (*Triticum aestivum*), triticale (*Triticosecale* spp.), and rye (*Secale cereale*) in mixtures with annual ryegrass (*Lolium multiflorum*) generally provides forage for grazing during the late fall as well as during the winter. Small grains grow better from late December to mid-February. Ryegrass results in rapid forage growth during March to late May, and often requires frequent increases in stocking rate to efficiently use forage production.

There are several cultivars of small grains and annual ryegrass available for purchase, but the selection should be based on comparative regional variety test reports from universities. Seeding rates for small grains and annual ryegrass are approximately 80–100 and 20–30 lb/acre, respectively.

The CP concentration of cool-season grasses is strongly influenced by the available soil N. Application of N fertilizer to grasses usually increases CP concentration and forage growth. CP concentrations in annual ryegrass tend to be high, commonly averaging 15%–25%. In vitro digestibility of annual ryegrass and small grains may range from 60% to 85% and is dependent upon of fertilization, maturity, and season of the year.

After an extensive research program with cool-season grasses, Rouquette et al. [11] concluded that achieving economic optimum grazing management and use of cool-season grasses is not an easy task. A knowledge base of forage growth expectations and the art of managing proper defoliation regimens will allow for the greatest opportunity for positive economic returns and an acceptable transition from cool- to warm-season pastures.

Cool-season annual legumes

Most of the cool-season legumes cultivated in the I-10 Corridor are annual clovers and should be reestablished from seed each fall. The most cultivated clovers in this region are crimson (*Trifolium incarnatum*), white (*Trifolium repens*), red (*Trifolium pretense*), and ball (*Trifolium nigrescens*). Some clovers, such as ball and white clovers (a true perennial that acts like an annual or biannual), produce a high percentage of hard seed that allows them to reseed if managed properly. Clovers can be grown in mixtures with annual ryegrass. Ryegrass provides earlier grazing and decreases potential bloat caused by some legumes. Clovers are an attractive option to decrease the production cost associated with N fertilization because legumes have the ability to fix atmospheric N. Annual clovers can contribute about 75–100 lbs N/acre for the subsequent grass crop. Clovers, however, are only able to fix N from the air if specific strains of *Rhizobia* bacteria are present in nodules on their roots. To ensure that the best strain of *Rhizobia* is present for each clover species, seed must be inoculated with the proper *Rhizobia* strain before planting. Preinoculated seeds of most legume species are available and recommended for use.

Cool-season perennial legumes

Alfalfa (*Medicago sativa*) has been cultivated in well-drained, higher fertility soils in the I-10 region; however, the stand may have a decreased life span (1–3 years) due to climatic conditions. Alfalfa can be used for hay production or grazing during the winter–spring with herbage accumulation of approximately 8000 lb DM/acre and nutritive value of 15% – 20% CP and 65% – 80% digestibility.

Conserved forages

Hay

> ***Since extending the cutting interval beyond 6 weeks reduces crude protein, vitamin A equivalent, and digestibility and does not increase annual dry-matter yields, there is no reason for allowing Coastal bermudagrass to grow more than 6 weeks between cuttings.***
>
> **Glenn W. Burton, J.E. Jackson, and R.H. Hart (1963)**

Hay is the most commonly used source of conserved forage in the I-10 Corridor, and warm-season perennial grasses are the main species used for hay production. Cool-season forages can be used for hay production, however, decreased temperatures in the winter may extend the field drying periods, which is detrimental to hay nutritive value. According to Sollenberger at al. [12], there are significant obstacles to making hay in the subtropical and tropical regions. Warm-season perennial grasses grow faster, and nutritive value decreases rapidly during the growing season. This may coincide with greater rainfall and inadequate climatic conditions to dry forage for baling. In addition to poor drying conditions, the drying period in the field may be extended due to thick-lignified stems of warm-season perennial grasses. The ideal time to harvest forage varies among species and seasons of the year. In general, better hay quality is achieved in the spring due to better climatic conditions. Proper management practices, such as weed control and fertilization, are also crucial to optimize hay quality.

If hay is stored with low moisture and protected from the weather, the storage losses will be minimal. However, if the forage is baled with greater moisture concentration, losses of up to 10% DM and nutritive value losses will occur due to heating and microbial activity. In addition, the DM loss of hay stored outside can be approximately 15%. It is important to prevent hay from touching the bare ground under storage conditions. Hay can absorb soil and moisture, which increases DM losses, mold proliferation, and proportion refused by livestock. Additives to preserve hay with greater moisture, such as propionic acid and potassium sorbate, may be important tools to decrease hay losses during storage.

Silage, Haylage, and Baleage

There are different methods to preserve forage by fermentation, and the definition of each category may be confusing. The unofficial definition of the major terms used in forage conservation by fermentation includes: (1) Baleage—Forage preserved by fermentation in a bale with less DM concentration than hay ($<80\%$ DM) but greater than or equal to silage ($\geq 35\%$ DM); (2) Haylage—Forage preserved by fermentation with less DM concentration than hay ($<80\%$) but greater than silage ($\geq 35\%$ DM); and (3) Silage—Forage preserved by fermentation with DM concentration $\leq 35\%$ DM.

There has been an increase in forage conservation by fermentation due to advances in machinery and development of new technology. Silage and haylage are feasible alternatives to overcome weather-related limitations on conserving warm-season grasses in tropical and subtropical regions. Despite the high yields produced by perennial warm-season grasses during the growing season, high moisture, low water-soluble carbohydrates concentration, and a low water-soluble carbohydrates/buffering capacity ratio may limit the success and subsequent adoption of silage using these species. Although cool-season annual forages have greater nutritive value and better fermentation characteristics, they have reduced herbage accumulation, which may increase the cost per unit of DM. There are management practices that have the potential to increase the nutritive value of warm-season grass silage. Dry matter concentration affects the number of bacteria, rate of fermentation, and amount of carbohydrates needed for complete fermentation. Fermentation is restricted as DM concentration increases; therefore, it is necessary to wilt warm-season grasses to increase dry matter concentration and obtain desirable fermentation rates.

Microbial fermentation inoculants are used in silages primarily with the intent of shifting acid production in the direction of lactic versus acetic, and to improve fermentation efficiency, dry matter recovery, and animal performance. According to Sollenberger et al. [12], unlike silage using temperate forages, silage made from warm-season grasses in tropical and subtropical areas is characterized by relatively high concentrations of acetic acid. Acetic acid is not as strong an acid as lactic, and its accumulation buffers against a decline in silage pH below 4.8. The results of using inoculants in corn or cool-season forages have been positive, however, the results have been less consistent for warm-season perennial grasses.

There are some practical recommendations to optimize the production of baleage in the I-10 Corridor: (1) wilt forage to 50% DM; (2) remove bales from the field and wrap immediately after baling; and (3) wrap bales with a minimum of six layers of plastic. If plastic is kept intact there are minimum losses after the fermentation processes are stable.

Stockpiled forage

Stockpiled forage is an alternative strategy to supply forage for ruminants during the periods of forage shortage, usually late autumn and winter. Stockpiling is a practice that allows forage to grow for a certain period for utilization at a later time. Stockpiled forage is a low-cost option to maintain pregnancy and body condition score (BCS) in beef cows during winter. In the I-10 Corridor stockpiling warm-season perennial grasses is a common practice. A significant decline in nutritive value should be expected in stockpiled forages, and the use of a supplement is often necessary to meet the nutritional requirements of livestock feeding on stockpiled forages. The success of stockpiling is highly dependent on favorable climatic conditions at the time of stockpiling. The initiation of the stockpiling period depends on the historical climatic conditions of the location and may vary from August (northern latitudes in the I-10 Corridor) to October (south Florida). Evers et al. [13] stockpiled different cultivars of bermudagrass, bahiagrass, and kikuyugrass for 2 years and observed that Tifton 85 had the greatest herbage accumulation. Forage accumulation varied approximately from 5000 lb DM/acre in year 1 to 7000 lb DM/acre in year 2. There was a linear decline in CP concentration and an increase in NDF and ADF in all tested cultivars and species. Length of the stockpiling period before grazing is also crucial to the balance of forage quantity and nutritive value. Wallau et al. [14] observed that increasing the stockpiling period of limpograss from 8 to 16 weeks increased herbage accumulation from 4700 to 6600 lb DM/acre; however, there was an increase in dead plant material from 1% to 10%, and CP concentration decreased from 4.4% to 3.2%. In south Florida limpograss has been an attractive forage species for stockpiling due to the slower decline in digestibility with advancing maturity during the growing season compared to other warm-season grass species. In addition, limpograss is a feasible option as stockpiled forage because it can produce approximately 35% of annual herbage accumulation during Florida's winter months.

Grazing management—reports from grazing trials in the I-10 Corridor

Stocker cattle

Warm-season

In North-Central Florida, Pedreira et al. [15] compared Florakirk and Tifton 85 bermudagrass cultivars in a 3-year grazing study. Pastures were continuously stocked and fertilized with 187 lb N/acre in four applications per year. Although animal average daily gain (ADG) was similar between bermudagrass species (1.3 lb/day), Tifton 85 pastures supported higher average stocking rates (2.4 vs 1.6 heifers/acre), which resulted in greater gains (578 vs 330 lb/acre). Examination of the 3-year total season (169 days) gains of steers grazing high quality bermudagrass pastures revealed that steer ADGs were 2.0 and 1.9 lb, respectively for Tifton 85 and Tifton 78, from April to July, but only 0.9 and 0.7 lb, respectively, from July to October [16]. The authors suggested that decreased ADG was the consequence of an increased maintenance requirement of heavier steers and lower nutritive value of pastures later in the season.

Stewart et al. [17] compared bahiagrass grazing systems with different management intensities: (1) Low [36 lb N $(\text{acre/year})^{-1}$, 0.5 animal units (AU, 1 AU = 1100 lb liveweight)/acre target SR]; (2) Moderate (108 lb N/acre/year, 0.9 AU/acre target SR); and (3) High (320 lb N/acre/year, 1.6 AU/acre target SR). Herbage mass (3000 vs 2600 lb/acre) and herbage allowance (4.8 vs 1.4 lb forage per lb animal weight) were greatest for Low and decreased as management intensity increased to High. CP (14.0% vs 9.9%) and IVDOM (50.5% vs 45.9%) were greater for High than Low systems. Heifer ADG was greater for Low than High (0.75 vs 0.62 lb), but gain per acre rose with increased management intensity (198–495 lb/acre, respectively). Increasing management intensity increased the bahiagrass herbage accumulation and nutritive value, but cattle gain per acre did not increase sufficiently to compensate for the additional costs, especially for the High treatment.

Bungenstab et al. [18] observed that ADG of steers grazing continuously stocked dallisgrass pastures during the growing season in Alabama was 0.5 and 0.9 lb/day in 2007 and 2008, respectively. Herbage allowance was 0.79 and 1.0 lb DM/lb BW, respectively, which likely justified the lower ADG in 2007. Gunter et al. [19] reported that increasing the stocking rates from 2.8 to 5.0 steers/acre decreased the ADG of steers grazing dallisgrass from 1.4 to 0.9 lb/day.

Grazing studies with stargrasses at the Range Cattle Research and Extension Center at Ona, FL produced a 3-year ADG of 1.1 lb/day and liveweight gain of 663 lb/acre on Florico stargrass, and an ADG of 0.92 lb/acre and gain of 585 lb/acre on Florona stargrass. Both stargrasses were stocked at 3 yearling steers per acre over a 200-day, warm-season period. Average weight of the steers was 500 lb at the start of the period. Grasses were allowed a 4-week rest period between grazing periods [20].

Sollenberger et al. [21] evaluated animal performance, nutritive values, and carrying capacity of continuously stocked bahiagrass and limpograss pastures. Pastures were stocked using a variable stocking rate to maintain stubble height of 6 and 12 in. for bahiagrass and limpograss, respectively. Limpograss showed greater IVDOM compared to bahiagrass at 53.9% versus 48.4%; however, CP was greater for bahiagrass than for limpograss at 9.3% versus 5.8%. There was no difference in ADG between species at 0.77 lb/day. Despite the greater digestibility of limpograss, CP was deficient to promote better animal performance. Similar conclusions were reached by Sollenberger et al. [22] when comparing Floralta limpograss and Pensacola bahiagrass in a 3-year study evaluating animal and forage performance. Pastures were rotationally stocked to 8 and 3 in. stubble height for limpograss and bahiagrass, respectively. On average, Pensacola had greater CP concentration than limpograss at 11.6% versus 8.3%. IVDOM was greater for limpograss (61.3 vs 58.1% for bahiagrass), but there was no difference in ADG between species (0.9 and 0.8 lb/day for limpograss and bahiagrass, respectively). Limpograss supported a greater stocking rate than bahiagrass, 1900 versus 1500 lb liveweight/acre per day, and produced greater liveweight gain at 410 versus 283 lb/day.

Hill et al. [23] reported beef heifers grazing 'Tifleaf 2' pearl millet had an ADG of 1.5 lb/day and gains of 476 lb/acre in an 84-day grazing study period. Vendramini et al. [24] evaluated the performance of beef heifers grazing Mulato II, 'Tifleaf 3' pearl millet [*P. glaucum* (L.) R. Br.], or 'Hayday' sorghum–sudan grass [*S. bicolor*] pastures using a continuous stocking rate. In year 1 forage allowance (0.9 lb DM/lb BW), ADG (1.1 lb/day), and gain per acre (149 lb/acre) did not differ among forage types. In year 2 Mulato II had greater forage allowance (2.0 vs 0.7 lb DM/lb BW) and ADG (1.7 vs 0.9 lb/day) compared to Tifleaf 3 and Hayday, but gain per acre (269 lb) did not differ between forage types.

Performance of steers on bahiagrass monocultures and rhizoma peanut–bahiagrass mixtures was tested by Williams et al. [25] in Brooksville, FL during the warm seasons of 1986 and 1987. Rhizoma peanut proportion in mixed pastures ranged from about 10% to 60% of the forage mass. Means for forage allowance were higher in 1987 than in 1986, although it was not statistically evaluated. There was a year × treatment effect for ADG, as animals on bahiagrass gained 1.1 and 1.2 lb/day while animals in mixed pastures gained 1.5 and 2.0 lb/day in 1986 and 1987, respectively. This interaction occurred because gains were greater in the second year for peanut/bahiagrass pastures; whereas they were similar in both years for bahiagrass pastures. Gain per acre means for 1986 and 1987 were 103 and 109 lb/acre for bahiagrass pastures and 135 and 488 lb/acre for mixed pastures, respectively. When the same values were calculated on a daily basis, means were 0.7 and 0.6 lb/acre/day for bahiagrass and 0.9 and 1.3 lb/acre/day for mixed pastures in 1986 and 1987, respectively. Hernandez Garay et al. [26] compared the performance of Holstein heifers grazing two genotypes of rhizoma peanut pastures in the warm-season for three consecutive years at Gainesville, FL. Pastures were continuously stocked with variable stocking rates in order to maintain canopy height between 6 and 8 in. Annual ADG ranged from 1.1 to 1.5 lb with the gain per area ranging from 372 to 550 lb/acre for the whole period, or from 2.7 to 3.7 lb/acre/day.

To address the potential protein deficiency in animals grazing limpograss pastures, Rusland et al. [27] measured animal performance on limpograss pastures overseeded with aeschynomene (LA) or fertilized with nitrogen (LN) over a 3-year period. Animals grazing LA had on average 80% greater ADG than animals grazing LN. Hand plucked aeschynomene samples had 25% CP and 72% IVDOM; whereas hand plucked limpograss sampled from LN pastures had greater CP compared to samples from LA. Total diet consumed by animals had greater nutritive value for animals grazing LA, which led to an increase in animal performance. In addition, carrying capacity was greater for LN pastures than for LA (1960 vs 1520 lb LW/acre/day). The authors also concluded that N fertilization can be used to increase nutritive value in limpograss pastures.

Cool season

Dubeux et al. [28] tested the performance of beef steers grazing annual ryegrass mixed with: (1) cereal rye (FL401); (2) oat (Horizon 201); and (3) triticale (Trical 342) using continuous and variable stocking rates adjusted for forage allowance. Steer ADG averaged 2.0 and 1.9 lb/day; whereas, total gain per acre averaged 327 and 279 lb/acre in year 1 and 2, respectively. Total animal production did not differ by variety, but cereal rye was the earliest available for stocking. Oat and triticale had an even seasonal growth, which facilitated the grazing management.

Bransby and Gamble [29] compared ADG and liveweight gain from pastures planted to 'Bonel' rye only or to Bonel rye plus ryegrass. The inclusion of ryegrass resulted in greater stocking rates and ADGs, which resulted in greater gain per acre. At a stocking rate of five, 310-lb steers/acre, gains were ~294 and 463 lb/acre for rye and rye-ryegrass, respectively. In Louisiana, Feazel [30] evaluated Marshall and 'Gulf' ryegrass in pure stands and 'Elbon' rye—Gulf ryegrass mixtures for 3 years. The average stocking rates were similar among the three treatments at 1.4 hd/acre. Gains ranged from 464 lb/acre for heifers grazing Gulf ryegrass to 612 lb/acre for Marshall ryegrass. In the 3-year study there was no advantage to including Elbon rye in a mixture with ryegrass. In north Florida, Bertrand and Dunavan [31] studied length of grazing season for calves (374 lb/hd) grazing ryegrass and ryegrass—triticale (*Triticale hexaploide*). The inclusion of ryegrass in the triticale mixtures extended the grazing season from 215 to 263 animal/acre/day.

Heifer development and supplementation

Voluntary forage intake may be increased or decreased by the feeding of supplemental concentrate.

John E. Moore and William E. Kunkle (1995)

Heifer development in the I-10 Corridor differs from other regions of the United States because of the influence of *Bos indicus* genotypes and environmental challenges that reduce growth efficiency. Heifers with *B. indicus*-influence reach puberty at an older age than *Bos taurus* animals and must receive a high level of nutrition to attain puberty within a defined breeding season. Table 6.1 demonstrates a summary of heifer supplementation studies conducted in Florida. Those studies utilized Brangus crossbred heifers grazing bahiagrass pastures from August (weaning) to March (end of a 90-day breeding season). Heifers were offered a variety of supplement types at approximately 1.0%—1.5% of BW per day (DM basis). Despite the high quantity of daily supplements, heifer overall ADG, percent of mature BW achieved at the start of breeding season, and final pregnancy rates were relatively low and unacceptable in some instances. The major reason for the impaired heifer growth was the combination of exposure to high temperatures and moisture during summer, and relatively low concentrations of CP and TDN compared to forages in temperate regions. Daily nutrient requirements of yearling heifers are approximately 9% − 10% CP and 55% − 65% TDN [32].

Stocking rate also impacts the performance of beef heifers developed on pastures. Vendramini et al. [33] evaluated the impact of two stocking rates (0.5 and 0.7 animal

Table 6.1 Summary of studies evaluating the growth and reproductive performance of Brangus beef heifers grazing bahiagrass pastures and offered a wide variety of supplementation from 8 to 15 months of age at Range Cattle Research and Education Center, Ona, FL.

Authors	Citation	Supplementation	ADG (lb/day)	Mature weight (%)	Pregnancy (%)
Arthington et al. (2004)	Prof. Anim. Sci.	2.7 kg molasses slurry	0.97	53.7	76.3
	20 282–285	2.4 kg range cubes	1.04	54.0	49.2
Cooke et al. (2007)	J. Anim. Sci.	2.1 kg molasses slurry	0.66	52.0	58.0
	85 2564–2574	2.7 kg citrus pulp	0.88	53.0	60.0
Cooke et al. (2008)	J. Anim. Sci.	2.6 kg supp. Daily	0.73	48.6	50.0
	86 2296–2307	6.0 kg supp. 3 times/week	0.90	49.4	60.0
Cooke et al. (2009)	J. Anim. Sci.	2.7 kg soybean hulls supp.	1.19	64.0	60.0
	87 3403–3412				
Moriel et al. (2012)	J. Anim. Sci.	2.3 kg soybean hulls supp.	0.59	51.5	16.6
	90 2371–2380				
Moriel et al. (2014)	J. Anim. Sci.	1.5% of body weight soybean hulls supp.	1.54	58.9	60.0
	92 3096–3107				
Martins et al. (2016)	Prof. Anim. Sci.	2.7 kg molasses slurry	0.37	50.0	49.5
	32 302–308				
Moriel et al. (2017)	J. Anim. Sci.	1.8 kg molasses supp.	0.55	53.7	64.2
	95 3523–3531	2.9 kg molasses supp.	0.90	57.6	70.0
		4.4 kg molasses supp.	1.12	58.6	70.0

ADG, Average daily gain.

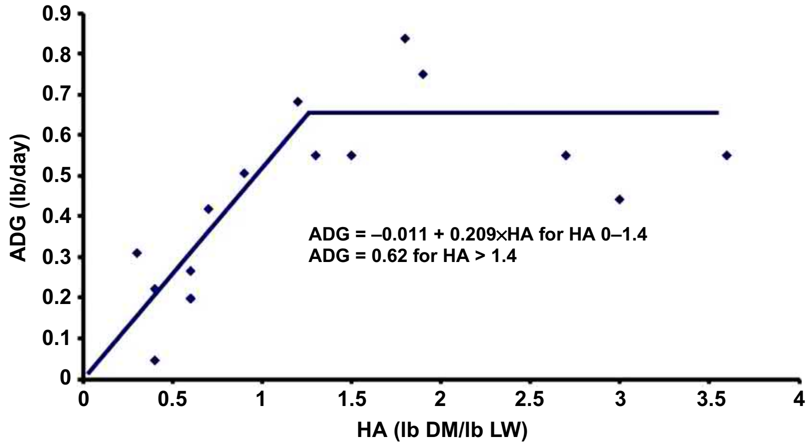

Figure 6.1 Relationship between herbage allowance (HA) and average daily gain (ADG) in Brangus heifers grazing bahiagrass and brachiariagrass pastures in Florida. *Adapted from U. Inyang, J.M.B. Vendramini, L.E. Sollenberger, B. Sellers, A. Adesogan, L. Paiva, et al., Forage species and stocking rate effects on animal performance and herbage responses of 'Mulato' and bahiagrass pastures, Crop Sci. 50 (2010) 1079–1085.*

unit [AU; (560 lb BW/acre)]) on the growth performance of Brangus crossbred heifers grazed on bahiagrass pastures and supplemented with 1.0 lb/day DM of concentrate (14% CP and 78% TDN) for 86 days. Stocking rate treatments had similar forage mass from June to July, but the higher stocking rate decreased forage mass from August to September. Heifer ADG was greatest for pastures with 0.5 AU/acre in August, but ADG did not differ in July and September compared to pastures with 0.7 AU/acre. Gain per acre tended to be greater on pastures with the higher stocking rate (78 vs 53 lb/acre). Stocking rates that result in forage allowance below 1.4 lb DM/lb BW should be avoided if the primary goal is to optimize ADG [34] (Fig. 6.1).

Aguiar et al. [35] evaluated the effects of different stocking rates on growth performance of beef heifers and forage characteristics of Jiggs bermudagrass. Pastures were continuously stocked at stocking rates of 1.2, 3.0, and 4.2 AU (1000 lb LW) from May to August. Heifers received concentrate supplementation daily at 1% of BW (DM basis). Forage nutritive value did not differ between treatments, but there was a linear decrease in forage mass (3400–2100 lb/acre) and forage allowance (2.3–0.4 lb DM/lb BW) with increasing stocking rate. Heifer ADG decreased from 0.6 to 0.3 lb/day; whereas, gain per acre increased from 600 to 950 lb/acre as stocking rate increased from 1.2 to 4.2 AU.

Vendramini and Arthington [36] evaluated the performance of beef heifers grazing stockpiled limpograss pastures supplemented with cottonseed meal or grazing part time on annual ryegrass from February to April (2.4 heifers/acre). Limpograss pastures were stockpiled from October to February. Treatments consisted of increasing cottonseed meal supplementation rates (0, 2.5, and 5.0 lb/head per day) or part-time annual ryegrass grazing (3 days/week). Limpograss forage mass was greater for pastures with heifers grazing part time compared to other treatments. Heifers supplemented with 2.0 lb/day had similar ADG (0.60 lb/day) but greater gain per acre (260 vs 170 lb/acre) compared to heifers grazing part time on annual ryegrass.

Cow–Calf

Cow–calf operations make up the biggest beef cattle production system in the I-10 Corridor. After weaning, usually from July through December, most beef calves are shipped to western states for stocker grazing and eventual feedlot residence. The remaining calves, primarily replacement beef heifers, may be retained on pastures after weaning.

Warm-season perennial grasses mostly grow in mid-spring and early fall, and their chemical composition is relatively good from April to December. Forage containing about 10% CP and 52%–57% TDN will meet the requirements of dry pregnant cows (8% CP; 53% TDN), almost meet the needs of mature lactating cows (10% CP; 57% TDN), but will not meet the requirements for lactating 2-year-old cows (11% CP; 64% TDN) [31]. Dry cows grazing warm-season perennial grasses with no supplement should increase BCS from June to October (start of calving season). During winter, warm-season perennial grasses contain about 7% CP and 46% TDN, which are well below the requirements of cows nursing calves and even of dry pregnant cows. In addition, the breeding season occurs from December to March, which is the most critical period in terms of nutrient requirements because cows are at early lactation and must resume estrus to be rebred. Hence, feed supplementation is often provided during the winter season. The amount of supplement depends on the severity of the winter and the BCS of the cows. In general, mature beef cows grazing perennial warm-season grasses should be fed about 2.0–3.0 lb/day TDN of a supplement containing 12%–16% CP; whereas, young first-calf cows should be fed 3.0–5.0 lb/day TDN of the same supplement (ideally, 50% of supplemental CP derived from natural protein [37]).

Early weaning of beef calves is an effective management practice to enhance reproductive performance of first-calf beef heifers in the southeast United States [38]. Cows restore BCS promptly due to a decrease in energy requirements and start cycling due to hormonal responses from calf removal. Calves can be weaned at 3 months of age and placed on annual ryegrass pastures with 1.0% BW daily concentrate supplementation, or wintered on warm-season perennial grass pastures or hay with 2.0% BW daily supplementation.

Creep-feeding supplementation can be a feasible strategy to increase calf preweaning performance on cow–calf pairs grazing warm-season perennial grass pastures.

However, the gain:feed efficiency is usually low for calves receiving significant amounts of concentrate (~1% BW/day). Conversely, calves receiving reduced amounts of supplement (1 lb/day) had efficient gain:feed ratio (1:3). In general, cow performance is usually not affected by creep-feeding supplementation.

Calving season

The decision of calving date must take into account the entire beef production system, available resources, and lifestyle goals. In addition, environmental conditions such as ambient temperature, annual rainfall, humidity, wind, elevation, and forage growing season are highly unpredictable and variable, and contribute to the complexity of choosing a calving date [39]. Most cow—calf operations in the United States utilize a spring calving season to match cow nutrient requirements to seasonal changes on forage chemical composition. Nutritional demands of beef cows are highest during early lactation, and if peak nutrient demand occurs at highest forage mass availability and chemical composition, cows will achieve optimal BCS before subsequent breeding season.

Fall and winter appear to be the most commonly used calving seasons in the I-10 Corridor. One of the potential challenges of this decision for the production system is that cows calving in the fall have high nutritional demands when forage is less abundant and forage chemical composition is low. Hence protein and energy supplementation for the cowherd is often required during winter. Reasons for choosing a fall calving season include: (1) avoiding heat stress—induced depression in performance; (2) avoiding the hurricane season; and (3) timing of calf marketing.

By selecting a fall calving season, breeding season occurs during winter avoiding the combination of high temperature and humidity that cause extreme heat stress. Heat stress negatively affects male and female reproductive performance. This effect on reproduction also includes disruptions in spermatogenesis and oocyte development, oocyte maturation, early embryonic development, and fetal and placental growth and lactation. In addition, Pate and Kalmbacher [37] evaluated the impact of timing of breeding season for brood cows grazing winter range and bahiagrass pastures in south Florida. In that study Brahman-crossbred cows were exposed to bulls during a 90-day spring (March to May) or summer (May to July) breeding season. Although pregnancy rate did not differ between treatments (72.6% vs 76.4% for summer vs spring breeding season, respectively), cows assigned to a summer breeding season had less BCS at time of weaning (4.1 vs 4.8, respectively), and their calves were 55 lb lighter at the time of weaning when they reached 230 days of age

According to the National Agricultural Statistics Service from the US Department of Agriculture, hurricane season historically occurs from May to November with most storms occurring between August and October. This means that retaining calves during the peak of the storm season may become a liability.

Seasonal variation on the cattle market within a given year enables producers to match their production system with calf prices [38]. Historically, most spring-born calves are marketed in November which leads to an abundant calf supply, and consequently, lower prices [40]. However, calves sold at a time other than November, generally receive a higher price at marketing due to decreased calf supply [39].

Cattle breed types and environmental aspects of climatic diversity of the I-10 Corridor

About 30% of the cowherd of the United States is located in the Gulf Coast region, but cattle in this subtropical region are prone to problems associated with heat, parasite and disease exposure, and a seasonally affected feed supply [41]. Animals must be able to cope with the harsh environmental conditions of subtropical areas to repeatedly reproduce during their production lifetime [42]. Brahman and Brahman × English F1 cows have proven to be ideal cows for subtropical regions [41] by expressing greater heterosis for most traits compared to *B. taurus* crossbreds [43].

Cattle residing for multiple generations in an area to which they were not originally adapted may lead to the development of aspects of adaptation [42]. A limited number of Angus cattle have been raised and maintained in Florida for many years and would be of special value in the region if they could acquire the necessary adaptability. Riley et al. [42] compared the performance and adaptability of cattle from a 50-year Florida Angus bloodline (local source) to modern Angus bloodlines (outside source) in subtropical conditions. Embryos from both sources were transferred to Brahman crossbred cows in south Florida, and calves were born in each year during a 3-year period. Calves from outside sources had a 1.6-in. greater hip height at weaning, 26% less exit velocity (suggestive of a less temperamental disposition), but no differences in other assessments of disposition (chute or pen score) compared to calves from the local source. Outside source heifers were also heavier at 17 months of age, younger at first conception (454 vs 550 days), and had greater pregnancy and calving rates (70% vs 29% and 62% vs 19%, respectively) within a year from weaning than heifers from the local source. Bulls from the outside source were heavier at 320 days of age and had in average a 0.8-in. greater scrotal circumference from 14 to 17 months of age than local source bulls. Although the long-term performance of both sources needs to be evaluated (i.e., cow longevity), Riley et al. [42] suggested that there appeared to be no performance or adaptation advantages for the local versus outside sources of Angus until 17 months of age.

Conclusion

Warm-season perennial grasses are the dominant forages used for beef cattle in the I-10 Corridor; however, there are opportunities to cultivate cool-season annual forages during autumn, winter, and early spring. There is a need to match forage management to cattle requirements during different seasons of the year. Defining the most appropriate forage species, fertilization program, and stocking rates are among the most important strategies for forage management. Those decisions should be conditional to the breeding season and heifer development program.

During the forage growing season, well-managed warm-season perennial grasses can meet the requirements of mature lactating cows, but growing heifers and steers may need supplementation to reach desirable performance. Forage fertilization and grazing frequency and intensity are important factors to balance warm-season perennial grass production and nutritive value.

During autumn and winter, stockpiled warm-season grasses and concentrate supplementation can be economically viable options to maintain mature cows at a target BCS. Conserved forage, such as hay, haylage, or silage, may be needed during years with unfavorable climatic conditions. Cool-season annual forages have superior nutritive value and are important components of the forage systems in the I-10 Corridor. Cool-season annual forages are commonly used to develop heifers or for backgrounding steers, but can also be efficiently used as part-time grazing for mature cows. Adding conserved forages and/or supplement to cool-season annual forage pastures may allow an increase in stocking rate and also increase the length of the grazing season.

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CHAPTER 7

Management strategies for pastures and beef cattle in the Middle-South: The I-20 Corridor

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The I-20 Corridor

The Interstate-20 Corridor extends from the Pineywoods Vegetational Zone in East Texas on the western side to the Atlantic Ocean—bordering states of Georgia, South Carolina, and North Carolina on the east side. The I-20 Corridor states ($n = 6$) are located primarily in USDA Hardiness Zone 8 with parts of Mississippi, Alabama, Georgia, and South Carolina in Zone 7. Thus, the extreme minimum temperatures generally range from 10°F to 20°F with some occurrences of extreme winter temperatures of 0°F—10°F (Fig. 1.3). The long-term annual rainfall averages 40—60 in. in the I-20 Corridor states, which includes some dry periods in summer-fall. Rainfall events during spring to fall are influenced by easterly waves that originate in West Africa and move westward across the Atlantic Ocean and into the warm waters of the Caribbean Sea and the Gulf of Mexico. Tropical storms and hurricanes, created by low-pressure systems in summer-fall, make landfall in those states bordering the Gulf of Mexico and/or those bordering the Atlantic Ocean. Moisture and warm air generated by the Gulf of Mexico, in addition to weather pressure systems from the Pacific Ocean and/or Canada, supply rainfall and sometimes turbulent weather conditions across the Southern region during late winter to early summer.

These climatic factors and acidic, low-fertility soils are primarily responsible for the classes and types of forages and a wide array of other vegetation that is abundant in this Corridor. The average frost-free period in the I-20 Corridor is from about April 15 to November 15. Climatic conditions and soils are responsible for the primary vegetation in the I-20 Corridor, which includes vast acreages of pine and hardwood timber on private, state, and federal property; cropland for soybeans, cotton, corn, etc.; and native and introduced forages for pasture and hay. Soils in the I-20 Corridor are diverse and range from Coastal Plain sands and sandy loams on upland sites to

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clay and loam soils on river flood plains. In general, soils are mainly acidic with low-nutrient status. Additional specific details of soils and pasture-fertilization requirements are presented in Chapter 3, Maintaining soil fertility and health for sustainable pastures. The introduced warm-season perennial grasses are the primary forages that make up the basic pasture units. In parts of the upper area of the I-20 Corridor, however, tall fescue is well adapted, and mixtures of warm-season perennial grasses and cool-season perennial grasses are used to complement the year-long grazing needs for the cowherd. Additional information on tall fescue pastures is available in Chapters 8, Management of pastures in the upper south: the I-30 and I-40 Corridors and Chapter 9, Management strategies for pastures, beef cattle, and marketing of stocker-feeder calves in the Upper South: the I-64 Corridor. Forages and zones of adaptation and use in pastures may be assessed in Appendix Tables 7.1 and 7.2.

Warm-season perennial grasses

Warm-season perennial grasses are the primary forages that form the basic pastures of the I-20 Corridor. These grasses were identified as C_4 plants by Hatch and Slack [1] who documented that their carbon assimilation had a different pathway than C_3 cool-season forages. The C_4 photosynthetic system is responsible for high forage dry matter use efficiency compared to C_3 grasses. Moser et al. [2] provided research review information that documented a higher N-use efficiency for C_4 compared to C_3 grasses. In addition, C_4 grasses respond well to high light flux in that photosynthetic rates continue to increase at full sunlight; whereas, C_3 grasses reach a peak photosynthesis at about one-third of full sunlight. Thus, C_4 grasses are the main-stay of livestock systems throughout the world. Although C_4 grasses are more productive and sustainable under haying and grazing management, they represent the class of forages with the lowest nutritive value. Coleman et al. [3] provided a good overview of forage nutritive value, forage quality, and utilization of C_4 grasses by livestock. They cited research that showed the impact of cell wall (neutral detergent fiber, NDF) content and maturity on reduced intake and digestibility. The challenges for managers in the I-20 Corridor are focused on management strategies to match seasonal variations in available forage DM and nutritive value with animal requirements for maintenance and production performance.

The primary warm-season perennial grasses used for pastures in the I-20 Corridor include bermudagrass, bahiagrass, and dallisgrass. These sod-forming grasses are sustainable, persistent, and productive on the various soil types and climatic conditions in this hardiness zone. These three species of forages were introduced into the United States and are not native forages. However, these grasses, especially common bermudagrass, are often termed as "native forages" because of their long-time, historical adaptation to the region. Taliaferro et al. [4] cited Kneebone [5] who suggested that bermudagrass may have been on ships of early explorers to the West Indies in the late 1400s and early 1500s. It was speculated that bermudagrass likely arrived in Savannah, GA in the early 1700s. By the early 1800s, bermudagrass was regarded as one of the most important grasses in the South [6,7], and by the early 1900s, it was distributed from Maryland to California [8].

Bermudagrass

> ***In 1937 two tall-growing strains of bermudagrass from South Africa and common Bermuda and Tift Bermuda (discovered in old cotton patch near Tifton, GA in 1929) were interplanted so that many hybrids might be produced naturally. In all of these comparisons, a selection carrying the number 35 ranked unusually high. When it became evident that this hybrid would have a place in Southeastern agriculture, it was named "Coastal Bermuda" in recognition of the Experiment Station where it was developed.***
>
> **Glenn Burton (1954)**

Until the 1940s, selection of bermudagrass cultivars for pastures and hay was dependent on the selection of naturally occurring biotypes that were best adapted to specific environments. The genetic diversity within bermudagrasses resulted in multiple genotypes with varying adaptation and performance attributes [4,9]. Perhaps the biggest transition in the use of bermudagrass in the southeastern United States was the breeding program of Dr. Glenn Burton with USDA/ARS at Tifton, GA and the release of "Coastal" bermudagrass in 1943 [10,11]. The novelty of this "new bermudagrass" was that establishment for pastures and hay would be accomplished using vegetative material (sprigs) and not seed. Thus, with the significant increase in DM production and persistence, the release of Coastal bermudagrass involved a multidiscipline team of plant breeders, agronomists, and agricultural engineers.

Taliaferro et al. [4] provided a chronological listing of bermudagrasses that require either sprigging or seeding, including Coastal in 1943 to "Tifton 85" in 1992 to "Midland 99" in 1999. Other seeded bermudagrasses have been released since that time and include new genotypes as well as blended types. Blends may include common bermudagrass and versions of "Giant" bermudagrass. Before selecting an old or newly released bermudagrass, managers should seek comparative research trials from state land grant university systems. This source of data on DM production, resistance, and nutritive value is available from county Extension Agents and state Forage Specialists.

More state research experiments concerned with fertilization, harvest frequency and nutritive value, defoliation regimens, etc. have been conducted in the United States with bermudagrass than any other warm-season perennial grass. Research with nitrogen fertilization and N-P_2O_5-K_2O ratios for enhanced production and sustainable bermudagrass have been active since the late 1940s and early 1950s and are summarized in Chapter 3, Maintaining soil fertility and health for sustainable pastures. A component of many N-fertility studies included defoliation frequency and severity on DM production and nutritive value [4].

Bahiagrass

Bahiagrass (*Paspalum notatum* Flügge) was introduced into the United States by the Bureau of Plant Industry and evaluated for forage traits by Florida AES in 1913 [12]. Two of the most common varieties grown in the I-20 Corridor are "Pensacola" which may have arrived at Pensacola, FL from Argentina ships before 1926 [13,14]; and "Argentine," which was sent to US Plant Introduction Office in 1944 [15].

Bahiagrass is used for pastures throughout the I-20 Corridor by design and default. Bahiagrass is well adapted to sandy soils and may become an invader or "weed" on low-fertility sites. Thus, bahiagrass becomes dominant under low-input management strategies, and when grown on low-N soils, forage protein is usually low ($<$6% CP). Bahiagrass pastures are best suited for meeting the nutrient requirements of mature cows. Young, growing cattle grazing bahiagrass would require supplemental protein and/or energy to meet production expectations. Additional information on establishment, production, and nutritive value are discussed in Chapter 6, Management of forages and pastures in Lower-South: I-10 Corridor.

Because of the dense sod and rhizomes of bahiagrass, any overseeding with cool-season annual forages requires some small degree of disking or sod-disturbance for germination. During the active growing season, bahiagrass has strong, shallow-soil depth rhizomes. Plant growth is characterized by short, stout internodes that are often covered with old leaf sheaths when allowed to grow without defoliation or with only intermittent defoliation. This growth form is responsible for lowered nutritive value for hay and grazing. Bahiagrass, however, can tolerate frequent, severe defoliation by grazing. Defoliation studies showed that bahiagrass tolerated weekly clipping to soil level because the vegetative growing points were primarily on the underside of the rhizomes. This made the growing points nearly impossible to remove under grazing conditions [16,17]. Close defoliation improves nutritive value by eliminating the amount of dead leaf material that accumulates under reduced defoliation. With these growth traits, bahiagrass is not a preferred forage for hay due to nutritive value. However, with supplemental protein and energy sources, bahiagrass hay can be acceptable for lactating cows.

Dallisgrass

Dallisgrass (*Paspalum dilatatum* Poie) is an introduced forage in the United States with native plants originating in South America [18,19]. Although dallisgrass grows on a wide range of soils, it is best adapted to loam or clay loam soils that are poorly drained [20]. Thus, dallisgrass is one of the best "indicator forages" that identifies soils that are not good growing sites for hybrid bermudagrass due to the wet-soil ecosystem. In the I-20 Corridor, dallisgrass is primarily used for grazing, and is not a preferred forage for hay due to soil-site and leaf discoloration during the drying-curing period.

Dallisgrass has an open-form growth habit and is often found mixed with common bermudagrass. This mixture of warm-season perennial grasses has advantages for grazing due to DM growth, nutritive value, and tolerance to frequent, close defoliation. Because of the soil-site adaptive nature of dallisgrass, these pastures are excellent sites for establishment of white clover. White clover stands can be reliable as reseeding annuals or as weak perennials during frequent rainfall in summer. Active grazing of white clover with dallisgrass and common bermudagrass is usually from about March until early June in the I-20 Corridor. Thereafter, dallisgrass may be actively grazed until the time of the first frost.

During the summer months, dallisgrass pastures that have a low stocking rate or are not defoliated produce an abundance of seed. On certain occasions, dallisgrass seed can be infected with ergot (*Claviceps paspali*), which is a fungus that affects developing seed [21,22]. Ergot can be visually detected due to seed fungus that is small, and dark brown to black in color. Cattle are sometimes addicted to eating the ergot-infested seed because of a "honeydew" fluid produced by the fungus that accumulates on the seed. Continued consumption of ergot on dallisgrass can cause severe animal disorientation, and cattle should be removed and provided a diet free of infected seed. Animals usually recover in 5—10 days; however, continued consumption of ergot-infected seed can cause animal death [20]. Additional information may be found in Chapter 6, Management of forages and pastures in Lower-South: I-10 Corridor.

Switchgrass

Switchgrass (*Panicum virgatum* L.) is a native grass of the United States and is widely adapted to prairie soils, open woods, brackish marshes, and pinewoods openings [23]. Two varieties of switchgrass have been classified as lowland: "Alamo" and "Kanlow." Upland varieties include "Caddo," "Cave-in-Rock," "Shawnee," and "Blackwell." These varieties fit into the I-20 Corridor and the I-30 Corridor. Lowland types are best adapted to flood plains and areas of inundation; whereas, upland types occur in areas that are not subject to flooding [24,25].

Switchgrass can be used for pasture or hay in the I-20 Corridor. Some have called switchgrass a "niche grass" since it may be best used as: (1) an early grazing forage (usually 2–4 weeks earlier growth than bermudagrass); and (2) a summer-fall deferred grass for stockpiling use. Since switchgrass is a bunchgrass and not a sod-former, the most sustainable use is via rotational stocking. Continuous stocking to a low-stubble height allows for some plant mortality and an invasion by common bermudagrass.

Under grazing conditions, switchgrass is sustainable and provides adequate ADG and gain per acre when grazed to a stubble height that is not shorter than 8–12 in. [26]. As is the case with all grasses, nutritive value of switchgrass decreases after flowering and seedhead formation [27,28]. Switchgrass has been successfully overseeded with arrowleaf clover in the autumn following stockpiling grazing conditions. Arrowleaf can be a dependable reseeder and add to the seed bank by deferring initial grazing until early July (personal communication, F.M. Rouquette, Jr. and G.R. Smith). A large amount of DM produced by arrowleaf clover and its seed production in June–July does not present a competitive issue for switchgrass because of its early, upright, and tall growth (Fig. 7.1).

Warm-season annual grasses

The most important annual forage grasses used for pasture, hay, baleage, or silage in the I-20 Corridor include pearl millet, forage sorghum, sorghum × sudangrass, and crabgrass. All annual grasses generally have higher nutritive value traits, crude protein, and TDN compared to warm-season perennial grasses. For pasture × livestock production systems, all warm-season annual grasses are best suited for establishment on prepared seedbed conditions as opposed to sod-seeding into a perennial grass. Except for crabgrass, these annual grasses have the potential for rapid growth and high total DM production. With adequate soil fertility, especially nitrogen, and "normal" rainfall frequency and amounts, pearl millet and sorghum × sudangrass can be grazed within 35–45 days after planting. The specific variety of each annual grass should be confirmed via state forage extension variety trial information on the state's web site.

Pearl millet

Information on pearl millet has been addressed for the I-10 Corridor (Chapter 6: Management of forages and pastures in Lower-South: I-10 Corridor). The same general establishment and forage growth responses to nitrogen fertilizer are applicable for the I-20 Corridor. Pearl millet is adapted to sandy, acidic, drought-prone soils; however, it thrives best under normal rainfall-temperature conditions of the I-10 and I-20 Corridors. Seeding rates may be variety specific; however, most varieties are seeded at 12–15 lb/acre when drilled or 30–40 lb/acre when broadcast. Establishment in early May to early June can provide grazing in 35–45 days when

Figure 7.1 Deferred grazed switchgrass with reseeding Apache arrowleaf clover in late June to early July, and rotational stocking of switchgrass pasture.

plants are about 16–20 in. in height. With the rapid growth rate of pearl millet, management strategies include: (1) preparations to make stocking rate adjustments, depending on rainfall, may be required at 2–4-week intervals; (2) rotational stocking with movement schedules at 3–7-day intervals may be warranted; (3) mechanical harvesting of excess forage for hay (pre-boot stage) may be a necessity to make the best use of forage production.

Many varieties are day-length sensitive; thus, these plantings attempt to reach maturity in late summer to early fall. The dwarf-types of pearl millet (Tifleaf) have shorter internodes, and thus do not reach heights of the nondwarf types of 10 feet or more. Since pearl millet is not a sorghum-type forage, it does not accumulate prussic acid. However, plant nitrate levels may accumulate under certain climatic and/or management conditions to the point of toxicity for beef cattle. Under drought conditions, Krejsa [29] found pearl millet accumulated alkaloids that made it unpalatable, and it also accumulated nitrate. Under grazing conditions when leaves were stripped off, the remaining stems reached toxic levels of nitrate. Thus, when assessing plants for potential nitrate toxicity, the stems have higher concentrations than leaves and should be included in the sample for analysis.

In a stocking rate study with pearl millet [30], stocker cattle (550 lb) stocked at 4.5, 3.3, and 2.2 hd/acre had respective ADG of 0.7, 1.7, and 2.1 lb/day. The forage allowance for optimum ADG showed to be about 3.5 DM:BW. Gain per acre based on moderate to low-stocked pearl millet was about 400 lb/acre during a 90-day period.

Forage sorghum

Forage sorghum varieties grow 8–14 feet in height and produce 6–12 tons DM/acre for primary use as silage. Normally, forage sorghums are used for conserved forages and not for grazing. Overall performance is variety dependent, and specific updated information should be available on state forage websites. Optimum silage or hay may be obtained when forage sorghum is harvested at the mid-dough stage before mature seed is set. Although prussic acid may accumulate in forage sorghums, this potentially toxic compound is released from the grass as hydrogen cyanide (HCN) during the drying-curing process after harvest.

Sorghum × sudangrass

Sorghum × sudangrass variety preferences vary among states and evaluation locations, and updated information is usually available on state Forage Extension websites. These hybrid varieties have rapid growth rates and high dry matter production potential. The "easiest management" practice is to mechanically harvest sorghum × sudangrass as hay, baleage, or silage because of the fluctuation in DM production during the summer with dry conditions.

The brown midrib (BMR) varieties of forage sorghum and sorghum × sudangrass hybrids have higher nutritive value than non-BMR varieties. Well-drained soils with pH of 6–7.5 are best suited for these forages, and nitrogen fertilization and other soil nutrients are required for optimum DM production. Under stocking conditions, managers should be prepared to alter or change the stocking rate during the growing season due to forage growth responses to nitrogen fertilization and rainfall. Rotational stocking is a preferred strategy of grazing for better control of forage utilization. Managers should always be prepared to harvest forage for hay on a portion of the planted acreage to achieve optimum utilization for forage production and nutritive value.

With management requirements and costs of soil-site preparation (via disking, etc.), seed, planting, fertilization requirements, electrical fencing and water facilities, etc., these high DM producing annual forages are expensive. Thus an advanced utilization strategy is required for forage whether harvesting as a conserved product and/or grazing with stocker cattle.

Crabgrass

Large crabgrass [*Digitaria sanguinalis* (L) Scop] and smooth crabgrass [*Digitaria ischaemum* (Schreb.) Muhl.] are often considered as weeds when encroaching into newly planted forages. However, because of nutritive value and reliable reseeding, "Red River" crabgrass was released in 1988 by the Noble Foundation. Other ecotypes of crabgrass include "Quick N Big" from Estel Farm and Seeds in Oklahoma, and "Impact" which is the latest release from the Noble Foundation. In the I-20 Corridor, the most common use of crabgrass is in a prepared seedbed previously planted to cool-season annual forages in the fall, and then planted to crabgrass occupying the same site during the summer months. When allowed to set seed, crabgrass will be a volunteer reseeding forage following a cool-season forage-grazing system.

Crabgrass can be established in March—May using 3—5 lb/acre pure live seed (PLS), and can be broadcast planted with a fertilizer mixture. Crabgrass grows best on well-drained sandy loam to clay loam soils at pH 5.5—7.5. Although an annual grass, crabgrass is tolerant of moderate to moderate-high stocking rates to a stubble height of about 3 in. Crabgrass forage growth responds well to rotational stocking with a movement schedule based on stubble height of 3—4 in. at time of removal, and 6—12 in. at the initiation of grazing. As an annual grass, crabgrass forage production is closely related to rainfall events. Under average rainfall frequencies, crabgrass can provide grazing for two 500-lb stocker calves per acre for 60—100 days with a variable ADG of 1—1.5 lb/day. A 5-year grazing evaluation with Impact crabgrass resulted in an average ADG of 1.6 lb/day and 192 lb/acre (http://www.noble.org).

With favorable soil fertility and climatic conditions, an abundance of crabgrass forage will provide for a hay crop. Although crabgrass nutritive value when harvested as hay could be 15% crude protein and 60% TDN, crabgrass leaves are wider, and thus curing time for hay may require a longer time period than bermudagrass [31]. In addition, the darker color of crabgrass hay may not be as "visually acceptable" as bermudagrass; however, forage value often exceeds that of bermudagrass. Additional management strategies for forage or hay may be found on some state websites such as Florida (http://edis.ifas.ufl.edu) or Noble Research Institute (http://www.noble.org).

Warm-season annual legumes

Warm-season annual forage legumes may be considered a "specialty crop" in livestock production systems in the I-20 Corridor. These legumes are commonly planted on prepared seedbed and used as hay, cover, double crops in annual cropping systems [32], or as supplemental browse for wildlife [33]. Forage cowpea (*Vigna unguiculata* [L.] Walp.) and lablab bean (*Lablab purpureus* [L.] Sweet) are the most important warm-season annual forage legumes for the I-20 Corridor. Forage cowpea is used across the I-20 Corridor as browse for wildlife and has the potential for increased use as a summer cover crop, hay, baleage, and silage crop. In general, forage cowpeas are not well accepted (palatability) by cattle as a grazing crop in the mid-south. In studies at Overton, TX, multiple lines of forage cowpea were refused by cattle, while lablab bean was readily grazed [34].

Cowpea

Cowpea is a multi-purpose crop in the United States with cultivars developed as dry pulse for human food, fresh vegetable types [35], and many older cultivars [36] as multi-use (forage + fresh vegetable). One cultivar described by Piper [36], "Iron," is still in use today as a component of the variety mix "Iron and Clay." Iron and Clay is a late flowering type used across the I-20 Corridor as supplemental browse plantings for white-tailed deer [33]. Cowpea forage is high in nutritive value, and the plants are very water efficient, drought tolerant, and quick to establish [37].

"Ace" forage cowpea is a new cultivar released by Texas A&M AgriLife Research in 2018 (personal communication, G.R. Smith). Ace is a small seeded cultivar of forage cowpea developed for use in wildlife plantings, legume hay, and cover cropping systems. Biomass production of Ace ranges from 2 to 3 tons/acre with crude protein of about 16−18%. Root galling of Ace by southern root-knot nematode is very low, and nematode reproduction is low relative to susceptible cowpea lines.

Lablab bean

Lablab is a vining, herbaceous tropical legume with high-nutritive value for forage, deer browse, and silage [38,39] for ruminant animals. The qualities of this tropical forage include: drought tolerance, high palatability, high-nutritive value, excellent forage yields, and adaptation to diverse environmental conditions. "Rio Verde" lablab was developed at the Texas A&M AgriLife Research and Extension Center at Overton through selection for tolerance to defoliation, forage production potential, and Texas seed production. Rio Verde was released by the Texas Agricultural Experiment Station in 2006 (PVP # 200800221) as the first lablab cultivar developed in the United States. It also has the value-added trait of seed production in the United States [40]. Seed of Rio Verde is produced in Texas and California. Seed production of this cultivar is limited in Texas by leaf and stem blight caused by anthracnose (*Colletotrichum* spp.). Anthracnose-resistant and improved pod-type lablab germplasm has been identified, and new cultivar development is in progress [41].

Cool-season perennial forages

Tall fescue

Tall fescue [*Lolium arandinaceum* (Schreb.) Darbysh] is the most used and adapted cool-season perennial grass in the mid- to upper Southern states (Fig. 1.6). Complete discussions of management strategies for tall fescue has been addressed in chapters pertaining to the I-30, I-40, and I-64 Corridors. Within the vegetational zone of the upper I-20 Corridor, tall fescue pastures and mixed pastures of bermudagrass and tall fescue are well adapted and sustainable for beef production. The awareness of the widely infected tall fescue pastures with the endophyte fungus (*Neotyphodium coenophialum*) and potential problems with fescue toxicosis will enable managers to implement appropriate stocking strategies. Use of novel or endophyte-free tall fescue pastures provide opportunities for stockers during the summer (Fig. 7.2).

A 19-year calving date study in Tennessee compared spring- versus fall-calving cows stocked on tall fescue [42]. Although spring-born calves had greater ADG, the cows were subjected to a reduced calving interval due to endophyte activity. The fall-calving cows produced more calves, heifer calves could be retained and the need for replacement females reduced, and more total income was produced. Tall fescue pastures have been overseeded with clovers which reduces the incidence of fescue toxicosis and increases the nutritive value of the diet and overall cow—calf performance.

Figure 7.2 Long-yearling Bonsmara-Angus steer grazing novel endophyte tall fescue during the summer.

Interseeding ladino white clover and other clovers into tall fescue pastures has shown to double stocker ADG from about 0.8 lb/day to 1.6 lb/day [43]. Backgrounding stocker calves by adding legumes to tall fescue and moving cattle to non-fescue pastures, such as bermudagrass during the summer, proved to enhance overall gain per acre from 300 to 500 lb/acre during a 125−150-day period [44].

There has been only minor to no impact of endophyte infection status on stockpiled tall fescue for wintering beef cows. The reduced ergot alkaloid concentrations in tall fescue during the winter period provided most of the rationale for the accepted management strategy for stockpiled tall fescue pastures [45].

Alfalfa

Alfalfa (*Medicago saliva* L.) is recognized as an important forage crop in the United States for hay, dairies, and some beef operations. However, the adaptation of alfalfa to the acidic, infertile soils of the southern United States has been limited for multiple reasons, including toxic effects of Al^{+3} on root growth [46]. Alfalfa can be used for grazing or hay in the mid-south, but both systems require specific attention to site selection, soil nutrient and pH management, pest control, establishment, and harvest management [47]. Hay production of two alfalfa cultivars was evaluated at five sites in east Texas over a 5-year period. Stand survival of "Amerigraze 702" and "GrazeKing" after four years of hay production ranged from 47% to 76% and 41% to 64%, respectively [48]. A three-year grazing study conducted at Overton, TX evaluated "Alfagraze" alfalfa sod-seeded into established bermudagrass pastures at multiple row-space treatments [49]. The alfalfa component of these pastures did not persist well after two years of rotational grazing. Percent alfalfa in these systems decreased after two years to 14.4%, 10.5%, and 4.8%, respectively, for the 10, 20 and 30 in. alfalfa row spacings. Alfalfa, when grown in a pure stand, can be productive in mid-south forage-animal systems, but careful management is needed to fit this high-nutritive value, perennial legume into the current warm-season perennial grass-based systems used across the I-20 Corridor. Some management strategies for grazing alfalfa in the I-20 Corridor include the following [50].

1. Establish alfalfa on an appropriately fertilized-limed, prepared seedbed during autumn.
2. Harvest alfalfa for hay only during the first spring-summer season of active growth, and cut at about 10% bloom stage.
3. Incorporate a flexible, rotational stocking strategy beginning in the second season of growth. Use electric fencing for easy-adjustment of pasture size which can control grazing intensity.
4. Use Stage of vegetation growth [51] as an indicator for initiation of stocking. Stocking should be delayed until alfalfa has reached Stage 5 to Stage 6. This is a necessity to prolong stand.

5. Stocking on pasture should be appropriate to allow for a grazing duration of 3–5 days to reach an average 3–4 in. stubble height. Stubble height and duration of grazing are major factors influencing stand survival.
6. Stocking strategies should be flexible to alter utilization regimens as rainfall events and temperatures fluctuate in the different seasons.
7. During prolonged, hot, dry conditions, consider "skipping" or "omitting" a grazing cycle, and harvest alfalfa as hay to enhance stand persistence.
8. Provide bloat guard blocks in grazed pastures for protection against bloat and potential death loss.
9. Animal consumption, or intake, is directly linked to body weight; thus, cow–calf pairs will consume 3–4 times the daily amount of alfalfa compared to lighter weight weaned calves.
10. The best use for alfalfa pastures is for either weaned, stocker steers or replacement heifers, or as a creep-graze strategy for suckling calves which does not allow lactating or dry cows to graze.

White clover

> ***A cardinal requirement of successful management (of white clover) is controlling the height and density of associated plants to expose the clover to light. Violation of this requirement is a common mistake in the management of clover-grass pastures.***
>
> **P. B. Gibson and W. A. Cope, 1985**

White clover (*Trifolium repens* L.) is a cross-pollinated, highly variable tetraploid species adapted to wet, poorly drained soils [52]. The growth habit of this clover is prostrate with stolons that root at the nodes. Growth forms range in plant size from large (ladino) to small with corresponding leaf sizes and variation in flowering. White clover is a perennial in mild, humid climates, and can persist as a reseeding annual in regions with winter rainfall and hot, dry summers [53]. In the mid-south I-20 Corridor, the combinations of climate and soil conditions often prevent white clover from persisting as a perennial. White clover is well-adapted to bottomland clay and clay loam soils with moderate to poor drainage, and will persist on these sites through reseeding. White clover may also survive and live as a perennial in some years if summer rainfall is abundant. The large white clover types require long-day lengths (12–16 hours) for optimum flowering and never flower profusely in this region [54]. Stolon survival and seed production with subsequent reseeding under grazing are two mechanisms for improved white clover persistence in southeast United States pastures [55]. Types that flower earlier and produce seed earlier can take advantage of the spring weather in the mid-South to build soil seed banks, thus improving stand longevity and pasture reliability. Recent white clover cultivars developed for improved persistence and reseeding potential in southeastern United States pastures include "Durana" [56] and "Neches" [57] (Fig. 7.3).

Figure 7.3 Neches white clover as a perennial and reseeding annual forage grazed by fall-calvers in June.

Cool-season annual forages

Overseeded annual forages, including clovers (*Trifolium* spp.), ryegrass (*Lolium multiflorum* Lam.), vetch (*Vicia* spp.), and small grains, can provide valuable and critical winter forage production in the mid-South when the warm-season grasses are dormant. Bermudagrass and bahiagrass cultivars are more tolerant of low pH levels (4.5−5.5) and the corresponding high Al^{3+} concentrations than most annual forages that are used for overseeding [58]. With the exception of cereal grain rye (*Secale cereale* L.), soils in the mid-South should be limed to pH 6.0 or above for optimum forage production of cool-season annual forages.

Grasses

Rye

Rye is important worldwide as both a cereal and forage crop. Combinations of high seedling vigor, high forage production, and tolerance to Al^{3+} toxicity in acid soils propel this species to prominence as a winter forage crop in the mid-South. Rye has exceptional tolerance to Al^{3+} levels that cause root development problems with other small grains [59], ryegrass [60], and clovers [61]. Multiple genes condition resistance to Al^{3+} toxicity in rye through mechanisms that include the release of organic anions from the roots [62].

Ryegrass

Annual ryegrass has been used for winter pasture in the southeastern United States for more than 80 years [63]. The primary use of annual ryegrass in the mid-South is that of overseeding warm-season perennial grass pastures, either alone or in mixtures with rye and/or clovers. Annual ryegrass is a very versatile, high-nutritive value forage crop. It can be established with minimum seedbed preparation, is adapted across a range of soil types, and tolerates intensive grazing. In this region, forage production of annual ryegrass is directly related to N fertilization [64,65]. Three to four split applications of 50−70 lb N/acre are needed for optimum forage production on the sandy, infertile soils of this region. Nitrogen fertilization of clover-ryegrass mixtures is complex due to the very different N requirements of the two forages. In a two-year study at Overton, TX, very low amounts of N were actively transferred from companion clovers grown with annual ryegrass [66]. In a mixture of ryegrass and clover with no N fertilization, the clover dominated (2635 lb/acre), and ryegrass production was very low (325 lb/acre; [67]). The same mixture fertilized with 220 lb N/acre produced more total forage (4425 lb/acre) with a 1:2 ratio of clover:ryegrass. Two applications of 60 N/acre, applied in January and March, gave a total yield of 3790 lb/acre with a 1:1 ratio of clover:ryegrass forage. The treatment with two applications of N applied in January and March to the clover-ryegrass mixture was the most efficient use of seed, fertilizer, and biological N fixation resources.

Improvement of ryegrass for winter pastures in the United States southern region traces back to the development and release of "Gulf" ryegrass by the Texas Agricultural Experiment Station and USDA/ARS in the early 1960s [68]. Ryegrass breeding programs in Texas, Florida, and Mississippi have continued to improve this important winter annual grass over the past five decades. Important advances in cold tolerance of ryegrass were made with the release of "Marshall" ryegrass [69] and later with "TAM 90" [70]. Tetraploid ryegrass such as "Nelson" [71] and "TAMTBO" [72] offer improvements in the seasonal distribution of forage growth (earlier and later) and are generally higher in forage production relative to older, diploid cultivars (Fig. 7.4).

Forage legumes

Crimson clover

> ***Crimson clover has long been recognized as an important annual legume in the winter grazing programs of the South.***
>
> **E. A. Hollowell and W. E. Knight, 1962**

Crimson clover (*Trifolium incarnatum* L.) is the most important annual clover to US agriculture, with primary use as a winter annual forage legume overseeded on warm-season perennial grass pastures in the southeast United States. This annual clover is a component of forage production systems from Virginia to east Texas, and the beautiful crimson flowers enhance the landscapes of both pastures and roadsides in this region. Seed production of crimson clover in the United States (all in Oregon) averaged 8.1 million lb/year for 2011 through 2013 [73] with a conservative estimated seed sales value of $12 million per year. Crimson clover is native to southern Europe and has been grown in the United States for more than 150 years, but with increasing use in the last 60 years [36]. As introduced from Europe, this forage legume did not have high hard seed levels. It also was not reliable in producing volunteer (reseeding) stands in the temperate, year-round-rainfall climate of the east and southeast United States [74].

Duggar [75] noted the potential of crimson clover as a green manure crop for use in cotton cropping systems in Alabama. Interest in the use of crimson clover as a grazing crop in the southeast increased in the 1940s as reseeding strains became available [76]. Crimson clover was grown as a seed crop and as a combination grazing and seed crop in the southeast United States for 40 years beginning in the 1930s. Crimson clover seed yields in Alabama ranged from 100 to 800 lb/acre, depending on soil type, plant nutrition, and insecticide treatments [76]. Insecticides were necessary to control clover head weevil (*Hypera meles* F.) in these southern seed production systems. Crimson clover seed production in the southeast United States declined rapidly in the 1960s and early 1970s (personal communication, Dr. Jim Bostick, Alabama Crop Improvement Association). Some possible reasons for this decline were: loss of seed

Figure 7.4 Bermudagrass overseeded with Nelson ryegrass and grazed at two stocking rates with fall-calving cows and calves.

harvest and processing infrastructure; shift from clover and grass pastures to nitrogen-fertilized grass pastures; and clover head weevil damage to the crimson clover seed crop (Fig. 7.5).

Figure 7.5 Bermudagrass overseeded with Dixie crimson clover and grazed with fall-calving cows and calves in mid-April (top), or deferred for reseeding and potential hay (bottom).

"Dixie" crimson clover was developed in Georgia in the early 1950s in response to the need for a cultivar with improved reseeding traits that could also be produced as certified seed. Dixie is a composite of three crimson clover farm strains that exhibited excellent field reseeding, high forage yields, and high hard seed test results in laboratory evaluations [77]. As recent as 1959, common crimson clover had less than 5% hard seed at harvest [78]; however, improvement in the hard seed level through recurrent selection could be demonstrated. The hard seed trait in Dixie crimson clover was shown to be very stable over years and environments in a nine-year study conducted in Alabama, Mississippi, and Georgia in the 1950s [79]. The hard seed level of Dixie was consistently 60%−80% at harvest with little effect from seed production location or year. In a three-year experiment in Texas beginning in 1994 [80], Dixie crimson clover averaged 33% hard seed at harvest, but did produce acceptable reseeding stands (>11 seedlings per ft^2) in each year. This indicates a reduction in hard seed level for this cultivar (reduced from levels reported in 1963) and may explain the variability in crimson clover reseeding in years with sporadic fall rains.

> ***Crimson clover thrives on both sandy and clay soils and is tolerant of medium soil acidity.***
>
> **E. D. Donnelly and W. A. Cope, 1961**

"Chief" crimson clover was developed in Mississippi [81] through nine cycles of recurrent selection for hard seed, with the final generation stabilized at 65% hard seed (as measured at harvest with hand-cleaned seed). Both "Flame" and "AU Robin" are crimson clover cultivars selected out of Dixie for early maturity [82,83]. Parental lines of AU Robin were selected based on bloom date, dry matter yield, and nitrogen yield. Flame was selected from a population of Dixie that had reseeded for seven years in warm-season perennial grass sod under winter grazing and summer hay management.

"Sabine" is a new cultivar of crimson clover selected in Texas for late flowering and improved hard seed content. Recurrent selection was used to shift flowering date and to improve hard seed production and reseeding. Sabine flowers about 10 days later than Dixie crimson; thus, allowing a better match for ryegrass in grazing management systems. Compared to Dixie and "Tibbee," Sabine has a much higher hard seed level and corresponding improved ability to build a soil seed bank [34]. Sabine averaged (two-year progeny test) 20% seed survival after a 320-day soil incubation, compared to 7% for both Tibbee and Dixie. Sabine was developed in the Forage Legume Breeding Program at Overton and released by Texas A&M AgriLife Research in 2012. Additional crimson clover cultivars are described in Table 7.1.

Table 7.1 US cultivars of crimson clover.

Cultivar	Year of release	Organization	Eligible for certification in Oregon
Dixie	1953	Georgia AES	X
Chief	1960	Mississippi AES; ARS	X
Auburn	1961	Alabama AES	
Frontier	1963	Mississippi AES; ARS	X
Tibbee	1972	Mississippi AES; ARS	X
Flame	1989	Florida AES	X
AU Robin	1992	Alabama AES	X
AU Sunrise	2000	Alabama AES	X
Sabine	2012	Texas AES	

Arrowleaf clover

Arrowleaf clover (*Trifolium vesiculosum* Savi.) is a highly productive annual clover that is used across the United States southern region as an overseeding component of perennial warm-season grass forage systems [84,85]. This clover is productive later in the spring (March through May) contrasted to crimson clover, which flowers and ceases growth in mid- to late April. Arrowleaf clover was widely used in the United States southern region in the 1960s and 1970s. Various disease and pest problems were reported on arrowleaf clover [86,87], and forage production from this clover was unreliable by the late 1970s. A breeding program was initiated by Texas A&M AgriLife Research (formerly Texas Agricultural Experiment Station (TAES)) in 1979 to develop improved, disease resistant arrowleaf clover cultivars.

"Apache" arrowleaf clover was developed through six cycles of recurrent selection for tolerance to bean yellow mosaic virus (BYMV) disease and was released by TAES in 2000 [88,89]. Plant Variety Protection (PVP) status was granted in 2005. The BYMV tolerance [90,91] of Apache has restored the utility of arrowleaf clover in livestock production systems in the mid-South. Over 1.1 million pounds of Apache was sold during the first eight years of commercialization (Fig. 7.6).

Fungal pathogens in the soil can attack arrowleaf clover and cause damage at different growth stages [92]. *Pythium ultimum*, *Pythium irregular, Rhizocotonia solani* AG4, and *Fusarium proliferatum* were shown to infect, kill, or damage germinating seed and emerging seedlings of arrowleaf clover. *P. ultimum* was noted to cause particularly severe symptoms which often resulted in 100% death of arrowleaf clover seedlings.

"Blackhawk" arrowleaf clover was developed through three cycles of recurrent selection for tolerance to the soil pathogen *P. ultimum* and one cycle of selection for tolerance to bean yellow mosaic virus. The origin of this variety traces back to

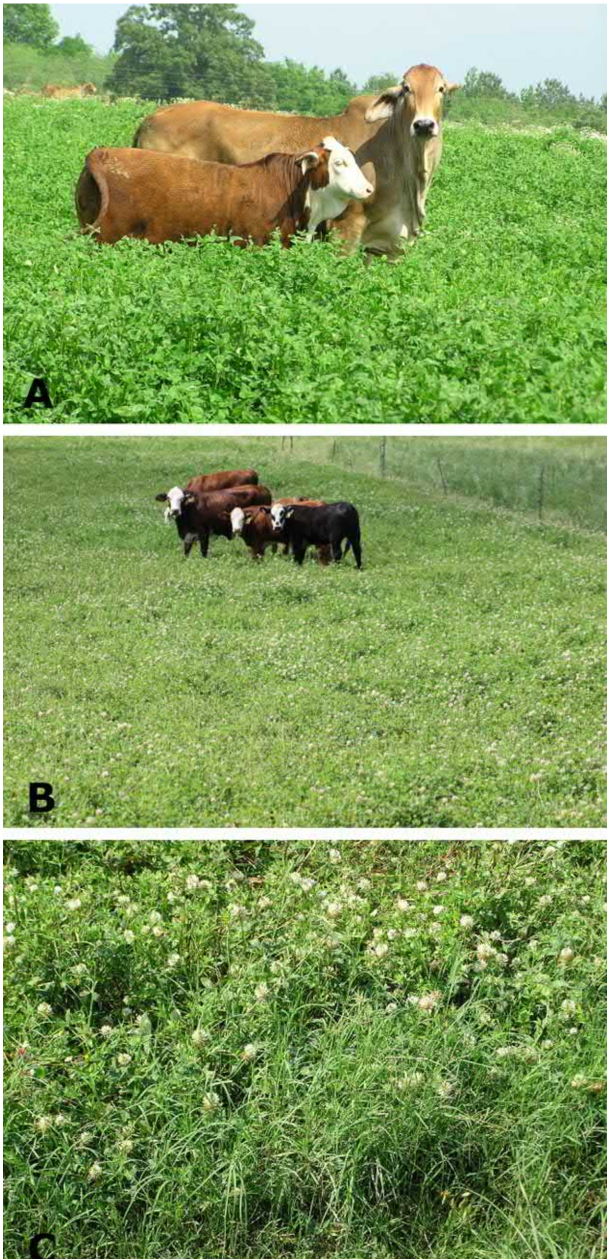

Figure 7.6 Apache arrowleaf clover grazed by fall-calvers at medium stocking rate in late April (A), and early May (B). Bermudagrass with arrowleaf closeup in late May (C).

dark-seeded, half-sib lines from the 1984 field selection nursery at Overton, TX, which was planted to individual plants of the arrowleaf cultivars "Yuchi," "Meechee," and "Amclo." Blackhawk was released as a cultivar by Texas A&M AgriLife Research in 2013 and PVP was granted in 2016 [93].

Ball clover

Ball clover (*Trifolium nigrescens* L.) is an annual plant, similar in appearance to white clover but without stolons. Ball clover is well adapted to loam and clay loam soils and tolerates moderately poor drainage [94]. This annual clover will tolerate heavy grazing and can be managed to reseed under grazing.

See Appendix Table 7.1 for additional information on other forage legumes not discussed earlier.

> ***Ball clover is successfully grown on various soil types but is best adapted to loam or clay soils*... *but will not tolerate poor drainage as well as white clover*... *and is an excellent seed producer even under heavy grazing.***
>
> **Carl S. Hoveland, 1962**

Management of annual forage legumes for reseeding

Reliable reseeding of annual forage legumes depends on many factors including: seed production, seed survival, and seed germination at the appropriate seasonal timing. For clovers such as crimson and arrowleaf, heavy grazing or hay harvest during flowering can limit or eliminate seed production due to plant morphology (erect, ascending stems) [52]. Ball, white, and subterranean (*Trifolium subterraneum* L.) clovers are more successful at producing seed under grazing due to their growth habit of prostrate, decumbent stems [52]. Clover seed survival in the mid-South is controlled by the development of hard (water impermeable) seed. This trait is very species dependent and varies widely among the commonly used clovers in this region. Arrowleaf, ball, rose (*Trifolium hirtum* All.), and white clover are all species that produce high levels of hard seed (personal communication, G.R. Smith) and are usually efficient reseeding plants. Crimson clover, as originally imported to the United States, was very low in hard seed [74], but has been modified through selection and breeding for improved hard seed and reseeding ability [77] [79].

The production of clover seed in a pasture system where the clover is growing as an overseeded crop in warm-season perennial grass requires a careful balance of clover forage utilization, reduction or elimination of spring grazing to coincide with clover flowering, and removal/utilization of mature clover plants to allow growth of the warm-season perennial grass. In a mid-South reseeding system, crimson clover over-seeded on warm-season perennial grass pastures should be grazed until about 15 April, and then allowed to flower and set seed until late May without grazing. After late May, the mature clover will be mixed with the first growth of warm-season perennial grass and can be grazed or harvested for hay. The relative early maturity of crimson clover allows this system to function with little negative impact on the warm-season perennial grass production. Because of later maturity relative to crimson clover, arrowleaf clover is more difficult to manage for reseeding without causing negative effects on the warm-season perennial grass. Arrowleaf clover should be grazed until early or mid-May and then allowed to flower and set seed until mid-June with either no grazing or grazing at a low-stocking rate. After mid-June, the mature arrowleaf clover/warm-season perennial grass mixture can be grazed or harvested for hay. Arrowleaf clover should not be managed for reseeding on warm-season perennial grass sod where the first priority is early hay production. Arrowleaf clover is a very productive forage legume and can be a valuable component of warm-season perennial grass pasture systems in this region when managed as a nonreseeding (planted every fall season) forage [95].

Conserved forages

Warm-season perennial grasses have an active growth period from early April to mid-November in the I-20 Corridor and respective Hardiness Zones of 7 and 8 (Fig. 1.3). From the time of first-killing frost in mid-November to the last killing frost in mid-March, actively growing bermudagrass, etc. are not available for consumption. Thus, during this late fall to early spring period, alternative pasture systems such as cool-season forages and/or conserved forages are necessary components of the year-round livestock operation.

Sollenberger et al. [96] provided a thorough review of some of the factors that affect the nutritive value and DM production and utilization of hay and silage. Factors for hay included: choice of species and defoliation management, field drying processes, DM and nutrient losses, storage losses, feeding losses, additives to preserve wet hay (baleage), treatments to enhance nutritive value, and harvesting systems. Factors for silage were: ensiling processes, plant factors affecting fermentation and preservation, additives, losses of DM, harvest and storage losses, and feeding losses.

Hay

Of all warm-season perennial grasses available for pasture in the I-20 Corridor, bermudagrass has received the most research emphasis for grazing and hay production. Since the release of Coastal bermudagrass in 1943 on sandy loam soils that were acidic and relatively infertile, several researchers have evaluated the effects of rate of N fertilization × defoliation severity, frequency, and stubble height on DM production and nutritive value [97–102]. Taliaferro et al. [4] provided a more detailed accounting of bermudagrass production and management strategies to conserve bermudagrass as hay.

> ***Height of cutting appears to be less important in Coastal bermudagrass production than either frequency of defoliation or level of fertilization, but Coastal bermudagrass will tolerate a wide range in both height and frequency of defoliation.***
>
> **Ethan C. Holt and J. A. Lancaster, 1968**

Bermudagrass growth allows it to be well-suited for mechanical harvesting and conservation as hay. Clipped plot experiments provided management recommendations of a 4–6-week harvest interval for hay as a means of optimizing nutritive value × DM production. Curing of bermudagrass for hay is affected by climatic conditions, humidity, season of year, ambient temperature, forage mass, and forage moisture [103,104] (Fig. 7.7).

All landgrant agronomy departments and forage specialists have detailed procedures online for hay-making. The bale package size and shape and storage method all have direct impact on nutritive value and dry matter losses. In addition to potential storage losses, the method of feeding hay free choice versus protected area (hay ring) may allow DM hay losses of 10–25%. Suggested feeding guidelines on county and state extension websites provide strategies to control and reduce these hay losses during feeding.

Figure 7.7 Tifton 85 bermudagrass conserved as round baled hay in July.

Haylage and baleage

Forage that requires harvesting during inclement weather conditions for field drying as hay may be harvested and stored as haylage or baleage. Management strategies using these methods of conservation may be found in Chapter 6, Management of forages and pastures in Lower-South: I-10 Corridor. Recommendations listed for methods to optimize baleage production in the I-10 Corridor are the same for the I-20 Corridor. Each state and most counties in the I-20 Corridor have web-based information from their Forage Extension Specialist.

Stockpiled forage

Warm-season perennial grass that has been deferred and not grazed or harvested for hay during late summer and early fall may be stockpiled and grazed during fall and early winter in the I-20 Corridor. Forage that is to be used for a stockpiled grazing system should be deferred (no grazing) for 6—8 weeks prior to first killing frost. A longer deferment period drastically reduces the nutritive value of the forage. Bermudagrass that is deferred for 10—12 weeks is very mature with a low nutritive value and may require supplementation for dry cows.

> ***The protein content of bermudagrass decreases with the age of the plant and may drop below the minimum requirement for grazing animals when the plant matures.***
>
> **Ethan C. Holt, R.C. Potts, and J.F. Fudge, 1951**

Methods of utilization are management strategy-specific to best fit overall cattle requirements. In general, utilization of stockpiled forage fits into the categories of: (1) an "open gate policy," wherein cattle have unrestricted access to forage; or (2) some system of restricted use via electric fencing, etc. [105—108]. Management strategies to obtain maximum utilization of stockpiled forage on an area (pasture) prior to movement to another area, and/or the reluctance to offer hay, often has negative effects on the body condition score and desired level of performance from lactating cows. Although restricted or strip-stocking can be a good strategy to optimize efficiency of use of stockpiled forage, this method can also result in weight loss situations that can negatively affect body condition score, lactation, and rebreeding.

Management strategies for matching calving seasons with forage-pasture options

Time of calving is a management decision. Certainly, given no boundaries for selection and management of warm-season perennial grass pastures with overseeded cool-season annual forages and/or hay and supplement, calving seasons will move toward the time for optimum forage availability and nutritive value. The selection of a calving season or seasons offers the challenges of matching forage production and nutritive value of pasture systems with the opportunities for rebreeding the cow herd. Opportunities for management also includes a desired level of weaning percent, weaning weight, and percent rebreeding. Regardless of the calving season(s) selected by management, one of the most important considerations for calving and rebreeding for a consistent 12-month calving system is that of body condition score (BCS) of the cow at time of calving [109]. Although there may be some "it depends" scenarios, cows should have a BCS of about 5 or greater at time of calving. A body condition of 5, along with appropriate forage dry matter and nutritive value, will allow management strategies for use of stockpiled forage and/or energy-protein supplementation. The nutritive requirements for various classes of cattle are presented in Appendix Table 8.1.

The most appropriate management strategies to attain BCS and reliable 12-month calving intervals are uniquely related to the forage-pasture conditions during the dry cow period from the time of weaning to the next calving event. Too often, dry cows are pastured on reduced levels of forage mass and nutritive value that do not allow for increased body weight or condition. Thus, the success of a 12-month calving system is largely due to management strategies for cows and pastures during the approximate 3-month period when the cows are dry (approximately 90-days pre-calving).

In order to answer the question, "When is the best season of the year for calving on my property?" some of the following objectives and decisions must be explored by management:

- The warm-season perennial grass pasture that allows for overseeding with cool-season annual forages such as small grain, ryegrass, and clover.
- The calving season that offers the best opportunity to wean heavy weight calves.
- The calving season that offers forages/pastures that meet nutritional requirements for dry cow weight gain and with reduced costs for supplementation and labor.
- The calving season that offers best opportunities for merchandizing/selling calves and cull cows.
- Pasture availability for retained ownership of calves from the time of weaning for an additional 100–200 days grazing.

Fall-calving cows

Forage and pasture options for fall-calving animal activities are shown in Table 7.2. Fall-calving cows wean calves in June or early July depending upon management choice and climatic impact on growing conditions for bermudagrass or bahiagrass. Two of the positive factors for fall-calving include the potential for heavy weight calves at weaning, and having dry cows during the hot, summer months along the I-20 Corridor. During the summer, the nutritive value of any moderately managed warm-season perennial grass meets or exceeds the nutritive requirements of a dry, pregnant, mature cow to maintain a BCS of ≥ 5, without the need for protein-energy supplementation. The initiation of breeding on 1 December will result in early September calves. With a suggested 75-day breeding season

Table 7.2 Forage and pasture options for fall-calving cows.

Month	Animal activity	Forages and pastures
Aug	Dry cow	Warm-season perennial grass (WSPG) pasture[a]
Sep	Calve	WSPG pasture
Oct	Calve; Suckling calf	WSPG pasture
Nov	Calve; Suckling calf	Stockpiled forage; WSPG pasture; Hay and/or supplement
Dec	Cow—calf; Suckling calf	Stockpiled forage; hay and/or supplement; limit-graze small grain[b] + annual ryegrass (option)
	Dec1: Initiate breeding	
Jan	Cow—calf; Suckling calf; Breeding continues	Limit-graze small grain + annual ryegrass (option); hay and/or supplement
Feb	Cow—calf; Suckling calf	Full-time graze small grain + annual ryegrass (option); Ryegrass and/or clover
	Feb 15: Terminate breeding	
Mar	Cow—calf; Suckling calf	Full-time graze small grain + annual ryegrass (option); Ryegrass and/or clover
Apr	Cow—calf; Suckling calf	Ryegrass and/or clover; WSPG
May	Cow—calf; Suckling calf	Ryegrass and/or clover; WSPG
Jun	*Jun 15*: Initiate weaning	WSPG
	Cow—calf; Dry cow	
Jul	*Jul 15*: Finalize weaning	WSPG
	Dry cow	

[a]Bermudagrass, bahiagrass; native grasses.
[b]Rye, oats, and wheat.

(December 1 to February 15), calving will be completed on actively growing bermudagrass by mid-November. Forage, hay, supplementation, and other pasture options for fall-calvers are shown in Table 7.2. With advanced planning and preparation, small grain with or without annual ryegrass can be available for grazing by late November on prepared seedbed, or by mid- to late December if sod-seeded (Appendix Table 7.3). Small grain plus ryegrass pasture costs may range from $150 to $250/acre depending upon the magnitude and extent of fertilization required. With average climatic conditions and forage growth during December—January along the I-20 Corridor, about 2—4 acres may be required for full-time stocking of one 1200-lb cow and 200-lb calf during the winter. One stocking strategy that may be used to reduce costs per cow is that of limit grazing [110]. Limit grazing is a method of stocking 2—4 cows and calves per acre on small grain plus ryegrass and allowing active grazing for only 2—3 hours per day. During the first 2—3 hours on small grain plus ryegrass pastures, cows will fill and reduce or terminate active grazing. At this time, cows and calves are removed from these pastures and returned to an adjacent pasture with free choice, unrestricted access to hay or stockpiled forage. This limit grazing system can be used on a daily or every-other-day basis to match defoliation and regrowth of small grain pastures. This stocking strategy also provides a method to prevent overstocking of the winter annual grasses. A creep-gate scenario will allow calves to graze winter pasture more often than the limited time that cows have access to small grain-ryegrass.

By about mid-February, annual ryegrass should be available for full-time grazing, and this additional pasture area will also allow for full-time grazing on small grain plus ryegrass pastures (Table 7.2). Forage establishment, fertilization regimens, and stocking strategies with cows and calves in the I-20 Corridor have been presented in detail by Rouquette [109] and Mullinex and Rouquette [111]. The initiation of stocking cool-season annual forages overseeded on bermudagrass is dependent upon planting conditions, date of planting, fertilization timings, climatic conditions, and whether stocking is to be limited or full-time. Establishment strategies and management for small grain plus ryegrass pastures and annual ryegrass or clover pastures (Appendix Table 7.4) provide a calendar of expected events and dates of implementation for pastures. It is important to remember that not all stocking activities occur on all pastures at the same time. Therefore, multiple pastures are needed in the overall system of stockpiling forage, establishing cool-season annual forages, and supplying hay and supplementation, and methods of flexible grazing that incorporate graze:rest periods (deferment) allow for best management of utilization and sustainability of forage with optimum desired animal performance. These strategies allow for stocking rates that provide for risk aversion during unfavorable climatic conditions of drought and/or cold temperatures.

Fall-calving cows and calves can be stocked at levels that match forage production in spring and early summer. Depending on stand of cool-season annual forages and

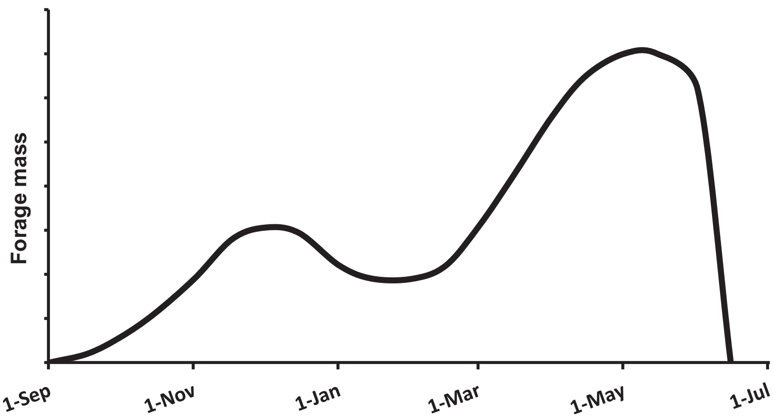

Figure 7.8 Illustration of bimodal forage mass production from small grain + annual ryegrass during growth seasons.

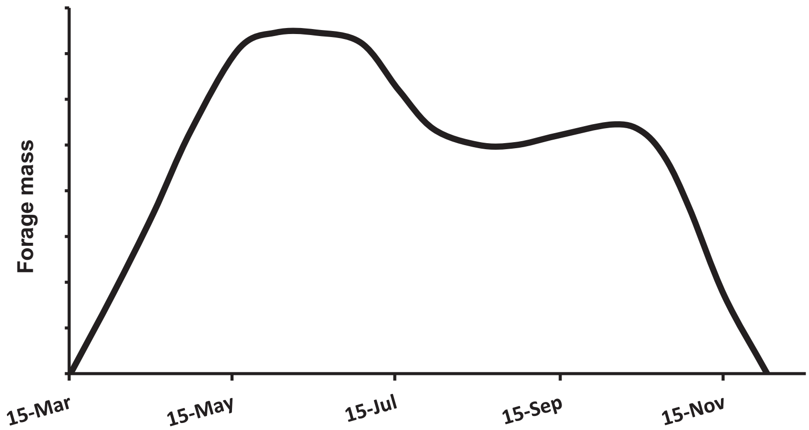

Figure 7.9 Illustration of forage mass production from bermudagrass during growth seasons.

Figure 7.10 Common bermudagrass pasture overseeded with Nelson ryegrass and grazed with F-1 (Hereford × Brahman) cow and fall-born Angus-sired calf weighing more than 900 lb at weaning in mid-June. Calf will fit into niche marketing as pasture-finished, or go directly to feedlot.

fertilization regimens, stocking rates can vary from 2 to 3 acres per cow—calf to 1 acre per cow—calf. The abundance of spring-summer forage growth for small grain and ryegrass (Fig. 7.8) and for bermudagrass (Fig. 7.9) allows for flexible stocking and increased stocking rates for 30—60 days. This increase in stocking rate/grazing pressure on part of the property allows for forage accumulation and hay or baleage production from other pastures. Weaning weight expectations for fall-born calves weaned in early to late June may range from 650 lb to more than 900 lb. These weights are dependent

Figure 7.11 Common bermudagrass pasture overseeded with Apache arrowleaf clover and grazed with F-1 (Angus × Brahman) cow and fall-born Simmental-sired calf weighing more than 900 lb at weaning in mid-June. Calf will fit into niche marketing as pasture-finished, or go directly to feedlot.

upon stocking period on cool-season annual forages from February to mid-May, productive bermudagrass in spring and summer, breedtype of cow and lactation potential, and breed of sire with growth attributes. Often, a sire may be a different breed than the cows and/or a Continental breed wherein all offspring are sold and not retained for replacements (terminal sire) (Figs. 7.10 and 7.11).

Winter-calving cows

Forages and pasture options for winter-calving cow activities are shown in Table 7.3. Winter-calving cows, if bull-exposed from 15 April to 1 July (75 days), will start calving in early January. From the time of weaning in mid- to late October, cows can have access to stockpiled bermudagrass until mid- to late December. In general, stockpiled bermudagrass has an optimum time for grazing and utilization until the onset of winter and accompanying cold, wet weather. Thus, an appropriate stocking strategy is to make near-complete utilization of stockpiled bermudagrass before Christmas. After that time, climatic conditions or grazing frequency causes the bermudagrass to lose its upright growth stature and become prostrate, which creates

Table 7.3 Forage and pasture options for winter-calving cows.

Month	Animal activity	Forages and pastures
Dec	Dry cow	Warm-season perennial grass (WSPG)[a]; Stockpiled forage; Hay and/or supplement;
Jan	Calve	Hay and/or supplement
Feb	Calve; Suckling calf	Ryegrass and/or clover
Mar	Calve; Suckling calf	Ryegrass and/or clover
Apr	Cow—calf; Suckling calf *Apr 15*: Initiate breeding	Ryegrass and/or clover
May	Cow—calf; Suckling calf; Breeding continues	Ryegrass and/or clover; WSPG
Jun	Cow—calf; Suckling calf; Breeding continues	WSPG
Jul	Cow—calf; Suckling calf *Jul 1*: Terminate breeding	WSPG
Aug	Cow—calf; Suckling calf	WSPG
Sep	Cow—calf; Suckling calf *Late-Sep*: Initiate weaning	WSPG
Oct	*Late-Oct*: Finalize weaning Dry cow	WSPG; Stockpiled forage
Nov	Dry cow	WSPG; Stockpiled forage; Hay and/or supplement

[a]Bermudagrass, bahiagrass; native grasses.

problems with grazing-intake. During the dry cow period before calving, a protein-energy supplement may be necessary to achieve the desired BCS of ≥ 5 at calving.

During calving, from January to March, annual ryegrass and/or clovers provide an excellent, high-quality forage for grazing. Annual ryegrass and clover produce their maximum DM from March to mid-May. These cool-season annual forages with or without hay can provide adequate nutrition to meet the nutritive requirements of winter calvers during the first half of the breeding season. Thereafter, fertilized bermudagrass or bahiagrass pastures can satisfy nutritive requirements for the lactating cow during the remainder of the breeding season (Table 7.3). A 75-day or shorter breeding season has been long-suggested by animal scientists as a management strategy to increase overall reproduction efficiency of the cowherd. A cow that requires more than 100 days to rebreed may be a result of stocking rates that reduced BCS to levels

Figure 7.12 Winter-calving cow and calf grazing low-stocked Coastal bermudagrass in late September prior to weaning.

which prevented the onset of estrus, or perhaps the cow is not an efficient reproductive animal for the herd or the economy of operation. Calves that are born within an approximate 75-day window provide for reduced labor inputs for castration, vaccinations, etc., and can all be weaned on the same day. Weaning all calves at the same time enhances marketing-merchandizing of calves; improves efficiency of pasturing dry cows to meet nutritional requirements; and decreases labor and costs of "working cattle" to accomplish the weaning event.

During the last 30−45 days of the breeding season, and throughout the lactation period for winter calvers, the primary forage will be warm-season perennial grass pastures (Table 7.3). During the summer, there may be opportunities to incorporate summer annual grasses in certain soil types and climatic conditions. White clover may offer some restricted stocking. If a stand of white clover is available, but the acreage is too small for full-time grazing, an excellent opportunity is created for calves to creep-graze white clover. In most areas in the I-20 Corridor, summer often includes periods of reduced rainfall events. Thus, to improve efficient forage utilization without engaging in stocking rates that would be detrimental to sustainability of pasture and/or animal performance, having multiple pastures allows for grazing-haying options for the

Table 7.4 Forage and pasture options for spring-calving cows.

Month	Animal activity	Forages and pastures
Feb	Dry cow	Hay and/or supplement
Mar	Calve; Suckling calf	Ryegrass and/or clover
Apr	Calve; Suckling calf	Ryegrass and/or clover
May	Calve; Cow–calf; Suckling calf	Ryegrass and/or clover; Warm-season perennial grass (WSPG)[a]
Jun	*Jun 1*: Initiate breeding cow–calf; Suckling calf	WSPG
Jul	Cow–calf; Suckling calf; Breeding continues	WSPG
Aug	*Aug 15*: Terminate breeding	WSPG
	Cow–calf; Suckling calf	
Sep	Cow–calf; Suckling calf	WSPG
Oct	*Oct 15*: Initiate weaning	WSPG
Nov	*Nov 15*: Finalize weaning	WSPG; Stockpiled forage; Hay and/or supplement
	Dry cow	
Dec	Dry cow	WSPG; Stockpiled forage; Hay and/or supplement
Jan	Dry cow	Hay and/or supplement

[a]Bermudagrass, bahiagrass; native grasses.

overall system. Once the breeding season has been completed, stocking rates could be increased for short periods of time (30–45 days), which could reduce cow BCS. This reduction in BCS of the pregnant, lactating cow can be reclaimed post-weaning if necessary. Flexible stocking methods that include several (4–8 or more) pastures can provide for cattle residence and deferment (movement) without a strict rotational stocking scheme. However, there are numerous stocking methods that can achieve individual management objectives such that pasture sustainability and cow reproductive performance are not compromised (Fig. 7.12).

Spring-calving cows

Forages and pastures of spring-calving cow activities are summarized in Table 7.4. Spring calving has traditionally been defined as calves born from March through May.

As a consequence of warm-season perennial grass base for pastures and the occurrence of the first killing frost in the I-20 Corridor, calves are usually weaned from mid-October to mid-November at 5–8 months of age. The highest nutritive value of pastures for these cows and calves occurs from March to May with overseeded annual ryegrass and/or clovers. From June until the time of weaning, bermudagrass or bahiagrass pastures, which have lower nutritive value, are available for grazing. These lower nutritive value pastures and time spent as a suckling calf on these pastures result in reduced weaning weights of spring-born calves, generally ranging from 400 to 650 pounds. This season of calving also mandates a breeding season from 1 June to mid-August for a 75-day period. Since forage nutritive value is low during the breeding season, cow body condition score must be watched closely for a successful rate of rebreeding. Cows that have BCS <5 and/or with the first calf will likely require energy-protein supplementation during breeding.

With spring calving, cows are dry from late fall until late winter. Thus, small grain pastures are usually not a part of the spring-calving pasture system due to the status of the dry, pregnant cow. Spring-calving cows may be dry for 6 months of the year; thus, nutritive requirements for maintenance and/or gain may be met with stockpiled warm-season perennial grasses and/or hay with or without supplementation. Although pasture input costs may be lower compared to fall-calvers, calf weaning weights are also significantly lower. Spring calving allows management to retain ownership of lightweight, fall-weaned calves as stockers on small grain plus ryegrass pastures. Pasture options for these stocker cattle would follow the guidelines presented in Appendix Table 7.3.

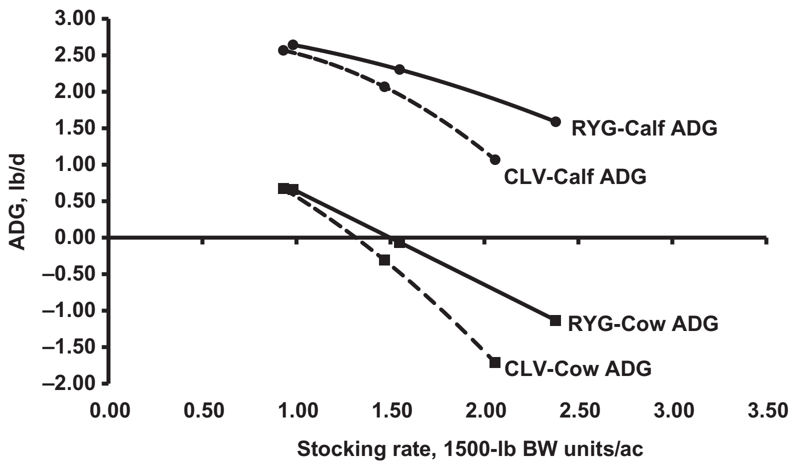

Figure 7.13 Average cow and calf average daily gain (ADG) at different stocking rates on common bermudagrass overseeded with annual ryegrass (RYG) + N fertilization or clover (CLV) without N fertilization during 29-year period.

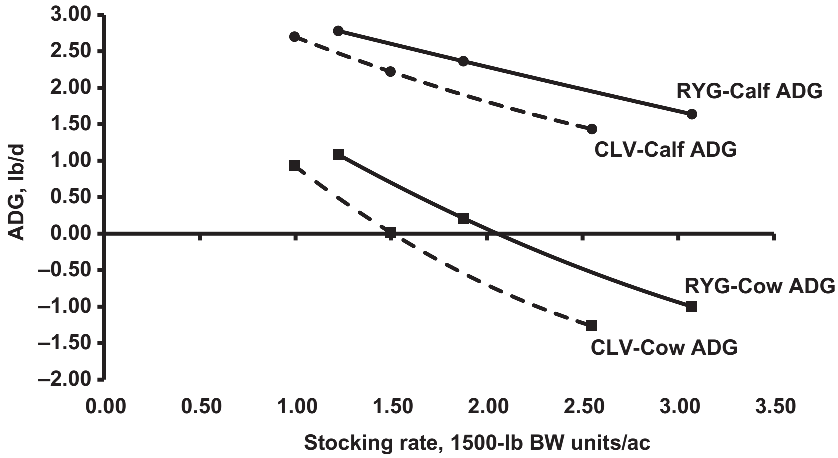

Figure 7.14 Average cow and calf average daily gain (ADG) at different stocking rates on Coastal bermudagrass overseeded with annual ryegrass (RYG) + N fertilization or clover (CLV) without N fertilization during 29-year period.

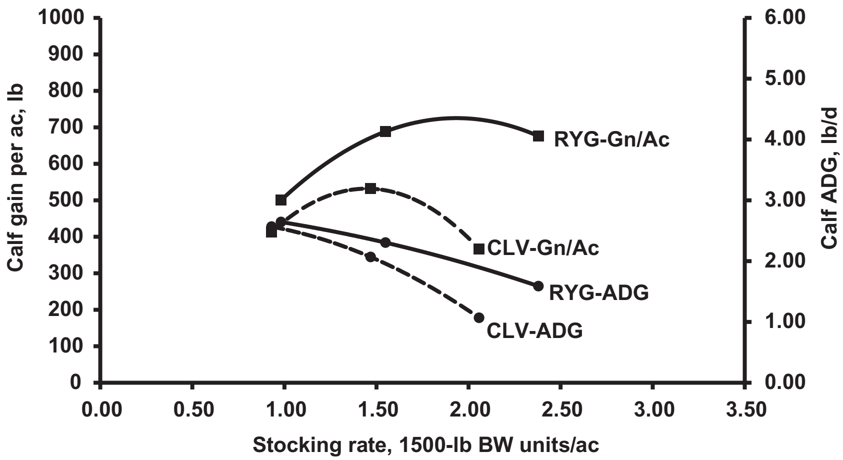

Figure 7.15 Relationship of suckling calf average daily gain (ADG) with gain per acre at different stocking rates on common bermudagrass overseeded with annual ryegrass (RYG) + N fertilization or clover (CLV) without N fertilization averaged over 29-year period.

Cow and calf performance from bermudagrass pastures overseeded with ryegrass or clover

Both fall- and winter-calving cows have nutrient requirements for lactation, rebreeding, and enhanced weaning weights that can be met with overseeded annual ryegrass and/or clovers. Rouquette [109] showed cow and calf responses during a 29-year period to stocking rates on both common and Coastal bermudagrass pastures

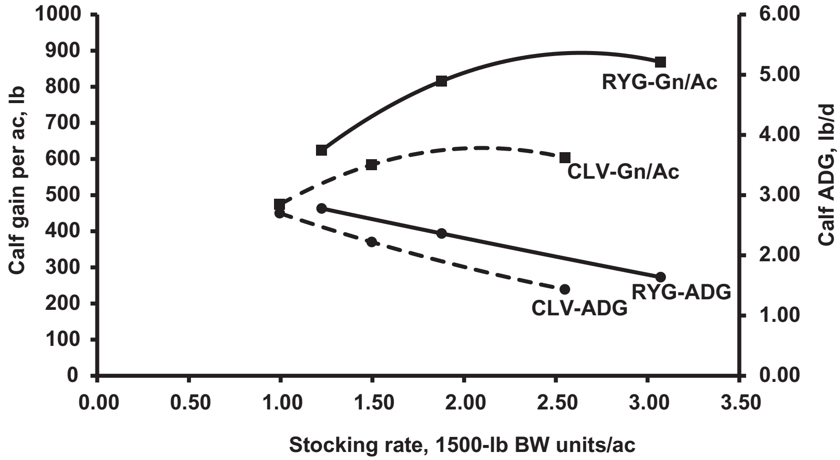

Figure 7.16 Relationship of suckling calf average daily gain (ADG) with gain per acre at different stocking rates on Coastal bermudagrass overseeded with annual ryegrass (RYG) + N fertilization or clover (CLV) without N fertilization averaged over 29-year period.

overseeded with either annual ryegrass or clover. Bermudagrass overseeded with ryegrass received split applications of nitrogen fertilizer; whereas, pastures overseeded with clover were not fertilized with nitrogen. As shown in Chapter 3, Maintaining soil fertility and health for sustainable pastures, nutrient cycling under stocking conditions can provide some levels of nitrogen for forage production. Data summaries for the 29-year grazing study at Texas A&M AgriLife Research at Overton showed an effect of stocking rate on both cow and calf ADG on common bermudagrass pasture overseeded with ryegrass or clover (Fig. 7.13). Fig. 7.14 shows these same effects of stocking rates on ADG on Coastal bermudagrass. For both bermudagrass pasture systems, cow and calf ADG decreased with increasing stocking rate.

Bermudagrass overseeded with annual ryegrass resulted in better ADG than pastures overseeded with clover at the high stocking rates. The DM production advantage of ryegrass compared to clover was evident at the high stocking rates. At the low stocking rates, where forage mass was not restricting free-choice intake, calf ADG was similar from overseeded ryegrass or clover. Examples of cow and calf ADG and gain per acre for fall-born and winter-born calves stocked on annual ryegrass or Apache arrowleaf clover were shown by Rouquette et al. [95].

The relationship of stocking rate effects on ADG and gain/acre for suckling calves stocked on overseeded common bermudagrass (Fig. 7.15) and Coastal bermudagrass (Fig. 7.16) shows the forage DM production advantage for Coastal bermudagrass. Calf gain per acre was greater for Coastal compared to common bermudagrass, and for nitrogen-fertilized pastures with ryegrass compared to pastures with clover. From the perspectives of stocking strategies and stocking rates for cow—calf performance, the

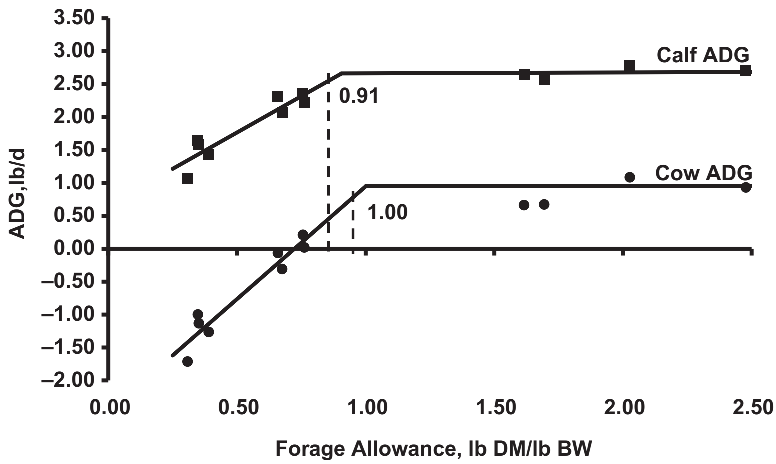

Figure 7.17 Relationship of lactating cow and suckling calf ADG with forage allowance (DM:BW) averaged over 29-year period for overseeded bermudagrass.

Figure 7.18 Visual appraisal of grazing pressure and selective (patch) grazing of low (A) to high (D) stocking rates with fall-calvers near weaning on bermudagrass overseeded with ryegrass.

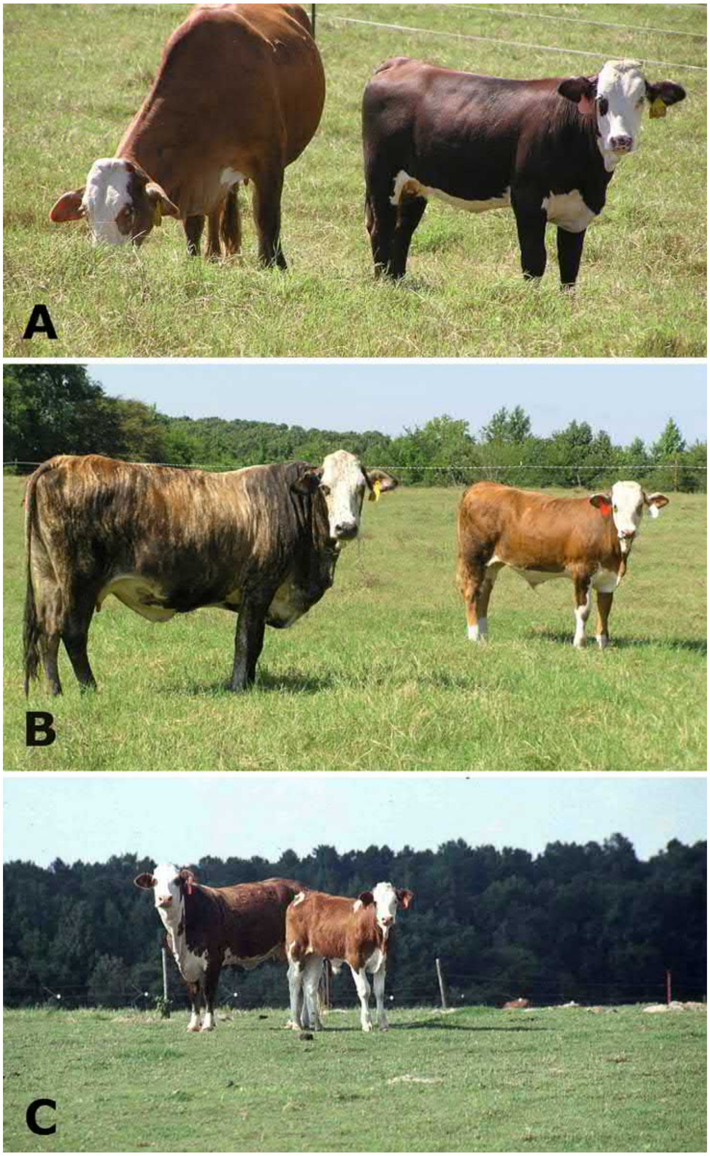

Figure 7.19 Visual appraisal of Coastal bermudagrass pastures and grazing at low (A) to high (C) stocking rates with winter calvers in August.

amount of forage available for consumption, or forage mass, was the pasture attribute that had the greatest affect on ADG. Data from long-term stocking studies [109] showed the amount of forage available for optimum ADG for cows was about 2300 lb/acre and for suckling calves was about 2100 lb/acre. Thus, an increase in forage mass in pastures above these levels did not improve ADG. However, with reduced

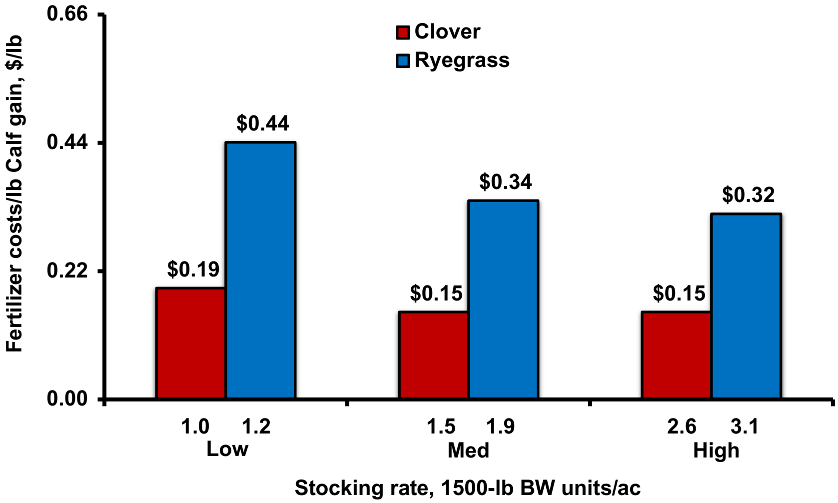

Figure 7.20 Fertilizer costs per pound of suckling calf gain for Coastal bermudagrass pastures overseeded with annual ryegrass + N fertilizer or clover without N fertilizer each at three stocking rates using 29-year average performance.

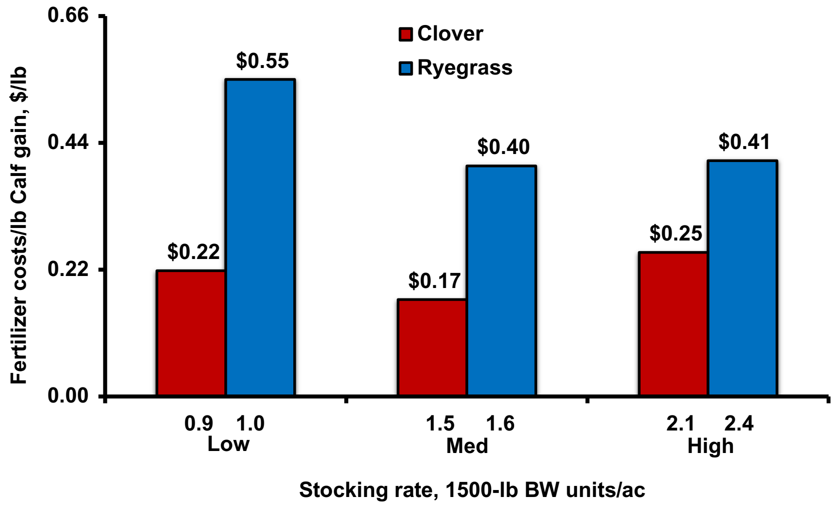

Figure 7.21 Fertilizer costs per pound of suckling calf gain for common bermudagrass pastures overseeded with annual ryegrass + N fertilizer or clover without N fertilizer each at three stocking rates using 29-year average performance.

forage mass likely due to increased stocking rate, there was a moderately rapid decrease in ADG. Fig. 7.17 shows the relationship of cow and calf ADG with forage allowance which is a ratio of forage dry matter (DM) per acre to animal body weight (BW) per acre (DM:BW). This showed that a forage allowance at about 1:1 (DM:BW) was the point at which lower stocking rates and more forage available for consumption did not result in greater ADG (Fig. 7.18, Fig. 7.19).

An economic comparison using only fertilizer costs per pound of calf gain is shown for Coastal (Fig. 7.20) and common bermudagrass (Fig. 7.21) when overseeded with either ryegrass or clover and stocked at three rates during a 29-year period. The fertilizer cost per pound of calf gain was substantially less for pastures overseeded with clover compared to ryegrass. However, ryegrass pastures may be available from mid-February to early March for full-time stocking in the I-20 Corridor. Annual clovers, however, may not be available for full-time stocking until mid- to late March in this area of the Southern United States [109]. It is also noteworthy to view differences between common and Coastal bermudagrass for fertilizer costs per pound of calf gain for both overseeded clover or ryegrass. Coastal bermudagrass is more productive than common bermudagrass and therefore will accommodate higher stocking rates and greater gain per acre. Some experiments have shown Coastal bermudagrass to produce as much as twice that of common bermudagrass using at least 200 lb N/acre [4]. Knowledge of forage production potentials for a vegetational zone and soil test information allows managers to make cost-effective decisions and strategies for analyses, timing, and rate of fertilization for pastures and hay meadows. Although there are several factors and management strategies that are responsible for cow—calf production, the economy of scale and operating costs are dependent on forage-cattle sales for positive cash flow. The level of stocking rate for sustainable pastures may depend on overseeding with annual cool-season grasses and legumes and on fertilization. Increased levels of N fertilization along with increased stocking rates may not be an appropriate strategy for all management. However, with some comparative forage × cow—calf production information from land grand universities and/or county Extension Agents, management can choose the levels of grazing intensity and stocking rate that best fit their objectives for sustainable pastures.

> ***Since grazing intensity can be manipulated by adjusting animal numbers, it is the fundamental variable under control of the grazier. Additionally, it has a pronounced effect on animal production and profit. Grazing intensity is therefore of very great importance to both producers and researchers.***
>
> **Dave Bransby, 1988**

Management strategies for stockers and replacement heifers

Calves kept after weaning for a retained ownership program, steer calves purchased for sale as feeders, heifer calves purchased for sale as feeders, or heifer calves purchased as replacement heifers have some of the same requirements: (1) an animal health program that includes vaccines, dewormer, implant, dehorn, branding, etc., as outlined by Beef Quality Assurance (BQA) (Appendix Table 7.5); (2) properly fenced, small acreage (trap, drylot) area to allow for fence-line weaning and becoming familiar with people and other cattle in the group; (3) adequate availability to fresh, clean water from water troughs; (4) high-nutritive value hay offered free choice; and (5) a daily allotment of energy-protein supplement for maintenance and slight gain in weight, and to serve as calming animal husbandry for a workable, gentle herd.

Before the stocker/replacement heifer program has been initiated, forages should be selected and/or prepared to provide an abundance of forage mass with appropriate nutritive value for ADG. To match forages available in the I-20 Corridor with stocker availability, stocker programs in this mid-South zone include summer and/or winter pastures. Flexible grazing systems [112] are targeted at implementing stocking strategies to optimize forage utilization and animal performance [113]. These flexible grazing management strategies may be used for any class of livestock and forage system; however, stocker steers and replacement heifers exhibit the most profound effects in ADG. Some of the specific management strategies for summer and winter are presented in the following sections.

Stocker programs on warm-season perennial grass pastures

Management concerns for stocker performance and gain per acre from warm-season perennial grass pastures have focused primarily on stocking strategies that allow for gains to exceed the "pound-a-day syndrome" [4]. Some of the combinations of animal genotype, forage cultivar, stocking rate, stocking method, and supplementation have been examined by forage-animal scientists. In an assessment of the impact of stocking strategies on pasture-animal production efficiencies, some of the following management practices were considered [114]:

Animal breedtype and class

The lowest, comparative ADG for stockers on bermudagrass pastures has occurred with young ($<$6 months age), lightweight ($<$450 lb), and non-Brahman-influenced cattle [114,115,116]. Some of the highest ADG on bermudagrass pastures, on the other hand, has been attained with long-yearling ($>$12 months age) Brahman-influenced steers, with initial BW of more than 650 lb and body condition score of $\leq$4. Compensatory gain was a significant factor influencing ADG on these older, less fat steers. However, for commercial stocker operators, compensating gains and proper animal health programs are major components of profitable grazing ventures (Fig. 7.22).

Forage variety

With the advancement of bermudagrass breeding and selection programs, there have been some notable enhancements in stocker ADG using "Coastcross I" [117], "Tifton 44" [118], "Grazer" [119], and "Tifton 85" [120]. To date, Tifton 85 bermudagrass

Figure 7.22 Long-yearling F-1 (Hereford × Brahman) (top) and Brahman steers (bottom) stocked on Tifton 85 bermudagrass in July.

has shown to have the greatest digestibility and resultant stocker ADG [121]. Tifton 85 has also shown to be one of the top varieties for DM production and for drought tolerance [122].

Stocking rate

For forages that have high DM production but lower nutritive value that may restrict stocker ADG to a pound-a-day, the best management strategy is to increase the stocking rate to obtain maximum gains per acre [123,124]. The most important stocking strategy affecting stocker ADG is stocking rate. Stockers adapted to climatic conditions within the I-20 Corridor can be stocked at 3–4 hd/acre and produce 1000 lb/acre gains during the summer months.

Stocking method

> ***Rotating animals among pastures at set dates or hours as compared to controlling AP (available forage in pasture) can be harmful to plants and animals, and may nullify beneficial effects from controlled rotational grazing.***
>
> **Roy E. Blaser, 1986**

Scientists have conducted several experiments comparing the stocking methods of rotational versus continuous on warm-season perennial grass pastures. Although stocking method may affect forage growth, there have been few studies that show advantages of either stocking method on stocker ADG. There are some substantial improvements in stocker ADG when incorporating the first-last grazer rotational stocking method [125]. The first-last rotational stocking method on bermudagrass has shown enhanced ADG for the first grazers using a two-herd [126] or a three herd system [127]. With this stocking strategy, the second or third (last) grazers will have reduced ADG due to lowered nutritive value and forage mass. Thus, if the second grazers are dry cows, for example, there could be minimum change in weight or BCS.

Supplementation

Supplementation strategies using protein and/or energy sources for stocker cattle have been targeted to enhance ADG and/or buffer reduced forage mass and stabilize or increase stocking rate. Numerous experiments have been conducted using supplements for stockers on warm-season perennial grass pastures [128–132]. Regardless of source of protein [133] or corn [134], some of the most important considerations for supplementation of stocker cattle include: (1) method of delivery (hand-fed vs self-limiting); and (2) amount of daily supplement as percent of BW and the resultant feed efficiencies of the supplement:extra gain ratio. Previous research with daily supplement rations offered at 0.2%–0.3% BW have shown the best efficiencies [133].

Figure 7.23 Fall-born stockers weaned in mid-June, retained, and stocked on Tifton 85 bermudagrass in early July with hay harvesting in background.

Retained ownership on bermudagrass pastures

Fall-born calves that wean early to late June may be retained on bermudagrass to fit into a niche market for grass fat calves, replacement heifers, or backgrounding for feedlot. In the I-20 Corridor, Tifton 85 has higher nutritive value than other bermudagrasses, and has DM potential and drought tolerance to provide for acceptable stocker grains during the summer. Two 3-year, retained ownership grazing experiments with fall-born calves and Tifton 85 bermudagrass with supplementation were conducted at the Texas A&M AgriLife Research and Extension Center at Overton [135,136]. In each year of both 3-year studies, fall-born ½ Simmental × ¼ Angus × ¼ Brahman steers and heifers were weaned in mid-June. Calves were fence-lined weaned, and received an 8-way clostridial vaccine, injectable dewormer, Revelor G ear implant, and a fly tag (Fig. 7.23).

In the first 3-year study [136], stockers grazed Tifton 85 pastures either without supplement or with a daily rate of 0.4% BW of a 2:1 soybean meal:cracked corn supplement with Rumensin. The 3-year average stocking rate was 4.6 hd/acre for pasture only and 5 hd/acre for supplemented cattle, with 1 stocker = 700 lb. During a 90-day period through September, stocker ADG was 1.23 lb/da for pasture only

Figure 7.24 Fall-born steers retained after weaning, stocked on Tifton 85 bermudagrass, and receiving daily 0.5% BW level dried distiller's grain.

and 1.84 lb/da for the 36% protein soybean meal:corn. The supplement:extra gain ratio was 5.6:1, and final body weight was 878 lb for pasture only and 936 lb for supplement. At this stocking rate, 3-year average gain per acre was 529 lb/acre for pasture only and 936 lb/acre for supplemented. In the second retained, 3-year ownership experiment [135], the same breedtype of fall-born steers and heifers was used, and the same animal health program was provided for stockers. In addition to pasture only and daily allotment of 0.4% BW of the 2:1 soybean meal:cracked corn with Rumensin, other supplements included 0.4% corn gluten, 0.4% cracked corn, and 0.8% BW cracked corn. All pastures were stocked at 5.1 700-lb stockers per acre. Stocker ADG from 22 June to 14 October was 0.78 lb/da (pasture only), 1.64 lb/da (0.4% BW soybean meal:corn), 1.45 lb/da (0.4% BW corn gluten), 1.71 lb/da (0.4% cracked corn), and 2.14 lb/da (0.8% cracked corn). For these listed supplements, the supplement:extra gain was 4.2:1, 5.1:1, 3.6:1, and 5:1, respectively. The respective gain per acre was 412 lb/acre (pasture only), 929 lb/acre (0.4% BW soybean meal:corn), 813 lb/acre (0.4% BW corn gluten), and 1237 lb/acre (0.8% cracked corn). In this same treatment order, final stocker weights were 855 lb, 931 lb, 899 lb, and 973 lb. Retained ownership of fall-born, summer weaned calves offer opportunities for increasing body weight and gains per acre using Tifton 85 bermudagrass (Fig. 7.24).

Retained ownership on small grain + ryegrass

A calendar of events for establishing pastures and stocking opportunities are shown in detail for small grains (Appendix Table 7.3) and annual ryegrass or clover (Appendix Table 7.4). Fig. 7.8 depicts generally expected forage production from small grain + ryegrass pastures. There is an abundance of fall-weaned calves available in the I-20 Corridor due to winter and spring-calving cows. Since most calves are weaned during October and November, but before the first killing frost in mid-November, there is a 30- to 60-day period from the time of weaning to initiation of grazing small grain pastures. During this period, calves must be weaned, receive animal health program, and graze stockpiled warm-season perennial grass pasture and/or hay plus an energy-protein supplement (Appendix Table 7.5).

Depending upon animal health, breedtype, and available forage mass, stocker calves or replacement heifers may gain from 2 to more than 3 lb/hd per day on small grain pastures. The most challenging management objectives with stocker cattle on small grain + ryegrass pastures is to attain an acceptable ADG, and to be prepared to match the "spring flush" of growth (Fig. 7.8) with appropriate stocking rate for efficient forage utilization. Thus, the initial stocking rate and adjustments to stocking rate from March to May become necessary components for forage utilization strategies. The additional forage produced in late winter and spring can be accommodated with extra cattle or electrical fencing and harvesting via baleage of small grain-ryegrass forage. Beck et al. [137] suggested an initial stocking rate equivalent to forage allowance of about 3.5 DM:BW. Rouquette et al. [138] found that when using Maton rye—TAM 90 ryegrass, an initial stocking rate was best with a forage allowance of 1.5–2.0. These

Figure 7.25 Winter-born steers weaned in October, retained, and stocked on rye + ryegrass at two stocking rates until late April to mid-May.

moderate to low stocking rates in the fall allow for maximum ADG in fall and early winter, and also reduce the potential of de-stocking in mid-January due to climatic conditions. Rouquette et al. [138] also reported that by initiating fall grazing of small grain + ryegrass at a low to moderate stocking rate and then doubling the stocking

Figure 7.26 Winter-born steers weaned in October, retained, stocked on rye + ryegrass plus supplemental cracked corn, and weighing 575 lb in mid-December. Photo on top taken in early February, and photo of same red steer on bottom taken in mid-May weighing 1140 lb and ready for niche marketing as pasture-finished or directly to feedlot.

Table 7.5 Effect of daily corn-based supplement level on average daily gain (ADG) on rye-ryegrass pastures.

Daily supplementation (% BW)	Stocking rate[a] (hd/ac)		
	1.5	2.1	3.0
	ADG (lb/da)		
0	2.80[b]	2.21[b]	1.13[b]
0.4	3.13[ab]	2.86[a]	1.94[a]
0.8	3.24[a]	3.11[a]	2.10[a]

[a]Stocking rates based on 550 lb = 1 stocker at initiation of grazing on 12–20-04.
[b]ADG followed by a different letter within a supplement column, differ at $P < .05$.

Table 7.6 Gains per animal, per acre, corn-based supplement (SUP) gains, and supplement to extra gain ratios on rye-ryegrass pastures.

Daily SUP	STK rate[a]	ADG	Gain/ Animal	Gain/ Acre	Extra gain due to SUP	SUP Fed	SUP: extra gain ratio
% BW	hd/ac	lb/da	lb/hd	lb/ac	lb/hd/da	lb/hd/da	lb:lb
0	1.5	2.80	414	630	–	–	–
0	2.1	2.21	327	697	–	–	–
0	3.0	1.13	167	502	–	–	–
0.4%	1.5	3.13	463	681	0.33	3.64	11:1
0.4%	2.1	2.86	423	876	0.65	3.53	5.4:1
0.4%	3.1	1.94	287	890	0.81	3.17	3.9:1
0.8%	1.5	3.24	480	725	0.44	7.44	16.9:1
0.8%	2.2	3.11	460	1008	0.90	7.52	8.4:1
0.8%	3.0	2.10	311	936	0.97	6.47	6.7:1

[a]Stocking rates based on 550 lb = 1 stocker.

rate in early March, stocker ADG could be maintained at 2.75 lb/da, and pasture gain could be increased from 495 to 980 lb/acre. This strategy would be that of a fixed stocking rate in the fall, and then increasing the stocking rate in the spring as part of a flexible grazing system (Fig. 7.25).

Supplementation of stockers grazing small grain + ryegrass

Providing a supplement with roughage sources or energy (corn) has been evaluated as an opportunity to buffer reduced ADG caused by high-stocking rates and reduced forage mass. These high stocking rates × supplementation strategies have been used as proactive management to increase gain per acre, or as a recovery-plan in response to nonanticipated climatic conditions. (Fig. 7.26).

Rouquette et al. [139] reported stocker performance on rye + ryegrass pastures at 3 stocking rates (1.5, 2.1, 3.0 hd/acre) based on 550 lb = 1 stocker, and at three levels of a daily corn-based ration (0, 0.4% BW, 0.8% BW). Stocking rates remained fixed throughout the small grain + ryegrass forage production period and were not adjusted to affect forage utilization in pastures during March—May. Table 7.5 shows the effect of stocking rate at each level of supplement. Without supplement, the winter-born, fall-weaned steers and heifers had ADG of 2.8 lb/da when forage mass did not limit nor restrict ad libitum intake at 1.5 hd/acre. Increasing the stocking rate to 2.1 hd/acre and 3.0 hd/acre resulted in reduced ADGs of 2.21 and 1.13 lb/da, respectively. Both 0.4% and 0.8% BW supplement increased ADG at each stocking rate on rye-ryegrass pastures. However, there was no difference in ADG between 0.4% and 0.8% BW supplement. Table 7.6 shows ADG, gain per animal, and gain per acre from this grazing study. Of special interest is the supplement to extra gain ratio (lb:lb) that showed an increased efficiency of supplement gain relative to increasing stocking rate.

An economic perspective of the stocking rate × supplement study [140] showed: (1) increasing N fertilizer costs from \$0.50/lb N to \$0.70/lb N produced only a gradual decline in returns per acre; (2) increasing supplement costs from \$125/ton to \$400/ton had a dramatic, negative impact on returns per acre; (3) as overall value of cattle declined, the opportunities for positive returns declined on most all treatment scenarios; and (4) the magnitude of negative margin had the most profound effects on positive returns per acre.

> ***The economic optimum stocking rate depends upon both economic and biological variables. The economic optimum stocking rate will increase with a positive margin and decrease with a negative margin. As costs other than pasture associated with keeping the animal increases, the economic optimum stocking rate decreases; and this is a particularly important feature in a cow-calf program. The costs of maintaining the cow will materially affect the economic optimum stocking rate. As the level of animal gain increases (as a response to biological factors), the economic optimum stocking rate increases.***
>
> **R. J. Hildreth and Marvin E. Riewe, 1963**

Replacement heifer development on pastures

In the I-20 Corridor of the southeastern United States, forages and pasture management for replacement heifers are the same as for stockers. Weaned replacement heifers are stocker cattle; thus, a deworming program is a necessary component of post-weaning gain and performance. Management strategies for replacement heifers are similar to those with stocker steers, except that replacement heifers have a different goal to achieve (breeding for heifers vs feedlot for steers). From a forage-pasture perspective, it is easier for replacement heifers to make optimum-maximum ADG of >2.5 lb/da on cool-season annual forages because of higher nutritive value. Hence,

Figure 7.27 Developing potential winter-calving F-1 (Hereford × Brahman) and Brahman heifers on small grain + ryegrass pastures.

stocking heifers from mid-December through May provides an opportune time for weight gain on pasture with or without supplementation.

Several research studies have shown that: (1) the "target body weight" for replacement heifers at time of breeding should be about 65% of the mature body weight for a specific breedtype; (2) the time for first breeding of virgin heifers should be initiated about 30 days before the "normal" breeding date for a particular calving season for the herd. This allows these first-calf heifers some "extra time" to return to estrus for subsequent rebreeding and second calf, and to enter the resident cowherd; and (3) supplementation with an energy source is usually required during the post-weaning period until the heifers enter a higher nutritive value pasture. Suggested daily or periodic rate of supplement for levels of expected gains are shown in Appendix Table 8.2 in Chapter 8: Management of pastures in the upper south: the I-30 and I-40 Corridors.

Some of the primary considerations when breeding virgin heifers include the following: (1) desired age of heifer at calving (24—30 months); (2) season of calving; (3) breedtype and percent Brahman; (4) desired body weight of heifer at time of first exposure to bull; (5) breed of bull and info on calving ease; and (6) desired length (days) of breeding season. Randel [141] provided a summary of heifer age at puberty from 17 breedtypes based on several research studies. Age at puberty ranged from an average of 413 days for Hereford to 459 days for Angus to about 600 days for

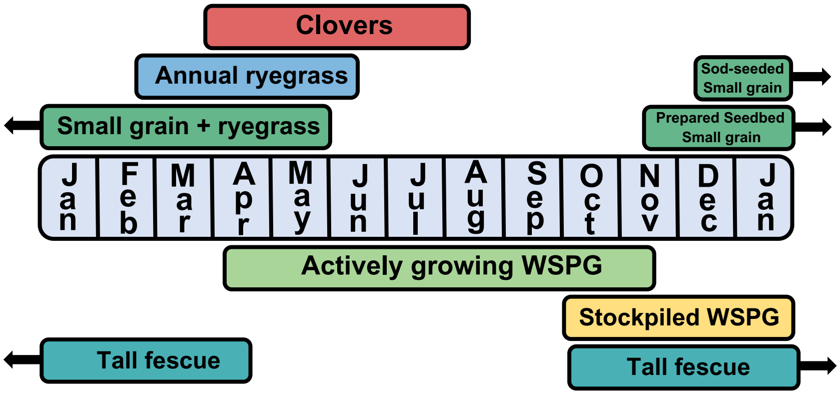

Figure 7.28 Management strategies and timing of events for a 365-day grazing program in the I-20 Corridor [143] using warm-season perennial grass (WSPG) pasture with use of cool-season forages and stockpiled WSPG.

Brahman. The Brahman × *Bos taurus* heifers reached puberty at an average of 438–478 days. In a 4-year study at Overton, TX, 179 F-1 (Brahman × Hereford) heifers that were winter-spring born and weaned in the fall weighed about 575 lb in early January [142]. These heifers grazed rye + ryegrass pastures and weighed an average of 684 lb at the initiation of breeding on 15 April for expected calving at 24 months of age. At termination of a 75-day breeding period, 84% of the heifers were bred, and average weight of the bred heifers was 800 lb. Open heifers, with an average weight of 775 lb, were removed from the herd. By removing and selling the nonbreeders from the herd, 93% of the remaining heifers rebred after their first calf; thus, the herd was more efficient and productive. The efficiency of the cowherd is dependent upon management strategies for culling cattle that do not reach or maintain expected reproduction and weaning rates (Fig. 7.27).

Summary and implications

365-Day grazing programs

A multitude of warm-season perennial and annual grasses plus cool-season perennial and annual grasses and legumes are options for pasture systems, specific soils, and climatic zones throughout the Middle-South I-20 Corridor. Combinations of multiple forages along with deferred, stockpiled forage are components of year-long grazing that complement the base perennial warm-season grass pastures system. Rouquette [143] presented considerations for 365-day grazing systems by matching warm-season perennial grasses with cool-season forages, hay, and/or stockpiled forage (Fig. 7.28). Some of the management strategies required for a successful 365-day grazing program includes: (1) a diversity of forage types that complement growth seasons of warm-season perennial grasses and cool-season annual forages; (2) multiple pastures to provide for an array of stocking options, deferment periods, prepared seedbed site, etc; (3) matching calving season with reliable, seasonal forage production and nutritive value of forage with nutritive requirements of cattle; and (4) an overall forage production, stocking rate, and forage utilization management strategy that is flexible to adjustments for changing climatic conditions. The costs associated with a "no hay program" may fit only a special niche of calving season and management options. Without the availability of hay or other stored forage, a 365-day grazing program may not be a best management option for many due to variation in climatic conditions and the desire to implement stocking strategies that minimize economic risks.

Management strategy considerations

Management strategies for forage-pasture livestock systems should consider the principles and factors discussed in Chapter 1, Introduction: management strategies for sustainable cattle production on Southern Pastures, with specific reference to sustainable cattle production (Figs. 1.1 and 1.2). Successful managers always have a multi-level decision-indicator that includes current, weekly, monthly, and seasonal expectations of forage production as influenced by climatic factors. The "best strategy" is to "know" and "expect" the potential surplus or deficits in forage production for the near-future. Managers then need to implement the "best approach" for optimum utilization via grazing, changes in stocking rate, changes in stocking method, and/or mechanical harvesting. Planning and implementing management strategies require the same "mindset" as preparing for a competitive event. The competitors for managers are climatic diversities and timing to match soil-forage attributes with animal requirements for sustainable beef production and an economically viable product.

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Appendix

Appendix Table 7.1 Forages and zones of adaptation for pastures.

Forage	Hardiness zones	Preferred soil			Establishment			Growth period	Use[4]
		Type[2]	pH	Drainage[3]	Depth inches	Date	Rate lb/ac		
Warm-season perennial grasses									
Bahiagrass	8–10	SL	5.5–6.5	WD	0.25	Spring	8–12	Apr–Oct	1,2
Bermudagrass[1]	7–10	SL, CL	5.5–7.0	WD	0.25	Spring	6–8	Apr–Oct	1,2,5
Dallisgrass	8–10	SL, CL	5.5–7.0	PD	0.25	Spring	8–12	Apr–Oct	1,2
Eastern Gammagrass	7–10	CL, C	5.5–7.5	WD, PD		Spring		Apr–Oct	1,2
Switchgrass	7–10	SL, CL	5.5–7.5	WD		Spring		Mar–Oct	1,2
Warm-season annual forages									
Grasses									
Forage sorghum	8–10	CL	6.0–7.5	WD, PD	0.5–2	Spring	15–25	Apr–Oct	2,4,5
Sudangrass	8–10	CL	6.0–7.5	WD, PD	0.5–2	Spring	20–25	Apr–Oct	2,4,5
Pearl millet	8–10	SL	5.5–6.5	WD	0.5–2	Spring	20–25	Apr–Oct	2,4,5
Legumes									
Cowpea	5–10	SL	5.0–7.5	WD	1.0	Spring	30–40	May–Oct	2,3,5,6
Lablab bean	5–10	SL	5.0–7.5	WD	1.0	Spring	30–40	May–Oct	2,3,4,5,6
Cool-season perennial forages									
Grasses									
Tall fescue	5–8	CL, C	5.0–7.5	WD, PD, VW	0.25	Fall	10–16	Nov–May	1,2
Legumes									
Alfalfa	5–9	SL, CL	6.5–7.0	WD	0.25	Fall	20	Mar–Oct	2,5,6
White clover	5–10	CL, C	5.8–7.0	PD, VW	0.25	Fall	3–5	Mar–Nov	1,6
Cool-season annual forages									

Grasses									
Rye	5–9	SL	5.0–6.5	WD	1–2	Fall	100	Oct–Apr	3,4
Ryegrass	7–9	SL, CL, C	6.0–7.0	WD, PD	0.25	Fall	35	Nov–May	2,3,4,5
Legumes									
Arrowleaf clover	8–9	SL	5.0–7.0	WD	0.5	Fall	10	Mar–May	4,5,6
Ball clover	8–9	SL, CL	6.0–7.0	WD, PD	0.25	Fall	4	Mar–May	4,5,6
Crimson clover	7–9	SL	6.0–7.0	WD	0.5	Fall	20	Feb–Apr	3,4,5,6
Hairy vetch	7–9	SL, CL	6.0–7.0	WD	1.5	Fall	30	Mar–May	3,4,5,6
Sweetclover	5–9	CL, C	7.0–8.0	WD	0.5	Fall	20	Mar–Jun	3,4,6

Appendix Table 7.2 Forages and zones for adaptation of pastures = codes descriptions.

[1]**Bermudagrass**	[2]**Soil types**	[3]**Drainage**	[4]**Use**
May be established by either seed or vegetative propagation	SL = sandy loam CL = clay loam C = clay	WD = well drained PD = poorly drained VW = very wet and poorly drained	1 = permanent pasture/grazing 2 = hay 3 = cover crop 4 = annual grazing 5 = silage/haylage 6 = wildlife browse

Appendix Table 7.3 Small grain + ryegrass management calendar for cattle in the I-20 Corridor.

Month	Prepared seedbed	Sod-seeded
August	First—Disk site and roller-pack to conserve soil moisture.	1st–15th Initiate defoliation practices on bermudagrass (graze or hay) do not fertilize.
September	Plant from 5th to 15th; Drill or broadcast and roller-pack; Plant small grain at 2″ deep; Plant ryegrass at 0–1/2″ deep; Fertilize at planting to soil test with N-P_2O_5-K_2O (i.e., 250 lb/ac 21-8-17).	Graze, harvest hay and/or shred, disk lightly (2″ to 3″ depth), do not “turn sod”; Initiate planting on 25th—drill or broadcast; Plant small grain at 2″ deep; Plant ryegrass broadcast; Use pasture-drag/chain-link to insure seed contact with soil; do not fertilize (Nitrogen will stimulate bermudagrass growth).
October	Check for Army Worms and be prepared to treat. Read label for rates and restrictions for grazing.	Planting date acceptable until late October.
		Fertilize to soil test with N-P_2O_5-K_2O (i.e., 250 lb/ac 21-8-17) when forage reaches 4″ height ± usually late October to early Nov ±; climate dependent.
November	Fertilize on first ± at 50–65 lb N/ac; Initiate grazing by November 15th to December 1st with approx. 1 to 1.5–500-lb stockers/ac or limit-graze with fall-calvers; Check for Army Worms until frost.	Fertilize late-planted areas as above.
December	Graze with 1 to 1.5–500 lb stockers/ac or limit-graze with fall-calvers; Fertilize on 15th ± at 50–65 lb N/ac	Fertilize on December 1st–15th at 50–65 lb N/ac; Initiate grazing from 15th to Jan. 15 with approx. 2–500-lb stockers/ac or limit-graze with fall-calvers.
January	Graze with 1 to 1.5–500 lb stockers/ac or limit-graze with fall-calvers; Be prepared to offer hay and/or extra pasture area depending on stocking rate, forage availability, and climatic conditions.	Graze as in Dec.
		Be prepared to offer hay and/or extra pasture area due to climatic conditions.
February	Graze.	Graze as in January
	Fertilize on 1st–15th at 50–65 lb N/ac.	Fertilize on 1st–15th at 50–65 lb N/ac.
March	*NOTE*: Pasture and forage productivity will increase dramatically which will allow for increased stocking rate of 50%–100%. Additional stockers or cows and calves will be required by March 1–15 to the first of April to optimize forage utilization and animal performance per acre.	

(*Continued*)

Appendix Table 7.3 (Continued)

Month	Prepared seedbed	Sod-seeded
April	Graze with 2 to 3 650-lb stockers or with cows and calves; fertilize on first at 50–65 lb N/ac. IF. . . Forage is Needed!! *NOTE*: Fertilization on this date will be dependent upon ryegrass conditions and stocking rate.	Graze with 2 to 3 650-lb stockers or with cows and calves; Fertilize on first at 50–65 lb N/ac or to soil test and if forage production is needed.
May	Graze.	Graze. Stockers may be removed in mid-May and other cattle (stockers or cows and calves) placed on pastures for full-time.
	Ryegrass will mature mid- to late May. Plan to terminate stocking by mid- to late May.	Fertilize Option ± 15th to 30th with 50–65 lb N/ac. . .IF. . ..ryegrass pasture and bermudagrass grazing is needed. *NOTE*: Fertilization on this date will be dependent upon forage conditions and stocking rate desired during the summer.
June	If available, graze summer annual “weeds” such as crabgrass, bermudagrass, etc., with cows and calves, etc.	Graze bermudagrass with cows and calves or other stockers.
July	15th; Disk and prepare for planting ± .	Graze bermudagrass with cows and calves or other stockers.

Appendix Table 7.4 Clover or ryegrass overseeded in bermudagrass management calendar for cattle in I-20 Corridor.

Month	Clover	Ryegrass
August	Bermudagrass is primary forage; about 15th initiate planting plans.	Bermudagrass is primary forage; about 15th initiate planting plans.
September	Initiate close defoliation of bermudagrass via hay harvest or stocking	Initiate close defoliation of bermudagrass via hay harvest or stocking.
October	15th, with closely defoliated bermudagrass pastures, lightly disk pastures (≈2–3" deep), plant via drill or broadcast.	15th, with closely defoliated bermudagrass pastures, lightly disk pastures (≈2–3″ deep), plant via drill or broadcast.
November	15th–30th, after first-killing frost, fertilize via soil test with P, K, etc.	15th–30th, after first-killing frost, fertilize with complete fertilizer of N-P_2O_5-K_2O (i.e., 200 lb/ac 21-8-17 via soil test).

(*Continued*)

Appendix Table 7.4 (Continued)

Month	Clover	Ryegrass
December	IF. . .Pastures not fertilized to date, fertilize with P, K, etc., by 10th.	IF. . .Pastures not fertilized to date, fertilize by 10th. Fertilization at 50 ± lb N/ac is needed before December. 10th ± .
January	No Grazing.	Grazing at low SR may be possible (2 acres/cow–calf) ± —climate dependent.
February	15th, Potential to initiate grazing at 1 to 2–500-lb stocker/ac or 2 acres/ cow–calf.	1st–15th, Fertilize with 50–65 lb N/ac; 15th initiate grazing at 2 to 3–500-lb stockers/ac or 1.5 to 2 acres/cow–calf.
March	First—initiate grazing at 1 to 2–500 lb stockers/ac or 1 cow–calf/ac	Graze 3 to 4–500 lb stockers/ac, or 1 to 1.5 cow–calf/ac.
April	Graze; 15th Crimson in full flower; Arrowleaf is vegetative.	First, fertilize with 50–65 lb N/ac 1.5 cow–calf/ac.
May	First—crimson clover matures; First—initiate another set of stockers ± or continue with cow–calf 15th Arrowleaf initiates flowering; 1–15 Harvest Hay ± .	First initiate another set of stockers ± , or continue with cow–calf at 1.5 to 2 cow–calf/ac.
		15th ryegrass may start seed set
		15th ± fertilize with 50–65 lb N/ac.
June	15th to 30th arrowleaf clover matures	First—ryegrass matures; Hay harvest ± , bermudagrass is primary forage.
	Bermudagrass is primary forage.	
July	Bermudagrass is primary forage.	First ± fertilize with 50–65 lb N/ac for bermudagrass as primary forage.

Appendix Table 7.5 Beef Quality Assurance Program (www.BQA.org).

The National Beef Quality Assurance Program (BQA) is a voluntary program provided at the state and national levels. The BQA programs are designed for cow–calf and stocker producers to ensure that beef products are safe and wholesome, and with humane practices that incorporates environmentally sound production systems. Completion of BQA training results in a certification of knowledge of the practices. The BQA provides information for management strategies that will strengthen consumer confidence in beef products.
The basic BQA producer program includes some of the following components and Best Management Practices (BMP) that can be affected by management strategies:

1. *Food safety*
   a. Injection site management and animal health products such as vaccinations and dewormers.
   b. BMP for herd health, residue avoidance, and foreign objects.

(*Continued*)

Appendix Table 7.5 (Continued)

2. *Record keeping*
   a. BMP for animal husbandry (breeding season, weaning, vaccinations, etc.).
   b. BMP for feeding, supplementation, hay, minerals, etc.
   c. BMP for chemicals used on pasture or cattle.
3. *Animal handling and well-being*
   a. BMP for penning and handling
   b. Fencing, corral designs, alleyways, load-outs
4. *Nutritional management*
   a. Body condition scores
   b. Nutritive Requirements for classes of cattle and activities
   c. Feedstuffs and nutritive value
   d. Animal performance, rebreeding, weaning
5. *Environmental concerns*
   a. BMP for grazing, stocking, and water quality
   b. BMP for soil fertility
   c. BMP for pesticide handling and storage
   d. BMP for dead animal disposal

The BQA has identified standards for pasture-animal management and operations that will result in a safe, wholesome and healthy beef supply for consumers. The BQA program is funded by The Beef Check-off and "is a cooperative effort between beef producers, veterinarians, nutritionists, state extension staff, and other professionals from veterinary medical associations and allied industries."

CHAPTER 8

Management of pastures in the upper south: The I-30 and I-40 Corridors

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Overview of forages and livestock systems and temperature zones in the upper south

The upper south region is bounded by I-30 in the south and I-40 in the north. It encompasses most of the area between northern Texas and northern Oklahoma on the west, to northern Georgia and North Carolina on the east. This area is a transition zone for both temperature and precipitation. This zone can be further refined by examining the temperature gradient, which runs north and south and rainfall gradient running east to west [1]. This climatic gradient has a large impact on the forage species that prevail and their season of growth.

Across the upper south region, variation in annual precipitation ranges from 30−40 in. in the central Oklahoma plains to 50−70 in. in the Carolinas annually [1]. Temperature ranges across this same region are not nearly as dramatic, with the majority of the region experiencing mean average daily temperatures from 55°F to 65°F [1]. While the crops and forages producers grow are influenced by climate, it is the year-to-year variations in temperature and precipitation that challenges the management abilities of producers.

The United States Department of Agriculture (USDA) [2] divided the country into plant hardiness zones based on air temperature. The upper south region is divided into three zones. The most southern zone would have the longest growing season with a large prevalence of warm-season perennial forages as the base forage, and cool-season annuals used to fill forage gaps [2]. Moving north through the zones the growing season shortens, and we begin to see a transition along the I-40 corridor and north to more cool-season perennial forages as the forage base, and warm-season forages to fill forage gaps [2].

In summary, a region's rainfall, temperature, and soils dictate the forages that predominate in that region. Rainfall and temperature will fluctuate across and within years and are out of a producer's control. However, a producer can moderate these

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effects through their grazing management. On the other hand, a soil's type cannot be changed. A sandy soil will always be a sandy soil. Soil fertility can be altered with fertility inputs, organic matter can be depleted or gained over time, soil erosion can be stopped or stabilized, but the basic components of soil will remain the same. It then becomes very important for the producer to select and manage forages that are adapted not only to the region's climate but to its soils as well for long-term persistence and grazing management success.

Typical management schemes have developed under the low grazing management strategy of harvesting as much hay as possible during the growing season and then feeding hay over an extended winter season. Across the upper south, hay is commonly fed for 140 days or more through the fall/winter period [3]. While this strategy is effective from a standpoint of ensuring available forage, reliance on harvested forage is very expensive and time consuming compared to a planned forage and grazing program to extend the grazing season [3].

Selecting adapted cool- and warm-season forage species makes potentially long grazing seasons possible. Average grazing periods for various forages are shown in Fig. 8.1. The primary perennial cool-season grass is tall fescue due to its persistence [4]. Other cool-season perennials are occasionally grown but have poor stand persistence in the upper south. Annual cool-season grasses, including ryegrass and several small-grain species, are successfully grown for forage [4]. The dominant perennial warm-season grasses in the region include bermudagrass, bahiagrass, and dallisgrass [4]. Native warm-season grasses such as big bluestem, switchgrass, and Indiangrass can be important forages especially in the drier western areas and in cattle operations where a strong interest in wildlife management exists. Annual

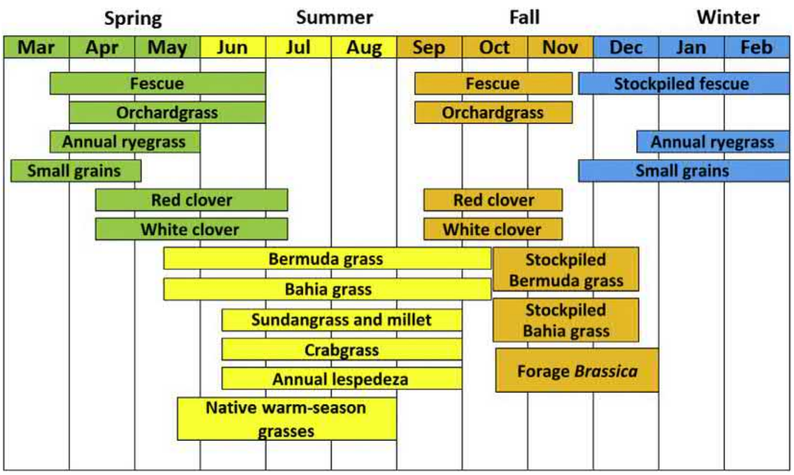

Figure 8.1 Season of growth and usage for various common forage species in the upper South.

warm-season grasses are grown as emergency forage crops or alternative forage crops, the most common of which include crabgrass, pearl millet, and sorghum/sudan [5,6].

Livestock systems and forage nutritional patterns

> ***Grazing management practices should be applied to achieve a specific animal response. The response should be considered individually for each class of livestock and physiological state such as young - growing calves or the dry pregnant cow, etc. Consideration and knowledge of both the plant and animal factors in a grazing environment and managing the grazing systems accordingly will permit specific animal responses that are most economical.***
>
> **J. C. Burns (1984)**

Nutrient requirements of cow–calf systems

Cow–calf nutrient demand

Nutrient requirements of beef cows are dependent on mature cow size, stage of gestation, and milk production potential. As a cow goes through the production cycle of weaning, gestation, calving, lactation, and rebreeding, her nutrient demands increase and/or decrease with each stage of the cycle. The changes in the nutrient requirements throughout the annual production cycle are shown in the accompanying appendix. As shown in Appendix Fig. 8.1 the minimum nutrient requirements are at weaning, when cows in a managed breeding system are usually in the middle trimester of pregnancy. At this stage, nutrient requirements for a 1200-lb dry pregnant cow are 6.7%–7.0% crude protein (CP) and 47.6%–48.5% total digestible nutrient (TDN). From the middle trimester throughout the rest of her pregnancy, the cow's nutrient requirements increase with fetal growth and development. In the final month of pregnancy the dry cow's nutrient demands have increased to 9.1% CP and 57% TDN. After calving, the cow's nutrient requirements increase dramatically with the onset of milk production. Peak nutrient demand occurs with peak milk production at 3 months postcalving. At peak milk production, the lactating cow requires 11.5% CP and 60.2% TDN. As lactation continues past 3 months postcalving, nutrient demand decreases to 8.9%–9.5% CP and 54.0%–56.5% TDN for the late lactation cow. Appendix Table 8.1 shows how the intake of dry matter increases after parturition. The increased rumen capacity from expelling the fetus and the increased metabolic demand from milk production drives increased intake during early lactation. DM intake decreases during late lactation with reduced milk production. However, as the cow's nutrient demand and forage intake requirement decreases, the forage demand by the calves increases.

Calf growth impacts stocking rates and is often overlooked by producers. For example, assume the average mature cow weight is 1200 lb or 1.2 animal units, and the average calf weaning weight is 550 lb or 0.5 units. In a herd of 50 cows that wean

50 calves, each weighing 550 lb, the total weaning weight would be 27,500 lb (50 × 550). Therefore removing the weaned calves is equivalent to removing the weight of 23 mature cows (27,500/1200 = 23) from the forage system!

Replacement heifer nutrient demand

Developing replacement heifers is one of the more intense enterprises in the traditional cow—calf system. Heifers grown to 65% of mature bodyweight by 15 months of age must grow at an average of 1.3—1.5 lb/day to achieve bodyweight goals and puberty before the breeding season. Appendix Table 8.2 and Appendix Fig. 8.2 show the nutrient demands of the developing replacement heifer from weaning at 7 months of age to calving at 2 years old. The peak nutrient demand of the growing replacement heifer is just after weaning when the heifer requires a diet containing over 12% CP and nearly 65% TDN (Appendix Fig. 8.2). The heifer's dietary nutrient requirements slowly decline as their bodyweight increases. Following breeding, heifers are usually grown at a slower rate in order to reach 85% of mature bodyweight by calving. At this time CP requirements fall below 8% and TDN falls to 55% or less. Nutrient requirements stay relatively low for these heifers until the last trimester of pregnancy where, as with the mature cow, demands for fetal growth and development increase nutrient requirements.

Forages for summer grazing

Native grasses

The native grass system for beef cattle production is nearly ideal for spring calving cows in the southern plains and upper south (Appendix Table 8.1 and Appendix Fig. 8.1). Native grasses (big bluestem, little bluestem, indiangrass, switchgrass, eastern gamagrass, etc.) developed under nomadic grazing by wildlife. These grasses tend to be very deep rooted, drought tolerant, and adapted to a wide range of soils. They are adapted to the entire region from Oklahoma to the Carolinas. East of the Mississippi River, much of the land area that once supported native grasses has been replaced by introduced forages and crops. Native grasses are highly productive, require little soil fertility (unless grown on a highly degraded site), and if grazed properly, require few herbicide applications. Native grasses tend to have a bunch-type growth habit that will vary by species from strong to weak. This type of growth habit makes them a suitable habitat for ground-dwelling birds and animals, and a host of wildlife consumes the seed produced by native grasses.

The key to using native grasses is management. Most native grasses have elevated growing points, which means they are intolerant of close and frequent grazing. This does not mean that they cannot be grazed closely, but they must be given an adequate period of rest following close grazing to allow for regrowth to occur and the replenishment of stored carbohydrates. Bermudagrass, on the other hand, has growing points very close to the ground and the ability to reproduce from stolons and/or rhizomes. It can have a high utilization rate of 60%–65% in continuously grazed systems and up to 70%–75% in rotational systems. Native grasses, because of their morphological differences, can have a recommended utilization rate of 25%–35% in the western end of the region to 50% in the eastern higher rainfall regions. In short, this means that the land area required to support a beef cow on native grass is greater than that required for bermudagrass. However, in the western regions at proper stocking rates, the native range can support year-round cow/calf production with little hay or feed supplementation. Native grasses can serve as a compliment to an introduced forage system, especially in areas where tall fescue is predominant. Native grass seasonal production will peak in early to mid-July, providing ample production and quality to support beef cows during a time of tall fescue slump.

Native grasses will break dormancy earlier in the spring than many of the introduced perennial warm-season grasses and can produce grazeable forage 30 days prior to bermudagrass. Forage quality will begin to decline 60–75 days following the onset of growth in the spring. Forage quality will rapidly decline once native grasses flower. A common management practice for native grass is to graze spring and early summer forage growth then defer grazing once plants reach maturity in mid-summer. Forage biomass is then ungrazed until after frost, and the standing forage is utilized as a standing hay crop. Native grass standing forage will be low in CP (typically 5%–8%) and will need to be supplemented with protein in order to improve forage digestibility and intake. This type of system works well as a compliment to bermudagrass.

Native grasses can be tedious to establish. Many native grasses have fluffy seed that requires specialized planting equipment with oversized cups, drop tubes, and a seedbox agitator to allow the seed to flow from the seedbox to the seedbed. Other issues with establishing native grasses include low germination, poor seedling vigor, and hard dormancy. Patience is a virtue when establishing native grasses. Knowing the land area and potential weed pressure that may incur during establishment can reduce frustration in establishing native grasses. For example, Johnsongrass, if prevalent, can be a very competitive grass weed and should be controlled prior to planting. There are few chemical options for controlling grass competition in establishing native grasses, and care must be taken to read and follow label directions as some native grass species have tolerance for particular herbicides, while others do not.

Introduced grasses

Bermudagrass (Cynodon dactylon)

Bermudagrass is a warm-season C_4 perennial grass that is native to Southeastern Africa. Occasionally an area of bermudagrass may be described as "native Coastal" bermudagrass, which is an incorrect description. Bermudagrass is not a North American native plant; it is an introduced species [7,8]. The term "Coastal" refers to the first named variety of bermudagrass released by the Tifton Georgia Experiment Station back in the 1940s. Bermudagrass was introduced in Savannah, Georgia sometime around 1751 by the governor of Georgia at the time, Henry Ellis. Soon after its introduction, the value of bermudagrass as forage was recognized. In 1917 the USDA Farmers Bulletin No. 814 had this quote concerning bermudagrass: "Bermudagrass is the most common and most valuable pasture plant in the Southern states, being of the same relative importance in that region as Kentucky bluegrass is in the more Northern states." Despite being recognized as a valued forage plant, bermudagrass has had its share of detractors. J.R. Harlan in a 1969 issue of Crop Science described bermudagrass as a "ubiquitous, cosmopolitan weed." Bermudagrass is both a versatile forage plant that can be a valuable part of a grazing system or an invasive, hard to kill weed.

In the United States, bermudagrass is best adapted to the southern states from North Carolina west to southern California and south. It can be found north into the coastal plains of Virginia and in the southern counties of Kentucky, Missouri, and Kansas. Common bermudagrass is quite predominant on the Missouri State Fairgrounds in Sedalia, probably getting its start from hay coming in with livestock from southern states. Optimal growth for bermudagrass will occur when daytime temperatures are above 75°F and nighttime temperatures above 60°F. Bermudagrass will grow to a lesser degree at temperatures between 40°F and 50°F, and plant dieback of stems and leaves can occur with sustained temperatures of 26–28°F. There is quite a bit of variation in cold tolerance between bermudagrass varieties. In the southern part of this region, bermudagrass has a very long growing season, breaking dormancy in April, and continuing growth to a killing frost which usually occurs mid-November. In southern Missouri, the active growing period will be shorter, from approximately May to late September or mid-October.

Bermudagrass can grow on a wide range of soil types from sand to clay, but it is best adapted to sandy loam soils. Bermudagrass spreads by rhizomes (below ground stems) or stolons (above ground stems) which spread very rapidly through lighter soil types [8]. Often, when conditions are right, bermudagrass can be established in a year on lighter soils. In clay soils, the rate of spread by rhizomes and stolons is greatly reduced, resulting in increased establishment time. Stand failures have occurred on heavy clay soil as a result of delayed establishment that led to weed invasion [7]. Once bermudagrass becomes established on clay soils, it can be highly productive.

> ***Research obtained in 1936 show that, if a small amount of bermudagrass is present, good stands can be obtained by plowing and fertilization.***
>
> **Ethan C. Holt, R. C. Potts, and J. F. Fudge (1951)**

Bermudagrass can be established either by seed or by planting a portion of a live plant called a sprig [7]. Many of the improved bermudagrass types are hybrids and can only be established with sprigs. Some of the more common hybrids are Midland,

Midland 99, Ozark, Russell, Tifton 44, Tifton 85, and Coastal. There are many regional ecotypes that have been developed and released that are very productive. Local variety tests and research data should be consulted when selecting a variety for establishment. Tifton 85 and Coastal have poor cold tolerance which should be considered when selecting a variety in the I-40 corridor. Hybrid bermudagrass is generally more productive, higher in nutritive value, and tends to have greater cold and drought tolerance than common or seeded type bermudagrass. There are always exceptions, and in recent years some seeded varieties have been released that yield similarly to hybrids. Common seeded types include Cheyenne II, Wrangler, Giant, and Texas Tough. There are many other seeded bermudagrass varieties on the market. Often these named seeded varieties may contain a blend of one or more varieties of seeded bermudagrass. Common and Giant bermudagrass are frequently used as a base with other varieties added. Giant bermudagrass is often included because it establishes quickly, yields well, and can act as a nurse crop for other types within a mix. However, Giant bermudagrass has very little cold tolerance and will disappear from the stand in one to two years. In northern areas, it would not be recommended in a mix due to its lack of cold tolerance.

Bermudagrass is an easily managed forage crop that is tolerant of close grazing and many management miscues. It compliments tall fescue by providing alternative forage during the summer months. Bermudagrass is also versatile as it can be grazed, hayed, and interseeded with cool-season annuals during the dormant season. A problem with bermudagrass is that because it can develop a dense sod and is an aggressive plant, it is difficult to grow companion forages with it during the active growing season. In some areas, alfalfa is grown with bermudagrass. Clovers can be grown with it as well, but elevated management is required for legume establishment and persistence. As with all grazing systems, determining the proper stocking rate is important to grazing management success of bermudagrass. One must understand the forage production potential of bermudagrass and match this potential to the appropriate number of grazing animals. Rotational grazing is preferred to continuous, and if practiced, forage utilization of bermudagrass can be 65%–75%.

As with any forage plant, pasture fertility is important, and P and K levels should be adequate to meet production goals. In Oklahoma, expected base production for bermudagrass is 1 ton (T) of dry matter (DM)/ac with no nitrogen (N), and an additional 1 T DM/ac for each 50 lb N/ac applied [9]. In areas of higher rainfall, dry matter production and response to N would be higher. Poultry litter is an excellent source of fertility for bermudagrass in areas where it is available. Nutritive value of bermudagrass will vary with stage of maturity and fertility as it does for other forage plants. Overly mature bermudagrass or bermudagrass that is unfertilized may have CP levels of less than 10%, while fertilized bermudagrass that is harvested at 28-day intervals can have CP content of 12%–16% or higher (Table 8.1).

Table 8.1 Effect of bermudagrass maturity on forage nutritive value.

Maturity stage	%CP	%NDF	%ADF	%TDN
Early vegetative	16.0	66	30	61
Late vegetative	16.5	70	32	54
15–28 days growth	16.0	74	33	55
29–42 days growth	12.0	76	38	50
43–56 days growth	8.0	78	43	43

%CP, percentage of crude protein; *%NDF*, percentage of neutral detergent fiber; *%ADF*, percentage of acid detergent fiber; *%TDN*, percentage of total digestible nutrient.
Source: Management of Hay Production MP434, University of Arkansas.

Table 8.2 Nutritive value of bermudagrass pastures with a spring only nitrogen application, stockpiled, or interseeded with wheat compared to wheat only pasture [15].

Treatment	November		December		January		February	
	%CP	%TDN	%CP	%TDN	%CP	%TDN	%CP	%TDN
Spring N	15.16	60.38	11.10	55.72	11.93	57.87	9.19	43.37
Stockpile	12.73	60.09	13.61	58.26	13.54	60.74	8.21	44.88
Interseed wheat	17.64	63.65	15.21	62.19	17.84	65.09		
Wheat	27.95	71.77	21.60	81.86	23.65	75.71		

%CP, percentage of crude protein; *%TDN*, percentage of total digestible nutrient.

Another management option for bermudagrass during the late summer and through the fall is the ability to stockpile it for additional grazing after frost [10–12]. To accomplish this, bermudagrass is grazed close in August, then nitrogen is applied to produce fresh forage growth up to frost. After frost, cattle are allowed to graze, which can also help manage tall fescue if toxic endophyte is a problem. By delaying tall fescue grazing until after bermudagrass stockpile is depleted, the tall fescue will then be grazed during cooler time periods when alkaloid levels in the tall fescue have dropped. Bermudagrass can also be interseeded in the fall with cool-season forages to provide additional quality grazing in early spring, if needed [13,14]. Table 8.2 [15] shows the nutritive value of bermudagrass pastures sampled through the fall and winter and which received one of the following treatments: (1) 75 lb N/ac applied in May (*Spring N*), (2) spring N application + 50 lb N/acre in August for stockpile (*Stockpile*), or (3) spring N application + interseeded with wheat in September and fertilized with 60 lb N/acre (*Interseed Wheat*). These were compared to a wheat only monoculture fertilized with 60 lb N/acre in October.

If we compare the nutritive value of the bermudagrass pasture in Table 8.2 to the nutrient requirements of beef cows in Appendix Table 8.1, we see that the nutritive value of managed bermudagrass pasture can be adequate to meet the nutrient demands of beef cows through fall and into winter. It is not uncommon for managed bermudagrass pastures to have higher nutritive value than hay (Tables 8.1 and 8.2). It should be noted that even with only a *Spring N* application, bermudagrass held its nutritive value much later in the year than many producers might realize. Stockpiled bermudagrass works well when winters are dry. During wet winters, the forage can become prostrate and come in contact with the soil surface. This will accelerate deterioration and decrease utilization.

In summary, bermudagrass is a versatile forage plant that offers potential as an excellent warm-season compliment to cool-season forages. In the more northern regions of its adaptation zone, care must be taken to select a variety with good cold tolerance. Bermudagrass is easily managed and tolerates a wide range of growing conditions and management. As with all forages, the better it is managed, the better it will respond.

Bahiagrass (Paspalum notatum)

Bahiagrass is a warm-season C_4 perennial grass grown primarily for pasture, but it may also be used for hay. It is very drought tolerant and can survive well on rocky, shallow sites and low fertility, light texutured soils where even bermudagrass grows poorly. Bahiagrass is easy to maintain because it is tolerant of close grazing, low fertility, and is generally free from diseases or insect pests. Weed invasion tends to be lower in bahiagrass compared to bermudagrass due to its extremely dense sod. It is also more shade tolerant than bermudagrass. Hay quality and yield are generally lower than for other forage grasses at similar levels of maturity. However, it does respond well to improved grazing and fertility management. Grazing livestock may spread viable seed in manure, which can easily allow bahiagrass to become a weed in other pastures where it may not be wanted. Bahiagrass can be stockpiled for fall grazing which helps extend the grazing season [8,16].

Bahiagrass is often thought of as a low-quality forage that does not require high levels of fertility. Nevertheless, it has been shown to respond to fertilization. Research conducted in Southern Arkansas by personnel from the University of Arkansas Southwest Research & Extension Center looked at seasonal forage production and forage nutritive quality of common (aka Pensacola) bahiagrass in response to seasonal rates of 0, 50, 100, or 150 lb N/acre fertilizer as either ammonium nitrate or ammonium sulfate. The bahiagrass growth rate responded weakly to N fertilization (Table 8.3), yet CP and TDN concentrations increased with N fertilization. The increase in TDN is related to reductions in cell wall fiber fractions (neutral detergent fiver (NDF) and acid detergent fiber (ADF)), which are tied to decreased maturity.

Dallisgrass (Paspalum dilatatum)

Dallisgrass is a fast-growing warm-season C_4 perennial grass used primarily for pasture. It has wide, smooth leaves, and a deep root system [16,17]. Dallisgrass is found across

Table 8.3 Effect of whole season application of N on forage production and nutritive quality of bahiagrass harvested biweekly in Southern Arkansas.

	N fertilization rate					
Item/date	**0**	**50**	**100**	**150**	**SE**	***P*-value**
Forage mass (lb/acre)						
June 4	498	593	509	588	60.0	.63
June 18	696	783	812	827	70.5	.74
July 1	820	928	1095	1130	74.3	.06
July 15	712	689	833	839	51.8	.13
July 29	313	320	349	360	25.5	.60
August 12	247	221	194	264	26.3	.30
August 26	145	165	183	211	12.1	.02
Crude protein (% of DM)						
June 4	14.6	16.7	16.5	17.3	0.47	.03
June 18	12.8	14.3	14.2	14.5	0.44	.16
July 1	12.4	13.3	14.5	14.6	0.32	< .01
July 15	11.4	12.1	12.2	12.9	0.28	.04
July 29	11.3	12.1	12.3	12.7	0.26	.05
August 12	11.4	11.6	12.2	13.9	0.58	.04
August 26	12.9	13.7	12.7	16.1	0.48	< .01
TDN (% of DM)						
June 4	62.2	64.6	64.6	65.4	0.68	.08
June 18	57.5	60.3	60.0	60.4	0.62	.06
July 1	56.1	57.3	59.0	59.4	0.50	< .01
July 15	54.9	56.3	56.4	57.8	0.52	.03
July 29	55.2	56.5	57.1	58.0	0.42	< .01
August 12	55.3	57.2	57.2	60.8	0.94	.01
August 26	53.7	55.3	53.5	59.0	0.97	< .01

the upper south and typically grows on heavy textured low-lying moist soils. Forage quality and palatability are very suitable for most grazing livestock. Livestock will graze dallisgrass very closely unless rotational grazing is used. Hay yield of dallisgrass is similar to that of common bahiagrass. It is very competitive in wet soils and tends to invade bermudagrass or other forages growing in those sites. Dallisgrass is often considered a contaminant or weed in bermudagrass grown for horse hay, as it will often turn dark brown in color when baled resulting in poor eye appeal of the hay. Infestation of seedheads from ergot is a common problem, which can lower animal performance and even cause death in extreme cases (Fig. 8.2).

Gunter et al. [17] conducted a dallisgrass N rate response trial in which nitrogen fertilization treatment rates of 100, 200, and 300 lb N/acre were applied to pastures

Figure 8.2 (A) Ergot (orange fungal mass) in dallisgrass seedhead; (B) Photo of dallisgrass seedheads infected with ergot.

Table 8.4 Grazing days and performance by stocker steers stocked at different rates grazing dallisgrass pasture fertilized with different rates of nitrogen during the summer.

	Stocking rate (steers/acre)				
Item/N fertilizer rate (lb/acre)	**1.5**	**2.5**	**3.5**	**4.5**	**SE[a]**
Grazing days					
100	140	126	119	79	8.3
200	140	140	128	117	
300	140	140	128	121	
ADG (lb)					
100	1.39	1.39	1.01	0.81	0.17
200	1.30	1.43	1.14	0.73	
300	1.54	1.47	1.36	1.08	
Total BW gain (lb)					
100	194	174	121	57	19.4
200	180	200	143	86	
300	213	207	174	130	
Gain per acre (lb)					
100	291	436	420	253	51.3
200	271	500	504	385	
300	325	520	608	579	

[a]Standard error of the mean.

with stocking rates of 1.5, 2.5, 3.5, and 4.5 steers/ac over 3 years. Average daily gains and bodyweight gain per steer were maximized with 1.5 steers/ac at the 300 lb N/ac fertilization rate (Table 8.4). The greatest total bodyweight gain per acre was with 3.5 steers/ac at the 300 lb N/ac fertilization rate. The greatest economic return was found between the points of greatest individual animal performance and greatest production per unit land area: 2.9 steers/ac at the 300 lb N/ac fertilization rate. For each fertilization rate, the optimal stocking rate which would give the greatest economic return was at 79%, 81%, and 82% of maximum bodyweight gain per acre for 100, 200, and 300 lb N/ac, respectively.

Old world bluestems (Bothriochloa spp. and Dichanthium spp.)

Old world bluestems (OWB) are warm-season C_4 perennial grasses originating from Africa, the Middle East, and southern Asia [18]. The name 'old world bluestem' is the common name given to a group of several different varieties of bluestems. This group can be divided into two different species: *Bothriochloa* spp. which includes the varieties Plains, King Ranch, Caucasian, WWSpar, WW-B. Dahl, and WW-Iron Master; and *Dichanthium* spp. which includes the varieties Kleberg and T-587.

The OWB have good drought tolerance and will persist under heavy grazing pressure, becoming stoloniferous and or rhizomatous [19], depending upon species. As with most forages, heavy and repeated grazing of OWB will cause a reduction in root mass, but with OWB this results in an odd advantage. In OWB, heavy grazing pressure actually improves its water use efficiency, reduces water stress, increases stomatal conductance, and increases soil moisture. This improvement in water conservation is thought to be due to reduced leaf area which reduces evapotranspiration in relation to root mass [19].

Variation exists in cold tolerance between cultivars of OWB. Caucasian (*Bothriochloa caucasica*) has very good cold tolerance and is adapted to more northern areas of the region. It has limited use as an alternative to tall fescue during the summer months in northern transition areas where bermudagrass is not well adapted. The variety Plains (*Bothriochloa ischaemum*) also has good cold tolerance and can be found in Oklahoma, Kansas and eastward across the region, although in areas where bermudagrass predominates, it is a minor forage plant. WW-B. Dahl (*Bothriochloa bladhii*) has good cold tolerance and is productive from the Texas High Plains east along the I-40 Corridor through Oklahoma. WW-B. Dahl is very productive, has good nutritive value, and establishes well on clay soils, making it a good alternative to bermudagrass on heavy textured soils.

OWB is adapted to a wide range of soil types and is persistent and productive in semiarid regions. It gained favor due to the ease in which it can be established, its persistence under heavy grazing pressure, and its tolerance to low soil fertility. Seeding rates for OWB are 1—3 lb/acre pure live seed (PLS), and successful seeding can be achieved using either tillage or no-tillage methods. Seeds can be light and fluffy making them difficult to handle. Using seed that have had the awns and glumes removed are much easier to handle and plant. Like all warm-season perennial grasses, seedling vigor is low, and controlling weed competition and shading of newly emerged plants will enhance stand establishment. In general, *B. caucasica* and *B. ischaemum* cultivars are not as productive as bermudagrass hybrids and not as responsive to N. A 50 lb N/acre application may be all that is required within a year to support grazing. For hay production, additional applications of N may be required. WW-B. Dahl is very productive and can yield similarly to bermudagrass. Because of this higher production level of WW-B. Dahl, it will need additional fertility.

B. ischaemum OWB has been indentified as an invasive weed in native rangelands and can spread very aggressively once it becomes established. If established, it is difficult to control in these areas and can outcompete more favorable forage plants in mismanaged environments. *B. ischaemum* has also been reported to have allelopathic effects which can hinder the establishment of other species even after the OWB has been removed. *B. ischaemum* has little to no beneficial effects for wildlife.

Warm-season annuals

When we think of warm-season annual forage crops, summer annual grasses such as pearl millet (*Pennisetum glaucum*) and sorghum−sudan (*Sorghum bicolor*) quickly come to mind. Often warm-season annual forages are thought of as an emergency source of hay for their ability to produce a lot of forage quickly during periods of dry weather, when other forage sources are limited. However, they are much more versatile than just providing a quick hay crop. Thanks to emphasis placed on cover crops and soil health, the role of warm-season annual forages in forage systems, in addition to being a source of hay, now includes providing quality grazing, adding soil organic material and soil cover, adding wind and water erosion control, increasing soil microbial diversity, silage, baleage, and weed suppression among others. The species considered for use as forage crops during the summer have also broadened beyond the sorghums and millets. An example is crabgrass, a weed in many southern gardens and lawns which can be a highly productive, high-quality forage crop that fits well as a double crop following cool-season annual grasses. Another example is grazing corn, which is more tolerant of cooler temperatures and can provide early high-quality forage. A summer annual broadleaf crop common in many gardens but not thought as a forage crop is okra. Surprisingly, okra produces a strong taproot (Fig. 8.3) that provides good soil penetration, it has good nutrient content, and cattle will graze it.

Sorghum−sudan and sudangrass (*Sorghum bicolor*)

Though still being grown, sudangrass has lost popularity with the development of the sorghum−sudangrass hybrids. The sorghum−sudan hybrids are very popular due to the amount of forage they can produce in a short period of time [6,20,21]. The average total yield of sorghum−sudan entries from a 2015 University of Tennessee variety trial was 6.6 T DM/acre with 120 lb N/acre split applied [20]. Often there is

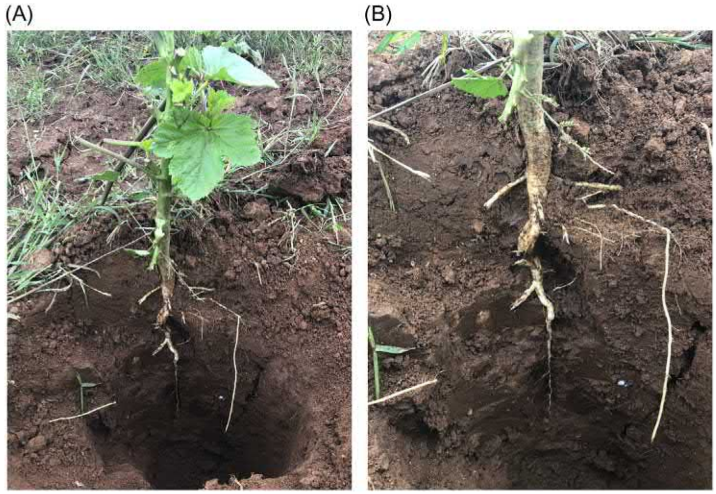

Figure 8.3 (A) Okra grown as part of a summer cover crop following wheat: (B) This image shows the taproot of okra growing down into an eroded clay soil.

little difference in yield between hybrids. There are several varieties currently available with the brown midrib trait, which is a genetic mutation that lowers plant lignin and improves digestibility [6]. There are also some photoperiod-sensitive genotypes that can delay flowering and maintain higher nutritive value longer than nonphotoperiod sensitive types [21].

Sorghum–sudan hybrids are well adapted across the upper south region and will perform well over a wide range of soil textures, but production may be reduced on very light textured or sandy soils [22]. Sorghum–sudan will tolerate soils down to a pH of 5.0 but perform best when pH is above 5.5. They also perform well on high pH soils up to a pH of 9.0 and have been used to reclaim alkaline soils. Planting can be done when the threat of frost is past and when soil temperatures have warmed to 55°F–60°F, although germination may be slow. Optimum soil temperature for germination is 65°F–70°F [22].

Monoculture stands are seeded at 25–30 lb/acre drilled, or 30–40 lb/acre if broadcast seeded [22]. Sorghum–sudan can be established with tillage in a weed free, firm seedbed, or with no-till. During planting, ensure good seed to soil contact is established and that seeding depth is maintained at 0.5–1 in. Seeding depth is much easier to control with tilled seedbeds than with no-till. In no-till pay attention to changes in soil texture when planting as this can greatly affect no-till drill performance and seeding depth. As with all forage crop establishment, soil testing is recommended to determine adequate levels of phosphorus (P) and potassium (K) for the region. If soil pH is below 5, lime should be added prior to planting. Sorghum–sudans are very responsive to nitrogen, but they are also very efficient in their use of nitrogen. Compared to bermudagrass, it will take approximately half of the nitrogen to produce 1 T of forage sorghum compared to 1 T of bermudagrass. If grown behind a winter crop such as wheat, it would be advisable to test the soil to determine the residual amount of nitrate available in the soil and then adjust nitrogen rates accordingly. Nitrogen drives yield and influences quality. Sorghum—sudan production will require 18—20 lb N/acre for each ton of dry matter produced [9].

For grazing purposes, sorghum—sudan should be grazed when it reaches 24 in. in height to help reduce potential issues with prussic acid poisoning [22]. Prussic acid can be found in any of the sorghum species and can build up any time the plant has undergone a period of stress [22]. Common plant stresses that can induce build up include drought, frost, and herbicide application. It is generally best to avoid grazing sorghum—sudan 14 days after any stress period. When harvested as a forage such as hay or silage, the prussic acid will dissipate through the curing process. If a producer suspects that a prussic acid potential exists, the local extension center should be contacted for advice on testing. Sorghum—sudan can be rotationally grazed. For re-growth to occur, it should not be grazed or hayed closer than 10—15 in. Another potential issue with any grazing or stored forage, including sorghum—sudan, is nitrate accumulation, which occurs when a plant takes up nitrogen during a period of rapid growth followed by a period of little to no growth [22]. This accumulation of nitrate is generally in the base of the plant stem. If nitrate accumulation is suspected, testing is recommended.

Insect pests can be a problem with sorghum—sudan. A devastating insect that can greatly influence yield, quality, and harvest is the sugar cane aphid (*Melanaphis sacchari*). This is a relatively new insect pest that attacks all sorghum species, including Johnsongrass, and has even been found on indiangrass (*Sorghastrum nutans*) which is a native grass species. Other common insect pests that can attack sorghum—sudan include armyworms, grasshoppers, chinch bugs, and cutworms. Producers must be aware of insect pressure in their region and be prepared to take the necessary control steps if insect damage reaches economic thresholds.

Average daily gains of stocker cattle grazing sorghum—sudan hybrids have been reported in excess of 2.0 lb [21,23]. A producer should always keep in mind that stocking rate, environment, and agronomic management all influence the animal performance on sorghum—sudan, or for that matter any forage. For grazing planning purposes, it will take sorghum—sudan approximately 45—60 days to reach a forage mass great enough for grazing to begin. Mature beef cows grazing sorghum—sudan hybrids should be expected to maintain body condition.

Sorghum—sudan can make quality hay if harvested prior to advanced maturity [6]. In general this forage should be cut for hay when it reaches 30—36 in. in height. There is variation in stem size between varieties, but it is recommended that harvest is conducted with a cutter-crimper in order to speed drying time.

Sorghum–sudan develops a massive root system and produces large amounts of above ground biomass. These growth characteristics have made it attractive for use in cover cropping and building organic matter. It can be blended with other crops such as cowpeas, sunn hemp, or other warm-season annual grasses. Due to the height that some of these sorghum hybrids can achieve, they can suppress production of lower canopy species in a blend. However, this canopy cover can also aid in the suppression of weed species such as pigweed and other broadleaf weeds. It has been reported that sorghum–sudan produces root exudates that play a role in weed suppression [24].

Pearl millet (Pennisetum americanum)

Pearl millet is the major millet used for forage in the United States. Other millets include proso, foxtail (German), and browntop, and these are finding their way into several cover crop or hay mixtures to add diversity. They are much lower yielding than pearl millet, therefore, concentration will be placed on pearl millet.

Pearl millet is an excellent warm-season annual forage which offers some advantages over sorghum–sudan. The main advantage is that since it is not a sorghum, it does not accumulate prussic acid, a major concern with sorghums during periods of plant stress. Pearl millet is very well adapted to the upper south region. It is not as sensitive to soil pH as sorghum–sudan, but soil pH should be maintained above 5. Pearl millet will tolerate drought well, but if drought is severe enough to slow plant growth, nitrate accumulation can then become a concern and forage testing is advisable. Pearl millet also works well on light textured soils and can out-yield sorghum–sudan on sandy soils. This advantage to sorghum–sudan is lost, however, on heavy textured wetter soils. There are several hybrid millet varieties on the market. Some of the varieties available are dwarf types, which fit well into a grazing scenario or perhaps a multispecies cover crop mixture. Some varieties will also carry the brown midrib trait. Varieties may vary in disease resistance. Consult regional variety trial information in making the appropriate variety selection for specific needs. Insect pests that affect pearl millet include grasshoppers and armyworms; however, sugarcane aphid has not been found to be a problem on this forage [22].

Establishment methods for pearl millet are very similar to those for sorghum–sudan. Seeding rates are 15 lb/acre drilled and 20–30 lb/acre when broadcast, and seeding should occur when soil temperatures reach 65°F [22]. Seeding depth is ¾–1 in. Pearl millet can be established with either tillage or no-till methods. If tillage methods are used, creating a firm seedbed will aid in controlling seed depth, improving seed to soil contact and germination. Soil testing to correct deficiencies in P, K, and pH is recommended, but pearl millet can be productive at lower levels of P and K compared to sorghum–sudan. Pearl millet is very responsive to nitrogen and is also very efficient in its use of nitrogen and water. Nitrogen application should be based on yield goal and moisture availability. If irrigation is available, higher nitrogen rates may be appropriate. In dryland conditions, higher nitrogen rates may be split across the growing season to improve nutrient use efficiency. A general recommendation is to apply 60–90 lb N/acre at establishment and then additional nitrogen as needed through the growing season based on yield goals and forage needs.

Grazing should be deferred until pearl millet reaches a height of 18–30 in., usually occurring 45–60 days after planting. Cattle readily consume pearl millet forage, and stocker gains can be good. Regrowth of pearl millet can be delayed or eliminated if grazed too closely. The recommended grazing or haying residual height is 6–8 in. Stocker ADG has been reported in excess of 2 lb [25] but can be greatly influenced by stocking rate and forage availability. Beef cows grazing pearl millet should be expected to maintain body condition.

Haying should be conducted when the canopy reaches a height of 30–40 in. tall. If not harvested closer than a 6- to 8-in. stubble height, peral millet should regrow, and with adequate growing conditions, multiple harvests can be obtained. Because of stem size and forage mass, harvesting with a cutter-crimper is recommended to speed drying time. Pearl millet can also be ensiled and will make a quality silage product.

Pearl millet can develop a massive root system that is a desirable characteristic in building soil health. It works well in cover crop mixtures with legumes such as cowpeas, soybeans, and sun hemp, okra, and other broadleaved cover crops (Fig. 8.3).

Crabgrass (Digitaria sanguinalis)

Giant crabgrass is cursed by many a gardener and row crop producers as being a prolific never-ending weed pest. In the eyes of a forage producer who grazes livestock, however, it is an excellent forage crop [26]. Crabgrass is a summer annual grass that germinates in spring, grows through summer, and dies at frost in fall. Daily weight gains or milk production of livestock grazing crabgrass can easily exceed that from bermudagrass. It is very productive under good management and works well to provide summer forage when grown in mixtures with cool-season grasses such as tall fescue or double cropped behind small grains. Natural ecotypes of crabgrass exist all across the upper south, with some being upright and highly productive, while others are more prostrate with low productivity. The most common species grown for forage is large or hairy crabgrass. There are improved varieties of crabgrass on the market such as Red River, Big and Quick, and a recent release called Impact from the Noble Research Institute [27]. Seedhead production begins at different times for different varieties. Red River is an early maturing variety, whereas Impact will head out, on average, 10 days later than Red River. Crabgrass can be a high producer with yields similar to bermudagrass and with excellent nutrient content (Table 8.5).

Crabgrass can be double cropped behind a small grain crop (June) for late summer forage production, or behind small grain graze out (May) for a longer period of forage

Table 8.5 Effect of harvest interval of crabgrass hay on dry matter yield, growth stage at harvest and nutritive characteristics [6].

	Harvest interval		
	21 days	**35 days**	**49 days**
Yield (lb DM/acre)	2527	6454	8613
Growth stage	Stem elongation	Early heading	Late heading
CP (%DM)	15.6	14.3	11.0
NDF (%DM)	61.3	66.6	69.8
ADF (%DM)	35.7	38.9	42.7
TDN (%DM)	62.6	59.1	54.8

production. Crabgrass has a clump-type growth habit and spreads by long stolons or runners that root down at the nodes. It can grow to 2 ft. tall, and although it is adapted to a wide range of environments, grows best on well-drained soils. Crabgrass tolerates drought, but for best production should be planted on sites that are not excessively droughty during summer [26].

Crabgrass is very easy to establish with the main difficulty being its light and fluffy seed. Unless it is de-linted, crabgrass seed will not flow through a conventional grain drill without large cups, drop tubes, and a seed agitator as found on native grass seed drills. Seeding rates are 3—4 lb/acre of pure live seed (PLS). Crabgrass is a prolific re-seeder, and if allowed to produce seed prior to frost, it can volunteer in the following years especially in no-till situations. If tillage occurs in late summer, seed drop could be prevented, and volunteer crabgrass would less dependable. Seed can be mixed with fertilizer and broadcast, but it will not broadcast far because of the light seed weight. The most common practice of seeding is to disk the area to be established, broadcast the seed, and roll it in. Crabgrass can also be no-tilled drilled but controlling seeding depth to ¼—½ in. can be difficult. Crabgrass is very quick to establish and can produce a grazeable biomass 30—45 days following emergence. It is also very responsive to nitrogen with total nitrogen rates of 60—100 lb/acre depending upon forage demand. Nitrogen rates can be higher, especially in regions of higher rainfall and irrigation. Higher rates of nitrogen should be split applied, but crabgrass can accumulate nitrates at rates above 150 lb N/acre in dry growing conditions [28].

Stocker cattle gains on crabgrass can be very good, with ADG in excess of 2.5 lb reported [6] when cattle were fed a crabgrass hay. Grazing of crabgrass should begin when it reaches 8—10 in. in height, which should occur 30—45 days after emergence under good growing conditions. To keep crabgrass in an actively growing vegetative stage, it should be grazed to a residual height of 3 in. Grazing utilization will be improved with rotational grazing. Crabgrass can be stockpiled in late summer and grazed after frost, but it needs to be utilized soon after frost as it tends to lie down following a killing frost and will deteriorate quickly.

Crabgrass can make high-quality hay (Table 8.5), but curing can be difficult. Crabgrass is pubescent (hairy leaf structures), and the leaves tend to hang onto moisture such as morning dew making drying difficult. If not cured properly, crabgrass hay easily molds which can cause animal refusal. If cured well, crabgrass hay if often preferred by livestock over bermudagrass hay. Insect pests are not a major problem with crabgrass. The exception is an armyworm outbreak, as crabgrass seems to be a preferred host for armyworms.

Corn (Zea mays)

Corn is an interesting species to consider as a grazing forage crop. Thought of mainly as a grain or silage crop, corn offers unique advantages as a grazing forage. Corn is very high yielding producing 5—10 T/acre of silage yields. Yields for grazing can also be high. Karsten et al. [29] measured the yield of four corn hybrid varieties at the milk-dough and silking stages of development in a grazing study and reported an average dry matter yield at silking of 5.4 T/acre to 7.1 T/acre at milk dough stage. In this same study, they also measured nutritive value at the same physiological stages and found CP ranged from 8.1% to 12.6%, with higher CP levels recorded at the silking stage. This combination of yield and nutritive value can provide a valuable forage alternative to cool-season perennial grasses for stocker gain during the summer months. Stocker cattle ADGs have been reported in the 2.5 lb range. Corn forage could also be stockpiled to extend the grazing season for mature cows during the fall and winter. Beef cows grazing corn during the winter can add body condition. To improve utilization and reduce trampling, corn can be strip grazed using an electric fence.

Corn is typically planted in rows 15—30 in. wide. Plant populations can range from 25 to 30,000 plants/acre for wide rows, up to 60,000 plants/acre in narrow rows. If a row crop planter is not available, corn can be planted using a conventional drill and plugging every other hole to increase row width. Corn can be established with either convention or no-till methods. Nitrogen fertility for grazing will typically range from 100 to 150 lb/acre. Prussic acid is not an issue with corn, but corn can accumulate nitrates. An additional concern with ear corn is the development of aflatoxins that can occur under certain environmental conditions.

Plantings of warm-season annuals can be staggered in order to provide a steady flow of forage through the summer and to avoid an overabundance of forage at any given time. Warm-season annuals can be creatively utilized. For example, a late summer planting can provide quality forage for stocker cattle prior to the development of a cool-season annual forage crop, such as wheat. Another variation could be to use warm-season annuals to further develop stocker cattle on forage following winter pasture graze out. A warm-season annual could also be used as a source of creep grazing for calves.

Warm-season annual grasses are productive and well adapted to the upper south region. They are also versatile in their use, supplying emergency forage in dry weather conditions, a soil cover for fallow ground, quality grazing, and erosion control. As with any grazed forage, stocking rate greatly influences both plant and animal performance. Warm-season annual grasses fit well and have their place in upper south forage systems.

Forages for fall and winter grazing

The greatest opportunity for improving profitability in Southeastern beef production lies in stockering weaned calves on high quality, cool season annual or perennial pastures.

Carl S. Hoveland (1986)

Tall fescue *(Lolium arundinaceum)*

Tall fescue is a deep-rooted, upright, coarse-leaved, and perennial cool-season grass. Leaves are long and dark green with distinct veins and rough edges. It is considered a bunch grass, but most types have short rhizomes and will form a dense sod when kept mowed or grazed. Height at maturity ranges from 2 to 4 ft. The typical forage yield range is 2−4 T DM/acre [8].

Tall fescue is adapted to a wide range of conditions. It tolerates short-term flooding, moderate drought, and heavy livestock and machinery traffic. It responds well to fertilizer but maintains itself under limited fertility conditions. It is well adapted to moderately acid and wet soils. Tall fescue does not persist well on droughty upland soils or deep sandy soils. On favorable sites, stands of tall fescue can persist indefinitely under good management, with some fields across the region being 30−50 years old.

Tall fescue is used mainly for pasture and hay, and is excellent for soil conservation and erosion control [8]. Approximately two-thirds of the annual growth of tall fescue occurs during spring, and about one-third occurs during summer and fall. Maximum growth rate occurs between 68°F and 77°F. Growth rate declines sharply at temperatures above 86°F and ceases below 40°F. Tall fescue should not be solely relied upon for year-round grazing because growth slows considerably or ceases during summer. Under good management, mixtures of fescue can be grown with warm-season forage species such as bermudagrass, crabgrass, or lespedeza to extend grazing through summer.

Tall fescue has two distinct periods of growth during the year—spring and fall. The fall growth can account for up to a third of the annual dry matter yield. To extend the grazing season and reduce winter-feed supplementation, tall fescue can be stockpiled. In northern areas of the upper south, stockpiling should begin in September to allow enough time to produce acceptable stockpiled forage yield before cold weather hits. In the more southern areas of the region many fescue pastures are mixed with warm-season grasses. In that case stockpiling should begin in late September to early October when the growth of the warm-season grass has slowed or stopped to avoid excessive competition with the fescue [3,4,10,30].

Stockpiled tall fescue forage is very resistant to freezing temperatures due to a heavy waxy cuticle on the leaves and a chemistry that preserves cell function at cold temperatures. Because of its cold tolerance, stockpiled fescue can provide palatable forage through the winter. Stockpiled tall fescue maintains green color and forage quality late into the winter and can be grazed until March. Tall fescue managed for fall growth out-yields sod-seeded annual ryegrass and small grains during the same period. Research conducted at the University of Arkansas Southwest Research and Extension Center near Hope found that tall fescue stockpiled from mid-September to early January yielded over 3000 lb/acre with a forage analysis of over 20% CP and 60% TDN [30]. In Extension demonstrations on Arkansas farms, stockpiled fescue yielded over 2500 lb/acre with some sites yielding up to 5700 lb/acre (J. Jennings unpublished data).

Tall fescue toxicity

Many tall fescue pastures are infected with a toxic endophyte which causes poor animal performance. This poor performance is caused by toxins produced by the endophyte fungus (endo = inside, phyte = plant), *Neotyphodium coenophialum*, that grows inside the plant. The endophyte's toxins cause "fescue toxicosis" in grazing livestock. Symptoms of tall fescue toxicosis in cattle include reduced feed intake, elevated body temperature (which causes cattle to stand in ponds), high respiration rate, reduced animal gain and milk production, lower conception rate, rough hair coat, and an overall unthrifty appearance. Broodmares are especially sensitive to the toxins and should not be allowed to graze toxic tall fescue several months before foaling. Toxins from the endophyte build up in the seed as the plant matures, which makes the seedheads the most toxic part of the forage.

Although the endophyte's toxins cause livestock disorders, the endophyte improves persistence of the plant by increasing tolerance to drought, insects, nematodes, and mismanagement. Endophyte-free cultivars alleviate tall fescue toxicosis symptoms, but they are less tolerant to drought and heavy grazing pressure. Certain strains of tall fescue endophyte have been found that do not produce the toxins that cause tall fescue toxicosis. These strains have been added to improved tall fescue cultivars to produce endophyte-friendly, or "novel endophyte," cultivars that have both good persistence and produce good animal performance [4,31–34].

Novel endophyte-infected tall fescue

Endophytes that improve tall fescue stand persistence but do not adversely impact animal performance have been identified in naturally occurring tall fescue stands worldwide. In the early 2000s Jesup MaxQ (Pennington Seed, Inc., Madison, GA), which is the tall fescue cultivar Jesup infected with the AR542 endophyte, was commercially released. Research from a wide range of environments indicated that tall fescue cultivars infected with nontoxic endophyte strains were as persistent as tall fescue with toxic endophytes. Research also showed that animal performance increased with the nontoxic endophyte tall fescue compared to the toxic endophyte tall fescue [31–35]. Since the release of MaxQ, multiple other releases of nontoxic endophyte tall fescues have been developed. Research has been conducted to evaluate cultivars of these nontoxic endophyte-infected (NE) tall fescues in Georgia [31], northwest Arkansas and southwest Missouri [33], southern Oklahoma and northeast Louisiana [32], northern Arkansas [34], and southern Arkansas [35]. During fall and winter, ADGs for cattle on nontoxic tall fescue was consistently ½ lb higher than ADGs for cattle on toxic fescue. During spring and early summer, nontoxic tall fescue ADGs increased to about 1 lb higher than toxic tall fescue ADGs [4]. The nutritive quality of toxic endophyte tall fescues is similar to that of the varieties containing nontoxic endophytes [4], so the reductions in performance are likely tied to decreased forage intake or general impacts of tall fescue toxins on the cattle [4,34,35].

Cool-season annuals to fill seasonal gaps

Prior to planting any forage crop, the right variety should be selected for that area. Many land grant universities conduct yearly variety trials of current and new varieties, including old varieties that serve as checks. Information is provided on forage and grain yield, nutritive value, disease tolerance or resistance, tolerance to soil pH, and other traits to help with selection.

Soil fertility is the driver of production. It is very important to soil test fields prior to establishment in cool-season annuals. Multiple soil samples should be taken to account for variations within the field such as soil texture, slope, eroded areas, and areas where production issues have been noted. If lime is required to adjust pH, the application must be made in a timely manner for neutralization of the soil to occur. The amount of liming material required will vary depending on the quality of the liming material used.

Annuals interseeded into permanent pastures

Cool-season annuals are commonly planted into permanent warm-season pastures. This practice accounts for the largest number of acres utilized for grazing cool-season annuals in the southeast [13,14]. Because these pastures are being managed for multiple uses, productivity is generally less for each season compared with pastures managed for single purposes [4,36,37]. For instance, because cool-season annual pastures are planted into existing warm-season perennial sods managed for haying or grazing, the cool-season annual plantings must be delayed until the growth of the warm-season pastures decreases in the fall. This decreases potential fall forage production. Also, the growth of cool-season annuals during late spring will delay warm-season forage production.

Timing of cool-season annual establishment

Planting cool-season annuals should be delayed until warm-season forage growth slows in the fall. If warm-season grasses are still actively growing, they will compete with the cool-season annual seedlings for sunlight, water, and nutrients. The seedlings can easily get shaded out, decreasing the eventual stand of the cool-season annual and decreasing overall forage yield. When nighttime temperatures are below 60°F for several nights in a row, the growth of warm-season grasses naturally slows considerably [13].

Research has shown that application of a light rate of glyphosate or paraquat will force the warm-season grasses into a fall dormancy, allowing for earlier planting dates for cool-season annuals. Research at the University of Arkansas Southwest Research & Extension Center near Hope [13] found that planting wheat and ryegrass into a warm-season sod of crabgrass and bermudagrass in mid-September, following an application of glyphosate at 1 pint/acre, increased forage yield in January by 1400 lb/acre compared with planting in mid-October with or without herbicide. Planting in September with the glyphosate application lead to 600 lb more forage, 4.6% greater CP, 6% lower NDF, and 5% lower ADF. Earlier planting with glyphosate application increased total steer grazing days per acre by 42 and total bodyweight gain per acre by 144 lb. Overall, glyphosate application increased ADG by 0.3 lb. Compared to the October planting date, net returns were estimated to be increased by $126/acre when planting in mid-September with the glyphosate application. If pastures were planted in September without glyphosate application, net returns were decreased by $87/acre.

Establishment of cool-season annuals in dedicated crop fields

Small grains can be established using tillage methods to create a weed-free, firm seedbed. They can also be established with no-tillage [36–39]. Clean-tilled pastures have been more common than no-till until recently, but no-till is gaining in popularity. Prior to no-till planting of small grains, the area should be chemically burned down to eliminate potential weed competition. When using a chemical burn down, always use caution and follow the label's directions for use. Any chemical use outside of the label is prohibited by law. Caution should also be used when selecting the type of chemical or chemical mixture used for burn down to ensure that there is no residual chemical soil activity present that would impede seed germination. Burn down applications should be made a week prior to seeding in order to ensure that good weed control is achieved, and to allow time to respray any skips that might have occurred during application.

No-till planting success hinges on the ability of the no-till planting equipment to get the seed through the residue and into the soil. No-till planting equipment quality has improved over the years. A good drill will have adequate weight to create enough down pressure to cut through residue and penetrate tough soils. Colters that run ahead of the drill openers should be the correct style for the conditions, and the drill should run at the correct speed for colter action to occur. Press wheels should follow directly behind the slot created by the drill in order to close the slot and press the seed firmly into the soil.

Seeding rates and managing establishment for cool-season annuals

Calibrating the planting equipment is good management protocol and helps to ensure an adequate stand for grazing. Seed size will vary by variety, test weights, and other factors, therefore drills should be calibrated each year. Procedures for drill calibration are readily available and easy to follow. Seeding rates for establishing small grains for grazing is higher than rates for grain only. Typical seed rate recommendations for grazing are 100−120 lb/acre. Planting date for grazing small grains is earlier than for grain only. In the western regions of the area the optimal date for planting is from mid-August to mid-September. Yearly nitrogen rates for small grains can be as high as 150 lb N/acre with a fall and spring split application. Well-drained soils work effectively for small grain stocker cattle grazing, as these soils hold up better in wet conditions with less damage to the forage from hoof action than what occurs on heavier soils. Under favorable weather conditions, fall grazing can begin in November and continue to May.

Small grain pastures for stocker cattle

Small grains make excellent forage for growing stocker cattle. A large stocker cattle industry has developed in the western part of the region, and opportunities for small grains grazing are available throughout the region. Stocker cattle are placed on small grains after weaning and will gain from 2 to 3 lb/hd per day through the grazing period. Stocking rates in the fall will range from 400 to 600 lb of animal weight per acre and will increase to 800−1200 lb/acre in the spring [4]. Having adequate forage biomass on hand when initially stocking a small grains pasture is important.

A key to making the economics of any stocker operation work is animal grazing gain per acre. This is a stocking rate compromise based on the animal's dry matter intake demand to meet gain requirements, the amount of forage biomass available, and the growth rate of the small grains. Overstocking will reduce forage intake and individual animal performance, while understocking will maximize the individual animal performance but underutilize the forage that is produced, minimizing total bodyweight gain per unit of land area.

The balance between individual animal performance and total bodyweight gain per acre defines the profitability of grazing systems. In all situations, the most profitable stocking rate is found between the maximum individual animal performance and the maximum total bodyweight gain per acre. Beck et al. [4] reported that maximum steer ADGs occurred during the fall when the average forage allowance was at least 3.5 lb of forage DM per pound of calf bodyweight. In the spring the increased forage growth rate allows for increased stocking rates. Forage allowance during the spring should be maintained at a minimum of 1 lb of forage DM per pound of calf bodyweight to maximize steer gains. Research has shown that in the fall the most profitable balance between steer ADG and total gain per acre on small grains is achieved by stocking at 1.5–2.0 lb forage DM per pound of animal weight. Following these suggested stocking rates will achieve a successful compromise between the growth rate of the animal and growth rate of the small grains.

Forage nutritive value of small grains

Small grains forage is low in calcium (≤0.55%), magnesium (especially for cows, ≤0.33%), copper (≤8 ppm), and zinc (≤27 ppm), but adequate in phosphorus (~0.2%) and most other macro and trace minerals. Research by Fieser et al. [40] in Oklahoma showed that providing a nonmedicated mineral supplement to steers grazing small grains increased gains by 0.25 lb/day. The mineral supplements used in these experiments were commercially available and supplied high levels of calcium (>12%) and low levels of phosphorus (4%–6%). When the ionophore Rumensin was included in the mineral supplement, additional gains of 0.2 lb/day were seen over the nonmedicated mineral treatment [41].

Nutritive value of small grains is high. When nitrogen is supplied in levels to meet production requirements, CP concentrations in excess of 30% are commonly observed in the fall, with levels from 25% to 29% being common through the winter and spring, until plant maturity leads to reduced protein concentrations [4]. The ratio of energy to protein available in the rumen (<4:1 ratio) leads to large amounts of nitrogen excreted in the urine [41]. This waste of protein is corrected by feeding low protein supplements to provide rumen degradable energy [41].

Strategies for stockers grazing small grains

Research conducted in central Oklahoma by Matt Cravey showed that daily feeding of corn or degradable byproduct (soybean hulls and wheat middlings) supplements, including supplemental calcium and an ionophore, at 0.65% of steer bodyweight (i.e., 3.25 lb/day for a 500 lb steer), allowed for a one-third increase in stocking rate on wheat pasture and increased steer ADGs by 0.3 lb [42]. Each pound of increased gain per acre only required about 5 lb of feed, which should be profitable in the majority of economic situations. Other research conducted over the years supports feeding a ground milo and wheat middling-based supplement as a carrier for needed vitamins and minerals, and an ionophore, either daily or every other day at a daily rate of 2 lb per calf (4 lb per calf each feeding on alternate days). This lower supplementation rate consistently increased calf ADGs by 0.4 lb over mineral alone, without increasing stocking rate.

These supplementation programs provide cost-effective options for supplementing growing calves on small grains pasture, whether increased stocking rates or improved performance is desired [41]. While small grains alone have an adequate nutritional quality to produce high animal gains, an energy supplement can be provided to cattle while on small grains to stretch the forage and add an additional bump to cattle gain. Supplementation works well when commodity prices are low, and the value of gain is high.

Some caution must be taken when grazing small grains. Due to small grains' high nutritive value, low fiber content, and low calcium content (which is tied to muscle contraction), bloat can occur with cattle on small grains [41]. The compound poloxalene is a curative for pasture bloat. Blocks containing this compound (bloat blocks) will reduce the incidence of bloat. The ionophore monensin also decreases the incidence and severity of pasture bloat. If monensin is fed to calves grazing small grains pasture, gains will be increased and the severity of bloat cases will be reduced, then any incidence of bloat can be treated with poloxalene, greatly reducing the effects of bloat. Providing long-stemmed grass hay to cattle grazing small grains can help to slow the rate of passage through the rumen and provide a source of fiber that can reduce bloat incidence.

Wheat (Triticum Vulgare)

Wheat is very popular as both forage and grain crop. Because of its dual-purpose capabilities, it is grown throughout the upper south region. Wheat is best adapted to loam and clay—loam soils with a minimum pH of 5.5. It is tolerant of cold and dry weather conditions making it suitable for some of the harsher environments found in the more western regions of production.

Other cool-season annual forages can be added to wheat to extend the grazing season. The most common is annual ryegrass, which can extend the grazing period later into the spring. Annual ryegrass is an excellent forage, which provides good production and excellent quality, but producers need to be aware that annual ryegrass can be a serious weed in wheat grown for grain.

Cereal rye (Seeale eereale)

Rye is the most cold-tolerant of the cool-season annual grasses with the earliest seasonal forage production. It is also the highest producer of forage biomass but is lower in nutritive value than other cool-season annual grasses. Compared to wheat, rye is more adapted to sandy acidic soils and will produce grazeable forage earlier in the fall. With earlier seasonal production, rye will enter the reproductive stage and lose forage quality earlier in the spring than other cool-season annual forages. This makes rye an excellent choice to double-crop with a summer annual forage such as crabgrass.

Agronomic production of rye is very similar to that of wheat. Seeding rates for grazing are 100—120 lb/acre with fertility requirements also similar to those of wheat. Like ryegrass, rye can be a weed pest in wheat for grain, and if grown in an area for wheat grain production, rye is generally discouraged. In recent years rye has seen a surging interest due to its use as a cover crop. Because of its high biomass production, it can suppress winter annual weeds. When terminated in the spring and rolled down onto the ground, rye produces a thick mat that can further suppress weeds for spring planting and serve as a source of organic material. Stocker cattle gains on rye will be similar to gains on wheat as long as rye is vegetative, but when stem elongation begins, forage quality and animal performance will quickly decline.

Oats (Avena sativa)

Oat forage has the highest nutritive value of all small grains. It is an excellent producer of early forage biomass and performs best on light textured soils. The major drawback to the use of oats is its lack of cold tolerance. There are varietal differences in cold tolerance, and it is important for producers to be familiar with their local varieties. Recently, plant breeders have placed more emphasis on cold tolerance. Oats have been successfully grown through the cool-season growing period from I-20 north to the Red River. Oats can be successfully blended with other small grains such as wheat to provide an early boost of forage production. In blends, oat cold tolerance may not be as important. When grown with a crop like wheat, if the oat component is frost killed, wheat will fill in the production. Livestock will choose to graze oats compared to the other small grains as their preference for oats is high. Oats can also be a nitrate accumulator.

Triticale

Triticale is a hybrid cross of wheat and rye. Forage production is higher than wheat and nutritive value is greater than rye. It produces a large, broad leaf that is grazed well by livestock. Triticale is a versatile crop that can be used for grazing, hay, and silage. Under the right growing conditions and management, triticale can be harvested more than once. Triticale will tolerate more acidic soils than wheat. Triticale has been around for many years, but lack of variety selection, seed sources, and a grain market have limited its use. Seeding rates are 100—120 lb/acre, and cultural practices will be as those for wheat and rye. Seasonal production of triticale will be earlier than that of wheat in the fall but later than rye in the spring.

Annual ryegrass *(Lolium multiflorum)*

Annual ryegrass is a high-quality, high-producing forage grass, although it is considered a pesky weed in grain producing areas. Annual ryegrass can be seeded as a monoculture at a seeding rate of 20 lb/acre and is very easy to establish. It prefers good moisture conditions and performs well on heavier textured soils. There can be cold tolerance issues, especially with tetraploid varieties. In monocultures, annual ryegrass will produce a thick sod and is tolerant of close grazing, but overgrazing should be avoided for higher productivity. In many areas annual ryegrass is overseeded into bermudagrass to provide high-quality forage prior to bermudagrass breaking dormancy in the spring. Caution should be advised with this practice because if underutilized in the spring, annual ryegrass could create a shading effect that can delay bermudagrass spring development and production. Annual ryegrass is an excellent reseeder, and after a few years a large amount of seed can be built up in the seed bank. It is sensitive to some of the new pasture herbicides (aminopyralid), which can cause yellowing, stunting, and seedhead suppression. It is responsive to nitrogen fertilizer, but due to a shortened growing season, yearly rates are lower compared to other small grains.

Legumes

Legumes including clovers, vetch, lespedeza, and alfalfa are beneficial forages in grazing and hay systems. Legumes host symbiotic rhizobia bacteria in root nodules that fix nitrogen from the air. This fixed nitrogen provides N to the legume plant making it unnecessary to apply N fertilizer when an adequate stand of legume is present. Legumes are higher in nutritive quality than grasses and can improve animal performance. Legumes do require improved management to maintain stands compared to bermudagrass and tall fescue. Most species are grown in mixtures with grasses, although alfalfa is often grown alone for hay production. Both annual and perennial legumes are adapted to this region [43].

Legume establishment

Fields should be clipped or grazed as closely as possible to remove the grass canopy and/or excess thatch prior to planting legumes. In heavy grass residue, no-till drills perform poorly, and broadcast seed will not reach the soil surface. A closely grazed grass stubble of 2 in. or less is ideal. No-till drills should be calibrated and set to plant the seed an average depth of ¼ in., but no more than ½ in. When planting with a broadcast planter, roughing up the short sod by pulling a harrow, tire drag, or even a cedar tree across the field exposes soil and improves legume establishment. Seeds that drop onto a slightly loosened soil surface will become anchored in place by frost or rain. Well-anchored seeds have a higher chance of forming established seedlings than seeds lying in thatch or on a hard soil surface.

Legumes can be planted into tall fescue sods during fall or in late winter. Planting in late winter (February to early March) is sometimes called "frost-seeding" because freezing and thawing of soil helps work the legume seed into the soil surface. The fescue should be grazed very short during winter making it possible for the small legume seed to reach the soil surface at planting. An effective planting method is to overseed legumes after stockpiled fescue has been completely grazed in late winter. Fall planting, in late September to mid-October, can be successful if the fescue is grazed short (2- to 3-in. stubble) to reduce competition for the legumes.

Fall (late September to mid-October) is the preferred season for planting legumes into bermudagrass or bahiagrass sod when the warm-season grasses begin to go dormant. Planting during this period allows enough time for adequate seedling development before the onset of cold weather. Fall establishment also allows the legume to have a developed root system for rapid growth in spring before warm-season grasses become competitive. Clipping or grazing the sod to a 2-in. stubble height before planting improves establishment success. Winter annual legumes are commonly grown in bermudagrass and bahiagrass pastures to provide forage in spring before the warm-season grasses become productive. Typical winter annual species include crimson clover, arrowleaf clover, and hairy vetch. Dry matter yield of winter annual legumes planted in February is lower, and the production is typically delayed compared to fall plantings [44].

Soil fertility management for legumes

Legumes require higher soil fertility than grasses. Soil pH should be 6.0 or higher, and soil P and K should be in the medium to high range. Nitrogen fertilizer is not needed for establishing legumes in grass sods. Addition of nitrogen fertilizer or animal manure will stimulate competition from the grass sod which will outcompete developing legume seedlings [44]. Legume seeds should be inoculated with the proper strain of rhizobia bacteria to ensure nitrogen fixation. Most newer varieties of clover and alfalfa are sold with seed coating already containing the inoculant and other products to enhance establishment.

Perennial legumes

White clover is the most commonly grown perennial clover. Its prostrate growth habit improves persistence in pastures because the growing point remains close to the soil and protected from grazing. It is best suited for grazing (as opposed to hay) and provides very high-quality forage for livestock.

Red clover is considered a short-lived perennial but may only survive as an annual in the southern section of this region. It is very productive and can be grown in mixtures with fescue or bermudagrass under good management. Red clover is well suited for hay or grazing.

> ***Red clover is a short-lived perennial that is productive for about three seasons. The highest herbage yields are obtained in the year after sowing.***
>
> **N. L. Taylor and R. R. Smith (1979)**

Alfalfa is most commonly grown for hay but can also be grazed. It is typically grown as pure stands; however, it can be interseeded into bermudagrass sod in the fall. The alfalfa will become dominant in the mixture due to shading of the bermudagrass, but after a few years, the bermudagrass will slowly increase in stand as the alfalfa thins.

Annual legumes

Annual legumes such as crimson clover, arrowleaf clover, and hairy vetch are grown throughout the region. These species are winter annuals and are planted in the fall. They are most commonly grown with bermudagrass or bahiagrass to provide spring forage before the warm-season grass becomes productive in summer.

Annual lespedeza is a warm-season annual legume that is compatible with tall fescue due to its summer growth period. It is not a high-yielding forage, but its growth comes at a key period when the fescue is unproductive.

Hairy vetch is a winter annual legume that is grown with tall fescue, bermudagrass, and with small grains intended for silage. It provides good spring grazing but is difficult to dry for hay and retain the high-quality leaves.

Summary

The upper south is a climatic transition zone from the west to the east and from the south to the north, and this transition has a major impact on forage and livestock production systems across the region. Precipitation ranges from 30 in./year in the west to over 60 in./year in the east. Thus, the forage base for the western part of the region tends to be native prairie along with drought tolerant, warm-season grasses and cool-season annuals. But in the east, forage species tend to be predominantly introduced, and both cool-season annuals and perennials are common. Forages in the southern extreme of the region are chiefly tropical and subtropical introduced warm-season grasses, while in the north the most common perennial is tall fescue.

The native grass system for beef cattle production is nearly ideal for spring calving cows in the southern plains and upper south (Appendix Table 8.1 and Appendix Fig. 8.1). Native grasses (big bluestem, little bluestem, Indiangrass, switchgrass, eastern gamagrass, etc.) developed under nomadic grazing by wildlife. These grasses tend to be very deep rooted, drought tolerant, and adapted to a wide range of soils. They are adapted to the entire region from Oklahoma to the Carolinas. East of the Mississippi River, much of the land area that once supported native grass has been replaced by introduced forages and crops. Native grasses are highly productive, require little soil fertility (unless grown on a highly degraded site), and if grazed properly, require few herbicide applications.

As one goes further east, with increased rainfall and intensified management, there is more reliance on introduced species for warm-season forages. Warm-season forages have similar timing of production and can be more productive than native grasses, but they also require more external management inputs. Bermudagrass is a warm-season C_4 perennial grass that is native to southeastern Africa. In the United States, bermudagrass is best adapted to the southern states from North Carolina west to southern California and south. It can be found north into the coastal plains of Virginia and in the southern counties of Kentucky, Missouri, and Kansas. Bahiagrass is a perennial warm-season C_4 grass grown primarily for pasture, but it may also be used for hay. It is very drought tolerant and can survive well on rocky, shallow sites, low fertility, and light textured soils where even bermudagrass grows poorly. Bahiagrass is easy to maintain because it is tolerant of close grazing, low fertility, and is generally free from diseases or insect pests. Dallisgrass is a fast-growing warm-season C_4 perennial grass used primarily for pasture. It has wide, smooth leaves, and a deep root system. Dallisgrass is found across the upper south and typically grows on heavy textured and low-lying moist soils. Forage quality and palatability are very suitable for most grazing livestock. Livestock will graze dallisgrass very closely unless rotational grazing is used. Hay yield of dallisgrass is similar to that of common bahiagrass. It is very competitive in wet soils and tends to invade bermudagrass or other forages growing in those sites. Warm-season annuals can also provide forage to fill gaps in production or in emergency situations. Sudangrass, forage sorghums, sorghum—sudangrass hybrids, millet species, corn, and crabgrass are all commonly used for grazing or hay production in this region.

In the northern part of this region, pasture and hay production is more reliant on the cool-season perennial tall fescue. Tall fescue is adapted to a wide range of conditions. It tolerates short-term flooding, moderate drought, and heavy livestock and machinery traffic. It responds well to fertilizer but maintains itself under limited fertility conditions. It is well adapted to moderately acidic and wet soils. Tall fescue is often infected with an endophyte that forms a symbiotic relationship with the plant. Tall fescue benefits from the alkaloids produced by the endophyte through improved plant persistence and resistance to animal grazing while the endophyte is provided nutrients, shelter, and a place to reproduce. Some of the alkaloids produced reduce animal performance. New tall fescue releases often are infected with novel endophytes which are beneficial to the plant but do not reduce animal performance and are highly recommended for new establishments.

Cool-season annuals are also relied upon heavily in this region for forages in the fall, winter, and early spring. Annual ryegrass and small grains (wheat, oats, and cereal rye) provide high-quality forage that can be used to offset concentrate supplementation for lactating cows and are adequate for stocker gains in excess of 2 lb/day.

Finally, legumes can reliably be grown for forage crops in this region. Selection of species and variety needs to take local climate and soils into consideration before planting.

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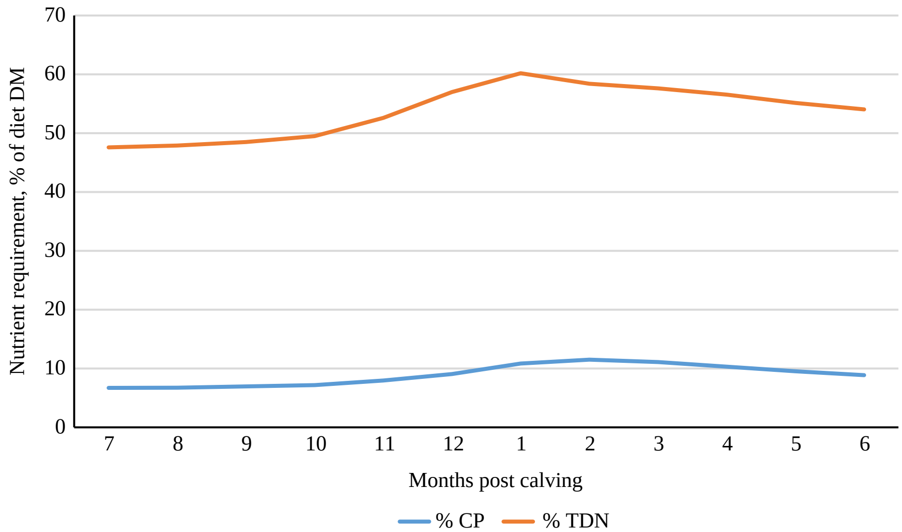
Appendix: Nutrient requirements of beef cows

Appendix Table 8.1 Effect of stage of production of beef cows on dry matter intake [45] and requirements for crude protein [46], metabolizable energy [45], and metabolizable protein [45].

Stage			Metabolizable energy (Mcal/day)				Metabolizable protein (lb/day)			
Months postcalving	Days postbreeding	DM intake (lb/day)	Diet	Maintenance	Pregnancy	Milk	Maintenance	Pregnancy	Milk	Crude protein (lb/day)[a]
7	120	21.6	16.87	16.42	0.45	—	0.9	—	—	1.45
8	150	22.1	17.27	16.38	0.89	—	1.0	0.1	—	1.49
9	180	22.4	17.81	16.41	1.66	—	1.0	0.1	—	1.56
10	210	23.2	18.84	15.89	2.95	—	1.1	0.2	—	1.67
11	240	23.3	20.12	15.18	4.94	—	1.2	0.3	—	1.86
12	270	23.8	22.24	14.42	7.82	—	1.4	0.5	—	2.16
1	—	25.0	23.43	15.82	—	7.62	1.7	—	0.8	2.71
2	—	25.8	24.72	15.63	—	9.09	1.9	—	1.0	2.97
3	—	25.4	24.01	15.73	—	8.29	1.8	—	0.9	2.82
4	30	24.5	22.73	15.93	0.04	6.76	1.6	—	0.7	2.53
5	60	23.7	21.44	16.17	0.10	5.18	1.5	—	0.5	2.26
6	90	23.0	20.39	16.37	0.22	3.80	1.3	—	0.4	2.04

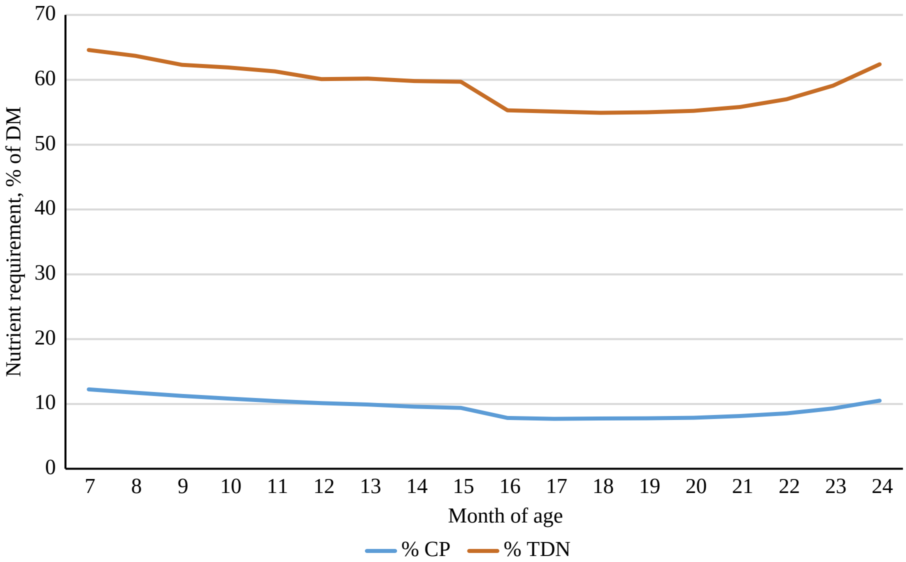
[a]Based on nutrient requirements of beef cattle update 2000 [46] Appendix Table 22, Diet nutrient density requirements of beef cows.
Source: Based on Nutrient Requirements of Beef Cattle 8th Revised Edition, Empirical Model. 1200-pound Hereford × Angus cross cow, 5 years of age, BCS = 5.0, and 20 pounds of milk produced/day in peak lactation.



Appendix Figure 8.1 Effect of stage of production of 5-year-old mature Hereford × Angus beef cow on requirements of crude protein (CP) and total digestible nutrients (TDNs) as a percentage of diet DM from Appendix Table 8.1. Calves in this scenario are weaned at 7 months of age and cows are expected to calve every 12 months [45,46].

Appendix Table 8.2 Effect of age and stage of production of developing beef replacement heifers on dry matter intake [45] and requirements for crude protein [46], metabolizable energy [45] and metabolizable protein [46]. Heifers are expected to gain 1.33 lb/day from weaning at 7 months of age to breeding and 0.86 lb/day from breeding until calving.

Stage			Metabolizable energy (Mcal/day)				Metabolizable protein (lb/day)			
Months of age	Average days postbreeding	DM intake (lb/day)	Diet	Maintenance	Growth	Pregnancy	Maintenance	Growth	Pregnancy	Crude protein (lb/day)
7	—	10.60	11.27	6.85	4.85	—	0.5	0.4	—	1.30
8	—	11.50	12.02	7.30	4.72	—	0.5	0.4	—	1.35
9	—	12.36	12.73	7.74	4.99	—	0.5	0.4	—	1.39
10	—	13.21	13.49	8.17	2.32	—	0.6	0.4	—	1.43
11	—	14.07	14.14	8.62	5.52	—	0.6	0.4	—	1.47
12	—	14.91	14.70	9.10	5.60	—	0.6	0.4	—	1.51
13	—	15.76	15.57	9.47	6.10	—	0.6	0.4	—	1.56
14	—	16.60	16.34	9.89	6.46	—	0.7	0.4	—	1.59
15	0	17.16	15.59	10.66	4.91	0.02	0.7	0.3	0.0	1.61
16	30	17.71	16.06	10.93	5.08	0.05	0.7	0.3	0.0	1.39
17	60	16.26	16.50	11.21	5.22	0.08	0.7	0.3	0.0	1.42
18	90	18.80	16.94	11.49	5.28	0.17	0.7	0.3	0.0	1.46
19	120	19.37	17.48	11.74	5.40	0.34	0.7	0.3	0.0	1.51
20	150	19.93	18.03	11.97	5.38	0.68	0.8	0.3	0.0	1.57
21	180	20.52	18.72	12.16	5.29	1.27	0.8	0.3	0.1	1.67
22	210	21.16	19.80	12.21	5.33	2.25	0.8	0.3	0.1	1.81
23	240	21.79	21.13	12.21	5.14	3.78	0.8	0.3	0.2	2.03
24	270	22.37	22.93	12.11	4.84	5.98	0.8	0.3	0.3	2.35



Appendix Figure 8.2 Effect of age and stage of production of replacement heifers on requirements of crude protein (CP) and total digestible nutrients (TDNs) as a percentage of diet DM from Appendix Table 8.2. Hereford × Angus heifers in this scenario are weaned at 7 months of age at 475 lb and developed at 1.33 lb/day average daily gain until breeding at 15 months of age to reach 65% of their mature bodyweight of 1200 lb. After breeding heifers are grown at 0.86 lb/day average daily gain to reach 85% of mature bodyweight by calving [45,46].

CHAPTER 9

Management strategies for pastures, beef cattle, and marketing of stocker-feeder calves in the Upper South: The I-64 Corridor

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> ***I'm really in the grass business. The cattle are the appreciating tools I use to harvest. . .***
>
> **Russell Hackley, deceased stocker producer from Grayson Co, KY.**

Introduction

The I-64 Corridor represents a region from St. Louis, Missouri to the Atlantic Coast and includes the area between lower Illinois, Indiana, Ohio, and the entire states of Kentucky, West Virginia, and Virginia (Chapter 1, Introduction: management strategies for sustainable cattle production on Southern Pastures, Fig. 1.3). In general, the first freeze (<32°F) in this region occurs in November, and the last freeze in mid-April to early May. Summers tend to be hot and humid with maximum air temperatures in July and August commonly above 90°F, and occasionally above 100°F. There is considerable annual variation in snow and ice; subzero temperatures can occur but are not the norm. Yearly rainfall in the region is generally above 45 in. with the driest period being from late August to early October. Extreme drought conditions can periodically occur from late spring to early fall.

Apart from the river bottoms, most soils in the region are not well suited for crop production, and the terrain varies. The Appalachia Mountains cover the area between the Upper Piedmont Prairie in central Virginia and central Kentucky. Pastures are generally in valleys with adequate top soil, but there are also pastures on steep hillsides with shallow and rocky soils. From central Kentucky to southern Illinois, pastures generally have minimal to moderate slopes.

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Forage-based cattle production in the I-64 Corridor is predominantly cow—calf. Missouri and Kentucky have the greatest number of beef cows in the region and rank third and eighth, respectively, in the United States in number of beef cows [1]. Farms along the corridor account for approximately 15% of the total US beef herd. Therefore cow—calf production is economically important to the beef industry of the region and the United States.

The number of seedstock producers in the I-64 Corridor is comparable to other regions. Stocker production is less prevalent here than in other areas, largely due to the fact that the predominant perennial cool-season grass in the region is toxic endophyte—infected tall fescue. Weaned calves are sold and transported directly to feedlots, or they are sent to other regions for pasture backgrounding with high-quality forages. There is an increasing trend for cow—calf operators to retain their calf crops in order to add value through health management and backgrounding to a targeted body weight.

Significance of tall fescue to the region

> ***The history of tall fescue (Festuca arundinacea Schreb.), the fescue toxicity problem, and its association with a fungal endophyte comprise a fascinating story. Research on this problem, and its ultimate solution, or the minimization of its negative effects, comprises one of the most important research problems in the forage-livestock area. The economic impact of this research is expected to be large, as results are put to use on the farm.***
>
> **John A. Stuedemann and Carl S. Hoveland (1988)**

Tall fescue (*Lolium arundinaceum*) has been the predominant forage in the region for over 70 years. The tall fescue that eventually became the cultivar Kentucky 31 was collected initially from a hillside on the Suiter Farm in Northeast Kentucky in 1931 by Dr. E.N. Fergus at the University of Kentucky (Fig. 9.1). From this seed Fergus developed and commercially released the cultivar Kentucky 31 in 1943. Vegetation in the region prior to the release of Kentucky 31 was primarily hardwoods and brush and with minimal acreage of grasses and legumes suitable for grazing. Tall fescue was quickly recognized as a grass that could open opportunities for expanding forage-based livestock production in the region. Acreage of tall fescue rapidly expanded, and the grass's productivity and persistence in the region allowed increases in cattle numbers. Therefore, the strong cattle industry along the I-64 Corridor can be directly attributed to tall fescue.

Soon after a substantial acreage of tall fescue was planted, cattle producers started complaining that cattle were not performing well, lacked thriftiness, and sometimes developed severe lameness and necrosis of the lower limbs, ear tip, or tails. It was not until the 1980s that this poor animal performance [2] was determined to be caused by a fungal endophyte living between the cells of the tall fescue plant. Ergot alkaloids produced by the endophyte were determined to be the cause of the malady collectively called "Fescue Toxicosis."

Figure 9.1 Hillside at Suiter Farm where the seed was collected in 1931 for the development and commercial release of "Kentucky 31" tall fescue in 1943.

Toxicity and seasonal patterns

Ergovaline is the alkaloid present in greatest concentrations in toxic tall fescue [3] and is highly toxic to cattle. Ergovaline concentrations in tall fescue vary by tissue and by season of the year. Toxins are lowest in the leaf blades, and much greater in the stem bases, leaf sheaths, and seedheads [4]. Ergovaline values peak during the rapid growth of May, at which time concentrations of ergovaline are generally as follows: (1) leaf blades <0.3 ppm (parts per million), which is considered low in toxicity, (2) leaf sheaths from 0.5 to 1.0 ppm, (3) stems from 0.9 to 2.0 ppm, and (4) seedheads from 1.3 to 6.0 ppm, considered highly toxic.

Excessive nitrogen fertilization (greater than 80 lb N/acre) can increase ergot alkaloid concentrations and should be avoided in the spring and summer. A single application of nitrogen should be in the range of 50–70 lb/acre, enough to generate fescue growth but without an excess that can be utilized by the endophyte to accelerate production of toxic alkaloids. A late fall application of 50 lb N/acre can promote early spring growth without causing excessive production of alkaloids.

Cattle should graze toxic tall fescue when it is leafy and vegetative to minimize intake of toxic seedheads, stems, and leaf sheaths. Fescue that has accumulated growth containing high proportions of leaf sheath, stems, and seedheads should be mowed to a 6- to 8-in. height before grazing. Toxic fescue should also not be grazed below 3 in. where leaf sheaths close to the plant crown can be highly concentrated with ergot alkaloids.

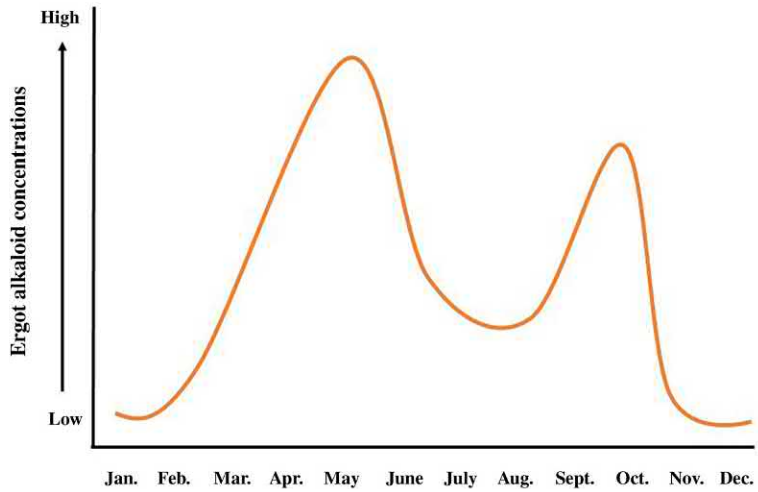

Figure 9.2 Seasonal trends in ergot alkaloid concentrations of toxic endophyte–infected tall fescue.

Ergot alkaloid concentrations in the plant are seasonal and follow a pattern to the growth distribution of the fescue plant (Fig. 9.2). These toxic concentrations are minimal between the first and last freeze (below 32°F). The alkaloids increase with vegetative growth in late March or early April and continue to increase to a maximum after seed has set and matured. Alkaloids decline as plant growth declines in the summer but will increase with fall growth and milder air temperatures. Therefore it is during the spring and fall growth when cattle are exposed to the highest concentrations of ergot alkaloids. Unfortunately these alkaloids can accumulate in cattle tissues over a period of time, prolonging the toxicosis [5].

Signs of fescue toxicosis

In cattle the major physiological effect of consuming ergot alkaloids is constriction of the vascular system, which limits blood flow to skin and incapacitating the animal's ability to regulate body temperature when air temperatures are above 70°F. Therefore cattle can become severely heat stressed as air temperatures and relative humidity increase. During spring and summer, cattle will normally graze in the early morning, late afternoon, and early evening. Cattle grazing toxic tall fescue will cease grazing earlier in the morning and later in the afternoon. Grazing in the late afternoon and evening can also substantially decline in the summer when temperatures are above 90°F. Over time, forage intake will substantially decline and negatively impact body weight (BW) gain and condition. It is common for cattle in toxic fescue pastures with low inputs of management to drop in body condition as air temperatures rise.

Figure 9.3 Cows standing in a pond to relieve themselves of excess body heat from grazing toxic endophyte–infected tall fescue.

It is natural for cattle to stand in ponds and shade during days when the temperatures are high, but cattle exposed to ergot alkaloids will spend more time in the ponds and shade than normal and will excessively pant and slobber (Fig. 9.3). Infected cattle in a pasture with a single water trough and minimal shade will create muddy areas around the trough or behind gates that provide some shade. If natural shade from trees is not available, shade structures are highly recommended to provide enough shade for all animals. The structures should be on skids to allow movement in order to control mudding under the structure.

To add to the severity of heat stress, cattle exposed to ergot alkaloids can maintain rough hair coats during the summer (Fig. 9.4). This is not a reliable indicator of toxicosis because there will be variation among animals due to genetic differences in the cattle. Cattle with rough, long hair coats during the summer will ultimately be poor performers and should be either culled or moved to nontoxic pastures.

Fescue-induced heat stress will decline as the temperatures decline in autumn. However, cattle can be vulnerable to "fescue foot" at this time due to constricted blood flow to peripheral tissues. Blood flow is most constricted when animals are saturated with ergot alkaloids. In the presence of freezing air temperatures, the reduction in flow of oxygen and warm blood to peripheral tissues will eventually cause tissue necrosis. Consequently, these cattle will slough ear tips, tail switches, and in extreme cases, hooves. There has also been an incidence of fescue foot before freezing weather on accumulated fescue heavily fertilized with nitrogen (100 lb N/acre) in a mild fall following a hot, dry summer.

Figure 9.4 Calves in toxic endophyte–infected tall fescue pasture that are exhibiting rough and muddy haircoats.

Fescue foot symptoms begin with the animal demonstrating lameness of the back legs, most often the back, left leg. If cattle remain on the toxic fescue pasture, there will be swelling below the pastern, and the skin above the hoof will eventually split. At this point reversal of the condition will be difficult. Like removing cattle from muddy areas with onset of hoof rot, cattle with fescue foot should be placed in dry lot or nontoxic pastures when they begin to exhibit lameness.

Ergot alkaloids also restrict the secretion of prolactin by the pituitary gland, which is required for mammary development prior to calving. With less than optimum development of the udder, milk yields will be negatively impacted. Low milk yields will be reflected by less than expected growth rates of suckling calves.

Exposure of cow herds to toxic tall fescue can reduce calving percentages by 15%–30%. Reproductive issues with fescue cattle can be linked to reduced prolactin and hormones necessary for conception (luteinizing hormone and follicle stimulating hormone) and pregnancy (progesterone). Genetics, alkaloid-related heat stress, body condition, and vaccination history are also factors that affect reproductive performance on toxic tall fescue pastures. Further, there are subtle effects of toxic tall fescue on bull fertility that can reduce reproductive performance [6].

Mitigation of fescue toxicosis

> ***Toxic endophyte-infected tall fescue is the one pasture grass that stocking rate has minimal effect on cattle performance. This is because with high forage availability, it is the fungal endophyte that limits animal performance, and with low forage availability, the limiting factor is the low availability of forage.***
>
> **Dave Bransby (1990)**

Mixtures with other grasses and clovers are beneficial

Fescue pastures are rarely 100% fescue, and not every tall fescue plant is infected with the toxic endophyte. Pastures often contain a variety of other forages as well as broadleaf and grassy weeds that are readily grazed and can be of high quality. These other species will dilute the concentration of ergot alkaloids in the cattle's diet. The common forages found growing with tall fescue include orchardgrass (*Dactylis glomerata*), Kentucky bluegrass (*Poa pratensis*), bromegrasses (*Bromus* species), and clovers (*Trifolium* species). Warm-season grasses, such as bermudagrass (*Cynodon dactylon*) and crabgrass (*Digitaria sanguinalis*), can also be found in well-drained areas of fescue pastures. Unpalatable pasture weeds are usually avoided by cattle unless forage availability becomes limited and cattle cannot meet their nutrient needs. Limited forage will force cattle to overcome preference and palatability issues (taste, odor, or texture) to consume nonpreferred or toxic weeds. Effects of fescue toxicosis is generally negligible if toxic fescue comprises less than 20% of the available forage [7]. As this percentage increases, there will be a proportionate increase in fescue toxicosis and decline in economic return from the cattle enterprise. Although not definitive, 20% toxic fescue is a reasonable threshold above which to implement measures to mitigate toxicosis.

Visual estimation of pasture composition is difficult with complex mixtures of grasses and clovers. A more practical method is to measure frequency of occurrence, which is not based on dry weight but rather the presence of the forage species relative to other species. This procedure can be done by walking diagonal lines in the pasture from corner to corner, and identifying the grass closest to the tip of one boot every three paces. Placing a chalk mark at the tip of the boot can serve as a good reference point for consistency. Assessing pasture composition requires the ability to distinguish between fescue and other species. A simple pasture inventory would contain estimates of fescue, other grasses, clovers, and weeds. Noting the percent of individual forage grasses may be more beneficial than just lumping them together in one category.

Counts of a species or group can then be used to estimate percentage in the aboveground forage. For example, assume 880 recordings are made for plants closest to the reference mark for a 20-acre pasture, and 550 of the recordings are tall fescue. The percent of tall fescue in the aboveground herbage is calculated to be 62.5 ([550/880] × 100). If orchardgrass occurs 115 times, its occurrence in the aboveground herbage is 13%. Consult with your county extension agent if assistance is needed in identifying tall fescue and other forage species.

Top managers will take a further step of determining the infection level of tall fescue in their pastures by having the fescue tested. Commercial tests are available for determining endophyte infection levels, and your extension agent or specialist can assist in determining how best to secure and submit samples. Typically, these assays require collecting the lower 2 in. of tillers (the stem bases) of randomly chosen tall fescue plants across a field. Sample numbers will vary with field size. Tillers must be stored on ice and submitted to the laboratory as soon as possible to minimize any plant drying. Or course, if there is no testing service available, or if testing is not practical, historical surveys of endophyte infection levels for the area may be available. Finally, cattle symptomology can be used as an indicator of the presence of an unacceptably high infection rate in tall fescue.

Strategies to mitigate fescue toxicosis

It is important to use management strategies that encourage and support the growth and persistence of good-quality grasses and clovers in pastures. Limit overgrazing or regrazing of these species by limiting time on individual pastures to one week or less. Use of rotational grazing with stocking densities above 2000 lb BW/acre will help ensure that all forage species are grazed. The higher stocking densities limit the ability of cattle to selectively overgraze the more palatable species. As always, maintain a 3- to 4-in. residual in the perennial cool-season grasses to speed regrowth, increase persistence, and lower weed encroachment. Although toxic endophyte fescue can tolerate lower fertility and lower pH, proper applications of needed fertilizer and lime will ensure the productivity of the other cool-season grasses and clovers.

Overseeding with red or white clover can reduce the need for commercial nitrogen and further dilute ergot alkaloids with a high-quality forage. Clover stands should contribute at least 25% of the available forage dry matter (DM) to obtain the most benefit from the clover. Ideally the clover present will be the taller growing, higher yielding red and ladino types. High clover percentages can be supported with rotational stocking, and maintaining proper levels of soil potassium (above 180 lb/acre), phosphorus (above 60 lb/acre), and pH (above 5.8). Consider herbicide applications to eliminate problem broadleaf weeds prior to planting clover.

Movement to nontoxic pastures during the summer

Ergot alkaloids accumulate in the vasculature systems of cattle. Effects of alkaloids on blood flow will last 5–7 weeks after cattle stop grazing toxic tall fescue [8]. However, prolactin will increase to normal concentrations in 1–2 weeks after moving to nontoxic pasture [9], and cattle will start to generate short summer hair coats. Moving cattle from toxic fescue to a warm-season grass in the late spring can mitigate heat stress and its effect on cattle performance in the early summer and alleviate it during the hotter part of the summer. Another advantage of this management strategy is that it places cattle in pastures with active growth during July and August when there is a slump in growth of tall fescue.

Move cattle from toxic fescue to nontoxic warm-season grass pastures when enough vegetative growth has accumulated to support grazing. This usually occurs in late May or early June for bermudagrass and the native warm-season grasses. Annual warm-season grasses will be ready for grazing approximately 45–60 days after planting.

Grazing of bermudagrass in the region can begin when it is 8–10 in., which is typically between the last week of May and the second week of June. The native grasses [eastern gamagrass (*Tripsicum dactyloides*), swichgrass (*Panacum virgatum*), big bluestem (*Andropogon gerardi*), and indiangrass (*Sorghastrum nutans*)] will be ready for grazing when they have attained a height of at least 2.5–3 ft., which is usually 2–3 weeks before bermudagrass.

Early grazing of productive warm-season grasses will depend on an application of commercial fertilizer at 50–75 lb N/acre soon after the grass breaks dormancy. A second application of nitrogen in late June or early July will be helpful in generating additional summer growth and maintaining forage crude protein (CP) concentrations. Bermudagrass will require more nitrogen fertilizer than native grasses. Amend soils according to test results to maintain levels of soil phosphorus above 60 lb/acre, potassium above 150 lb/acre, and pH above 5.5.

A system that splits grazing between cool- and warm-season perennial grasses will require a high stocking rate during warm-season grazing. Stocking rates of 1500–2000 lb BW/acre can be supported with intensive management that preserves enough postgraze residual herbage and provides for periods of rest that allow sufficient regrowth. Periods of rest should be 14–21 days for bermudagrass, 21–28 days for annual grasses, and 36–45 days for native grasses. Length of rest periods should be flexible to account for rainfall and speed of regrowth. Native grasses are sensitive to overgrazing, therefore strongly consider removing cattle from summer pastures and feeding hay when growth slows due to drought.

Culling poor performing cows or stockers will also be beneficial in preventing overgrazing and the subsequent stand loss. Waiting too late to feed hay or reduce stocking rates can be costly to herd performance and lead to expensive pasture renovation.

Chemical seedhead suppression

As previously discussed, seedheads are the most toxic part of the infected fescue plant. Unfortunately, immature seedheads of tall fescue are palatable, and cattle will selectively graze the seedheads, thereby consuming high amounts of alkaloids in a short period of time [10]. Cattle will graze seedheads soon after they emerge from the boot and become exposed. It is common for all fescue seedheads to be consumed in a week to 2 weeks after emergence.

Seedheads of tall fescue can be suppressed by spraying the pastures with metsulfuran-methyl herbicide (trade name Chaparral, Corteva AgroSciences Inc.) at labeled rates (Fig. 9.5). This herbicide suppresses emergence of tall fescue seedheads but does not inhibit seedhead emergence of other grasses [11]. For maximum

Figure 9.5 Chemically seedhead-suppressed toxic endophyte–infected tall fescue on the right and untreated tall fescue on the left.

suppression of fescue seedheads, pastures should be sprayed as late as possible during vegetative growth, or when the plants are either at or close to boot stage. Earlier applications cause excessive yellowing and a lag in fescue growth that can reduce subsequent fescue production. Commercial nitrogen should be applied within a week before or after the herbicide application to offset dampening of fescue growth.

Suppressing the emergence of toxic seedheads will remove them as a source of toxic ergot alkaloids, but it also maintains the fescue in a vegetative stage of growth which enhances the nutritive value in the late spring and summer. Cattle will selectively graze the vegetative fescue over other grasses mixed in the pasture, resulting in these other grasses maturing and setting seed. Under continuous stocking, cattle will overgraze areas of pastures with higher densities of vegetative tall fescue, which will eventually weaken the stand. Rotational stocking with higher stocking densities removes the ability of livestock to graze selectively, thereby causing mixed pastures to be grazed more uniformly, and improving overall forage quality [12]. Good management practices require moving cattle before fescue becomes overgrazed (3- to 4-in. pasture height).

Supplementation

Reduced DM intake of cattle that graze toxic fescue will ultimately make them deficient in energy, protein, vitamins, and minerals. Supplementation of fescue cattle in the spring and summer can be economically beneficial. Even though they can still be heat stressed, strategic supplementation of cattle on toxic tall fescue would mitigate the

Table 9.1 Nutritive value of various alternative feeds.

Alternative feed	Crude protein	Total digestible nutrients	Crude fiber
	Percentage of dry matter		
Dried distiller's grains	29.5	84.0	13.0
Corn gluten	23.8	80.0	7.5
Soybean hulls	12.2	77.0	39.9
Cottonseed hulls	4.2	42.0	47.8
Brewer's dried grains	29.2	66.0	7.8
Bakery waste	11.9	89.0	0.8
Citrus pulp	6.7	82.0	12.8
Beet pulp	9.8	74.0	20.0
Peanut hulls	7.4	8.0	65.4

Source: E.W. Crampton, L.E. Harris, Applied Animal Nutrition, second ed., W.H. Freeman and Company, San Francisco, CA, 1969; and National Research Council's Nutrient Requirements of Beef Cattle, eighth ed., The National Academic Press, Washington D.C., 2016.

negative impact on weight gain by raising the plane of nutrition. Free-choice minerals should always be available to fescue cattle.

Daily feeding of supplements in amounts above 0.5% of BW (1000 lb cow consuming at least 5 lb of supplement/day) can dilute the concentration of ergot alkaloids consumed by the animal. High cost grain supplements may be uneconomical to meet nutrient requirements and dilute dietary ergot alkaloids. Coproduct feeds processed from the milling of grains or alcohol or food products (such as soybean hulls, dried or wet distiller's grains, and bakers' waste) can have lower costs than other grain supplements which makes them cost effective choices to raise the plane of nutrition and dilute ergot alkaloids in the diet.

Soybean hulls have a nutritive value comparable to a moderate-quality hay. Feeding soyhulls to fescue cattle at 0.75%–1.00% of BW per day has shown to cost-effectively increase steer average daily gain (ADG), increase prolactin concentrations in the blood, and promote shorter hair coats in the summer [13]. Other coproduct feeds can be used to raise the plane of nutrition of the cattle and cost-effectively improve animal performance (Table 9.1). Choosing the best coproduct will depend on availability and proximity to the farm to reduce transport costs. High moisture coproducts are less economical to transport than dry on a pound of nutrient basis. Dried grains or coproducts are cheaper to transport, will be more consistent in nutrient composition, and can be stored for longer periods. In addition, wet grains can spoil in a matter of days.

Season of calving

Successful rebreeding in spring-calving herds grazing toxic tall fescue in the summer can be challenging due to heat stress and difficulty in maintaining body condition during summer breeding. In addition, weaning weights for spring-calving herds on toxic tall fescue can be up to 50 lb less than those on nontoxic pastures. These lower weights are due in part to lower milk yields from cows suffering ergot alkaloid-induced heat stress and lower prolactin. The weaning weights of suckling calves will continue to be negatively affected by the ergot alkaloids as the calves graze more and suckle less in the late spring and summer.

Converting to fall calving can avoid the problems of breeding of spring-calving cows and heifers in May and June when high ergot alkaloid concentrations combined with hot and humid conditions are most conducive to fescue toxicosis. With fall calving, cow herds are exposed to bulls during the winter months when ergot alkaloid concentrations in the fescue are negligible, and calves are not vulnerable to ergot alkaloid-induced heat stress. Providing high levels of nutrition during the late fall and winter months is critical in maintaining good performance in fall calving herds. Also, pregnant cows and heifers will likely need additional high-quality hay or coproduct feed in July, August, and possibly September to maintain good nutrition and body condition during the last trimester of pregnancy, thereby, allowing for timely rebreeding in the winter.

Cattle genetics

The influence of genetics on an animal's tolerance to ergot alkaloids is not well understood. Studies have shown that Brahman and Brahman-cross cows have improved body condition and reproductive performance and support higher weaning weights on toxic tall fescue than other breeds [14]. Brahman-influenced cattle are thought to be more effective in dissipating the excess heat loads caused by ergot alkaloids. It is speculated that Brahman-influenced cattle have a greater surface area of skin that allows them to efficiently dissipate body heat in hot and humid environments. In addition, these cattle do not produce as rough a haircoat as the English breeds, such as Angus and Herefords. These characteristics (greater skin area and smoother haircoats) allow them to better tolerate the excess heat loads caused by ergot alkaloids. However, ergot alkaloids will negatively affect their vascular systems.

It is unclear if continental breeds (such as Charolais, Limousine, and Salers) perform better than the English breeds (such as Angus and Hereford), which generally are the poorest performers on toxic tall fescue pastures. The continental breeds tend to have smoother haircoats in the summer while grazing toxic tall fescue, which may provide an advantage.

Alternatives for fescue areas: novel endophyte-infected tall fescue

Fescue toxicosis can be alleviated if toxic endophyte—infected tall fescue is replaced with nontoxic, novel endophyte fescues. Genetic strains of endophytes that do not produce toxic ergot alkaloid have been artificially introduced into

Table 9.2 Commercially available novel endophyte-infected tall fescues.

Brand name	Cultivar	Endophyte	Seed distributor
MAXQ	Jesup	MAXQ	Pennington Seed
Texoma MAXQ II	Texoma	MAXQ II	Pennington Seed
Baroptima	Baroptima	Plus E34	Barenbrug Int.
Lacefield MAXQ II	Lacefield	MAXQ II	Pennington Seed
Estancia	High Mag	Arkshield	Mountain View Seed
Duramax Gold	Triump	Armor	DFL Int.
Tower Protek	Tower	Protex	DFL Int.

productive fescue cultivars [15]. These "novel" tall fescues provide a nontoxic alternative to toxic endophyte—infected Kentucky 31. The first novel endophyte-infected tall fescue cultivar was released in 2001 under the trade name GA Jesup-MaxQ. There are presently several novel endophyte fescues commercially available (Table 9.2). Novel endophyte tall fescue cultivars have two-part names; the first is the host tall fescue variety, and the second is the commercial name for the genetic strain of the novel or nontoxic endophyte.

Prior to commercial release of a novel endophyte fescue, grazing trials with cattle are conducted over different environments to verify that no ergot alkaloids are produced by the endophyte, and that the cattle do not exhibit signs of fescue toxicosis. Although novel endophytes do not produce toxic alkaloids (such as ergovaline), they do produce peramine and loline alkaloids in similar concentrations as the toxic endophyte. Peramine and loline alkaloids help the host fescue to tolerate environmental stresses such as moisture, low fertility, and grazing. One should contact an extension agent or specialist when deciding which novel endophyte fescue to plant.

Cattle operations that rely heavily on toxic fescue pastures will have the greatest need to replace them with nontoxic fescue. Although upfront costs are high, replacement will be feasibly done incrementally and not all at once in most cases. Managing a pasture system that contains paddocks of novel endophyte tall fescue will be different than with an all-toxic fescue system. Paddocks of novel fescue will be grazed more closely in mid-summer than toxic fescue which stresses the stand and potentially reduces persistence. Toxic fescue induces heat stress in summer, and consequently, pasture intakes are reduced. This lower grazing pressure effectively "protects" the stand of toxic fescue. Resting fields of novel fescues and careful maintenance of residual forage by rotational grazing will help these valuable fields remain productive.

Replace the fescue on the most productive fields first. Let toxic fescue remain on less productive soils and on steeper terrain. These pastures can be used for early spring pasture and for stockpiling late summer and fall growth for winter grazing.

There are considerations when replacing toxic endophyte tall fescue with a non-toxic endophyte tall fescue: (1) establishment should follow procedures that minimize emergence of toxic endophyte—infected seed that is in the soil seed bank, (2) management should be implemented to control movement of toxic seed and vegetative material into pastures of novel tall fescue, and (3) grazing management of novel fescue is critical during warmer months when forage intake is not limited by ergot alkaloid-induced heat stress.

Establishment of novel endophyte tall fescue

Conversion of toxic to novel tall fescue requires careful management to obtain rapid emergence of novel endophyte seedlings while preventing contamination of the new stand with seedlings or surviving plants from the old stand. For a no-till renovation of toxic tall fescue to be successful, follow these steps: (1) Control seed production in the year of planting; (2) Completely kill the toxic tall fescue with herbicides with or without interim or smother crops; (3) No-till drill novel tall fescue seed into sprayed sod; (4) Allow novel fescue to get well established before grazing; and (5) Prevent the contamination of the novel tall fescue by preventing the reintroduction of toxic seed on the pasture and the emergence of seedlings from old seed in the soil profile.

The following methods (Fig. 9.6) have been used successfully.

Spray-smother-spray method

With the spray-smother-spray technique, conversion to novel tall fescue is achieved by (1) spraying the pasture with glyphosate to kill the toxic fescue; (2) smothering surviving or newly emerged toxic fescue with a tall, warm-season annual grass; and (3) spraying glyphosate again in the late summer to kill any late-season emergence of old fescue as well as any weeds that may have encroached.

In late March to mid-April, stock the toxic fescue heavily (greater than 20000 lb BW/acre) to graze to a 1- to 2-in. height. This heavy grazing will minimize thatch for subsequent planting of warm-season grass and will also stress the fescue. After grazing, spray with glyphosate at labeled rates, usually 2.0—3.0 qt/acre. After 2 weeks, plant a tall warm-season annual, such as corn, sorghum, sudangrass, sorghum—sudangrass hybrids, or pearl millet, which can generate heavy shade at the soil surface. The warm-season grass can be utilized for ensiling or hay, but not for frequent grazing. Grazed stands of summer annuals do not "smother" as effectively as hayed stands. Make the final harvest in early August and allow 2—3 weeks for emergence of fescue from seed on the soil surface. Apply the second application of glyphosate (2.0—3.0 qt/acre) and wait at least 1 week before no-till planting the novel fescue at a rate of 20—25 lb/acre. A dense and closed canopy of the novel fescue can be obtained quicker if planted in rows that are perpendicular to each

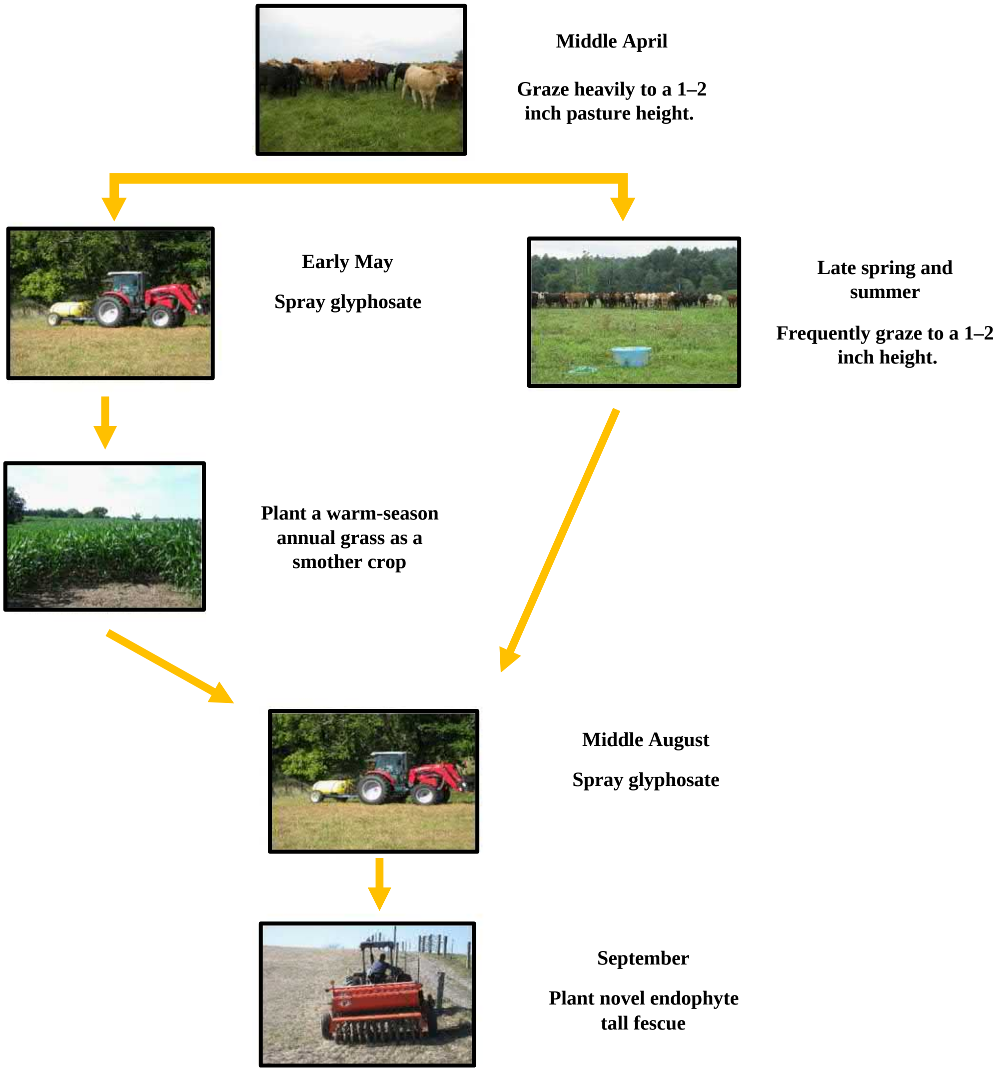

Figure 9.6 Options in establishing a novel endophyte–infected tall fescue to control volunteer emergence of toxic endophyte–infected tall fescue.

other. Seeding rate for each direction in the pasture will need to be 10–12.5 lb/acre. Fertilize with a light rate of nitrogen (30–40 lb N/acre) when plants average more than three leaves.

Graze and spray method

This technique grazes the toxic fescue frequently and intensively in the spring and early summer to weaken the stand and does not use a summer annual smother crop.

Figure 9.7 An emerging novel endophyte tall fescue that was cross drilled.

Application of metsulfuran-methyl (Chaparral) in early May will suppress emergence of seedheads and maintain the fescue in a vegetative stage of growth. This herbicide treatment will eliminate seedheads as a source of ergot alkaloids, and the cattle can effectively graze the vegetative fescue to 1–2 in. Graze again when the fescue is 4–6-in. in height. The close grazing and weakened fescue will allow emergence of summer weeds that should be periodically mowed to minimize seed production and accumulation of thatch. In early August spray glyphosate and wait 2 weeks to see if any old fescue or problem perennial weeds persist. Kentucky 31 tall fescue is somewhat tolerant of glyphosate and can require a second application in late summer prior to replanting. Wait at least one week after the final application of glyphosate before planting the novel tall fescue. As with the spray-smother-spray method, drill the field twice in opposite (perpendicular) directions using 10–12.5 lb/acre each time (Fig. 9.7). Apply a light rate of nitrogen fertilizer (30–40 lb N/acre) after seedlings reach the 3-leaf stage.

Break-even for establishment costs

Establishment costs for novel endophyte tall fescue can range from $175 to $275/acre. Economic return for this investment is greatest when highly infected stands of tall fescue are replaced. Under these circumstances (replacement of a highly toxic field), it is reasonable to achieve increases of 50%–100% in ADG of postweaned beef steers [15], 15%–30% in calving rates, or 30–50 lb of individual weaning weight [9]. With the additional revenue for these levels of improved cattle performance, establishment costs can be recovered in 2–3 years depending on the market.

Another consideration when deciding to replace toxic endophyte fescue with a novel endophyte fescue are opportunity costs, which is the loss of income when a new and proven technology is not adopted. Once establishment costs have been paid through alleviation of fescue toxicosis, the cattle producer has taken opportunity for their herd to perform at the maximum potential; otherwise, the producer is leaving money on the table.

Management to control encroachment of toxic fescue

Special management will be necessary to control reintroduction of toxic endophyte—infected tall fescue into pastures of novel endophyte fescue. Contamination from toxic tall fescue can come from seed movement from a toxic field or from emergence of seedlings from old seed present in the soil profile. Ideally, the levels of toxic fescue plants in novel fields will remain near zero, but low levels of toxic plants (even up to 20%) can be utilized by cattle without showing visible signs of toxicosis.

Pastures of toxic fescue can have high amounts of toxic endophyte—infected seeds in the soil that may germinate when exposed to optimum conditions of light and moisture. Contamination of novel fescue stands can be prevented by obtaining a thick, dense, and closed stand of novel fescue. When new stands are thick, dense, and closed, seeds of toxic tall fescue in the seed profile do not get an opportunity to germinate, emerge, and survive.

While the viability of the endophyte in bagged seed which is stored in warehouse conditions is substantially reduced in a year, the endophyte in toxic fescue seed dispersed in the soil can survive for 2 years. Therefore, it is critically important to maintain a thick, dense stand of novel tall fescue for at least 2 years to ensure there is no chance of contamination from old seed in the soil profile.

Novel tall fescue fields can also be contaminated by reintroducing toxic seed from cattle or in hay. Cattle moved from toxic Kentucky 31 fescue to novel fescue pastures can carry seed in hair, hoofs, or manure. Therefore, do not move cattle directly from a toxic fescue field with mature seed to a novel or nontoxic stand. It is generally accepted that seed can maintain some viability in the gastrointestinal tract of cattle for up to 3 days. If cattle have been exposed to toxic fescue seedheads and must be moved to a nontoxic field, it is strongly recommended that they be moved to an interim pasture or fed in dry lot for 3 days to a week prior to placement in a novel fescue pasture. It follows that cattle should not be directly moved from a toxic fescue pasture to a novel fescue pasture. Instead, they should be placed in dry lot and fed a nontoxic hay for 4—6 days prior to placement.

Toxic fescue hay should not be fed to cattle in novel endophyte fescue pastures. Seeds from the hay can litter the pasture or be consumed by cattle, potentially passing through the animal undamaged. Most fescue seeds consumed by cattle will be partially digested, but a small percentage may remain intact through the digestive tract.

The best way to minimize encroachment of toxic tall fescue is to maintain a dense stand of productive novel fescue and include application of any needed soil amendments. Soils should be tested every 2 years. Fertilization and liming recommendations should be followed to maintain healthy stands that can be productive with sufficient soil moisture.

Grazing management of novel endophyte

Novel endophyte–infected tall fescue should be rotationally stocked, leaving adequate residual heights after grazing (3–4 in.). Careful rotational stocking will maintain strong root systems, promoting good forage growth, and making the stand more tolerant of drought. This practice is especially important during summer. Because novel fescues do not induce heat stress, cattle will graze them closer and longer in summer compared to toxic tall fescue. In toxic tall fescue, the endophyte reduces forage intake in summer due to heat stress, which effectively limits overgrazing.

Adjust grazing management strategies with novel endophyte fescue to maintain a 3- to 4-in. residual height and prevent overgrazing. Six to ten in. of regrowth during paddock rest is needed before cattle are moved back into the padlock. Depending on the rainfall, these target grass heights can be reached in 14–21 days with active growth in the spring, but can take 28–42 days in the late summer depending on rainfall and temperature.

Grazing days per acre on novel tall fescue in summer will likely be less than on toxic fescue even if DM yields of forage are the same. This is because intake is reduced on toxic stands. Maintaining recommended residual grass height and limiting grazing periods per paddock to a week in mid-summer will help ensure a strong and persistent stand of novel tall fescue. A stocking density should be set, and cattle should be rotated to another paddock when the paddock is grazed to a 3- to 4-in. height.

Use of electrified polywire for cross-fencing and moveable waterers will allow rapid adjustment of grazed paddock areas to reduce stocking density and increase times for postgraze recovery and growth (Fig. 9.8). Paddocks can be increased in spatial area to reduce the stocking density and slow down cattle rotations with fewer paddocks (Table 9.3). As the number of paddocks are reduced, close attention must be given to ensure paddocks are not overgrazed.

Poor forage growth due to drought or high temperatures can lower pasture growth so that it becomes too limited to support even low stocking densities. Rather than weakening the stand by overgrazing, feed hay or move cattle to an alternative pasture of a nontoxic forage, such as warm-season perennial or annual grass. These pastures should be used to generate enough forage growth to carry the herd until there is 8–10 in. of novel fescue growth available for grazing.

Figure 9.8 Use of electrified polywire to subdivide rotationally stocked pastures for controlling paddock size and stocking density.

Table 9.3 Stocking densities for high, moderate, and low management intensities as paddock numbers are decreased to adjust stocking density in responses to declines in forage growth.

Management intensity	Total herd body weight (lb)	Stocking rate (lb/acre)	Paddock number	Stocking density (lb/acre)
High	125,000	1250	5	6250
			4	5000
			3	3750
Moderate	100,000	1000	5	5000
			4	4000
			3	3000
Low	75,000	750	5	3750
			4	3000
			3	2250

Orchardgrass

Orchardgrass is a perennial, cool-season bunchgrass, which is productive along the corridor. Orchardgrass is a desirable alternative to toxic endophyte−infected tall fescue (Fig. 9.9). Less competitive than toxic tall fescue, orchardgrass is well suited for mixing with red or white clover and can be planted with alfalfa for hay production or grazing. Orchardgrass is in high demand as hay, either in pure stands or especially with alfalfa because of its soft texture. Thinning stands of alfalfa can be drilled with orchardgrass to extend the productive life of the existing alfalfa stand.

Figure 9.9 Stocker calves grazing orchardgrass.

Orchardgrass can tolerate shallow, low fertility soils, but grows best on soils with adequate fertilization, especially nitrogen. As with tall fescue, soil potassium should be maintained above 180 lb/acre, phosphorus above 60 lb/acre, and pH above 5.8.

Rotational stocking is highly recommended for orchardgrass. Stands can rapidly deteriorate if continuously stocked with stocking rates that result in frequent defoliation below 4 in. Residual height management is important for orchardgrass because its tiller bases are the storage locations for soluble carbohydrates needed for regrowth.

Cattle should begin grazing orchardgrass pastures when forage height is 8−10 in., and removed when grazed down to 4−5 in. It is critical to reduce stocking densities as growth slows in mid- to late summer when air temperatures rise and rainfall declines. Overgrazing in these conditions can accelerate stand deterioration.

Warm-season grasses

Bermudagrass

Bermudagrass is a sod-forming warm-season perennial grass used for hay and pasture. Usually found more frequently in the Lower South, there are seeded types of bermudagrass genotypes that are successfully grown and maintained in the Middle and Upper South; however, acreage of bermudagrass remains low.

Although hybrids such as Tifton 44 and Quickstand have shown to be productive in the region, they must be planted with sprigs and not seed. Availability of sprigs and the equipment needed to dig and plant sprigs is low. Therefore winter-hardy seeded types such as Wrangler and Cherokee are more suitable for planting along the

I-64 Corridor. These seeded varieties were derived from common bermudagrass. Turf-type bermudagrasses such as Mohawk, Riviera, and Yukon can be planted for grazing, but their production of forage can be limited compared to other forage types [16].

New seeding of cold tolerant bermudagrasses are not as aggressive as sprigged bermudagrasses, and it can take 2 years to obtain a strong stand. Bermudagrass seed should be planted in May or early June when soil temperatures are above 60°F. Planting rate is 5–10 lb seed/acre at a depth of no more than ¼ in. deep in a tilled, fine-textured, and firm seedbed. Ideally the pasture should be plowed and cultipacked with heavy corrugated rollers prior to planting. The seedbed should be firm so boot tracks are no deeper than ½ in. Cultipack again after seeding to push the seed into the soil. If seed drills must be used, remove the seed tubes so seed is dispersed on the soil surface and follow with a cultipacking roller. It is difficult to calibrate drills to seed at the shallow depths required for bermudagrass.

Weeds will likely emerge with the bermudagrass and can be overly competitive with bermudagrass sprouts. If chemical control of weeds is necessary, use a postemergence herbicide labeled for bermudagrass. Remember that all weeds are easier to control when immature. Obtaining a stand in the first year will depend on early control of weeds.

After weeds are under control, topdress the bermudagrass with 30–50 lb N/acre. Another application of 50 lb/acre can be done during late September or early October to enhance green-up and early growth in the following spring. Soil phosphorus should be maintained between 60 and 90 lb/acre and potassium between 200 and 300 lb/acre. Adequate potassium fertility is required for winter survival of bermudagrass. Lime should be applied if soil pH is below 5.7.

Bermudagrass may be overseeded with white or red clover during the first dormancy period if it is well established. It is important to control thatch in bermudagrass because it restricts seedling survival and growth of clover in the spring. If there is more than 4 in. of growth and over 70% ground cover, the pasture can be grazed after the first freeze. Use a high stocking density to graze the dormant bermudagrass between 2 and 4 in. Broadcast clover seed on the pasture in late or early March in amounts that are not above the recommended planting rates. The objective of establishing and managing clover should be to obtain and maintain a clover stand that is visually estimated to be 20%–40% of the entire stand. Clover in a higher percentage of the stand can be too competitive with the new and developing bermudagrass. Dormant overseedings of clover work best on short grass and when precipitation is expected. Clover seed should be able to fall to the soil surface in order to be moved into the soil profile by the coming rain or snow. Overseeding clover can be successful during cycles of freezing and thawing, which can form ice crystals at the soil surface and push up bits of soil. As these crystals melt, the soil particles fall down, covering clover seed present at the surface.

Subzero temperatures can occur in the Upper South and will reduce spring green-up of bermudagrass. Bermudagrass will recover from these conditions, but the stand should not be heavily grazed in June to allow full recovery. Recovery can be accelerated if 30–50 lb N/acre is applied in May, even if clover is mixed with the bermudagrass.

Kentucky bluegrass, which encroaches into bermudagrass pastures, will extend the grazing season by providing additional growth in the fall and spring. Kentucky bluegrass matures early (mid- to late-April) and does not provide detrimental competition to the companion bermudagrass.

Bermudagrass can also be interseeded with cool-season annual grasses (rye, wheat, or ryegrass) to extend the grazing season with productive and high-quality forage. The small grains will mature before bermudagrass breaks dormancy. Rye matures in late April and wheat approximately 2 weeks later. However, the growing season of ryegrass extends into green-up and early growth of bermudagrass. Left unchecked, ryegrass growth can be detrimental to bermudagrass. Therefore, graze ryegrass during May with a grazing intensity to maintain it at 2–4 in. and provide the space needed for early growth by bermudagrass.

No-till drilling of bermudagrass with mixtures of small grains and ryegrass can provide a good distribution of growth in the spring with a slump in growth after the small grain matures (Fig. 9.10). Small grains will also provide more growth in the fall than ryegrass. As discussed, unchecked ryegrass growth in the late spring will weaken bermudagrass.

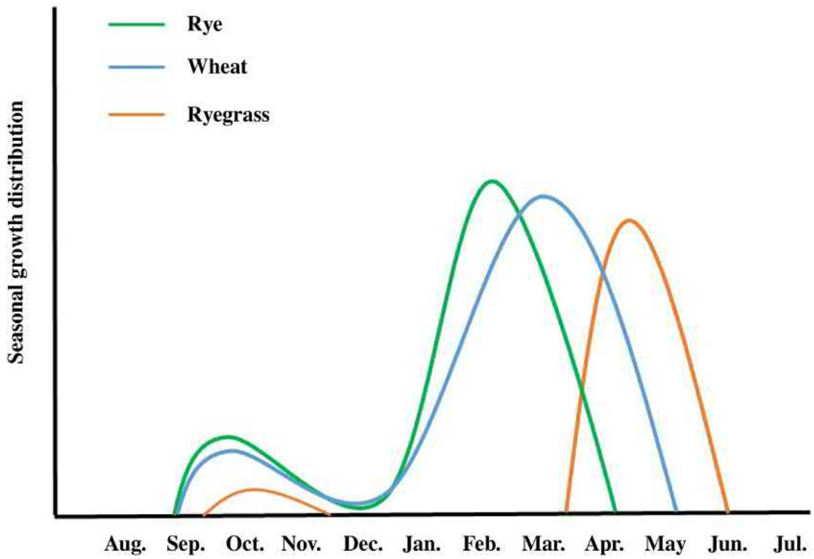

Figure 9.10 Seasonal growth distributions for rye, wheat, and ryegrass.

Warm-season perennial native grasses

Warm-season native grasses are another option to provide grazing during the growth slump of cool-season perennial grasses in July and August. The taller growing warm-season grasses (switchgrass, eastern gamagrass, big bluestem, and indiangrass) serve as excellent habitats and feed source for wildlife, and their deep and robust root systems will stabilize soils while improving soil structure.

Native grasses can provide high yields of high-quality forage, but good management will be necessary to sustain cattle production on these grasses. Grazing pastures of native grasses to plant heights less than those recommended can substantially reduce plant regrowth. Combined with low fertility and/or drought conditions, heavy grazing will cause plant loss and overall pasture deterioration.

When deciding whether to seed native season grasses, take into account the seed expense, slow establishment, and improved management required for their persistence. Seed of native grasses can be expensive, exceeding $12.00/lb of pure live seed in some instances. In addition, seedling emergence and growth can be slow and vulnerable to competition from broadleaf and grass weeds, which are more aggressive as seedlings. Stands may take 2 years to be productive, and there is a tendency to give up on new seedings too soon. It is common for newly seeded stands of native grasses to be very weedy and for the desirable grass to be difficult to see among the weeds. Therefore, the use of labeled herbicides (pre- and postemergence) is recommended where options exist.

While native grasses tolerate low soil fertility and marginal soils, the economic return is greatest when they are seeded on deeper, well-drained soils amended to recommended levels of P, K, and pH. Planting in deeper soils will produce higher yields and the more robust, healthy root systems needed for strong and productive native grass stands.

Eastern gamagrass

Eastern gamagrass should be planted into a firm, clean-tilled seedbed, or no-till drilled into pasture that has been treated with labeled rates of glyphosate (usually 2–3 qt/acre). Seed should be planted ½–1.0 in. deep, and should be scarified to break the chemical and physical barriers to germination. Seed scarification is the process of altering the seed coat to allow quicker water absorption and improve rates of germination. The seed or caryopsis of eastern gamagrass needs scarification because it is encased in a thick hull (called a cupule) that is only slowly permeable to water. This hull must be compromised or weakened to allow the water absorption needed to support germination. With eastern gamagrass, germination is accelerated by soaking the seed in cold water and then storing the moist seed in cold conditions for a short period of time. Seed that is not scarified can take up to 3 years to germinate.

Eastern gamagrass can require two growing seasons to fully develop and provide enough growth to withstand grazing. Eastern gamagrass should not be grazed until there is at least 2–3 ft. of growth. Grazing cattle should be removed when stand height reaches 12–18 in. Stands should then be allowed to reach 2–3 ft. in height (which usually takes 30–45 days) before regrazing.

Big bluestem and Indiangrass

These natives are tall prairie grasses that can be planted as monocultures or used as a mixture. Both have good heat and drought tolerance if not overgrazed.

Big bluestem and indiangrass should be planted in the late spring after soil temperatures are above 50°F. These grasses can be no-till drilled into short stubble following treatment with labeled rates of glyphosate. Drill seed ¼–½ in. deep at rates of 6–10 lb pure live seed/acre. Seeds can also be broadcast on a firm clean-tilled seedbed if the seeds are cultipacked into the soil using a corrugated roller. Seedling growth is slow; thus, new stands will be vulnerable to competition from summer annual weeds such as crabgrass. Establishment of the native grasses can be enhanced if 30 lb N/acre is applied 2–3 weeks after emergence if weed encroachment is not excessive.

Big bluestem and indiangrass should be rotationally grazed to maintain a 6 to 8-in. residual height after each grazing cycle. Fertilizing with nitrogen early in the season at 50–75 lb N/acre can enhance regrowth and support higher stocking rates. Allow 30–45 days of recovery between grazing cycles, and with regrowth slowing in late summer, recovery takes longer. Both grasses should not be grazed after the second week of September to allow root systems to replenish carbohydrate levels prior to winter dormancy. Apply needed fertilizer and lime as indicated by soil tests and remember that winter hardiness of native grasses is best when the potassium status of these grasses is adequate going into winter.

Warm-season annual grasses

Crabgrass

Crabgrass is a high-quality grass that readily volunteers in many pastures and is capable of reseeding. Monocultures of the grass are possible by planting one of the commercially available cultivars (Red River or Quick-N-Big) in April or May. Crabgrass should not be planted deeper than ¼ in., which is difficult to achieve using seed drills. Therefore, it is best to broadcast seed on clean-tilled firm seedbed followed by cultipacking with a corrugated roller to ensure proper planting depth and good seed–soil contact. Crabgrass can also be broadcast planted when drill planting rye or wheat into a clean-tilled seedbed. This can provide grazing from late fall to mid-April for rye, and late April to early May for wheat [17]. The small grains will mature and allow space for germination and emergence of crabgrass provided there is minimal thatch from other cool-season species.

Existing crabgrass can be increased in a mixture with other grasses by lightly disking to no more than 2 in. in the spring. This disturbance will increase exposure of crabgrass seed in the soil bank to sunlight, and will enhance germination. In addition, crabgrass seed can be broadcast over the disked pasture to further increase crabgrass cover for summer grazing.

Crabgrass can tolerate a wide range of soil pH between 5.5 and 7.5 [17]. For best production, apply 50–60 lb N/acre beginning in late May and again in July. Since crabgrass can accumulate nitrate, nitrogen rates higher than 60 lb N/acre should be avoided.

Crabgrass can set seed from July until first frost, and reseeding can continue indefinitely. Reseeding is more consistent if the pasture is grazed rotationally when plant height reaches 8–12 in., or when paddocks have been allowed to regrow for 14–21 days. Crabgrass will tolerate close grazing but will then form a low-growing, dense sod which provides limited grazing afterward. Therefore, cattle should be rotated when the grass is grazed down to a 3 to 6-in. height.

Marketing and managing beef feeder calves on cool-season perennial pasture

For a farm to be successful it must be economically as well as socially and environmentally sustainable. Maintaining optimal production at a relatively low cost is key to profitability. Another aspect of profitability for a farm is the development of a marketing program that optimizes the value of animals sold.

There are many ways to market beef feeder calves, such as (1) taking calves off the "momma cow" and sending them to the weekly auction, (2) weaning calves to get the "bawl" out of them and sending them to a graded sale, and (3) health-managing and backgrounding calves, then pooling with other producers to sell calves on a "board" or "video" sale in tractor trailer load lots directly off the farm. Other production and marketing options for beef cattle include (1) retaining ownership to growing yearling stocker cattle for sale off grass, (2) retaining ownership for feeding in a custom feedlot, and (3) finishing cattle on pasture and direct marketing beef to customers. Each production and marketing option has its own opportunities and challenges.

The majority of beef producers market their calves at or soon after weaning, but the best value may be from pooled marketing of health-managed, backgrounded calves. This management option should be carefully considered and implemented because both the profit potential and risks are greatest with these pooled calves.

Buyers for feeder cattle want a tractor trailer load (50,000 lb load) of healthy cattle of the same sex and a uniform weight. By pooling calves having similar genetics from different farms, it is possible to get tractor trailer loads of steers or heifers of uniform size. Using the same health-management protocol across farms ensures reduced health issues of calves. By backgrounding calves, they have learned to eat feed out of a bunk, and vaccinations have had time to increase disease immunity.

Several cow—calf operators are managing their weaned calves that follow protocols established by their state's Beef Quality Assurance (BQA) program. These programs are a cooperative effort between the states' extension service, cattlemen association, and department of agriculture. The program in West Virginia will be used as a typical example of cost-effective management and marketing of value-added feeder cattle.

Value of backgrounded-pooled marketing versus sale barn marketing

In West Virginia many farmers pool calves as part of the West Virginia Quality Assurance Feeder Cattle Marketing Program. This is a cooperative effort of West Virginia University Extension Service, West Virginia Cattlemen's Association, and West Virginia Department of Agriculture as affiliate members of the Mid-Atlantic BQA program. "The West Virginia Quality Assurance Feeder Cattle Marketing Program was established to enhance the reputation of West Virginia feeder cattle and to provide a marketing outlet for well-managed cattle. Applied and tested for more than 20 years, the health and management protocol has yielded excellent results for cooperating producers and buyers. Interested producers should contact their county extension agent or either of the state program contacts."

Over the last two decades West Virginia cattle producers have participated in about 14 marketing pools per year (Table 9.4). The majority of these producers (83%) are selling less than 50 head of steer and heifer calves, with all differing in weight. In an average year, the pooled sales account for 38% of the black- and black/white-faced calves sold in fall state-graded sales. The economic advantage of this program has been an increase in value of $68/head due to pooling, and an additional $88/head for steers and $68/head for heifers because of increased sale weight due to preconditioning. The total increase in cash value has averaged $150/head (Table 9.5).

Weaning and backgrounding on pasture

Producers wean and background calves on pasture or in a feedlot. Both systems work, but there are economic and health benefits from pasture backgrounding. To optimize the economic value of pasture backgrounding, management needs to understand three important factors (1) the value of added animal daily gain, (2) the cost of added gain when feeding supplements, and (3) the value of managing pastures for nutritive quality.

Table 9.4 Number and size of feeder calf marketing pools over 16 years in West Virginia with producer consignment size by calf sex compared to the similar grade of cattle sold in state-graded sales.

Feeder calf marketing pools	Avg.	Min.	Max.
Number of pools reporting data			
Gold Program	11	8	15
Silver Program	2	1	3
Total	14	9	18
Number of producers marketing			
1−9 head	21	10	38
10−24 head	61	33	93
25−49 head	56	31	77
50−74 head	15	7	23
75−99 head	6	0	9
100 or more head	7	3	11
Total	166	101	235
Number of feeder cattle marketed			
Total number of head	5876	4128	8107
Average consignment size	36	32	41
Total steers	3587	2561	4843
Average consignment size	23	20	27
Total heifers	2290	1463	3348
Average consignment size	16	14	18
Baseline data from graded sales			
Sale barns sampled	6	4	9
Sales reported and analyzed	23	14	35
Total cattle marketed	16,282	11,292	23,633
Total lots marketed	2014	1222	3790
Average lot size (number of head)	8	6	9
Total head under USDA feeder cattle grades	15,346	10,648	22,467
Total head comparable to pooled cattle	9661	5443	13,368
Number of feeder cattle marketed			
Total number of head	5876	4128	8107
Average consignment size	36	32	41
Total steers	3587	2561	4843
Average consignment size	23	20	27
Total heifers	2290	1463	3348
Average consignment size	16	14	18

Table 9.5 Economic impact of pooled marketing of feeder calves in West Virginia over 16 years.

Feeder calf marketing pool	Avg.	Min.	Max.
Value of BQA calf pool cattle			
Steers	$2,818,757	$1,721,752	$4,640,045
Heifers	$1,529,058	$880,371	$2,568,063
Total	$4,347,815	$2,602,123	$7,208,108
Calf pool prices versus Graded barn cattle			
Marketing advantage ($/Head)	$68	$40	$106
Total	$387,911	$177,813	$538,507
Calf pool weights versus graded barn cattle			
Steers—sale barn (lb)	560	529	582
Steers—calf pool (lb)	628	603	644
Difference (lb)	68	51	81
Added value ($/Head)	$88	$48	$195
Heifers—sale barn (lb)	523	499	546
Heifers—calf pool (lb)	574	548	589
Difference (lb)	51	40	66
Added value ($/Head)	$63	$34	$145
Total value added in weight gains	$448,597	$203,723	$835,411
Estimated savings in marketing charges			
	$24,771	$14,861	$51,690
Estimated total value added	$861,279	$501,755	$1,287,799
Estimated total value added ($/Head)	$150	$102	$271

Value of added animal gain

Most often, the value of beef cattle is in terms of price per pound or price per hundred weight (cwt). The historical trend is that as animals get larger, the price per pound decreases. This is referred to as the "price slide." More important to the producer is the value of the animal or dollars returned per head. Prices and value can be obtained from market news sources (Fig. 9.11).

Farmers who want to fine-tune their estimate of value of weight gain per head (Hd) can use the following relationship: Value of gain (V, $/lb) for animals weighing 600–699 priced at $134/cwt versus animals weighing 700–799 priced at $128/cwt is calculated as follows using weight class midpoint (M) weights:

MV = ($/Hd large animal − $/Hd small animal)/(Weight large animal − Weight small animal)

$$MV = ((\$/cwt_{large} \times cwt_{large}) - (\$/cwt_{small} \times cwt_{small}))/(cwt_{large} - cwt_{small})$$

$$MV = ((\$128 \times 7.5) - (\$134 \times 6.5))/(7.5 - 6.5)$$

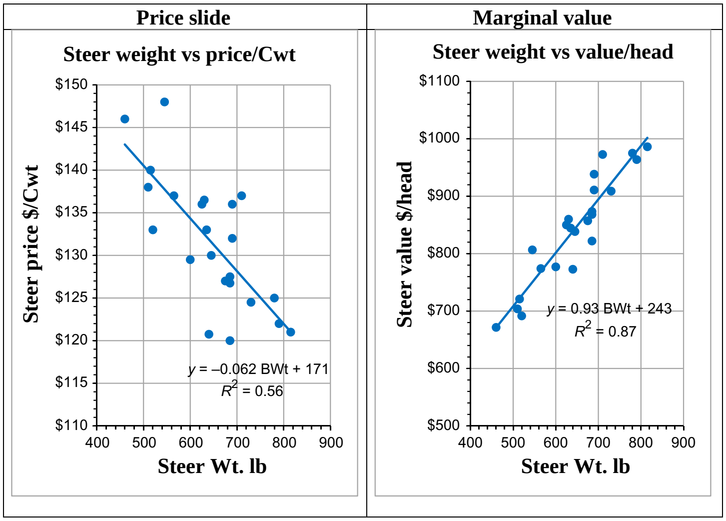

Figure 9.11 Comparison of steer price $/hundred weight and steer value $/steer body weight as steer body weight increases for health managed calves in the fall 2016 West Virginia Beef Quality Assurance sales.

MV = (($960) − ($871))/(1.0 cwt)

MV = $89/cwt gain or $0.89/lb gain

The same calculations can be done to evaluate the average price slide and marginal value of gain across the state in a given year (Fig. 9.11). For 2016, the average price slide for increase in weight for steers was $0.062/lb or $6.20/cwt. The average increase in value per head was $0.93/lb or $93/cwt gain. Knowing the value of gain is useful when deciding how much and what to supplement feed animals being backgrounded. In the West Virginia BQA sales from 2001 to 2017, the average marginal value of gain was equal to 0.75 times the price of 600−699 lb steers, for which 67% of the time ranged from $0.67 to $0.83/lb.

Annual variation in value of gain

Value of feeder cattle vary from year to year based on supply and demand of finished beef, feeder calves, and corn. As the value of finished beef increases, the value of feeder calves also increases. As the value of corn increases, the value of feeder calves decreases. When corn price is high there is increased value in retaining calves, and grazing them on pasture as stocker cattle for sale as yearlings.

Between 2001 and 2017 national finished steer and corn prices had a major impact on the national price of feeder steers. After adjustment for year and month, when corn price increased $1/bushel, 600−650 lb feeder steer prices decreased $6.35/cwt. When finished steer prices increased $1/cwt, 600−650 lb steer prices increased $1.44/cwt.

Year influenced feeder prices based on cowherd size and supply of feeder calves. Month influenced feeder prices due to the supply of feeder calves, with prices being \$6–\$11/cwt higher from April to September than in other months. Lightweight feeder steers (500–550 lb) had only a seasonal peak of \$8/cwt in June. Nationally, the price of 500–550 lb steer calves decreased \$8.39/cwt when the price of corn increased \$1/bushel and increased \$1.59/cwt when the price of finished beef increased \$1/cwt.

Yearling steers followed a trend similar to 600–650 lb feeder steers with peak prices being highest in June to September. This strategy works well in West Virginia for stocker operators who sell yearlings in July when prices are at their highest, and allows them to destock pastures prior to the reduced pasture growth rate which occurs mid-summer. Nationally, the price of yearling steers weighing 750–800 lb decreased \$4.85/cwt when the price of corn increased \$1/bushel, and increased \$1.15/cwt when the price of finished beef increased \$1/cwt.

Cost of adding gain when feeding supplements

When feeding supplements to animals on pastures, the net return depends on (1) the price of the feed, (2) the added gain provided from each pound of feed consumed, and (3) the value of the additional animal gain. Price of grain supplements change yearly based on the price of corn and protein feeds. Feed dealers can give price quotes for feeds based on specific formulations. The added gain achieved when feeding a supplemental grain on pasture can be determined by university or on-farm research. In West Virginia this was accomplished by on-farm research over 3 years on cool-season, grass–clover pastures. It was found that ground shelled corn increased ADG by 1 lb for every 3.7 lb fed, and a commercial 14% protein pellet increased ADG by 1 lb for every 4.7 lb fed (3.3 and 4.3 lb DM, respectively).

What and how much supplement to feed to calves backgrounded on pasture depends on the nutritive requirement of the growing animal (Table 9.6), the quality of the pasture grazed (Table 9.7), and the energy and protein content of the available supplements (Table 9.1). Calves stocked on grass–clover pastures respond best to a high-energy, low-protein feed such as corn, since the rumen bacteria need more energy to process the excess protein from the pasture. On a more mature grass pasture that is lower in protein, calves will respond to a high-energy, moderate-protein pellet since there is less excess protein in the forage.

The net return to feeding a small amount of cracked shelled corn to calves on a high-quality pasture may be estimated as follows:

- Cost of corn = \$5.60 per bushel (\$200/ton) or \$0.10/lb
- Cost of gain = 3.7 lb corn fed/1 lb added gain × \$0.10/lb = \$0.37
- Calf gain value = \$0.92/lb
- Estimated return to feeding corn = \$0.92 − \$0.37 = \$0.55

Table 9.6 Animal body weight (BW) and average daily gain (ADG) determine dry matter intake (DMI) and the requirement for crude protein (CP) and total digestible nutrients (TDN).

BW (lb)	ADG (lb)[a]	DMI (lb)	CP (%)	CP (lb)	TDN (%)	TDN (lb)
400	2.0	11	12.7	1.4	68	7.5
	2.5	11	14.2	1.6	74	8.1
500	2.0	13	11.4	1.5	68	8.8
	2.5	13	12.5	1.6	74	9.6
600	2.0	15	10.5	1.6	68	10.2
	2.5	15	11.4	1.7	74	11.1
700	2.0	17	9.8	1.7	68	11.6
	2.5	17	10.5	1.8	74	12.6

[a]Excess CP reduces ADG by 0.2 lb/10% units CP due to urea energy cost.

Table 9.7 Pasture nutritional value for dry matter (DM), crude protein (CP), total digestible nutrients (TDN), and neutral detergent fiber (NDF) grown for spring backgrounding of fall-born calves in Pender County, North Carolina, and fall backgrounding of spring-born calves in Monongalia County, West Virginia.

Pasture	DM (%)	CP (% DM)	TDN (% DM)	NDF (% DM)
North Carolina spring pasture				
Max Q2 Tall Fescue 1	18	25	75	40
Max Q2 Tall Fescue 2	21	17	73	45
Max Q2 Tall Fescue 3	14	25	71	49
Max Q2 Tall Fescue 4	28	15	66	57
Max Q2 Tall Fescue 5	15	19	66	61
West Virginia fall pasture				
Mixed grass–clover 1	22	19	71	40
Mixed grass–clover 2	24	24	69	45
Mixed grass–clover 3	23	18	67	50
Mixed grass–clover 4	25	15	64	55

When feeding 14% CP pellets:

- Cost of 14% CP pellets = $250 per ton or $250/2000 lb = $0.125/lb
- Cost of gain is = 4.7 lb pellets/1 lb gain × $0.125/lb = $0.59
- Calf gain value = $0.92/lb
- Estimated return to feeding pellets is $0.92 − $0.59 feed = $0.33.

What and how much to supplement?

Calves should be supplemented with nutrients if the nutritive value (determined by forage sampling and testing) or availability of forage (determined by measuring and forage budgeting) are limited in the pastures.

When backgrounding calves on pasture it is recommended to provide total digestible nutrients (TDN) and CP from pasture and supplement to achieve a 2.0–2.5 ADG or more (Table 9.6). To accomplish this, pastures should be sampled and air-dried forage samples sent to a certified forage testing laboratory to quantify the forage's TDN, CP, and NDF content. This can be done weekly prior to placing calves into a new pasture. When doing this over several years, a historical record of pasture quality is developed for the farm (Table 9.7). When supplementing calves on a high CP pasture, a small amount of high-energy, low-CP supplement such as rolled barley, cracked shelled corn, or hominy feed may be the most cost-effective option. When available and properly priced, some low-CP supplements with highly digestible fiber such as beet pulp, citrus pulp, and soybean hulls are useful. However, beet pulp is often overpriced since it is preferred by horse owners, and citrus pulp has become less available due to reduction in production from Greening Disease in Florida orange groves. When protein is needed, supplements high in TDN and CP such as corn gluten feed, distiller's grain, and soybean meal can be added to increase the mixed supplement's CP content. In the south, there are other by-products that should not be used in formulating backgrounding supplements. These include peanut hulls and cotton gin trash that are too low in TDN value to be beneficial to calves. These products are excellent for supplementing dry cows, but their energy content is too low for growing cattle.

The amount of supplement to feed can be estimated using the "Pearson square" method. The Pearson square takes three numbers: (1) the nutritional requirement of the animal (in CP or TDN, amino acids, minerals, or vitamins), (2) the percent of the nutritional requirement found in the first input (pasture, supplement, etc.), and (3) the percent of the nutritional requirement found in the second input. For example, in Table 9.8 the TDN requirement of a 600 lb steer calf having a 2.5 lb ADG is 74% (from Table 9.6). This number is placed in the center of the Pearson square diagram. On the left side, top and bottom, the percent TDN of the pasture (71%) and percent TDN of the supplement (90%) are placed. Cross-subtract each ingredient/pasture TDN from the animal's required TDN to get the proportion of each that is needed by the animal (use absolute value and ignore any negatives). For Table 9.8 we need 3 parts corn and 16 parts NC Pasture 3 to achieve the target 75% TDN. To convert these "parts" into percent, simply total the parts, then divide each part by the total to get the percent of that part needed by the animal. For example in Table 9.8, 3 parts Corn and 16 parts NC Pasture 3 are needed. Total parts = 3 + 16 = 19. Percent Corn needed = 3/19 = 16%. Percent NC Pasture 3 needed = 16/19 = 84%.

The input's CP contribution to the ration is calculated by multiplying the percent of the input needed by the CP of that input (i.e., Corn: 16% corn × 10% CP in corn = 1.6% CP; Pasture: 84% pasture × 25% CP in pasture = 21% CP). These are added together to get the total CP percent in the ration (total ration CP = 1.6% + 21% = 22.6%).

Table 9.8 Balancing supplements with pasture for energy (TDN) using the Pearson Square method.

Balancing supplement rations

A. **Corn on high CP pasture**

Feed	TDN in feed (%)	TDN ration (%)	Proportion in ration	Fraction in ration	CP in feed (%)	CP in ration (%)
Corn	90	74	3	0.16	10	1.6
NC Pasture 3	71		16	0.84	25	21.0
			19	**1.00**		**22.6**
Steer wt.	DMI			DMI	Air dry	
600	15		Corn	2.4	2.7	
			Pasture	12.5		
			Total	**14.9**		

B. **Corn on moderate CP pasture**

Feed	TDN in feed (%)	TDN ration (%)	Proportion in ration	Fraction in ration	CP in feed (%)	CP in ration (%)
Corn	90	74	8	0.33	10	3.3
NC Pasture 4	66		16	0.67	15	10.0
			24	**1.00**		**13.0**
Steer wt.	DMI			DMI	Air dry	
600	15		Corn	5.0	5.4	
			Pasture	10.0		
			Total	**15.0**		

C. **Pellets on moderate CP pasture**

Feed	TDN in feed (%)	TDN ration (%)	Proportion in ration	Fraction in ration	CP in feed (%)	CP in ration (%)
14% Pellets	80	74	8	0.57	16	9.1
NC Pasture 4	66		6	0.43	15	6.4
			14	**1.00**		**15.5**
Steer wt.	DMI			DMI	Air dry	
600	15		Pellets	8.6	9.4	
			Pasture	6.4		
			Total	**15.0**		

Intake of DM (DMI) from each input is based on these percentages and estimated by multiplication (corn 0.16 × 15.0 DMI = 2.4, pasture 0.84 × 15 = 12.6 for a total DMI of 15.0). Air Dry weight of supplement feed is calculated by dividing supplement DM by the DM content of the feed (i.e., corn 2.4 lb DM/0.90 DM = 2.7 lb Air Dry feed).

When feeding ground shelled corn on high-quality pasture, as little as 0.5% of BW may be needed to balance the energy and protein intake to achieve an ADG of 2.5 lb. Pellets are often feed at 1% of BW. It is desirable to minimize overfeeding CP since excess CP in the diet requires extra energy to break down protein into urea for excretion. Excess protein reduces calf ADG by about 0.2 lb for every 10% CP over the animal's requirement.

For pastures high in CP, feeding a high-energy, low-protein supplement is important. In Table 9.8 we have balanced TDN for a 2.5 lb ADG. However, the CP exceeds the calf's nutritive requirement by 11% (see Table 9.6); thus, ADG will be suppressed by about 0.22 lb due to the extra energy required to convert the excess CP to urea. In this case we would expect an ADG of about 2.3 lb and not the goal ADG of 2.5 lb. For a pasture lower in CP, which is also lower in TDN, more corn may be fed, and the ration is more in line with the CP needs of the calf with little excess CP to depress performance. When a 14% CP pellet is fed on a pasture with lower CP, more supplement may be needed since the TDN in the pellets is lower than TDN in corn.

How much pasture is needed?

A grazing animal on high-quality pasture may consume 2.5%–3.0% BW in DM. Pasture growth should be young (3–6 weeks of age) and preferably with 25%–35% legume content. New pasture should be provided every 1–7 days using rotational or strip grazing management that allows calves to consume one-third to one-half of the initial standing forage. Adequate NDF intake (NDF intake as 30% of DMI or greater from forage) can be ensured by providing free choice to dry hay, and allowing calves to eat as needed. Managers should budget an additional 10%–20% pasture acreage to allow for weather risk. Dry weather slows pasture growth, while wet weather reduces grazing efficiency. Pastures containing 25%–30% legumes have lower NDF content which can result in higher DMI and about 0.5 lb greater ADG than grass-only pastures at the same regrowth age. Likewise, less mature pastures that have lower NDF will allow greater pasture DMI than pastures with older growth, as older growth has higher NDF content and DMI less than 2.5% BW.

We can estimate pasture available for grazing as follows:

- Initial pasture, 10-in. tall has an estimated forage mass of 3060 lb DM/acre
- Residual pasture, 6-in. tall provides an estimated forage mass of 2080 lb DM/acre
- Estimated forage available for grazing = 3060 − 2080 = 980 lb DM/acre (32% initial forage mass)

Animal days grazing per acre can be estimated as follows:

- Supplement DM = 600 lb. Calf fed supplement at 1% BW DM = 6 lb
- Calf potential DMI = BW × 0.025 = 600 × 0.025 = 15 lb
- Pasture DMI = Calf potential DMI − supplement DM = 15 − 6 = 9 lb
- Forage available for grazing = 980 lb
- Animal days of grazing per acre = forage available/pasture DMI = 980/9 = 109 days/acre

Therefore to calculate the acres needed to graze 30 calves for 45 days:

- 30 head × 45 days = 1350 animal days
- 1350 animal days needed/109 animal days/acre = 12.4 acres
- Plan for 14−15 acres

Unintended consequences

Participating in marketing pools has several positive unintended consequences which include: (1) improved cow health from a health management vaccination program, (2) increased timely conception due to increased cow body condition after weaning, and (3) improved information for selecting most efficient cows using production records.

Judicious use of vaccinations for disease prevention and the use of appropriate parasite control are cost-effective ways of improving overall cowherd health. Less readily apparent is the value of improved cow body condition at weaning, increasing her chances for conception of next year's calf. Cows at weaning may have reduced body condition. By weaning calves prior to marketing and providing adequate pasture to the dry cow, it is easy to increase body condition of the cow prior to calving (Table 9.9). As cow body condition increases to 6 or higher,

Table 9.9 Weaning calves in September and grazing cows on tall fescue pasture to January, 1, increased body condition score (BCS).

Body condition of cows					
BCS	**Cows with this BCS in Sep (%)**	**Cows with this BCS in Jan (%)**	**Cows conceiving (%)**	**Cows conceiving if calving in Sep (%)**	**Cows conceiving if calving in Jan (%)**
3	0.03	0.00	0.30	0.01	0.00
4	0.26	0.03	0.55	0.14	0.01
5	0.45	0.31	0.80	0.36	0.25
6	0.23	0.46	0.95	0.22	0.44
7	0.03	0.16	0.95	0.03	0.15
8	0.00	0.05	0.95	0.00	0.05
Total	1.00	1.00		0.76	0.89

Cows calving in the improved BCS will potentially have a greater conception rate than they would if calved at the lower BCS.
Source: Adapted from Pasture based livestock production.

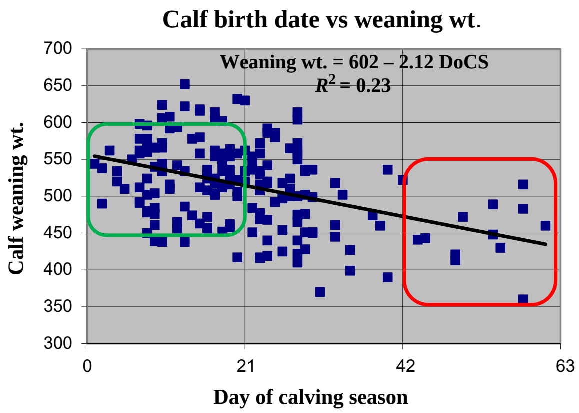

Figure 9.12 Weaning weight of calves within a herd compared to the day of the calving season on which they were born. Red box at right are cows that breed late producing lightweight calves. Green box at left are cows that breed early producing heavier weight calves and heifers that should be selected for potential replacements.

conception increases. As a higher percentage of cows are at the preferred body condition score, more cows will conceive providing a larger calf crop the following year.

Production records on each cow provide management with the information to evaluate which cows are making money. The first consideration in retaining a cow is if she is pregnant. The second consideration is how early in the calving season she calves. Cows that calve in the first 21 days (conceived in the first heat cycle) produce heavier calves than those calving in later heat cycles. With an average weight gain of 2.12 lb/day, an additional 45 lb per calf can be achieved per heat cycle (Fig. 9.12). With a 63-day calving season, calves born in the last 21-day period will average 90 lb lighter than calves born in the first 21-day period. Late-calving cows should be considered as culling candidates after removing open cows from the herd.

Heifer calves from cows that consistently calve in the first 21 days should be the primary candidates for replacement heifers since their dams have proven ability for consistent rebreeding. Often producers will select the "best looking" heifers (largest, sleekest looking) for their replacements. However, choosing replacement heifers based on size will result in selecting for larger cows in the herd. When evaluating cow efficiency, smaller cows are often more efficient than large cows. For example, Fig. 9.13 shows increasing the cow size by 100 lb increased adjusted weaning weight by only 5 lb in the herd. When measuring cow efficiency as a calculation of calf weaning or sale weight divided by cow weight, cows weighing 1000 lb produced at 50% efficiency while cows weighing 1300 lb produced at 40%. The smaller cows were

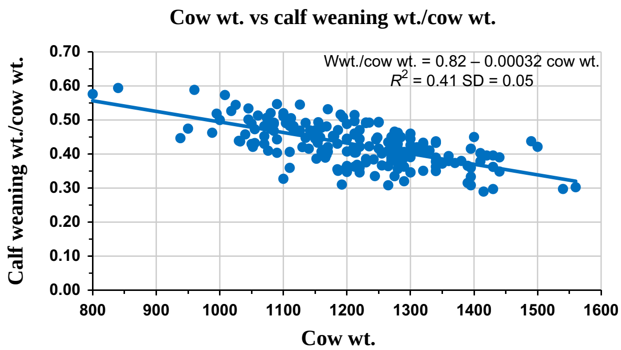

Figure 9.13 Cow production efficiency expressed as calf weaning weight per unit of cow weight across the range of cow weights in the herd.

25% more efficient than the larger cows. Even when adjusted for expected DMI based on a metabolic weight, the smaller cows were still 15%–18% more efficient than the larger cows. Moderate frame heifers from cows consistently breeding in the first heat cycle are the best candidates for replacement heifers since they will be more efficient based on calf weight per cow weight and more consistent in producing a calf each year in the first heat cycle.

Pooled marketing provides an opportunity for increased net income, improved herd health, and increased potential herd performance. It does require cooperative efforts and compromises between individual managers as they strive to make the local beef industry more sustainable.

Summary

The soils and climate of the I-64 Corridor are highly conducive to forage-livestock agriculture. Beef cows and calves comprise the dominant livestock enterprise in the region. Farms along the corridor account for approximately 15% of the total US beef herd. The forage base for these beef farms is predominantly cool-season perennial grasses and a diverse mix of cool- and warm-season grasses, as well as clovers. The dominant grass in the region is tall fescue, and most of this is infected with the toxic endophyte. Mitigation and replacement options exist for toxic tall fescue that can provide improved per acre returns to livestock producers. Economic returns from the forage-livestock enterprise in the I-64 Corridor are important at the state, regional, and national levels. Some cattle producers are taking advantage of retaining ownership of their calf crops to add value by backgrounding on pasture and following a certified health program.

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CHAPTER 10

Pasture-finished beef production in the south

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All Flesh is Grass

Isaiah 40:6

The current system for commercial beef production in the United States is composed of cow/calf farms spread across the country that produce feeder calves, and feedlots in the high plains and midwest where cattle are finished on high-concentrate diets. It is estimated that 97% of the finished beef in the United States comes from feedlots [1]. For many years forage scientists and other forage enthusiasts have envisioned a system of pasture-finishing that would allow feeder cattle to move only short distances from southern cow/calf farms to pasture-based finishing systems. The mild winters in the south which lead to potential year-round forage production have kept the dream alive of a radically different beef production system. Despite decades of research evaluating forages and feeding systems for finishing cattle on pasture, there has been little commercial scale production, due to the lack of a well-defined market and large packers to support the envisioned industry.

In the past, there has been a market for "freezer beef" across the south that was supported by small local packers who processed on a custom basis. In this system the producer finished beef animals (usually on high-grain diets) and sold them to customers who paid for the processing and picked up the beef (which was labeled "not for sale"). This system still exists on a small scale, and it bypasses USDA-FSIS inspection, but it only works well for consumers who want to purchase a whole animal. Over time, the dramatic loss of these small custom packers, and a decrease in consumers wanting to purchase whole animals greatly reduced this system. In the past 20 years

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there has been increasing demand for pasture-raised beef based on social concerns about animal welfare in the feedlot production system, the widespread use of growth-promoting hormones, the widespread feeding of antibiotics, and perceived health benefits of the meat produced in "grass-fed" systems [2].

The advent of farmers' markets, the internet, and the local food movement have created demand for "niche meats" from all food animal species. This niche meat market is being explored by many farmers across the south, especially near metropolitan areas where the population is concentrated. Much of the demand for these products is based on the fact that they are "local" [3]. There is no clear definition of local, but in our experience, local has been defined as being produced in the same state, or adjacent states, to the point of sale. A further distinction between these products includes the type of production system used and may include claims that the beef is certified organic, 100% grass-fed, pasture-raised, pasture-finished, corn-fed, animal welfare certified, along with others. Many of the points raised in this chapter impact all these types of local beef production; however, we will refer primarily to systems of pasture-raised beef. This may include production on pasture with a 100% forage system (100% grass-fed or forage-fed), or it may include some supplementation to achieve carcass quality targets at a specified time. The key attribute is that the animal remains on pasture throughout its life, and forages make up a majority of its diet.

While demand for pasture-raised beef is growing across the region, the growth of local beef and other niche meat production has been especially rapid in North Carolina. Independent farmers registered as meat handlers with the North Carolina Department of Agriculture and Consumer Services increased from 2 in 2002 to 1291 in 2018 [4]. Most of these producers are selling a few head at a farmers' market, while some have worked with an aggregator who provides a wholesale market. Others have scaled to the point of having enough supply to work with grocery stores and food distributors. Direct marketing by meat handlers surveyed totaled 1531 beef cattle; 3461 pigs; 35,695 chickens; 2244 sheep; and 89 goats [5]. Because this survey did not include marketing by aggregators, nor were all North Carolina farmers surveyed, the total production in the state was underestimated. The survey did, however, demonstrate the mix of livestock being raised for the local niche meat market.

The lure of producing niche beef is clearly stimulated by the market prices being received. In North Carolina, there is a USDA monthly report on prices received for grass-fed beef. Typically, retail beef cuts from grass-fed cattle are about twice the price of commercial feedlot beef cuts [6]. The price for other local beef products is similar to grass-fed, depending somewhat on the local market. Despite these higher prices, 71% of producers in the most recent survey indicated they were not making a profit [5]. Key factors that contribute to challenges in profitability include high infrastructure costs, high input costs, and lack of economy of scale. Despite this, 92% of producers plan to either grow or maintain their level of production. Marketing challenges remain a major concern with farmers, and most recognize that it is very difficult to scale their production systems without access to a wholesale market. In short, many of the farmers would rather raise the animals and let someone else handle the marketing, but lack of wholesale markets limits that option. There is great potential for "aggregators" to expand the market penetration of these products by coordinating production among groups of farmers using uniform finishing guidelines [7].

Types of local beef production systems in the south

Production systems in the South vary widely, from small feedlots with cattle receiving high levels of concentrate feeds, to 100% grass-fed cattle. In the 2016 survey of local beef producers in North Carolina [5], results showed that 56% use concentrate supplements; whereas 44% do not use concentrates.

Feedlot systems

While most consumers are looking for beef products which do not come from a feedlot-type system, there are examples of farmers who have created small feedlots and feed cattle typically on corn silage and concentrates [8]. Most of these do not use implants or feed antibiotics, as those inputs are widely discriminated against in the local beef market. These systems produce very high-quality products that are popular with chefs and other markets demanding a high choice or prime product; however, they lack the attribute of pasture-based production and often utilize corn as a concentrate. While some of these systems are successful across the region, the problems with mud during confinement feeding and the necessity of being competitive with other high-quality conventional branded beef products on the market limit the interest in these systems.

Pasture-raised and pasture-finished beef

Most of the production of "local beef" in the south is found in pasture-based systems. Most consumers want to know that cattle were not kept in confinement, that they were on pasture with good ground cover, and the majority of their diet came from forages [5]. While the basis for the system is pasture and forages, concentrates may be fed to improve performance during times when forage quality or quantity are limited. Usually concentrate feeding is limited, but in some cases, cattle may be fed with self-feeders or hand-fed all they can eat of a total mixed ration while on pasture. Pasture-raised and finished systems have the advantage over 100% grass-fed systems in that the farmer has the ability to maintain growth in the cattle even when grazable forages limit performance to levels known to impact meat quality.

With typically low forage quality in southern systems, use of a supplement can greatly improve the performance of cattle, thereby allowing them to reach finishing at the desired age. In Arkansas [9] feeding 1% of body weight of soybean hulls to cattle grazing either fescue or orchardgrass improved average daily gain from 1 (with no supplement) to 2 lb/day. The supplemented cattle also had dramatically improved carcass quality and weight when harvested at the same age as the nonsupplemented cattle. Fatty acid composition showed that beef from the soybean hulls supplemented cattle was similar to 100% grass-fed cattle.

There are a wide variety of concentrates that may be useful for supplementing cattle grazing Southern pastures. These can be classified as "starchy concentrates" including corn, small grains, and processing by-products with a high level of starch like hominy feed or wheat middlings. Other concentrates are primarily fiber-based, including soybean hulls and corn gluten feed. The fiber-based concentrates are digested more slowly than the starchy concentrates, and as a result, have fewer negative effects on fiber digestion and ruminal pH. Also, when the potential supplement contains fats or oils, it can have an impact on the fatty acid composition of the meat. Supplements rich in corn or soybean oil (like full-fat distiller's grains) would result in more omega-6 polyunsaturated fatty acids ($n-6$) being deposited in the meat, causing the n-6 to omega-3 ($n-3$) ratio to be higher. If a low $n-6$:$n-3$ ratio is desired, then supplements should be low in corn oil and other oils, which are high in $n-6$. Since lipids in forages are high in $n-3$ fatty acids, when the diet is kept low in $n-6$, the $n-6$:$n-3$ ratio in the meat will naturally be low. Some concentrate supplements, such as flaxseed, contain a high level of omega-3 fatty acids and would be beneficial to the $n-6$:$n-3$ ratio [10].

In many markets for local beef, there is an aversion to the use of corn as a supplement. This is sometimes due to the concern that corn is not a "natural" feed for cattle, and the concern that feeding a very high level of starch may lead to acidosis, liver abscesses, and other problems sometimes seen in feedlots [11]. Feeding high-starch diets can cause some production problems in cattle, but at a low level, starch can be quite beneficial [12]. Even though there is no clear biological reason not to use a small level of corn in the diet, many chefs and other consumers still do not want beef that has been fed corn at any level. This aversion to corn is also related to social concerns about the domination of the corn industry in our food system as described well by Michael Polan in *The Omnivore's Dilemma* [13].

100% grass-fed beef

One hundred percent grass-fed refers to beef from cattle that have been fed nothing but forages for their entire lives. Feeds usually can include grazed or harvested grasses, legumes, and forbs. While it is quite possible to finish cattle on forages, it generally takes specialty forages (annuals) and a very high level of management that allows for high-quality forage on a year-round basis. When farmers must rely on the base forages common in the south, including bermudagrass, bahiagrass, and tall fescue, there will be periods of low forage nutritive value and low performance. Also drought conditions can limit the production of these high-quality grazable forages, so many producers turn to high-quality harvested forages to keep cattle gaining in these systems. It is a generally held concept that average daily gain needs to be more than 1 lb/day at all times to achieve adequate carcass quality [14]. Most farmers in the south with a grass-fed system use annual species, high-quality perennials such as alfalfa and novel endophyte fescue, and high-quality harvested forages to plug gaps in the forage base so that average daily gain is high and cattle achieve finish at a reasonable age (20−30 months). Often, farmers with pasture-based systems that produce very high-quality beef do not consider marketing cattle at less than 20 months of age, when their skeletal and muscle growth rates slow, and they begin to deposit most of their retained dietary energy as fat.

> ***One of the major problems associated with producing forage-finished beef in this area (Upper South) is the seasonality of maximum and high-quality production of forage. A forage-finishing program almost dictates the use of the faster maturing cattle.***
>
> **A.E. Spooner and Maurice L. Ray, Arkansas (1977)**

Currently about 70% of the grass-fed supply in the United States comes from imported beef, which runs counter to the demand for "local beef" and seems confusing to consumers and farmers. This imported supply is typically less expensive than domestic grass-fed beef. Therefore it is attractive to restaurants that want to serve grass-fed beef, need a reliable wholesale supply, and are averse to the high price of local grass-fed beef.

Certified organic

There are examples of farmers in the south who produce "certified organic" beef for local markets, but they are relatively few. There is some demand for organic beef, but the cost of production is high due to the limited inputs allowed and the requirement to use "certified organic" feeds. Also producing cattle in the south without access to dewormers, antibiotics, etc., is especially challenging. Additionally, the requirement for an organic certified processor greatly limits potential for organic systems. Because of these limitations, much of the certified organic beef supply comes from outside of the south.

Biological and system efficiency

Cost of production of beef produced in a pasture-based system is high relative to commodity beef, due to inherent system inefficiencies (biological) and small scale of production. When cattle are fed on a high-forage diet, relative to a high-concentrate diet, they develop a larger gut to process the bulky feed. Dressing percentage of cattle finished in a forage-based system is typically about 58% compared to about 62% for cattle fed on concentrates [15]. Much of this is due to more gut tissues that have a high maintenance requirement, which cuts into energy available for growth [16].

Some theoretical assumptions and projections have been made recently to determine the impact on the US beef industry if all finished cattle came from a 100% grass-fed system compared to the conventional feedlot system [16]. Based on this work, it would take a 30% increase in the national cow herd to produce the same amount of beef. Also, if the land base currently used for the beef system (including pasture and feedlot phases) were converted to support a grass-fed system, we could only produce 61% of the beef currently produced in the United States.

Capper [17] modeled three beef production systems: (1) conventional feedlot with all growth-promoting inputs; (2) "all natural" feedlot with no growth-promoting inputs; or (3) grass-fed on the farm of origin. This analysis showed that from an energetic standpoint, the conventional feedlot beef system was more efficient than the natural feedlot beef system, and both of those were much more efficient than the grass-fed system. Using inputs for the grass-fed system, it was also the least desirable from an environmental perspective. The authors assumed that half the acreage grazed to produce grass-fed would be irrigated, and that they would have lower average daily gains and end weights than what can be obtained with conventional feedlot cattle. However, no credit was given for carbon sequestration in pastures, which could offset some of the gaseous emissions from the cattle. Carbon sequestration in well-managed pastures is an important component to study in the future to better understand the net impact of finishing cattle on pasture. Additional modeling and production research are needed to clarify the efficiency of these diverse production systems.

Some of the lack of efficiency in local beef production in the south is due to limited access to local processors. While there are some small processors remaining across the region, there is still inadequate processing capacity to support a growing level of production. In North Carolina there are approximately 15 small packers spread across the state who are under federal or state inspection, that work with individual farmers, and also provide all the basic services needed for that farmer to sell a professionally packaged and labeled product. The need for inspection makes the old "custom" harvest plants poorly situated to meet the needs of customers who require inspection for direct marketing through most market chains, and who also require advanced processing capability, including packaging and value-added processing, to enhance the marketability of their products. Federal inspection is needed for interstate marketing of beef. Therefore it is critical that federally inspected processors are close enough to the farm of production to make it easy to transport cattle to the processor and then to return to pick up the meat. The work of the NC Choices program in North Carolina [18] has helped local processors to retool to meet the needs of their new customer base including the production of added value products, such as various types of charcuterie. Also programs like the Carolina Meat Conference [19], a semiannual event that attracts farmers, small processors, and other allied industry personnel to discuss all aspects of production, processing, and marketing, has helped improve efficiency throughout the supply chain. Unfortunately the cost of processing for these small processors in NC may be as much as five times higher than is typical for large-scale commercial processing, due to their small throughput and lack of markets for offal, hides, etc.

Most farmers wishing to add some finishing cattle currently have cow/calf operations [5]. When calves are kept after weaning and backgrounded on their home farm, they begin to compete with the cow herd for forage resources, as their total digestible nutrients (TDN) requirement increases by 10% (Fig. 10.1). Finishing calves in a high-grain local feedlot system adds a relatively small demand on forage resources, as cattle are marketed at a young age, and only a small amount of the extra feed is from forages. Alternatively, when a pasture-finishing system is used, substantially more forage resources are required. When cattle are raised on forages and fed 1% of body weight concentrate for the last 120 days, 62% more forage TDN is required than in the cow/calf phase. When cattle are finished on a 100% grass-fed system, 103% more forage TDN is required than in the cow/calf phase. If half the calves were finished in either of these systems, then the forage TDN requirement would increase by 31% or 51% for the pasture-finished and the grass-fed systems, respectively.

If the finishing is to be done on the same land base, then a farmer would need to reduce the cow herd to account for the extra forage needed by the finishing animals.

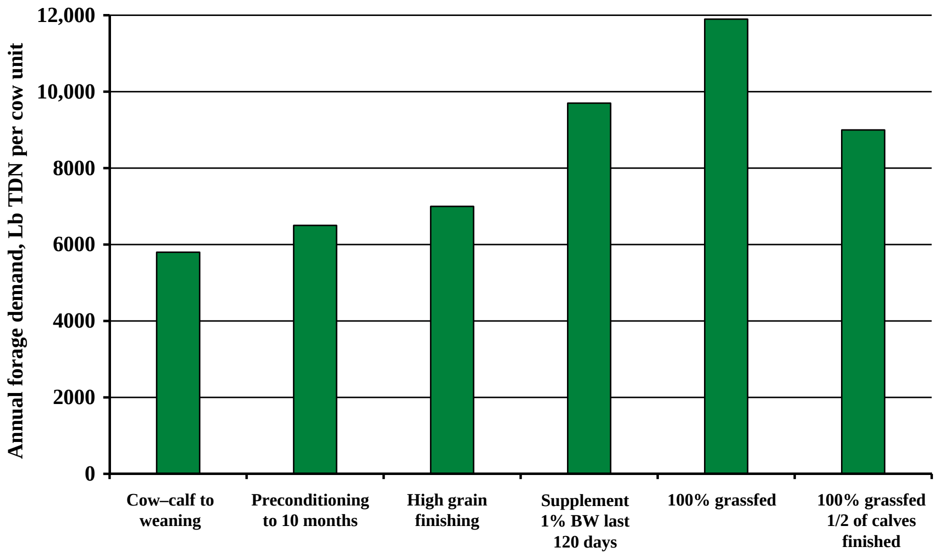

Figure 10.1 Forage total digestible nutrient demand for local beef finishing system. Calculated from Nutrient Requirements for Beef Cattle, 1996 [20].

Essentially, this analysis shows that if a farmer wishes to use their current resources in a finishing system, they would have to reduce their cow herd by one cow for every 1.6 calves finished in the pasture-raised system, or one cow for every calf finished in a 100% grass-fed system (Fig. 10.1).

Marketing

Most of the markets for pasture-raised beef are in the metropolitan areas where disposable income is high and "foodies" abound. However, these are niche markets, and production must be carefully tied to marketing. There is no commercial wholesale market for pasture-finished beef, so it is usually produced based on a clearly anticipated market (i.e., farmers' market), presold directly to customers, or managed under a marketing agreement with an aggregator. While the surge in farmers' markets has been a good opportunity for many local producers, high transportation and labor costs relative to gross sales are an issue. Also farmers' markets often control how many vendors they have for specific types of products, so in many cases there are limited opportunities for new producers to enter that market. Other markets include small grocery stores, direct sales to restaurants, and other direct-to-consumer mechanisms including the internet. Lack of scale impacts many of these opportunities, as grocery stores and restaurants want a steady supply of products with consistent quality, which is difficult for a small farmer to satisfy.

Marketing claims

Claims on the production system should be based on a written production protocol and/or documentation to be reviewed for approval by the state or federal labeling division. This document should ideally detail feeds, feeding management, pharmaceutical use, and other pertinent production information. Most claims are up for some level of interpretation by the reviewer with the exception of third party claims such as Animal Welfare Approved, Certified Organic, etc. Those claims have a public set of standards and the farms are audited against those standards.

Regardless of the system, having detailed documentation of the production system will help you explain your process and build trust when direct marketing to your customer. Third party certification with a brand that is valuable to your customer is the sure fired way to let customers know your farm was verified against a set of published standards. These claims are increasingly important in retail settings where customers don't have a direct relationship with their farmer. To appear on a label, or on point of sale marketing material, there must be a production protocol and farmer affidavits that they followed the protocol. A label application will be made to USDA-FSIS including this production information. These claims, including "grass-fed," "pasture-raised and pasture-finished," "raised without growth-promoting hormones," and many others, may help with marketing but require documentation. This topic is well described in a recent factsheet from NC Cooperative Extension, "Special Claims and the Approval Process for Niche Meat Production" [21].

Many small farmers limit the claims they make, especially when they are selling at a farmers' market or in other direct-to-consumer markets. Farmers tell the consumers what they do or do not use in their production systems and have a one-on-one relationship to back that up. Producers do not put claims on the label; therefore, they do not need to submit an application to USDA-FSIS to support such claims. However, farmers still need to document their production system so they can ethically make claims on their marketing materials. In larger markets, substantiated claims about the use of hormone implants, feeds (grass-fed), and production environment (pasture-based) are more important because there is no direct relationship between the farmers and the consumer.

Is "grass-fed" really 100% grass-fed beef?

There has been a great deal of debate during the last decade about appropriate labeling of local beef. For example, a USDA-AMS definition of "100% grass-fed" was adopted in 2007, and this definition was quite restrictive with 99% of the feed for the life of the animal being from either pasture or harvested forages. As of today, third-party certification organizations such as "American Grass-Fed" [22] use their own definition. They also require animals to be maintained on pasture with only grass or forage from weaning to harvest, to not be raised in confinement, and to never be fed antibiotics or implanted with growth promoting hormones. These stipulations were not required in the USDA definition. However, American Grass-Fed does allow the use of molasses and urea protein tubs in their current standards at a target intake of up to 3 lb/day, which would be over 10% of the diet of the animal. It is also common to find farmers selling "grass-fed beef" that may have been fed other by-products including soybean hulls, brewer's grains, corn gluten feed, and other concentrate ingredients that are high in fiber. There are also examples of production systems based on a relatively high level of corn silage and concentrate feeding in a pasture-based environment that are labeled "grass fed" [23]. In 2016 the USDA dropped its definition of grass-fed due to the very limited adoption of the standard. Producers currently have the option of adopting the old USDA definition for their own, creating their own definition, or using a third party with an established definition for grass-fed such as American Grass-Fed [24] (Fig. 10.2). It is important to remember that third party certified claims are the only claims that require an on-farm visit to audit the claim and are therefore up for less interpretation of meaning to the public.

As the popularity of grass-fed beef has increased, so has the importation of grass-fed beef from countries where forage-based systems dominate, such as Australia and Uruguay [25]. In all of these countries, however, there are still transitions in forage nutritive value and availability due to climatic conditions. The strict definitions for

Figure 10.2 Examples of pasture-raised ground beef purchased in Raleigh, NC during January and February, 2019. (Top left) Brasstown Beef, located in Brasstown, NC. This product is raised with a corn-silage based total mixed ration fed on pasture. (Top right) 100% grass-fed organic ground beef imported from Australia. (Middle left) Dr. King's 100% grass-fed organic. The business address on this product is Asheville, NC, suggesting it is "local" but the beef is processed and packaged in Denver, CO. (Middle right) Firsthand Foods ground beef. This company located in Durham, NC utilizes low level feeding of concentrates on pasture. (Bottom left) Trader Joe's 100% grass-fed organic beef, imported from Uruguay. (Bottom right) Strauss ground 100% grass-fed beef produced in Wisconsin.

grass-fed beef have limited the development of domestic supplies, and at the same time created the opportunity for imported products. Since many of the pasture-raised and pasture-finished products address many of the concerns consumers have about the current conventional beef supply, developing a more open and defined market opportunity for those products may help expand domestic supplies of "local alternative beef".

Aggregators expand opportunities for small farmers

Small farmers sometimes struggle to develop a profitable production system due to lack of economy of scale, and experience difficulty accessing markets due to their small volume of production and seasonal supply. Farmers selling at farmers' markets, for example, generally need to supply product consistently throughout the market season. This results in most of the products being offered frozen, because production can be stored for long periods; thus, an unsold product can be returned to the freezer for later selling. Maintaining an inventory of frozen products often limits the growth of these systems. Expanding frozen meat storage from upright or chest freezers to walk-in freezers is a major investment many small farmers cannot afford to make.

The local food industry has expanded dramatically due to the work of aggregators, which are companies that work with farmers to coordinate production and marketing. This model has been quite successful with local produce production and marketing [26]. The aggregator may be a farmer who has grown their market beyond what they can personally supply [27], or they may be an independent company that does not farm but focuses on coordinating a group of farmers [28]. This system gives farmers access to a wholesale market that can move more cattle than they could direct market on their own. It also opens opportunity for fresh product, which is key in restaurants, specialty butcher shops, and grocery stores. Additionally, it allows the farmer to be seasonal in their production, which can improve their production efficiency.

Production guideline examples

To help farmers develop local beef finishing systems, three production guidelines were developed by NCSU Cooperative Extension: "Local Beef," "Pasture-Raised and Pasture-Finished beef," and "Grass-Fed beef" [29–31]. These protocols were developed after considering results of industry surveys and discussions with many local beef producers. Each of the guidelines includes an affidavit form that producers can sign indicating that they followed the guidelines in raising their animals. While this is not a third-party verified approach, it does provide the minimum information necessary to support label and marketing claims and will help customers who want to know details of how their beef was produced.

The "Local Beef" guideline [29] is not at all restrictive in terms of inputs and supports minimal label claims. This guideline would be useful to farmers using a feedlot system who also wish to use various inputs. The key aspects to "local beef" are known origin of the cattle and Beef Quality Assurance Certification, which assures consumers that pharmaceuticals were used according to the label and that withdrawal times were observed.

The "Pasture-Raised and Pasture-Finished beef" guideline [30] is one of the most popular guidelines. Producers employing this guideline use a limited amount of supplement (0.5% of body weight from weaning to yearling, and 1% of body weight during finishing). "Pasture-Raised and Pasture-Finished beef" supports the claims of "pasture-raised," "produced without growth-promoting hormones or antibiotics," and the majority of the feed at all times comes from forages. Supplement ingredients are listed as either "high fiber" or "high starch," and the high starch feeds are limited to 0.5% of body weight per day throughout growing and finishing. This limited level of a starchy concentrate addresses concerns about potential negative implications of concentrate feeding and should have minimal impact on ruminal health. If a higher level of supplementation is needed to achieve production goals, then it must come from a "high fiber" supplement which has less impact on rumen health than starchy concentrates.

Finally, a "Grass-Fed beef" guideline [31] has been suggested for farmers developing a system without regular use of supplements. This guideline is less restrictive than some other grass-fed protocols but ensures that forages makeup 95% of the diet throughout the life of the animal.

While the routine feeding of antibiotics is not included in the "Pasture-Raised and Pasture-Finished beef" and the "Grass-Fed beef" guidelines, appropriate use of therapeutic antibiotics for treatment of common diseases is not restricted. Antibiotics are an important tool for treating disease and preventing widespread outbreaks in a herd. Producers are encouraged to monitor animals and treat early, to follow label directions for administering the antibiotics, and to observe withdrawal times. Our observation is that while some consumers may have an aversion to beef with any antibiotic use, most will accept therapeutic uses to enhance animal welfare.

While not directly related to the NC guidelines, it is important to mention that a common misconception exists that direct-market beef producers with claims pertaining to no antibiotic use ("never ever" programs) will not treat a sick animal. The vast majority of farmers will treat a sick animal with antibiotics even though their label claim states no antibiotics were used in the production system. In that case they market the animal or the meat without that label claim.

The above mentioned guidelines are only suggestions. They were developed as models that producers could adopt, making it simple for them to develop a system for producing their own local beef. There are many possible variations in the guidelines, so a downloadable, editable version of each is available for producers to customize to meet their production system.

Health claims about grass-fed beef

Health claims for pasture-finished beef are commonly cited but are difficult to support with current research data. There are characteristic differences between "conventional feedlot beef" and "grass-fed beef." Many medical doctors agree that while there are compositional differences, and nutritionists favor the use of "lean beef," there is limited evidence of significant health benefits. In fact, beef of any type can be part of a heart-healthy diet if not eaten in excess [32].

Grass-fed beef is often lower in fat than feedlot beef and is frequently marketed as a lean protein option. However, it is becoming a more common goal of grass-fed beef farmers to market a marbled product that is as high or nearly as high in fat as conventional grain-fed beef, which creates a contradiction in goals. In a comprehensive study of grain-fed compared to grass-fed beef, grass-fed strip steaks had lower fat, while the ground beef from the two finishing systems did not differ [33]. In most studies, grass-fed animals were fed to a lower fat endpoint compared to conventionally fed cattle because they were harvested at the same time. To enhance consumer acceptance of the product, many local beef production systems are being developed to provide well-finished grass-fed or pasture-raised beef with a substantial degree of finish (marbling) which is consistent with a USDA Choice grade. It is critical for a successful production system to vary the nutritional value of the diet and the time on feed to ensure that animals are at the desired fat endpoint (whatever it may be) at the appointed harvest date.

The fatty acids making up the fat in grass-fed beef also differ from the fatty acids in conventional beef. Grass-fed beef is consistently higher in omega-3 ($n-3$) polyunsaturated fatty acids than conventional beef, which leads to a lower omega-6 ($n-6$) to $n-3$ ratio. Omega-3 fatty acids decrease the inflammatory response and benefit the overall health of the cardiovascular system [34]. In the study of Leheska et al. [34], the $n-6$:$n-3$ ratio of the grass-fed ground beef was 2.45, while for the conventional beef it was 9.6. In a study comparing alfalfa, pearl millet, or mixed pasture to conventional feedlot finishing, Duckett et al. [15] reported no difference between forage species in the $n-3$ percentage of total fatty acids. However, the forage-finished beef had a higher level of total omega-3 fatty acids (2.67%) compared to 0.56% for conventional feedlot beef. The $n-6$:$n-3$ ratio in that study was also not impacted by forage species, but was higher for conventional beef (6.01) as compared to forage-fed beef (1.33).

Conjugated linoleic acid (CLA) is another fatty acid that has purported health benefits [34]. In the study of Leheska et al. [33], CLA on ground beef was 0.5% of fatty acids for conventional beef and 0.94% in grass-fed beef, while in strip steaks it was 0.38% in conventional and 0.66% in grass-fed. In the study of Duckett et al. [15], CLA did not differ between the forage treatments but was higher for the forage-fed beef at 0.64% as compared to 0.26% for the conventionally grain-finished beef.

Daley et al. [34] reviewed the literature in regard to the fatty acid and antioxidant characteristics of grass-fed versus conventional (feedlot) beef. Readers are referred to that review for a detailed description of the compositional differences between grass-fed and conventional beef. The review showed that grass-fed beef is generally leaner, higher in $n-3$ fatty acids, lower in $n-6$:$n-3$ ratio, higher in CLA and vaccenic acid (which is converted to CLA in the body), and higher in B-carotene and alpha tocopherol as compared to feedlot beef. One distinction that is important to make about the fatty acid content of grass-fed beef is that the health effectiveness of that depends on the fat content of the meat. These fatty acids discussed previously are expressed on a percentage of the total fatty acids. If the level of fatty acids (fat) in the beef is very low, then these differences in fatty acids would have a negligible effect on health [34].

Strip steak samples from 23 local beef farmers in North Carolina were collected with the intent of comparing production systems using: (1) a full feedlot diet including corn, corn silage, whole soybeans and commodity feeds; (2) a 100% grass-fed diet for the life of the animal; (3) a pasture-raised system with a starchy concentrate (corn or small grains) limited to no more than 1% of body weight; or (4) a pasture-raised system with a high fiber concentrate supplement at no more than 1% of body weight (M. Poore, unpublished data). A strip steak sample was obtained from two animals on each farm. Additionally, two samples each of choice strip steaks, wild caught salmon, pork loin, and chicken breast were bought (one each) from two local grocery stores. Results of the fatty acid analysis are shown in Table 10.1.

The NC local beef did not differ in total fat between production systems, with an average of 5.68% compared to 6.26% for the conventional beef purchased from the grocery store. The CLA percentage of total fatty acids was higher for the grass-fed beef than the starch-supplemented beef, which was in turn higher than the local feedlot beef. Omega-3 fatty acids showed a similar pattern, with the local feedlot and starch-supplemented being lowest, and the fiber-supplemented and grass-fed being highest. The $n-6$:$n-3$ ratio was different between each of the finishing systems, with grass-fed being lowest, fiber-supplemented next, followed by starch-supplemented and feedlot-finished. Levels of vaccenic acid were not different between the local beef sources. It is interesting that all three of the pasture-based finishing systems had CLA, omega-3 fatty acids, and $n-6$:$n-3$ fatty acids comparable to what is in the literature for grass-fed beef [33,34]. Additional research is needed to confirm, but based on these results, pasture-finished beef produced with limited levels of supplement would appear to have the same potential health benefits as 100% grass-fed beef.

When the local beef is contrasted with conventional meats (Table 10.1), several things should be noted. The local beef, regardless of finishing system, had a higher level of CLA, vaccenic acid, omega-3 fatty acids, and lower $n-6$:$n-3$ ratio compared to the conventional feedlot beef. This is likely because the local feedlot systems maintained cattle on grass longer than is typical for conventional feedlot beef. All the beef, regardless of finishing system, had higher CLA levels than the salmon, pork, or chicken because this fatty acid is created in the rumen of the ruminant animal. Salmon is by far the highest source of $n-3$ fatty acids and has the lowest $n-6$:$n-3$ ratio. Note that pork and chicken were very high in $n-6$:$n-3$ ratio due to the high levels of corn oil in the diets of those species.

Table 10.1 Total fat and fatty acid profile of locally produced NC beef, commercial beef, chicken, pork, and salmon (Poore, unpublished data).

System (number of samples)	Total fat	Percentage of total fatty acids[a]						
		CLA[b]	VAC	SFA	MUFA	PUFA-*n*-6	PUFA-*n*-3	*n*-6:*n*-3
NC Grass-fed (14)[c]	5.75%	0.586a	2.97	45.6	38.6	3.29	2.15a	1.58a
NC Feedlot (8)	5.97%	0.289b	2.50	46.6	40.2	4.71	0.88bc	4.71b
NC Pasture-finished, starch (10)	5.23%	0.455c	2.68	45.1	40.6	3.99	1.26b	3.18c
NC Pasture-finished, fiber (14)	5.78%	0.550ac	3.24	46.2	37.8	3.94	1.80a	2.29d
Standard error	0.78	0.046	0.382	0.69	0.89	0.36	0.17	0.17
Commercial feedlot (2)[d]	6.26%	0.273	1.64	44.9	40.1	5.04	0.46	10.19
Wild-caught salmon (2)	3.73%	0	0.32	21.9	19.8	2.58	30.46	0.08
Chicken breast (2)	1.03%	0	0	31.9	33.9	24.49	1.53	15.86
Pork loin chop (2)	3.21%	0	0	38.7	41.7	14.73	0.67	22.00

[a]Samples were analyzed by Dr. Susan Duckett at Clemson University. Fatty acid abbreviations: *CLA*, conjugated linoleic acid (18:2 *cis*-9, *trans*-11); *VAC*, vaccenic acid (18:1, *trans*-11); *SFA*, saturated fatty acids; *MUFA*, monosaturated fatty acids; *PUFA*-*n*-6, polyunsaturated fatty acids with *n*-6 bond; *PUFA*-*n*-3, polyunsaturated fatty acids with *n*-3 bond; *n*-6:*n*-3, ratio of *n*-6 and *n*-3 polyunsaturated fatty acids.
[b]Values followed by a different letter in a column differ statistically ($P < .05$).
[c]Sample strip steaks were obtained from beef producers in NC producing local beef. Producers were interviewed and their systems were classified as Grass-Fed (no concentrates fed), feedlot (full feed on corn silage and/or corn-based concentrates), pasture finished with less than 1% of body weight supplement from a starchy concentrate, pasture finished with less than 1% of body weight supplement from a high fiber concentrate.
[d]One sample of each of these commercial protein sources were purchased from two different Harris Teeter grocery stores. Commercial feedlot beef was Harris Teeter Angus, salmon was Alaskan Wild Caught, while chicken breast and pork loin chops were from commercial confinement production systems.

While the differences reported here between pasture-finished and conventional beef are consistent with most studies, the literature is nearly devoid of research studying health outcomes in subjects eating meat from grass-fed versus conventionally finished cattle. If one considers where beef fits in the overall diet, differences in nutrient content of pasture-raised versus feedlot-raised beef have little impact. The current per capita beef consumption in the United States is about 1 lb of beef per week, which represents about 1200 calories [35]. The recommended dietary intake of calories for a middle aged, moderately active man is 2800 per day, or 19,600 per week [36]. This means that beef is only about 6% of the calories in the average diet. Differences between pasture-raised and feedlot-raised beef might be more significant if a person eats a lot more beef than this, but most human nutritionists and health care professionals recommend eating no more than 1 lb of beef per week. One study in Ireland did compare a relatively small sample of healthy subjects that were fed either conventional or grass-fed meats at a level of about 1 lb/week as part of their normal diet. Intake of omega-3 fatty acids was increased, which led to higher plasma and platelet omega-3 fatty acids in subjects who ate the grass-fed meats [37] and presumed increased health benefits.

While there are potential health benefits of consuming pasture-raised beef, they are likely limited, and many of the same benefits can be derived from supplements such as fish oil. As mentioned earlier, modeling of alternative beef production systems to date has shown that pasture-raised beef systems are also inherently less efficient than feedlot systems because of the high level of forage in the diet, the lack of growth promoting technology, the lower levels of average daily gain, and increased age of animals at harvest. This contradicts the general notion that grass-fed beef is better for the environment. The most resounding arguments in favor of local pasture-raised beef are the benefits to animal welfare, traceability of product, transparency of the production system, and benefits to the local farming economy.

Recent research with pasture-finished beef systems in the south

Many studies have been conducted with pasture-based beef finishing systems in recent years, and there are several programs in the south that have done a considerable amount of research. In addition, several of the authors of this chapter have also done recent research relevant to the earlier discussion, and findings are summarized in the following sections.

Louisiana State University research: forage-fed beef systems for the Gulf Coast

The Southeast region, especially the area close to the Gulf Coast, has the opportunity to grow forages year-round. However, there are two seasonal transition periods, which, depending on management, can last for up to 3 months, when forage availability and nutritive value are limited. Additionally, frequent rainfall during the summer months makes it difficult to produce good-quality hay. Hence, the development of year-round forage systems with limited hay feeding would allow decreasing dependability on weather conditions, costs, and labor, and may provide better nutrition for grazing animals. Three different year-round forage systems were evaluated that targeted production of 1100-lb forage-fed steers at 17–19 months of age [38] (Fig. 10.3). These are not the only forage systems possible in this region, but they demonstrate a combination of forage resources that can be easily adapted by producers in the region.

> ***All forage systems are successful only when high-quality forages are available throughout the finishing period. The problem (of low-quality perennial forages in the Lower South) can be solved to some extent by using multiple plantings of high-quality winter and summer annuals as grazing crops and/or with the use of high-quality harvested forages.***
>
> **Warren G. Monson and Philip R. Utley, Georgia (1977)**

From June to May (12 months), and for four consecutive years, 54 crossbred steers (25% Brahman influence) were assigned to one of three forage systems a few days after weaning with an average weight of 550 lb. Excess forage in summer was harvested as hay and fed within the system when needed. For the purpose of total system evaluation, hay produced but not consumed was considered revenue for the system and included in the economic analysis. Fig. 10.3 shows when the different pastures were grazed during the course of the year and the time and duration of the hay feeding period. System 1 is the most common method in the region with a warm-season perennial grass, bermudagrass, for the summer, and annual ryegrass for the winter. Systems 2 and 3 should have had greater animal performance because there was an increase in forage mass production and quality. However, management complexity and inputs used were also increased. Systems 2 and 3 incorporated dallisgrass, a high nutritive value warm-season perennial grass, and a mix of white, red, and berseem clovers. In addition, the same clover mix and cereal rye were added to ryegrass for winter grazing. Since these clovers have a different growth pattern, they extended the grazing period. Berseem is available first, then red, and, finally white clover. Cereal rye provided forage mass earlier than annual ryegrass, but it was not enough to start the winter grazing period earlier.

System 3 was the most productive in terms of dry matter production and nutritive value because it added a sorghum–sudangrass hybrid and forage soybeans to System 2 for summer grazing. Average daily gains of the steers in the different forage systems were similar across the systems regardless of the time of year (Fig. 10.4). Even though the sorghum–sudangrass/soybeans area produced better-quality forage during the summer in System 3, the period during summer when animals grazed that area was short (45–60 days, depending on the year), while they spent the rest of the time on

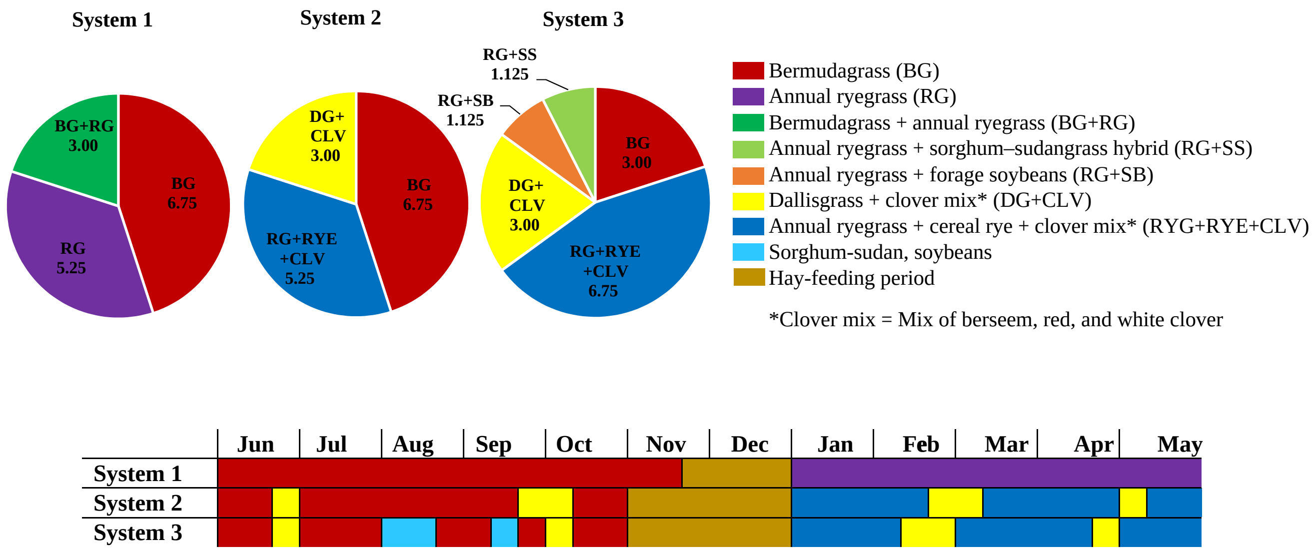

Figure 10.3 Schematic representation of the forage sequence for the different forage systems evaluated at the Iberia Research Station, LA.

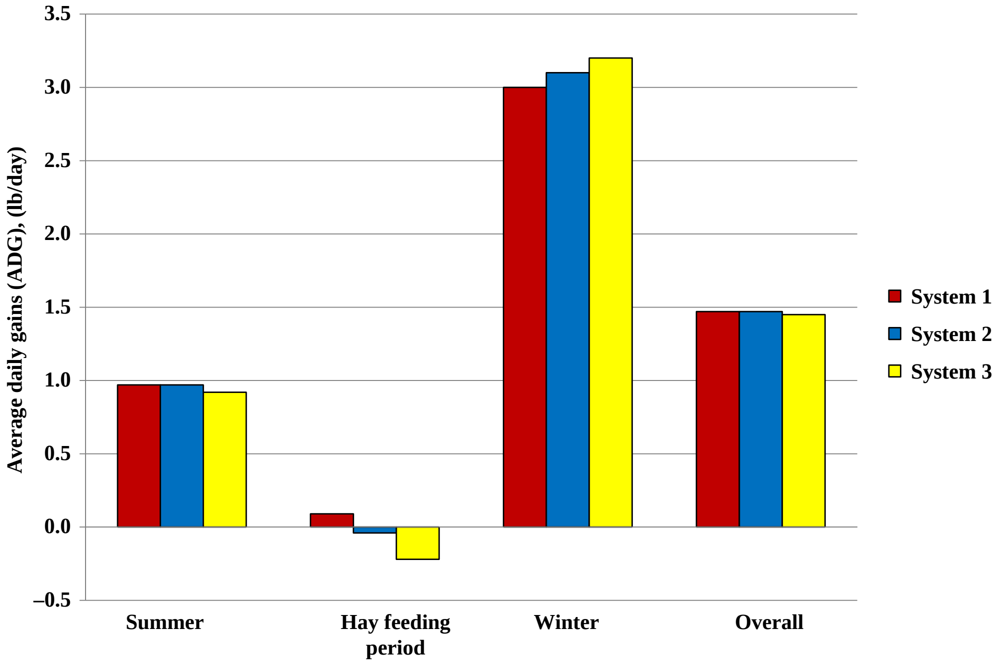

Figure 10.4 Average daily gains (lb/day) of steers in different periods (summer, hay-feeding, and winter) and overall (year-round) by forage system.

bermudagrass. Therefore, although gains were greater during that period, the overall gain in summer for steers in System 3 did not differ from the other two systems. It should be emphasized that steers were young (recently weaned, 8–9 months of age) when placed on summer pastures. Steers' nutrient requirements are greater than what bermudagrass or sorghum–sudangrass can provide, hence their reduced ADG [20].

Because of the greater area dedicated to bermudagrass in System 1, the grazing pressure on this pasture was lighter. Through management of residual forage height, it was possible to extend the grazing season for this system. This, in turn, reduced the hay feeding period and allowed a small weight gain on System 1, while steers in Systems 2 and 3 with longer hay-feeding periods lost weight (Fig. 10.4). Overall, gains were very similar across forage systems allowing steers to reach a target final weight of 1100 lb. These results showed that greater inputs and short periods of increased forage nutritive value may not result in greater performance and economic return.

Carcass traits and beef characteristics

Every year 18 steers (6 per system) were harvested to obtain their 9–11 rib section and carcass information. There were very few differences in these characteristics between carcasses from steers produced in the different systems. All steak samples

Table 10.2 Analysis of samples obtained from steaks of steers from three forage systems (S1, S2, S3) and commercial grain-fed steak (GRAIN) classified as USDA Choice.

System	Moisture (%)	Fat (%)	Protein (%)	Minerals (Ash) (%)
S1 (Forage)	74.1	3.80	22.2	1.00
S2 (Forage)	75.1	2.42	22.8	1.02
S3 (Forage)	75.4	2.76	22.6	1.02
GRAIN	86.8	14.16	18.8	0.76

Table 10.3 Fatty acid composition in beef samples from steers from three forage systems (S1, S2, S3) and commercial grain-fed steak (GRAIN) classified as USDA Choice.

	Percentage of total fatty acids		
System	Omega-6	Omega-3	Omega-6:Omega-3
S1 (Forage)	3.87	1.76	2.23
S2 (Forage)	4.30	1.96	2.21
S3 (Forage)	3.29	1.52	2.19
GRAIN	5.39	0.51	10.55

showed acceptable tenderness. Cook yields were calculated as the difference between initial weight and cooked weight [39].

Nutritional characteristics of forage-fed beef

Steaks taken from the ribeye of the harvested steers were compared to grain-fed choice steaks purchased from a local supermarket. Beef from forage-fed cattle was leaner, and hence had a greater protein and mineral concentration (Table 10.2). Both commercial and forage-fed beef had almost the same portion of stearic acid and palmitic acid. In this study, the concentration of $n-3$ fatty acids as a percentage of total fatty acids was three times greater in forage-fed beef than in grain-fed beef (Table 10.3). The $n-6$:$n-3$ ratio was much lower in the forage-fed beef, while the level of CLA was higher compared to grain-fed beef, both of which were comparable to other studies with forage-fed beef [40].

Consumer acceptance between American, Asian, and Hispanic populations of ribeye steaks from forage-finished steers

The sensory acceptability of cooked ribeye steaks from forage-finished steers representing the three forage systems (S1, S2, and S3; see Fig. 10.2) and commercial grain-fed (GRAIN) steers were evaluated [40]. A total of 336 consumers—112 Hispanics, 112 Asians, and 112 Americans (white and African-American)—participated in the study (Fig. 10.5). For juiciness and tenderness, GRAIN and S3 consistently had slightly greater mean scores compared to the other two systems for all populations. Interestingly, consumer preference

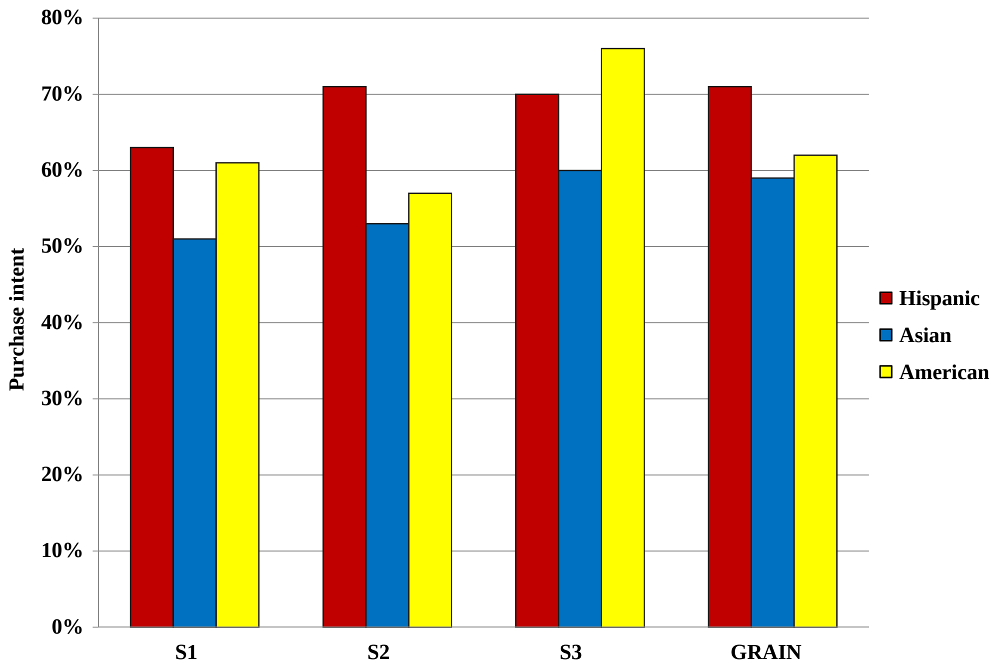

Figure 10.5 Purchase intent (%) of cooked steaks from the forage systems (S1, S2, S3) and GRAIN treatments among Hispanics, Asians, and Americans.

of forage-finished ribeye steaks differed among Hispanics, Asians, and Americans. The raw appearance and overall fat appearance of steaks from steers produced in S3 were the most visually preferred for Hispanics and Americans. However, Asians visually preferred S1 and S2 over S3 and GRAIN. For all populations, the overall preference for GRAIN and S3 steaks was greater compared to the other systems. Specifically for Hispanics, tenderness was the most relevant sensory attribute; whereas, overall cooked steak appearance was more important for Asians. However, for Americans, overall beef flavor was considered the most significant attribute.

Consumer preferences for forage-fed beef

In 2012 a survey was sent to 2000 grass- and grain-fed beef consumers nationwide requesting their opinions regarding preference and attitude toward grass-fed beef [41]. Results indicated that 58.9% of respondents recall eating grass-fed beef at least once in the past year. The average respondent indicated that of the last 10 times they consumed meat or seafood, they ate grass-fed beef 1.41 times compared to 2.32 times for grain-fed beef. This was not consistent with other data that show grass-fed beef remains a relatively small percentage of total beef consumption. Questions asked about consumers' knowledge and consumption of grass-fed beef before providing a

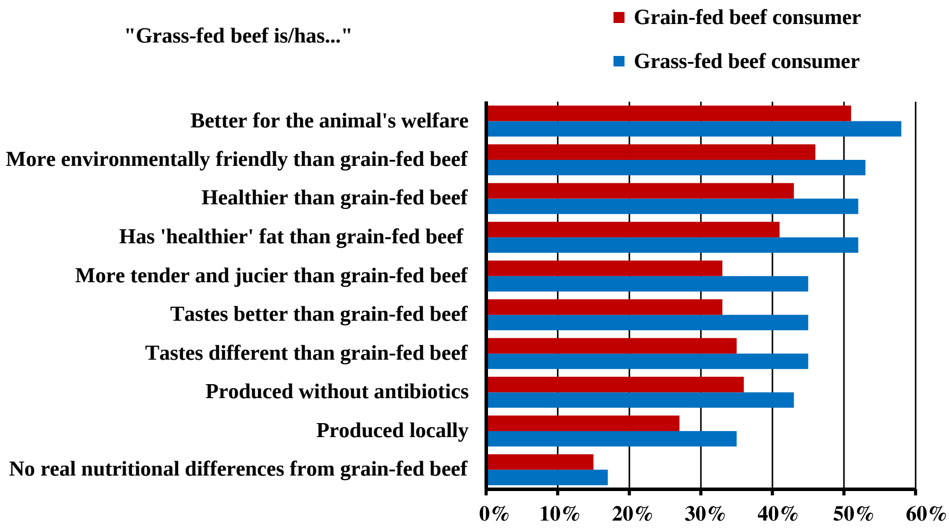

Figure 10.6 Percentage of consumers agreeing with selected statements about grass-fed beef.

definition of the production method revealed that 52.2% of respondents associated the raising of cattle on open pasture with grass-fed production, even though cattle spend some period of their lives on pasture but are finished on grains in a feedlot. In contrast, only 9.5% of respondents associated grass-fed production with cattle that have never been fed grains. Questions were also asked about consumer attitudes regarding the benefits of grass-fed beef. The statement pertaining to animal welfare received the greatest percentage of agreement among both grass- and grain-fed beef consumers (Fig. 10.6).

More than 50% of those claiming to be grass-fed beef consumers agreed with the statement that grass-fed beef is produced in a way that is better for the animal's welfare. Greater percentages of grass-fed beef consumers agreed with all statements tested. Animal welfare, environmental benefits, and health benefits received the top three rankings, respectively. Aside from the statement pertaining to animal welfare, all other statements received less than 50% of agreement from both grass- and grain-fed beef consumers. Analysis of respondent ratings of grass- and grain-fed beef showed that the average respondent preferred a grass-fed product with a USDA certification compared to uncertified grass- or grain-fed beef products. In addition, results also showed a higher preference for beef that was produced locally and domestically compared to imported beef. Consumers preferred USDA Choice and Prime beef steaks compared to Select beef steaks, which limits market development for lean forage-fed beef. Individuals who live in the West expressed a stronger preference for grass-fed beef relative to those living in other regions of the United States. Fig. 10.7 shows the relative importance of top-rated attributes by the average respondent in the sample.

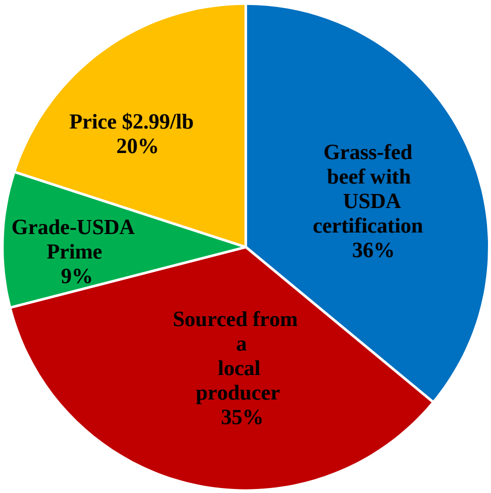

Figure 10.7 Relative importance of selected product attributes for grass-fed beef.

An important attribute was grass-fed with third party certification. The results also indicated a relatively high preference for locally produced beef, consistent with national trends which show an increased preference for local foods [41].

Effect of different breed types on grass-fed beef production in the Gulf Coast

Which breed of animal to use is just one of the many decisions grass-fed beef producers must make. Even though most grass-fed beef producers use British or British-cross breeds [42], dairy beef provides an opportunity to diversify dairy operations and boost income through the production of grass-fed beef, especially when the dairy farm is pasture-based. In the Southeastern United States dairy cow numbers are decreasing; however, numbers of grazing dairies are increasing for most states [43]. Holsteins, in particular, are valued by many feeders and meat packers because of the consistency of the breed. They have a uniform rate of gain and feed conversion and show predictable carcass characteristics in terms of yield, marbling, and cutability [44]. Holstein cattle typically have a smaller ribeye area and less fat thickness than beef breeds and tend to marble well [45]. They also yield a carcass with 25%–30% less external fat than beef breeds.

Criollo cattle, a traditional group of beef breeds, produce very lean beef, which is important to consumers interested in a low-fat diet. In addition, due to their smaller mature size and therefore lower forage requirements than traditional breeds, Criollo cattle may allow for more beef production per unit of land (more animals placed per unit of land) than Holsteins or traditional beef breeds. Pineywoods, a Criollo breed found along the Gulf Coast, has an attribute that may be marketed to consumers with an interest in the "heritage label" which has gained attention in recent years.

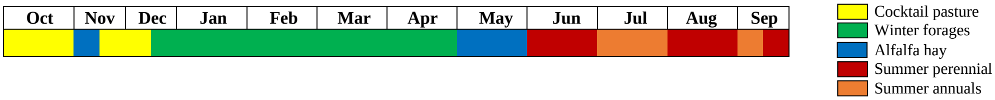

Figure 10.8 Forage system used in a year-round program with steers of four breed types.

Steers representing four breed types (Angus, Brangus, Holstein, and Pineywoods) grazed the same forage system year-round (Fig. 10.8). The "cocktail" pasture was a mix of summer annuals (pearl millet, forage soybean, and cowpeas), winter annuals (annual ryegrass, oats), brassicas (purple turnips, kale, radish), and clovers (red and berseem clover). The winter pasture was a mix of berseem clover + annual ryegrass. Alfalfa hay for the fall and spring transition periods was used. Summer pastures were annuals (Alyce clover + pearl millet + cowpeas) and perennials (Bermudagrass). Steers were rotationally stocked in three groups within each breed. This allotment of steers allowed the comparison between breed types based on their natural differences of mature body weight (Holstein > Angus = Brangus > Pineywoods), which affected animal performance and pasture utilization.

Calves were weaned in October and placed in their respective groups for the entire experimental period. Each year six steers per breed type were harvested in April and/or May after the winter forages, and the same number in late September/early October after summer grazing. These two times of harvest may help producers who, due to limitations of land area or labor, need to sell grass-fed steers at no more than 12–13 months of age. Their production system requires selling these steers when the nutritional demand of their herd(s) is increasing due to a new calving season. Other producers with larger farms, or because of their business model, need to produce steers at a different time of the year; thus, they keep cattle through the summer months. As demonstrated by Scaglia and Boland [46] and Scaglia [47], temperature and humidity during these months have a strong effect on animal performance, grazing behavior, and forage intake. These conditions add to the lower nutritive value of summer forages compared to winter forages, hence gains during the summer are small. Carcass characteristics, 9–11 rib section, and fatty acid concentration (only 1 year in the spring) were determined from each carcass.

Overall animal performance (from October to September), as expected, was different by breed type. Holstein and beef steers (Angus, Brangus) gained more (1.82, 1.92, 1.96 lb/day, respectively) than Pineywoods (1.51 lb/day). Pineywoods, a heritage breed, has not been selected for growth or any other trait directly affecting performance or maternal characteristics. Rather, Pineywoods is a breed type that has probably been naturally selected for adaptation to their environment (Gulf Coast). Due to this and their mature weight, maximum gains obtained probably reflect their genetic potential. On the other hand, if production per unit of land is evaluated, beef breeds (Angus and Brangus) and Pineywoods produced 522, 530,

Table 10.4 Animal performance (ADG) by season, breed type, and total gains and production per acre.

	Average daily gains (lb)				Gains
Breed type	**Fall**[a]	**Winter**	**Summer**	**Total**	**lb/acre**
Holstein	1.55a	2.75a	1.12b	1.80a	428b
Brangus	1.45a	2.50a	1.49a	2.00a	530a
Angus	1.48a	2.62a	1.30a	1.88a	522a
Pineywoods	1.20b	1.80b	1.29a	1.51b	521a

[a]Different letters within a column represent statistical differences ($P < .05$).

and 521 lb/acre while Holstein produced 428 lb/acre. These differences are explained by grazing management and the fact that, on average for all years, Holstein steers required more area (1.45 acres per steer) than Angus, Brangus, and Pineywoods (1.3, 1.3, 1.0 acres per steer, respectively). Table 10.4 presents a closer look at animal performance and the effects of pasture nutritive value (in terms of the season) and breed type.

Most responses were as expected if based on the nutritive value of forages affecting animal requirements, and on weather conditions. The latter was a major issue in autumn of the second year of evaluation. Excess rainfall affected planting dates and forage production, and even though the hay feeding period was extended in response to this factor, gains were 58% of that of a normal year. During summer, high temperatures and humidity affected Holsteins, and to a lesser degree, Angus steers. On the other hand Pineywoods closed the gap in ADG, probably due to a greater adaptation to this environment.

Carcass characteristics of steers from different breed types

Carcass characteristics and rib section parameters of the same steers harvested at the end of the winter grazing periods are shown in Table 10.5. In general, the data demonstrated the expected differences between the beef breeds, a dairy breed, and a nontraditional beef breed: the beef breeds had more fat, greater ribeyes, smaller KPH (kidney, pelvic and heart fat), and less bone.

We are unaware of any other published carcass data with regard to Pineywood (Criollo) cattle. Of these cattle harvested at the end of the winter grazing period, Pineywoods had the greater KPH as a percent of the 9–11 rib section than any other breed type. They also had a lean percent that was greater than the beef breeds and similar to Holstein. Their percent fat was intermediate, and percent bone was similar to Angus and Brangus.

Carcass data obtained at the end of the summer grazing period after a yearlong finishing period followed a similar pattern as the data obtained after the winter grazing season (Table 10.6). As expected, greater carcass weight, marbling scores, ribeye area,

Table 10.5 Carcass characteristics from steers of different breed types at the end of winter grazing (April/May).

Breed type	Live BW (lb)	Carcass Wt. (lb)	Dressing (%)	Skeletal maturity	Lean maturity	Marbling score	Fat thickness, in.	REA (sq in.)	KPH (%)
Angus	974	510	52.4	A50	A50	307	0.19	9.2	0.92
Brangus	938	502	53.5	A50	A50	283	0.16	9.4	0.89
Holstein	1098	547	49.7	A60	A60	293	0.07	8.0	1.17
Pineywoods	670	352	52.5	A60	A60	293	0.07	8.1	1.75

REA, ribeye area; *KPH*, kidney, pelvic and heart fat.

Table 10.6 Carcass characteristics from steers of different breed types at the end of summer grazing (September/October).

Breed type	Live BW (lb)	Carcass Wt. (lb)	Dressing (%)	Skeletal maturity	Lean maturity	Marbling score	Fat thickness (in.)	REA (sq in.)	KPH (%)
Angus	1145	621	54.2	A50	A50	372	0.27	10.4	1.30
Brangus	1137	646	56.9	A50	A50	420	0.31	10.6	2.50
Holstein	1200	635	53.0	A50	A60	350	0.04	8.7	1.75
Pineywoods	754	421	55.8	A60	A60	360	0.10	9.8	3.00

REA, ribeye area; *KPH*, kidney, pelvic and heart fat.

Table 10.7 Fatty acid concentration (%) in steaks from steers of different breed types.

Fatty acid type	Breed types				SEM	*P*-Value
	Angus	Brangus	Holstein	Pineywoods		
	Fatty acid concentrations (%)[a]					
$\sum$ *n*-6	1.01c	1.16bc	1.64a	1.49ab	0.0605	.005
$\sum$ *n*-3	1.22bc	0.90c	1.81ab	2.32a	0.1518	.009
$\sum$ *n*-6/*n*-3	0.85b	1.29a	0.92b	0.65b	0.0639	.009
PUFA	3.58ab	3.17b	3.82ab	4.75a	0.2324	.034
CLA	1.39a	1.12a	0.46a	0.94a	0.2813	.262

$\sum$ *n*-6, Total percentage of omega-6 fatty acids; $\sum$ *n*-3, total percentage of omega-3 fatty acids; $\sum$ *n*-6/*n*-3, ratio of omega-6 and omega-3 fatty acids; *CLA*, total conjugated linolenic acid; *PUFA*, total percentage of polyunsaturated fatty acids; *SEM*, standard error of the mean.
[a]Percentages are on a wet-basis based on LS means. Different letters within a row represent statistical differences ($P < .05$).

and KPH were observed as an effect of increased maturity (18−19 months of age). Even greater carcass weight, ribeye area, and marbling score would be expected if the steers had remained for another winter grazing season. However, many small producers in the Gulf Coast region cannot retain steers for a second winter, as they already have a new group of steers starting the yearlong finishing period after weaning (October).

Beef nutritional value and consumer acceptability

In the spring of the second year, steak samples were obtained from each carcass, and total fat, moisture, and fatty acid concentrations were determined. Table 10.7 shows that the ratios of $n-6$:$n-3$ fatty acids were lower than 2:1 for all biological types. This was consistent with studies that found lower ratios in grass-fed beef than in grain-fed beef. There were no significant differences among the biological types in total CLA concentration. Ribeye steaks from Angus and Brangus steers had CLA concentrations above 1% (measured as grams of CLA/100 g fatty acid methyl esters); whereas, ribeye samples from Pineywoods and Holstein steers contained 0.94% and 0.46%, respectively. The mean concentrations of CLA in the steaks from all biological types except Holstein were high and similar to those observed in grass-fed beef samples reported by others [35].

Carabante et al. [48] indicated that consumers rated steaks from the two nontraditional beef biological types (Pineywoods and Holstein) equally or higher than conventional biological types (Angus and Brangus) in several hedonic (9-point scale) categories. Mean overall preference scores were 6.1 for Pineywoods and 6.3 for Holstein steaks, versus 5.5 for Angus and 6.0 for Brangus. Hedonic attributes, especially overall preference and liking of beef flavor, accounted for most of the differences between breeds. Providing consumers with health benefit information regarding the diet and subsequent fat composition of grass-fed beef increased the overall preference and purchase intent of steaks from all biological types tested.

Clemson University research: examining summer forage species to improve animal performance and carcass characteristics in the Southern United States

Two cattle grazing studies conducted near Clemson University evaluated the impact of summer forage species on animal growth rates, carcass characteristics, and meat quality. Typically, there is adequate quantity and quality of forage available for high animal performance in this region. Small grains, annual ryegrass, annual legumes, and nontoxic tall fescue can support animal gains that exceed 2.5 lb/day. However, these forages complete their growth cycle in mid-late spring, or in the case of fescue, become semi-dormant in summer months, which is a critical time for the completion of forage finishing for spring-born calves.

In the first trial [49] five different forage species were examined specifically for their ability to provide high-quality summer forages for the summer finishing phase. Bermudagrass was used as the standard control forage and was compared to pure stands of alfalfa, chicory, cowpea, and pearl millet. Over a 2-year period, these forages were grazed during summer months with 60 steers using the put-and-take system to evaluate the carrying capacity of each pasture. Both summers of this trial had abnormally low rainfall; however, this provided an excellent "worst case" scenario for testing forages in dry weather conditions. Steers that grazed alfalfa and chicory had higher daily gains (2.8 and 2.5 lb/day, respectively) than all other forages. Cowpea, pearl millet, and bermudagrass all had similar average daily gains (average 1.6 lb/day). However, due to forage production differences, some forages were able to be grazed at higher stocking rates. In general, grass species and alfalfa had higher carrying capacities than chicory and cowpea. When the animal performance was combined with carrying capacity, this resulted in excellent gains per acre for alfalfa, Bermudagrass, chicory, and pearl millet.

Dressing percentage of the steers was best from those that grazed legume forages. Both alfalfa and cowpea steers had improved dressing percentage and also had improved tenderness as measured by Warner-Bratzler shear force. In a related consumer panel, steers that grazed alfalfa and cowpea also received higher ratings for palatability than other species. Steers finished on bermudagrass pastures consistently ranked lowest in palatability and preference by the consumer panel.

In a second trial [50] the impact of an all legume—finishing forage chain versus an all grass—finishing regimen was evaluated. Thirty-two steers were used over two finishing cycles. Each year one set of steers grazed novel endophyte (non-toxic) tall fescue followed by finishing on brown-midrib sudangrass. Steers finished in the legume chain grazed alfalfa followed by a forage type soybean. Each year a subset of steers was fed 0.75% BW of cracked corn daily as a starch supplement to determine the impact on animal gain and meat quality.

Forage quality was high among all forage species, regardless of whether the forage was a grass versus legume or annual versus perennial. The neutral detergent fiber (NDF) content of legumes was 27%–30% and grasses averaged 51% throughout the trial. Consequently, animal gains of all groups were similar and averaged 1.7 lb/day over the entire trial. Animals that grazed in the legume chains had 0.3 lb/day numerically higher gains, but these did not approach statistical significance. Animals finished on legumes had higher dressing percentages than those finished on grass, and there were several numerical advantages in weight gains. Animals finished on legumes also had higher amounts of $n-3$ fatty acids than those finished on grass.

Daily supplementation with cracked corn produced a consistent response regardless of whether it was supplemented to cattle grazing legumes or grasses. Corn-fed daily at 0.75% BW increased animal gains by 0.64 lb/day and also increased hot carcass weight, dressing percentage, KPH, and USDA yield grade. Corn supplement also increased overall tenderness and juiciness of the beef and tended to decrease "leather flavor" and increase "umami flavor." Supplementing with 0.75% BW of corn had few impacts on the fatty acid composition of the beef. There were no differences in $n-3$, polyunsaturated fat, or CLA content with corn supplementation. There was a slight increase in the $n-6$:$n-3$ ratio when supplemented with corn (3.28 vs 3.69), but this would not likely have implications to human health. Unfortunately the design of this experiment did not allow for determining if stocking rate could be increased with corn supplementation at this level; thus, it was not possible to calculate if the supplementation was economically justifiable on a per acre basis.

North Carolina State University research: influence of starch supplementation on growth and carcass characteristics of pasture-raised beef

In research at NC, Armstrong-Price [51] compared two supplements for pasture-based finishing. Due to demand in the local area, collaboration with a local meat aggregator allowed for determining whether there was a benefit to adding starch to the supplemental feed. Chefs and other customers in the area asked for beef that was produced without corn; thus, the company wanted to ensure omitting corn from the supplement was not detrimental to beef quality. Over 2 years, 63 Angus yearling steers and heifers (average starting weight of 708 lb) were finished on one of two supplements: (1) a high-fiber pellet composed primarily of soybean hulls and corn gluten feed; or (2) a starch-rich supplement (30% starch) composed of half high-fiber pellet and half corn and soybean meal with the same protein level as the pellet. The production system was consistent with the NCSU pasture-raised and pasture-finished production guidelines [31]. Supplements were fed at 1% of body weight during the entire finishing period. Cattle grazed on KY-31 tall fescue pastures and were selected for harvest when they reached a body condition score of 6.5. Harvest was done at a local processor over a 2-month period each year, and carcass data were collected after 11 days dry-aging in year 1 and after 8 days dry-aging in year 2. At the time carcass measurements were made, fat, color, and fatty acid composition were determined on steaks.

Average daily gain was not influenced by supplement type but was higher in year one (2.2 lb/day) compared to year 2 (1.83 lb/day). This resulted in a total finishing time of 181 days in year one and 245 days in year 2. Final backfat was slightly higher for the fiber-supplemented cattle (0.38 in.) than for the starch-supplemented cattle (0.34 in.). Other than backfat there were no differences in carcass weight (656 lb), quality grade (low choice), yield grade (2.6), or ribeye area (11.5 sq in.) between supplement types. There were few differences in fatty acid composition between the two supplement types with vaccenic acid level of 2.44%, CLA of 0.273%, $n-3$ fatty acids of 1.03%, and $n-3$:$n-6$ ratio of 3.81.

This research showed that there was no advantage (or disadvantage) to adding starch to the supplemental feed in these pasture-based systems when using a 1% body weight feeding level with these forages. The differences between the 2 years in the growth rate of the cattle were due to higher forage quality in year one. In both years cattle were grazed on the same tall fescue pastures, but in year one, forage had higher nutritive value because of management strategies implemented preceding the experiment. Producers with these systems should be aware that animal performance will be very much impacted by forage quality as it makes up the majority of the diet of the animal.

> ***Major problems in developing a forage-finished beef industry in the Piedmont are: a) perennial grasses too low in available energy; b) physiological stress components in forages; c) uncertain legume production and persistence; d) uneven seasonal distribution of forage; and e) lack of production systems to give a year-around supply of finished slaughter animals.***
>
> **C. S. Hoveland and W.B. Anthony, Auburn (1977)**

University of Georgia research: influence of forage species on performance and carcass characteristics of grass-fed beef

Demand for a year-round supply of fresh, locally grown, forage-finished beef products has created a need for alternative forage systems in the Southeast. In the spring, fall, and winter months, the use of cool-season annual and perennial forages allows for rapid muscle and adipose deposition required to produce a high-quality, forage-finished product. However, limited forage options in combination with challenging weather conditions during the summer months can make it difficult to finish cattle on pasture. An opportunity exists to utilize warm-season annual forages for pasture finishing due to their high DM yields, nutritive value, and drought tolerance. Harmon et al. [52] conducted a 3-year study to evaluate four warm-season annual forage systems for southeastern forage—finished beef production. Forage treatments included brown midrib sorghum × sudangrass (BMR), sorghum × sudangrass (SS), pearl millet (PM), or pearl millet planted with crabgrass (PMCG). Each year, forage treatments were planted about mid-May and rotationally grazed with 32 British-cross beef steers until forage production became limited. Steers grazed for 70 days in 2014, 63 days in 2015, and a severe drought limited the grazing study to only 56 days in 2016. Forage availability dictated the time of harvest, which was conducted at the University of Georgia's Meat Science Technology Center (Athens, GA) in late summer. Besides sampling pastures every 2 weeks for forage yield and every 4 weeks for nutritive value, animal body weight was recorded at the beginning, middle, and end of the grazing trial. Once harvested, chilled carcasses (24-hours) were evaluated for yield grade and quality grade attributes, and proximate analysis was done for measurements of moisture, protein, lipid, and ash.

In this study the sorghum × sudangrass forage systems (BRM and SS), with their ability to quickly establish and produce tonnage, required an increased level of management during the first few weeks after emergence. At the initiation of grazing, forage dry matter yield was greater for SS (2064 lb/acre), BMR (1900 lb/acre), and PM (1809 lb/acre) compared to PMCG (1591 lb/acre), but these effects were not seen after the first 2 weeks of grazing. Although some differences in forage nutritive value were detected, differences appeared to be sporadic and influenced by environmental conditions and grazing management. Failure to properly stock and graze both sorghum and pearl millet pastures can result in mature forage that has decreased nutritive value. Under the conditions of this research area, pregrazed forage mass and overall forage distribution of sorghum × sudangrass forage systems were skewed toward the beginning of the growing season.

Forage treatment did not affect total gain or total ADG, and steers grazing SS, BMR, PM, and PMCG gained 1.90, 2.18, 1.87, and 2.14 lb/day, respectively, during the study. Additionally, no differences of forage treatments were observed for hot carcass weight, dressing percentage, loin muscle area, kidney, pelvic and heart fat, fat thickness, marbling, yield grade, and quality grade, or for the proximate analysis variables of moisture, protein, lipid, and ash. The findings of this research suggested that cattle forage-finished during the summer months on BMR, SS, PM, and PMCG performed similarly, giving producers the option to use the most practical forage type for their production system. Moreover inclusion of a warm-season annual forage species should be based on other factors including seasonal production goals, production costs, seed availability, and adaptability into an already established forage program.

Conclusions

Pasture-based beef finishing systems have gained interest in the southern United States, primarily due to increased social concerns about the conventional beef production system. Many consumers perceive that local pasture-based beef is better than conventional feedlot beef for animal welfare, the environment, human health, and the local farming economy. There are some misconceptions concerning these issues, but nevertheless, many small farmers are taking advantage of the increased demand to improve the profitability of their beef cattle farms. While most consumers are looking for a "local" product, much of the grass-fed beef currently sold is imported. With the exception of third party certified claims, there is no consistent definition for grass-fed beef, and a farmer can define their system and name it what they want as long as the production system is documented so that the practices used are transparent. A broader understanding and acceptance of pasture-raised products that might use low levels of concentrate supplementation, as discussed herein, may lead to improved opportunities for local farmers. Most consumers of these niche beef products want beef from animals that (1) were housed on pasture for their entire lives with the majority of their diet from grazed or harvested forages; (2) remained in the local area in which they were born for growing, finishing and processing; and (3) were produced without added hormones, or routine feeding of antibiotics.

Recent research with forage-based beef production systems in LA, SC, NC, and GA showed little difference between forage types or forage systems with a high level of forage management. While there are subtle differences between forages, in general, keeping animals on high-quality forages throughout the year, or strategically adding concentrates, will result in improved consistency in performance and carcass quality. Additionally, most research has suggested that using a low level of supplement to improve performance on pasture has little impact on the compositional differences between pasture-raised and commercial feedlot beef. Although feeding of corn proved beneficial to performance and carcass quality, there seems to be little benefit to using a starch-based (corn) supplement as compared to a fiber-based supplement (such as soybean hulls or corn gluten feed), which is sometimes of importance due to consumer bias against the use of corn. While there is a great deal of research available on pasture-raised beef systems, many studies harvest cattle at the same time/age endpoint such that the pasture-raised beef is almost always leaner than conventional feedlot beef.

In recent systems research at LSU, and in forage comparisons at Clemson, SC, cattle were fed to a target body weight. Despite this, variable forage conditions (drought, seasonal hay feeding, etc.) resulted in early termination of some treatments, or periods when cattle did not gain well. Reaching a target final fat endpoint (most often based on body condition score of the animal) at a predictable date has been difficult to achieve with 100% grass-fed systems due to variation in forage performance. This often leads to cattle being harvested leaner than desired which results in variation of final product quality. More information is needed with systems that have flexibility to overcome anticipated and unanticipated variations in forage quality and yield, as these are the conditions that a farmer developing a pasture-raised beef system must negotiate. Most producers target a set fat end point, and feed cattle much longer when they use a high level of forages than the same cattle if they were fed in the feedlot. Many pasture-raised beef producers have struggled with consumer acceptance of very lean beef; therefore, most now target a level of marbling consistent with USDA Choice grade. However, most research with 100% grass-fed production has harvested cattle at a leaner end point than is generally desired by consumers. Farmers developing these systems must overcome many challenges with economy of scale, unsteady forage supply and nutritive value, lack of processing infrastructure, and consumer misconceptions about animal welfare, human health benefits, and environmental impacts.

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CHAPTER 11

Weed control in pastures

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Introduction

The following discussions represent general approaches to weed control in pastures [1]. A common pasture management problem faced by most hay and/or livestock producers is weed and brush infestation. Weed species effectively compete with the more desirable forage species for sunlight, moisture, and soil nutrients. Whether herbaceous or woody species, if enough weeds are present in the pasture, the carrying capacity is decreased, nutritive value of the forage base is reduced, and input costs are increased. Weed infestation generally occurs due to poor management or uncontrolled climatic conditions such as drought. With proper fertility inputs, bermudagrass stands will usually outcompete weed species. Under low fertility conditions, however, weed species generally have the competitive advantage. During dry years, reduced forage growth from desirable grasses offers weed species the opportunity to become established. If allowed to make seed, the year following a drought can result in a tremendous weed population. In this case herbicides are usually required to manage weed infestation.

Overstocked pastures often contribute to weed infestation. Since most weed species are generally not as palatable to grazing livestock, such as cattle and horses, these species are usually ignored while more grazing pressure is placed on the more desirable forages. If this practice continues, a shift in plant species composition from desirable to less desirable species occurs. Most managers respond to weed problems by applying herbicides or mowing. If no change is made in the overall management of the operation, however, managers are only treating symptoms and not addressing the direct cause of the problem. If there are no desirable forages present to respond to a release from weed infestation, many times pastures may have some bare soil following a herbicide application. Weeds can be beneficial in reducing the level of exposed soil and thus reducing water runoff. In certain situations a complete renovation of the pasture may be warranted.

Management Strategies for Sustainable Cattle Production in Southern Pastures
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Why control weeds?

Costs

Weeds compete heavily with forages for moisture, light, and nutrients. Chemical analyses of weeds indicate that most are as high or higher in nitrogen, phosphorus, and potassium than forage grasses. This is evidence that the weeds are using much of the applied fertilizer; thus, increasing cost and decreasing efficiency of forage production.

Animal health

Many of the common weeds such as bitter sneezeweed, Carolina horsenettle (*Solanum carolinense* L.), and silver leaf nightshade (*Solanum elaeagnifolium* Cav.) are considered toxic to livestock. Fortunately most of these weeds are not palatable and are not readily grazed unless pastures are overstocked. Adverse weather conditions such as drought, penned animals, or even rotational stocking at high stocking rates may cause livestock to graze toxic plants. Some weeds, such as buttercup (*Ranuncuylus arvensis* L.), are considered only slightly toxic but may cause chronic problems such as reduced milk production, decreased weight gains, and lack of breeding efficiency that are seldom recognized.

Aesthetics

Managers take pride in their property and want it to reflect their sense of ownership. Nothing looks worse than a weedy pasture, but care must be taken in control of weeds using herbicides. The knowledge of weed identification and density of weeds present and the effect on reduced forage production are the indicators that herbicide control may be required. Weed control may not always be motivated by potential profit. Stakeholders spray herbicides to increase the efficiency of forage production and improve the overall aesthetics of the property.

When is a “weed” a “weed”?

The old and longtime definition of a weed is that it is “a plant out of place [2].” In monoculture grass pastures, such as bermudagrass, many managers consider any plant other than bermudagrass to be a weed. If hay is being produced for certain niche markets, such as the horse or dairy industry, relatively pure stands of grass may be required to meet standards and repeat sales opportunities. For most beef cattle operations, however, pure stands of grass may not be necessary or even desirable. Many plants that are routinely mowed or sprayed with herbicides have high nutritive value and are readily consumed by cattle, especially early in the season. Grazing management can encourage livestock to graze certain weed species, and this can minimize either mowing or the use of herbicides.

One aspect of weed management that is often overlooked is whether the "weed" has an intrinsic value other than forage for beef cattle. Many weed species provide excellent food and cover for wildlife. Wildlife species play an increasingly important role in providing revenue and diversity to ranch operations. If wildlife is to be a viable part of the management strategies, some specifics should be given to the overall weed management program. Overgrown fence rows may appear unpleasing to the eye and require management; however, these areas may provide excellent habitat and food for both game (white-tailed deer, quail, rabbits, etc.) and nongame species (songbirds, small mammals, etc.). Likewise many broadleaf weed species, such as common ragweed (*Ambrosia artemisiifolia* L.), have been identified as an important quail food and may be a desirable plant depending on the overall management goals and objectives. Many woody species also provide excellent browse for white-tailed deer. Careful consideration should be given to meeting the overall management strategies when considering weed control.

Management options

> ***Pastures that have lost their productivity through mismanagement or severe weed encroachment may require complete renovation. Herbicides are especially useful on such pastures that are too steep, rocky, or poorly drained to be mechanically tilled.***
>
> **T.H. Taylor, E.M. Smith, and W.C. Templeton, Jr. (1969)**

Usually the first indication of the need for a weed control management strategy is the presence of weed flowers in the pasture. Unfortunately by the time weeds become reproductive and flower, it is usually too late to apply herbicide; thus, the weed has effectively removed most of the moisture and nutrients required for some or most of the growing season. Some management options may be used to prevent ripening of seed; however, there is probably already a large seed bank in the soil. A better strategy is to be proactive and scout pastures early in the growing season(s) to determine the level of infestation, and whether weed control will be required.

Prevention

The best weed management program is one of prevention. Proper plant identification is critical for effective management of weed species, regardless of the management option used. Proper grazing pressure and soil fertility level encourage stands of desirable forages that compete with weed species in the pasture. Even under the best of management schemes, however, some weed management will be necessary for most hay and/or livestock operations. Some weed management options are included in the following topics.

Biological

Biological management does not necessarily mean using technologically advanced bacterial agents, although this strategy has been shown to be successful with certain weed species. More likely, biological management in pastures would involve the use of grazing livestock and stocking strategies to place pressure on weed species at key times in the season. Rotational stocking with high stocking rates such as mob grazing may be necessary to encourage livestock to graze certain plants that would normally not be consumed. Continued defoliation can drain the plant of its store of energy before an adequate root system is developed, and thus, destroy the plant. However, this may not be a good management strategy if toxic plants are the targeted weeds to be controlled.

Prescribed fire

Prescribed fire is generally used to suppress woody species, and in many instances, follows an appropriate herbicide treatment. The use of fire can extend the effective treatment life of the herbicide application. Continued use of prescribed fire, especially warm-season fire, can open wooded areas that provide better livestock and/or wildlife habitat. The frequency or use of prescribed fire will depend on the species targeted for control and weather conditions. Local authorities should always be contacted before using fire as a management option.

Chemical

Chemical (herbicide) management of weed species can be both safe and cost-effective if used appropriately (Appendix Tables 11.1—11.6). The two most important considerations for using herbicides include: (1) correctly identify the problem plant, which is important because some herbicides are more effective on certain weed species than others; and (2) follow the label directions. Strict adherence to label directions is required by law. Paying close attention to label directions will also ensure safe, effective control, and economical use. Herbicide labels contain directions for proper rate and timing of application, a list of susceptible species, and information regarding cleanup and disposal following use. The product label should be checked each year to determine if any changes have been made regarding the application of the product. New herbicides that have been labeled in recent years are weed and forage specific.

Herbicide application

There are several methods of applying herbicide including aerial, ground-applied using both boom (Appendix Table 11.7) and boomless (cluster nozzle; Appendix Table 11.8) rigs, or using individual plant treatment (IPT) for woody species. IPT or spot spraying is an effective way to control isolated woody plants. Spot spraying also greatly reduces the possibility of herbicide drift. IPT fits well with many managers because it does not require a large investment in application equipment. Herbicide applications to foliage should be done during periods of active weed growth when the plants are not under stress. The following IPT options provide excellent woody species control.

Stem treatment

Stem treatment method uses a 15%–25% mixture of triclopyr (Remedy Ultra) in diesel or vegetable oil (Appendix Table 11.9). The mixture should be applied to the lower 12″–18″ of any smooth bark tree. The 25% mix should be used on rough, corky bark of more mature plants. This treatment may be made at any time of year unless there is frozen ground or standing water. This treatment method is most useful when there is only one or two stems per plant, or when plants are >8 ft. in height. Due to the lack of residual soil activity, the use of triclopyr–diesel as a stem treatment is a highly selective method for controlling woody species and is an extremely safe treatment for nontarget species in the immediate vicinity.

High-volume foliar spray

This specific IPT is done on a spray-to-wet basis. As the name suggests this method infers that plants should be sprayed until the majority of the leaves are wet. Coverage should be similar to that resulting from light rain. Over-wetting or spraying until runoff wastes herbicide and does not improve control. Excessive rates may defoliate plants too fast which results in less root kill. This treatment method usually requires 1% total concentration of a herbicide or combination of herbicides. It depends on the target species and requires 0.25% nonionic surfactant with at least 90% active ingredient combined in water. Herbicide is applied to all foliage to the point that leaves glisten, but not to the point that herbicide runs off. Timing of application is during the late spring/early summer when growing conditions are good and foliage has turned dark green. A private pesticide applicators license may be required depending on herbicide used. This treatment method is most useful when there are multiple stems per plant and when plants are <8 ft. in height.

Cut stump

This treatment is designed to reduce the resprouting of woody species stumps. With this method the target species should be cut close to the ground to minimize interference with mowing, etc. The same herbicide treatment should be used as for stems; however, adequate herbicide should be applied to thoroughly wet the surface and the edges of the stump. The herbicide should be applied to the cut surface as quickly as possible. The treatment may be applied at any time of the year if standing water or snow does not interfere with treatment to the ground level.

Mechanical

Mechanical treatments, primarily mowing or shredding, can make the management of some woody species more difficult. In general more than one mechanical treatment per season may be required. Even when two trips across the field with a shredder are considered, there is an economic advantage of using herbicides.

Which herbicides can be used in legume pastures?

At this time there are few, if any, herbicides that can selectively control broadleaf weeds in annual legume pastures. Since clovers and other legumes fit into the broadleaf category, only white clover has some tolerance to herbicides for selective control. When applying herbicides to grass pastures, some commonly used herbicides can reduce the germination of a broadleaf crop (i.e., legumes) the following season (Table 11.1). These herbicides are often recommended due to their substantial soil residual. Unfortunately the soil residual of these active ingredients can interrupt seed germination of desired broadleaf crops such as legumes. Timing and rate of application can impact the interruption of seed germination. It is critical to read the label of products prior to use if there is an interest in establishing legumes the following season.

Table 11.1 Common herbicide active ingredients that can reduce seed germination of legumes and other broadleaf crops in the following season.

Aminopyralid
Clopyralid
Fluroxypyr
Hexazinone
Metsulfuron-methyl
Nicosulfuron
Picloram
Sulfuosulfuron
Tebuthiuron
Triclopyr

Refer to product labels prior to use to determine if the product will cause injury to susceptible broadleaf plants.

The development of new technologies such as Roundup Ready Alfalfa provides options for weed control in specific legume species. Roundup Ready Alfalfa is resistant to glyphosate, which is a herbicide that can be used to provide weed control. To maximize the benefits of Roundup Ready Alfalfa, glyphosate should be applied to seedling alfalfa at the 3–5 trifoliate stage when weeds are less than 4 in. tall. If weed problems persist, an additional application of glyphosate can be made up to 5 days prior to harvest.

Summary

Weed infestation of pastures is a problem for landowners and pasture managers. The most commonly perceived solution is to mow and/or apply herbicide. Weeds are generally a symptom of something that has gone wrong in the pasture. If weeds are a persistent problem, careful analysis of current management strategies is necessary to determine the underlying causes for the dilemma. In most instances management strategies involving the use of an appropriate stocking rate and a good soil fertility program will do much to alleviate the problem. Managers and applicators should always read and follow the herbicide label for effective weed control and reduced contamination to the soil–pasture system.

References

[1] L.A. Redmon, P.A. Baumann, V. Corriher-Olson, Weed and Brush Management in Texas, Texas A&M Soil & Crop Sciences Publication, 2013. SCS-2013–2014.
[2] C.M. Frederick, Merriam Webster's Collegiate Dictionary, tenth ed., Merriam-Webster Incorporated, Springfield, MA, 1999.

Appendix

The following tables summarize key information about herbicides commonly used on pastures. Each table presents information relevant to specific forage types and management scenarios. Ensure that you select the table that best represents your needs and information desired.

Refer to product labels for specific weeds controlled, proper application method and rate, personal protective equipment needed, cleanup and disposal, and other recommendations for safe and appropriate use.

Appendix Table 11.1 Herbicides used to control weeds on pastures and management strategies.

Bermudagrass pastures—newly sprigged

Weeds controled	Active ingredients	Time to apply	Haying/grazing restrictions
Annual grasses and annual broadleaf weeds	2,4-D + dicamba	Preemergence 7–10 days after planting	None, except for lactating animals (7 days), do not mow for hay until 7 days after treatment
Annual broadleaf weeds	Diuron	After planting and before the emergence of bermudagrass or weeds	Do not graze or mow for hay until 70 days after treatment

Bermudagrass pastures—newly seeded

Weeds controled	Active ingredients	Time to apply	Haying/grazing restrictions
Annual grasses and weeds	Glyphosate	Before planting	Do not graze or mow for hay for 0–8 weeks (varies by manufacturer)
Annual broadleaf weeds and selected perennial weeds	2,4-D	After well-established and runners have developed and are well rooted	Do not graze dairy animals on treated areas within 7 days after treatment

Appendix Table 11.2 Dormant Bermudagrass pastures.

Weeds controled	Active ingredients	Time to apply	Haying/grazing restrictions
Annual broadleaf and grass weeds including little barley	Paraquat dichloride	Postemergence during dormancy	Do not graze or mow for hay until 40 days after treatment
Annual grasses and weeds in bermudagrass	Glyphosate	Active weed growth before bermudagrass growth (dormant bermudagrass)	Do not graze or mow for hay for 0–8 weeks (varies by manufacturer)
Sandburs in dormant bermudagrass	Pendimethalin	Preemergence	None

Appendix Table 11.3 Pasture sod suppression and renovation.

Weeds controled	Active ingredients	Time to apply	Haying/grazing restrictions
Sod suppression	Paraquat dichloride	Postemergence in late summer or early fall to sod not >3 in. tall. Apply before or at the time of seeding winter annuals	Do not graze in treated areas until 60 days after treatment or until winter annuals seedlings are 9 in. tall
Broadleaf weeds	Glyphosate	Apply before planting forage grasses and legumes	Do not graze or mow for hay for 0–8 weeks (varies by manufacturer)

Appendix Table 11.4 Permanent grass pastures and established grass crops—1.

Weeds controled	Active ingredients	Time to apply	Haying/grazing restrictions
Annual and perennial grasses and numerous broadleaf weeds	Imazapic	Postemergence after 100% bermudagrass green-up	No grazing restrictions specified. Seven day hay harvest restriction
Annual broadleaf weeds and selected perennial weeds	2,4-D	Postemergence when weeds are actively growing	Do not graze dairy animals on treated areas within 7 days after treatment
Annual broadleaf weeds and selected perennial weeds	2,4-D + dicamba	Postemergence when weeds are actively growing	Do not graze meat animals in treated areas within 30 days of slaughter. Treated grasses may be harvested for hay, but do not harvest within 37 days of treatment
Annual broadleaf weeds and selected perennial weeds	Aminopyralid + 2,4-D	Postemergence when weeds are actively growing	Do not harvest forage for hay within 7 days of application. No grazing restrictions
Annual broadleaf weeds and selected perennial weeds	Picloram + 2,4-D	Postemergence when weeds are actively growing.	No grazing restrictions except for lactating dairy animals (7 days). Thirty-day hay harvest restriction. Do not transfer livestock onto broadleaf crop areas without first allowing 7 days of grazing on untreated grass pasture
Annual broadleaf weeds and selected perennial weeds	2,4-D + triclopyr	Postemergence when weeds are actively growing	No grazing restrictions except for lactating dairy animals (next growing season). No hay harvest restrictions, unless feeding to lactating dairy animals (14 days)
Annual broadleaf weeds and selected perennial weeds	Aminopyralid	Postemergence when weeds are actively growing	No grazing or hay harvest restrictions
Annual broadleaf weeds and selected perennial weeds	Aminopyralid + clopyralid	Postemergence when weeds are actively growing	No grazing or hay harvest restrictions
Annual broadleaf weeds, selected perennial weeds and bahiagrass	Aminopyralid + metsulfuron-methyl	Postemergence when weeds are actively growing	No grazing or hay harvest restrictions
Annual broadleaf weeds, some perennial broadleaf weeds and bahiagrass.	Metsulfuron-methyl	Apply when weeds are actively growing	No grazing or haying restrictions

Appendix Table 11.5 Permanent grass pastures and established grass crops—2.

Weeds controled	Active ingredients	Time to apply	Haying/grazing restrictions
Annual and perennial broadleaf weeds and bahiagrass	Metsulfuron-methyl + aminopyralid	Postemergence when weeds are actively growing	No grazing or hay harvesting restrictions
Annual broadleaf weeds, some perennial broadleaf weeds and bahiagrass	Metsulfuron-methyl + chlorsulfuron	Apply when weeds are actively growing	No grazing or haying restrictions
Annual and perennial broadleaf weeds, sandburs, Johnsongrass, crabgrass (large), and bahiagrass	Metsulfuron-methyl + nicosulfuron	Postemergence when weeds are actively growing	No grazing or haying restrictions
Annual broadleaf weeds, some perennial broadleaf weeds, and bahiagrass	Metsulfuron + dicamba + 2,4-D	Apply when weeds are actively growing	No grazing restrictions except for lactating dairy animals (7 days). There is a 37-day hay harvest restriction
Annual broadleaf weeds and selected perennial weeds	Picloram	Postemergence when weeds are actively growing	No grazing restrictions except for lactating dairy animals (14 days). No haying restrictions unless spraying at a higher rate (refer to specific product label)
Annual grasses and numerous broadleaf weeds	Glyphosate	During active weed growth. For perennials apply at seedhead formation	Do not graze or mow for hay for 0–8 weeks (varies by manufacturer)
Smutgrass and other weeds in bermudagrass and bahiagrass	Hexazinone	Warm and moist soil conditions—weeds actively growing	Grazing and haying restrictions depend on the rate of application. Refer to product label for restrictions
Annual and perennial broadleaf weeds	Tebuthiuron	Postemergence when weeds are actively growing	No grazing restrictions. one-year hay harvest restriction
Annual and perennial broadleaf weeds	Triclopyr	Postemergence when weeds are actively growing	No grazing restrictions except for lactating dairy animals (next growing season). Fourteen-day hay harvest restriction
Annual and perennial broadleaf weeds	Triclopyr + clopyralid	Postemergence when weeds are actively growing	No grazing restrictions except for lactating dairy animals (next growing season). Fourteen-day hay harvest restriction unless feeding to lactating dairy animals (next growing season)

Appendix Table 11.6 Permanent grass pastures and established grass crops—3.

Weeds controled	Active ingredients	Time to apply	Haying/grazing restrictions
Annual and perennial broadleaf weeds	Picloram + fluroxypyr	Postemergence when weeds are actively growing	No grazing restrictions except for lactating dairy animals (14 days). No haying restrictions unless feeding to lactating dairy animals (14 days)
Annual and perennial broadleaf weeds	Triclopyr + fluroxypyr	Postemergence when weeds are actively growing	Do not harvest hay within 14 days after application. No grazing restrictions except for lactating dairy animals (next growing season)
Annual and perennial broadleaf weeds, some grassy weeds including Johnsongrass	Sulfosulfuron	Postemergence when weeds are actively growing	No grazing restrictions. No haying restrictions. However, allow 2 weeks for best results

Appendix Table 11.7 Calibration of boom sprayer.

Chart for nozzle spacing and length of calibration course

Nozzle spacing (in.)	18	20	30	40
Length of calibration course[a] (linear ft.)	227	204	136	102

1. Determine nozzle spacing.
2. Refer to the table for length of the calibration course.
3. Mark off the calibration course on the actual area to be sprayed.
4. Record the time required to drive the calibration course at the desired field gear and rpm to be used while spraying.
5. Park tractor, maintain rpm used to drive course, turn on the sprayer and set it at proper pressure for desired nozzle tips.
6. Catch water from one nozzle for the time equal to that required to drive the calibration course.
7. Ounces of water caught = gallons per acre.
8. Divide gallons per acre into the number of gallons in spray tank to determine how many acres will be sprayed. Add the appropriate amount of herbicide for the number of acres to be sprayed.

Example: Calibration distance for 19-in. nozzle spacing = 340÷19/12 = 215 ft.

[a]To determine the calibration course for a nozzle spacing not listed, divide the spacing expressed in feet into 340 (340 sq. ft. = 1/128).

Appendix Table 11.8 Calibration of boomless sprayer.

Chart for nozzle spacing and length of calibration course						
Effective Swath Width (ft.)	25	30	35	40	45	50
Length of calibration course[a] (linear ft.)	218	182	156	136	121	109

1. Determine swath width.
2. Refer to the table below for the length of the calibration course.
3. Mark off the calibration course.
4. Record the time required to drive the calibration course at the desired field gear and rpm.
5. Park the tractor, maintain rpm used to drive course, turn on the sprayer.
6. Catch water for the time equal to that required to drive the calibration course.
7. Pints of water caught = gallons per acre.
8. Divide gallons per acre into the number of gallons in spray tank to determine how many acres will be sprayed. Add the appropriate amount of herbicide for the number of acres to be sprayed.

[a]To determine the calibration course for a swath width not listed, divide the swath width expressed in feet into 5460 (5460 sq. ft. = 1/8 of an acre). Example: Calibration distance for 32-foot swath width = 5460 ÷ 32 = 171 ft.

Appendix Table 11.9 Herbicide/water mixing ratios to achieve various concentrations.

Concentration desired (%)	Amount to add to 1 gallon of water (oz)	Amount to add to 3 gallons of water (oz)	Amount to add to 100 gallons of water
0.25	1/3	1	1 qt
0.5	2/3	2	2 qts
1.0	1 1/3	4	1 gallon
1.5	2	6	1.5 gallon
2.0	2 2/3	8	2 gallons

CHAPTER 12

Management strategies of property and impact on wildlife

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> ***Food and cover are of equal importance to the covey range, and one is of little use without the other. Farms so intensively cultivated and pastured that there is no cover can have no quail; while cover, be it ever so attractive, without suitable food, will be equally barren of birds.***
>
> **Herbert L. Stoddard (1931)**

Where's the beef? Challenges of implementing stocking strategies with wildlife

The goal of livestock and wildlife managers alike can be said to maximize yield. For livestock producers, this may mean beef production or dairy yields. For the wildlife manager, this could imply increasing the number of harvestable game animals or sightings of songbirds on a property. However, while livestock and wildlife can be managed together, it is difficult to simultaneously maximize yield for both. Rather, the two must offer tradeoffs—either more livestock and less wildlife or vice-versa—and the objectives of the landowner will dictate the balancing point (i.e., optimization).

Conceptually, stakeholders can be placed upon a continuum (Fig. 12.1) [1]. On the far-right end of this continuum are those whose priority is livestock production, and who do not explicitly consider wildlife as part of their daily operations (*Note*: Livestock producers are always on the right). On the far-left end of this continuum are landowners whose main priority is wildlife management, and who do not consider livestock production. Leaning right on the continuum, but not far right, livestock production is prioritized, and wildlife is secondary. Leaning left, wildlife is prioritized, and livestock are secondary, or only used as a management tool. In the middle, livestock and wildlife are equally prioritized.

When managing wildlife and livestock in tandem, different scenarios may be more or less challenging for a livestock producer than a wildlife manager, and vice-versa. For example, a landowner managing holistically for wildlife might not mind predatory

Management Strategies for Sustainable Cattle Production in Southern Pastures
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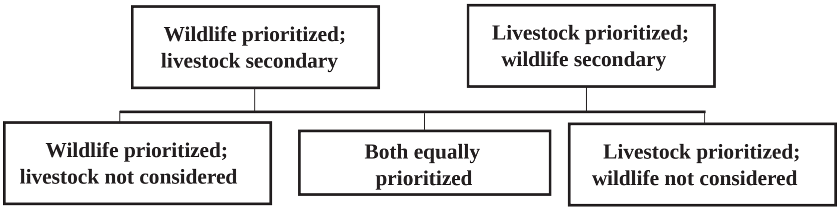

Figure 12.1 Conceptual continuum of stakeholder prioritization for livestock and wildlife management. *Adapted from D. Rollins, K. Cearley, Integrating wildlife concerns into brush management. in: W.T. Hamilton et al., (Eds.). Brush Management: Past, Present, Future. Texas A&M University Press, College Station, TX, USA, 2004.*

species such as coyotes (*Canis latrans*), black bears (*Ursus americanus*), wild pigs (*Sus scrofa*), or mountain lions (*Puma concolor*). For the livestock producer, however, these species serve as a challenge to optimize yields. Alternatively a livestock producer might prefer introduced forages to native forages; whereas, this can serve as a challenge for those seeking to enhance wildlife for recreational or aesthetic purposes.

Challenges faced in wildlife management are not always overt and can be difficult to address at the property scale. However, multiple decisions at a small scale can have a considerable effect at the landscape level. This concept is known as the tyranny of small decisions [2] and describes landscape level consequences resulting from independent and locally based management. William Odum is recognized for taking this concept, first applied to market economics, and popularizing it among wildlife ecologists [2]. An example he provides in his magnum opus is the loss of coastal wetlands along the east coast of the United States during the 1950–70s. In that time almost 50% of all wetlands were lost due to independent and local changes in land use. Odum purported, "If the public had been asked whether coastal wetlands should be preserved or converted to some other use, preservation would probably have been supported. However, through hundreds of little decisions and the conversion of hundreds of small tracts of marshland, a major decision in favor of wetlands conversion was made without ever addressing the issue directly." Similarly, because wildlife populations can operate at many different scales, local management can have larger consequences than what is realized on the "back forty." Approximately 66% of agricultural land and 34% of the total land mass in the United States is grazed or used for livestock production [3]. Thus it is easy to perceive how management of pasture conditions, even at the property scale, can affect a substantially large area.

With the same consideration of scale, goals can be difficult to achieve or realize when managing wildlife at a small scale. In Texas, for example, at least 65% of the number of land parcels within the triangle formed by Dallas, Houston, and San Antonio are smaller than 180 acres [4]. It is likely that these estimates are similar, if not smaller, across other parts of the southern United States. Though 180 acres may seem like a considerable amount of property, it is important to note that not only is this an average, but wildlife populations often interact on much larger scales. The area required to maintain a self-sustainable population of wild northern bobwhite quail (*Colinus virginianus*), for example, has been suggested to be around 3000 acres of habitat [5].

To understand how to manage pastures for enhancing or sustaining wildlife requires us to first step back and ask the question, "What do wildlife need?" Obviously, wildlife need habitat. But, what is habitat? Habitat is an inclusive term describing all the resources and conditions of an area that produces occupancy through survival and reproduction as it relates to a particular species, population, and individual [6]. That is, habitat is species-specific; habitat for wild turkeys (*Meleagris gallopavo*) is not the same as habitat for northern spotted owls (*Strix occidentalis caurina*). Though a large component of habitat is vegetation, the definition also implies other resources and their interspersion, including migration and dispersal corridors [6]. Habitat quality is, therefore, the ability of an area to provide these resources and conditions for population persistence and can be quantified using demographics rates such as survival and reproduction [6].

When managing habitat for any wildlife species at a small scale, manipulation of vegetation composition and structure tends to be the most realistic and attainable objective. Collectively, these two attributes can have a large impact on occupancy, survival, and reproduction. As a matter of fact, approximately 55% of avian community composition has been suggested to be attributed to floristic variation (i.e., plant diversity), while an additional 35% might be explained by physiognomy, or structure of a vegetation community [7]. The judicious application of grazing to alter vegetation with the desired outcome has been described as grazing management (see Chapter 5: Managing grazing in forage—livestock systems). Grazing management is a tool wildlife managers often employ to increase plant diversity and structure. The mechanisms of plant diversity on grazing lands tend to be a function of variation in biomass, among other things [8]. As such, the application of grazing management to meet various objectives is often dictated by region (Fig. 12.2), where different rainfall regimens affect biomass production.

In this chapter we expand upon these situations, and others, while discussing trade-offs and management strategies. Our goal is to help stakeholders identify challenges they could encounter in the field and offer ways to mitigate their occurrences to optimize operations.

Management of introduced and native forages for wildlife

Definitions

Native plants are described as those that occupied North America at the time of Columbus' arrival in 1492; whereas, introduced, non-native, and exotic all refer to

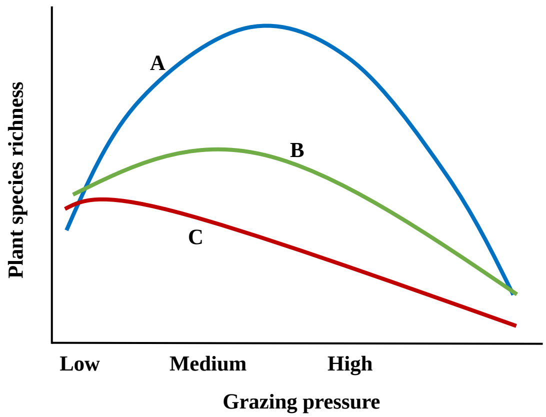

Figure 12.2 General and theoretical relationship of biomass and plant species richness. Letters describe (A) humid, (B) semi-arid, and (C) arid regions. *Adapted from J.L. Rotenberry, The role of habitat in avian community composition: physiognomy or floristics? Oecolgia 67 (1985) 213–217.*

species that were brought to the New World thereafter, either intentionally or accidentally [9]. The term "introduced" should not be confused with "invasive," which more appropriately describe aggressive plants that out-compete other species and often dominate vegetation communities because of a lack of natural competitors [10].

For grazing purposes our main focus of plants for forage production is grasses. Examples of commonly introduced grasses include Old World bluestems (*Bothriochloa* spp.), bermudagrass (*Cynodon dactylon* L.), bahiagrass (*Paspalum notatum* Flugge), kleingrass (*Panicum coloratum* L.), tall fescue (*Lolium arundinaceum* (Schreb.) S.J. Darbyshire), and bromes (*Bromus* spp.). Native grass examples include little bluestem (*Schizachyrium scoparium* Nash), big bluestem (*Andropogon gerardii* Vitman), eastern gamagrass (*Tripsacum dactyloides* L.), switchgrass (*Panicum virgatum* L.), and yellow indiangrass (*Sorghastrum nutans* Nash). Bahiagrass, bermudagrass, and tall fescue are the most common introduced forages in the southern region and will be the focus herein. The aforementioned native grasses are much less common but are nevertheless trending in their role in grazed systems.

The conversion of native pastureland to introduced grasses has been appealing to livestock producers because native plants are not able to sustain the same grazing pressure as introduced forages. Mechanisms among introduced forages that allow more extensive grazing pressure is called herbivory-induced forage compensation. Thus forage production (lb/acre) tends to be greater for improved grasses, and a large number of livestock can be supported in a land area. This has led to the colloquial term of "improved" grasses or pastureland among some circles.

So, it is clear that if a stakeholder is on the far right end of the conceptual continuum, planting introduced grasses from fence to fence would likely maximize livestock production compared to native range situations under most circumstances. But what are consequences for wildlife, and how can they be managed to compliment a wildlife plan?

Structure

No wildlife species yet has claimed the occupation of plant taxonomist—no Carl Linnaeus bobwhites scurrying about! In other words the particular species or origin of a plant is far less defining of its virtues to wildlife than other attributes such as structure, density, or food value. Mentioned previously, wildlife abundance and diversity is often associated with plant structure and diversity [7]. We can define structure at both the individual plant and community level. For individual grass plants the main growth structures are lumped into two general categories—bunchgrasses and sod-forming grasses. Bunchgrasses are characterized by tillers, or erect stems arising from the base of the plant; whereas, sod-forming grasses have stolons or runners. Of the grasses mentioned previously, bermudagrass and bahiagrass are considered sod-forming; whereas, all the rest were bunchgrasses. Bunchgrasses tend to be more favorable for wildlife because their structure allows access to the bare ground among a matrix of vegetation. This bare ground permits mobility for small mammals and birds [11] and promotes forb growth, which is a large food source for wildlife. When bunchgrasses become dense, they may also become problematic, especially for grassland and ground-dwelling avian species such as lark sparrows (*Chondestes grammacus*) or bobwhites.

Unfortunately, many introduced forages are aggressive invaders and have the propensity to form dense stands, regardless of their individual growth form. Tall fescue is an example of a bunchgrass that often becomes too thick for wildlife because it limits bare ground, food availability, and food quality for wildlife [12]. Buffelgrass (*Pennisetum ciliare* L.) and Lehmann's lovegrass (*Eragrostis lehmannniana* Lees) are introduced bunchgrasses common in the South Texas Plains. Because of their aggressive nature, native grass cover has been documented to be suppressed by 400% on sites where buffelgrass and Lehmann's lovegrass occurred [13,14]. Further, forb and grass species-richness, overall bird abundance, and arthropod abundance were all greater on native sites than sites with these exotic grasses [13,14].

Conversely, situations could arise when introduced bunchgrasses may be beneficial to both livestock and wildlife, such as during a drought when native grass production is limited. When managed properly (*see forage management*), buffelgrass and kleingrass, for example, may provide adequate nesting cover for ground-nesting birds [15,16]. Thus introduced forages might be best managed by designating them to specific areas and using those areas to carry the bulk of grazing pressure, while allowing the remainder of a property that is in native range to rest, especially during times of drought.

This is not to say that native species do not become invasive. For example, tanglehead (*Heteropogon contortus* L.) is a grass native to the southwestern United States that, in some scenarios, can exhibit invasive behavior and negatively affect abundance and distribution of bobwhite quail (Fig. 12.3) [17]. Though bobwhites use tanglehead for nesting, when off nest, they use areas with substantially less (38%) tanglehead cover than random locations [18] and avoid areas where overall tanglehead cover exceeds 20% [19]. Proper management, however, may mitigate these effects (*see forage management*).

Figure 12.3 Tanglehead (*Heteropogon contortus* L.) is a native bunchgrass that can exhibit invasive behavior. Note the contrast of bare ground at the roads edge to the dense, homogeneous, and impenetrable stand. Grazing is an influential tool to managing such grasses. *Photo courtesy: Bradley Kubecka.*

The key to managing forage is, therefore and ultimately, a manipulation of the amount of biomass. In the next section we identify management methods that are appropriate for varying situations in the field (Box. 12.1)

BOX 12.1 Bobwhites, Bahiagrass, and Bermudagrass: not on speaking terms

Bermudagrass and bahiagrass are commonly used introduced forage grasses in the southern United States. Their immense utility for the livestock industry cannot be overstated; however, their detriment on wildlife communities is equally immense. A thick, homogenous pasture of these grasses is the apple of a cow's eye but might as well be the Gulf of Mexico to a bobwhite. Bobwhites, especially broods, have difficulty traversing across the thick sod of bermudagrass and are exposed to hostile thermal environments as well [11] (Fig. 12.4). Bobwhites will nest in these grasses because the plant material can be easily made into a nest bowl—assuming the pature is not overgrazed (Fig. 12.5). However, winter cover is usually lacking due to the competitive nature of these species and management of the pasture itself (i.e., mowing and herbicide) to create a homogenous sward of grass.

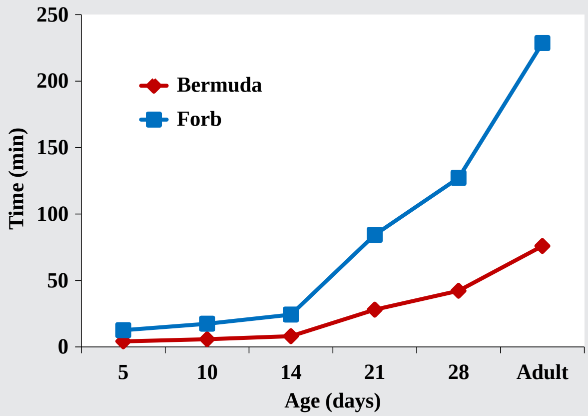

Figure 12.4 Bermudagrass creates a lethal thermal environment for bobwhites. The time (*y*-axis) it takes bobwhites of various ages (*x*-axis) to reach a hyperthermia in bermudagrass versus a forb dominated plant community. *Data from J.A. Martin, J.K. Burkhart, R.E. Thackston, J.P. Carroll, Exotic grass alters micro-climate and mobility for northern bobwhite chicks. Wildl. Soc. Bull. 39 (2015) 834–839.*

What strategies can be used to improve conditions for wildlife, particularly bobwhites? Assuming that growing beef is the primary objective, it will be difficult to create conditions in these systems which are favorable for bobwhites. A "land sparing" approach is to remove part of the pasture, perhaps the edge, and convert it to native vegetation to provide habitat (Fig. 12.6). The bigger the better, but financial considerations will dictate the willingness of a producer to remove the area from grazing. Another approach may be to use a "land sharing" approach, where the pasture itself is managed in a less intensive way for cattle production (i.e., more intentionally for bobwhites) such that plant diversity is increased and woody cover is allowed to grow intermittently (Fig. 12.7). This approach may entail a reduction in stocking

(*Continued*)

BOX 12.1 (Continued)

Figure 12.5 Author (JM) next to a clump of bluestem (*Andropogon* sp.) within a bahiagrass dominated pasture in south Florida. A bobwhite nest was found while mowing the pasture and was left to hopefully survive; however, the nest succumbed to predation a few days later. Notice the homogenous structure of the pasture and minimal plant diversity.

Figure 12.6 A pasture buffer between two introduced pastures. Cattle were excluded from the area and was subsequently managed with prescribed fire. Utility to wildlife will be proportional to the size of these buffers and the diversity of plants and structure within them. *Photo credit L. W. Burger, Jr.*

(*Continued*)

BOX 12.1 (Continued)

rate, altering timing of grazing, elimination of mowing and selective herbicides, and tolerance of a "rough" looking pasture. Like with the other approach a tradeoff between profit and wildlife will occur.

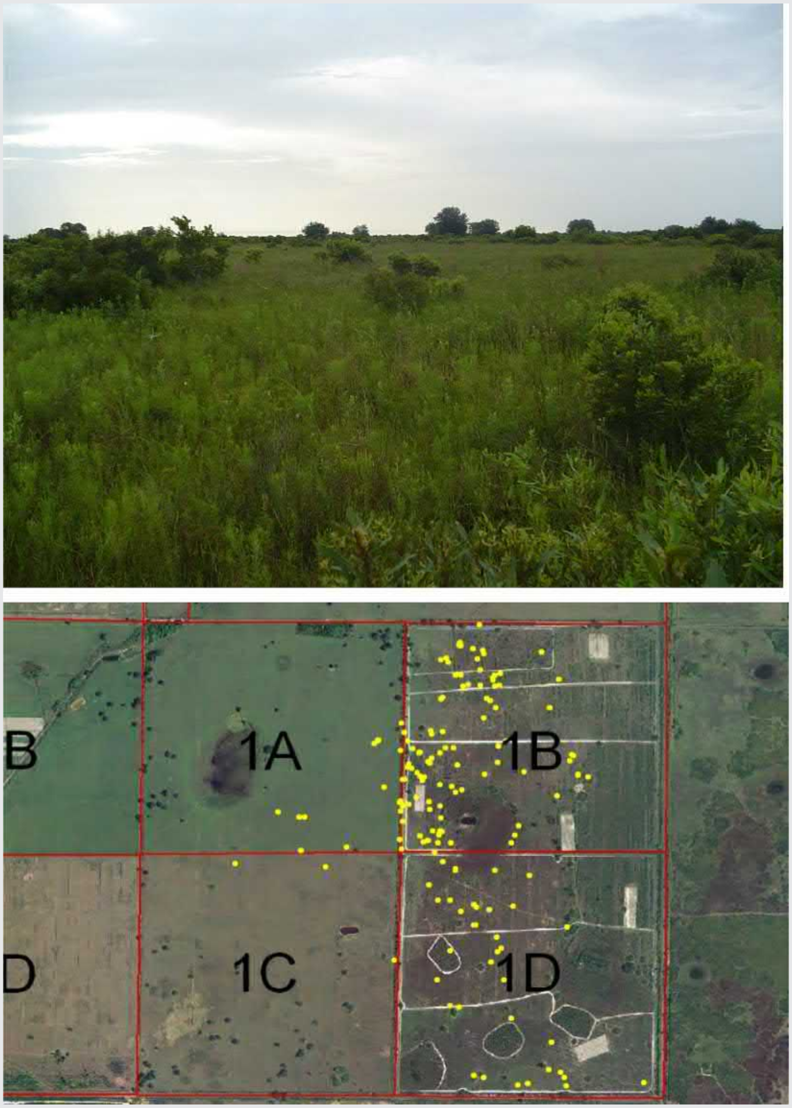

Figure 12.7 (Top) An introduced pasture, mostly consisting of bahiagrass before alteration, that was allowed to grow woody vegetation (e.g., wax myrtle [*Myrica cerifera*]) and maintain a greater vegetation height overall. (Bottom) Aerial view of the pasture above (1B and 1D) next to two traditionally managed bahiagrass pastures (1C and 1D). Each pasture is a quarter section (160 acres). The yellow dots represent locations of radio-tagged bobwhites during the course of a summer month.

Forage management and wildlife

Recognized over a century ago, Aldo Leopold, known as "the Father of Wildlife Management" astutely observed, "The central thesis of game management is this: game can be restored by the creative use of the same tools which have heretofore destroyed it—axe, plow, cow, fire, and gun... management is their purposeful and continuing alignment [20]." All of these tools can be important and even complementary to one another in their application to forage management.

The axe

The axe represents appropriate brush management on rangelands and timber management in forests. For rangelands some producers despise woody cover because it has the potential to limit grass production. But woody cover diversity and abundance can be important for wildlife such as white-tailed deer (*Odocoileus virginianus*), whose winter staple is predominantly browse (i.e., woody plants). Further, woody cover is perhaps the main mediator of excessive temperatures for wildlife on open range. The taller and shadier cover is often selected for by wildlife, especially during summer [21,22]. Areas without sufficient woody coverts may serve as thermal pinch points on the landscape. Thus, an objective for management should be to identify and focus on areas where resources such as woody cover, or lack thereof, may limit occupancy for the species of interest.

Structural diversity can be both vertical, as in the temperature example, but also "horizontal." How different resource patches are interspersed over an area is called landscape heterogeneity (Figs. 12.8 and 12.9) and is correlated with animal species diversity [23]. A stakeholder can apply this concept to brush management. The planned, selective control of the configuration, extent, and diversity of brush to enhance wildlife is called brush sculpting and is an appropriate consideration for pasture management [24]. Determining which woody plants to remove or keep and their distribution on the landscape, however, depends on the wildlife species being managed and where the constituent lies on the conceptual livestock-wildlife continuum.

The plow

Disking is another form of mechanical disturbance often used to increase soil exposure and stimulate forb growth through a matrix of otherwise homogenous vegetation. Light (i.e., with a tandem disk) dormant-season disking tends to promote forb growth more than disking in the spring, which could stimulate invasive grasses if present in the seedbank [25]. Thus, disking is limited in its application both spatially and temporally. For example, disking among tall fescue may increase forb growth, but these effects are typically short-lived, associated only with the growing season following disturbance [26]. Similarly, disking does little to increase plant diversity in bermudagrass

Figure 12.8 Aerial photo in which juxtaposed prescribed fire plots, disking, planted grasses, riparian area, and native rangeland provide accessibility to a variety of resources for wildlife. *Photo courtesy: Bradley Kubecka.*

pastures and actually may stimulate the growth of bermudagrass [27]. Moreover, disking tends to be limited to areas with deeper soils.

Fire

The use of fire to sculpt vegetation, and consequently wildlife distribution on the landscape, has been practiced by aboriginal and Native American cultures for centuries [28,29]. Applying fire to the landscape with an objective under specific conditions is considered prescribed burning. Similar to disking, the use of fire should be judiciously applied to avoid negative consequences, not only socially but ecologically; this includes knowing when (temporally) and where (spatially) fire should be applied on the landscape. Many exotic kinds of grasses have evolved with fire and sometimes thrive after burning. Alternatively, the proper use of fire can also be used to control invasive tendencies. Guinea grass [*Urochloa maxima* (Jacq.) R. Webster], for example, is a bunchgrass native to Africa and the Middle East. Prescribed burning during winter

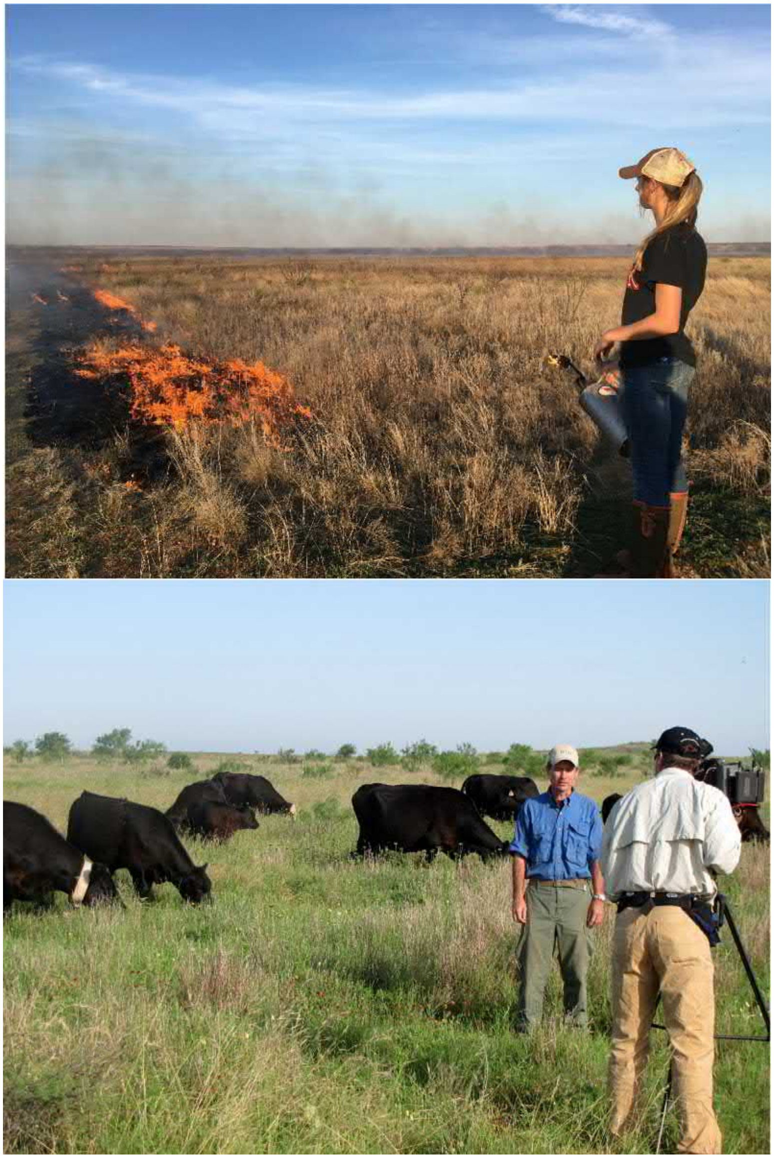

Figure 12.9 Prescribed fire (top photo) can be used to spatially manipulate grazing pressure (bottom) and heterogeneity across a landscape—a process called pyric herbivory. *Photos courtesy: Bradley Kubecka (top) and Dale Rollins (bottom).*

tends to increase guinea grass density; whereas, hot summer fires may actually be used to control guinea grass density and increase the number of native plant species within burn plots [30]. An area's response to fire depends on region, where virtues of fire might be more realized in wetter environments with short natural fire cycles (i.e., brief, historical return intervals of fire on the landscape due to lightning or deliberate setting of fires by Native Americans).

Grazing

Perhaps the most powerful tool in a manager's toolbox, however, has 4 legs and weighs 1100 lb. As with any tool the operator should use with care. Overgrazing is a ubiquitous concern for wildlife managers, but the judicious application of grazing can be beneficial as a source of mechanical soil disturbance (i.e., hoof action) to promote plant diversity. There are many adages and rules-of-thumb folks use when it comes to grazing. However, all rules of thumb are wrong at some place and some time. One of the oldest adages is "take half, leave half." This saying originated from a study in the mid-1950s evaluating root growth and plant health [31], which gave rise to yet another adage, "shoots grow roots." Indeed there is truth to both of these statements, but they fail to consider the specific requirements of wildlife, and at face value, the initial state of range health. Once specific wildlife requirements are considered, and grazing is still the appropriate management tool to achieve objectives, then a manager can make more detailed decisions like grazing intensity. Grazing intensity obviously varies by site and year and differs from stocking rate as it takes into account the amount of grazable area and the duration of grazing. Timing of grazing (discussed in Chapter 5: Managing grazing in forage—livestock systems) for sustainable forage management and to meet objectives for wildlife may also be important, but depends on the type of cattle operation.

The type of operation (cow—calf or stocker cattle) dictates the application of most grazing methods. For cow—calf operations, high intensity-low frequency grazing using paddocks and rotations are typically desirable for increasing forb growth, landscape heterogeneity, and wildlife use [32]. If paddocks are not available, a manager can spatially manipulate grazing pressure by moving molasses tubs or salt and mineral blocks. If a water system is available, grazing pressure can be altered by choosing which sites on a property have water. Using stocker cattle to meet various objectives can follow the same high intensity-low frequency grazing scheme, but may be subject to a contract between a lessor and lessee for when cattle will be destocked. Thus, an agreement between the lessor and lessee that destocking must be initiated within a specified grace period should be met. This grace period should be brief to avoid overgrazing.

Patch-burn-grazing

After application of fire to an area, nutritive value and palatability of plants tend to increase, attracting large herbivores (e.g., cattle, deer) to burned areas and allowing nonburned areas to rest. This forms a patchwork mosaic of multiple vegetation communities across an area and increases landscape heterogeneity. The mechanism of spatially manipulating grazing pressure using fire is referred to as pyric herbivory and has been documented to increase stocker cattle gains (with long-term use), increase the abundance of small mammals, and increase the diversity and stability of avian communities [33–35]. In practice this method is referred to as patch-burn-grazing and entails identifying and burning patches of old forage that may have declined in nutritive value or have become homogenous in structure and diversity.

Case study of patch burn grazing in southern Texas

Gulf cordgrass (*Spartina spartinae* [Trin.] Merr. ex Hitchc.) is a native bunchgrass that grows in many coastal counties of the southeastern United States. Gulf cordgrass can provide nesting habitat and cover for wildlife, but it decreases in palatability for livestock as it matures. In the months following application of fire in southern Texas, winter and summer burning increased crude protein of gulf cordgrass (Fig. 12.10) [36]. Consequently cattle home ranges shifted to overlap burned areas more than before the application of fire (Fig. 12.11) [37]. Similarly, tanglehead-dominated vegetation communities (discussed previously) subjected to patch-burn grazing were documented to

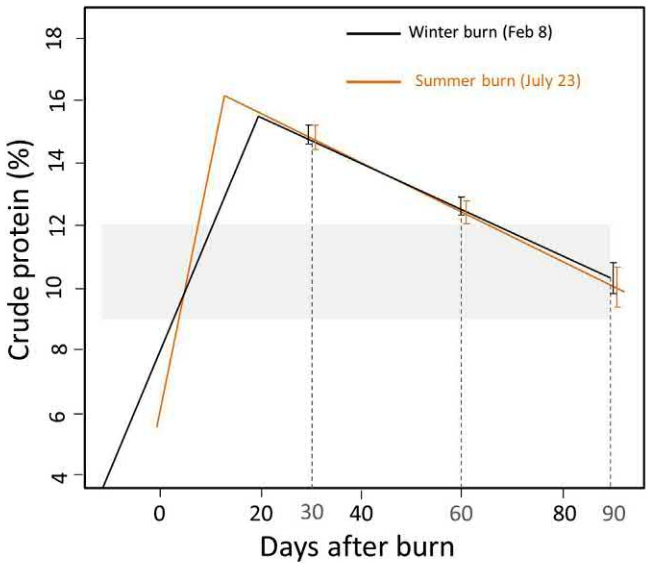

Figure 12.10 Prescribed fire's general effects on protein content of gulf cordgrass (*Spartina spartinae* [Trin.] Merr. ex Hitchc.) in southern Texas following winter and summer burning. Predicted values (±1 standard error) for 30, 60, and 90 days post-burn are indicated by dashed vertical lines. The shaded area indicates maintenance requirements for lactating cows. *Adapted from V.L. Haynes, J.S. Avila-Sanchez, S. Rideout Hanzak, J. Alfonso Ortega-Santos, D.B. Wester, T.E. Fulbright, H.L. Perotto-Baldivieso, T.A. Campbell, A. Ortega-Sanchez, Jr., Nutritive value of gulf cordgrass after burning, in: A. M. Fedynich, (Ed.) Report of Current Research: Ceasar Kleberg Wildlife Research Institute. Kingsville, TX, 2018, pp. 76–77.*

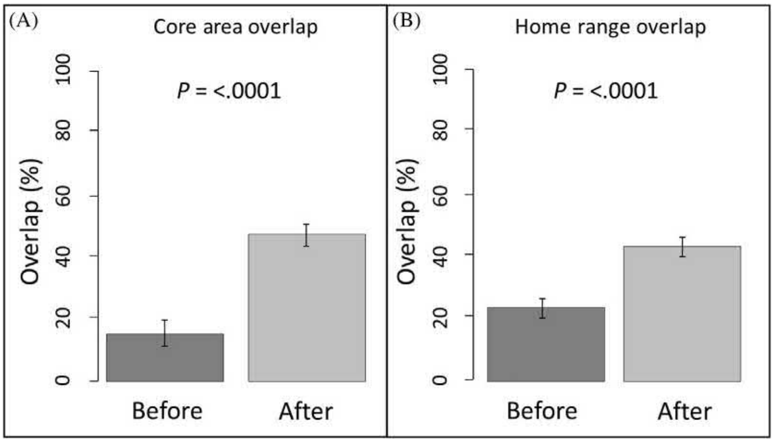

Figure 12.11 Prescribed burning of gulf cordgrass (*Spartina spartinae* [Trin.] Merr. ex Hitchc.) during summer and winter alters percentage of core area (A) and home ranges (B) of cattle overlapping burned areas in southern Texas. *Data from V.L. Haynes, J.S. Avila-Sanchez, S. Rideout Hanzak, J. Alfonso Ortega-Santos, D.B. Wester, T.E. Fulbright, H.L. Perotto-Baldivieso, T.A. Campbell, A. Ortega-Sanchez, Jr., in: A.M. Fedynich, (Ed.), Report of Current Research: Ceasar Kleberg Wildlife Research Institute, Kingsville, TX, USA, 2018, p. 79.*

host twice the number of native plants than communities not burned, and cattle were more than four times likely to use tanglehead sites after they were burned [38]. Moreover patch-burn-grazing of guinea grass plots in southern Texas increased native plant species richness by over 300% when applied during the summer [30]. This resulted in an increase or emergence of 10 important forbs used by white-tailed deer and six for bobwhite quail. Consequently deer gained a preference for areas after they were burned [30].

It is important to note, however, that grazing intensity and invasive species are significant regulators of heterogeneity and can influence the effect of fire on the spatial fuel loads, vegetation structure, and use of an area by wildlife [39]. Thus, many factors should be deliberated when considering patch-burn-grazing as a management tool. The scale at which these tools are applied is also important and should be determined based on the requirements for which wildlife are being managed.

Finding the best strategy for managing property

Poor land may be rich country, and vice versa. Only economists mistake physical opulence for riches. Country may be rich despite a conspicuous poverty of physical endowment and its quality may not be apparent at first glance, nor at all times.

Aldo Leopold (1953)

Landowner objectives come in a variety of flavors ranging from profit, to recreational, to aesthetics, just to name a few. Intrinsically most landowners, cattle producers, farmers, and others value wildlife and the overall environment. However, cattle production, in almost every instance, requires a tradeoff between some aspect of the ecosystem and economic return. Management of property involves finding the best strategy that optimizes the returns across multiple objectives that may be competing or conflicting. Competing objectives are those fundamental objectives that require satisfaction or fulfillment, but for which there are insufficient resources to fulfill completely. For example, the maximization of bobwhite and mourning dove abundance for hunting is not biologically opposed per se, but the more money spent on one diminishes the resources spent on the other when the budget is fixed. Conversely, conflicting objectives occur when the fulfillment of one or more objectives is in direct conflict with another. For example, maximizing bobwhite abundance and revenue from cattle conflict because neither can be 100% maximized under most realistic conditions. How to choose a strategy that can optimize outcomes among several objectives is the key to successful land management.

Let us walk through a simple example using a marginal rate of return as a quantitative approach to selecting the best strategy. A cattle producer is considering converting their introduced pasture to native grass (remember the benefits mentioned earlier). In addition to making a living producing beef in their cow−calf operation, they also value grassland birds—the beautiful chorus of singing males during their morning coffee is a source of connection to the land. We will use a tall-grass dweller, the dickcissel (*Spiza americana*), as an example (see Ref. [40] for a detailed analysis of this example). The producer is considering three options: (1) keep their introduced grass pasture (a mix of tall fescue and bermudagrass), (2) convert their pasture to a monoculture of Indiangrass, and (3) convert their pasture to a mix of Indiangrass, big bluestem, and little bluestem (hereafter, "NWSG"). Using a traditional marginal rate of return (MRR) analysis, ignoring the wildlife objective momentarily, the producer would need to know the benefit and cost of each option. The benefit is almost entirely driven by the total amount of beef produced each year for each option (Fig. 12.12). The two options using native grasses outperform the introduced grasses as far as beef produced, mainly because of their tolerance to drought [40]. But the producer must consider the cost of managing each option and the initial conversion costs. MRR for the NWSG option can then be calculated as:

$$\text{MRR}_{\text{Economic}} = \frac{\text{NetBenefit}_{\text{NWSG}} - \text{NetBenefit}_{\text{Introduced}}}{\text{Cost}_{\text{NWSG}} - \text{Cost}_{\text{Introduced}}} \times 100\%$$

where any MRR value > 0 indicates the NWSG option is a better economic option given the economic assumptions. However, to this point we have ignored the objective of grassland birds. To do so we need to treat dickcissels as a farm commodity [41]

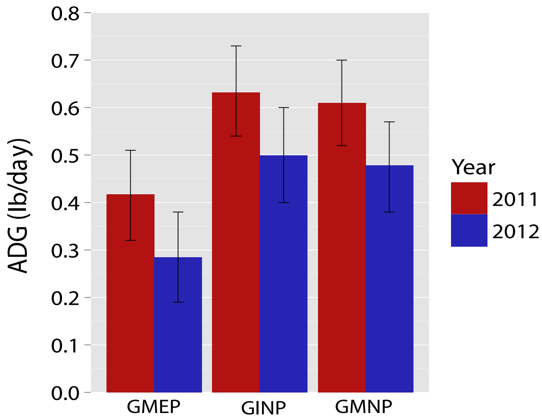

Figure 12.12 Average daily gain (lb/day) for cattle across three different pasture types including grazed mixed exotic grass pasture (GMEP), dominated be tall fescue and bermudagrass; grazed Indiangrass pasture (GINP); and grazed mixed native pasture (GMNP), consisting of little bluestem, big bluestem, and Indiangrass. *Data taken from A.P. Monroe et al., Economic and conservation implications of converting exotic forages to native warm-season grass. Global Ecol. Conserv. 11 (2017), 23–32.*

where we use the anticipated number of birds produced (marginal net benefit) divided by the marginal cost to yield a marginal rate of return in dickcissel productivity:

$$MRR_{Birds} = \frac{Fledglings_{NWSG} - Fledglings_{Introduced}}{Cost_{NWSG} - Cost_{Introduced}} \times \frac{100}{100}$$

This value can be interpreted as the change in dickcissel productivity for every $100 invested in NWSG conversion. MRR values >0 indicate more dickcissels produced relative to the introduced grass option per cost invested. For simplicity, we can plot these values and compare them in a 2-dimensional space (Fig. 12.13). The best options compared to the current option (introduced grass) would appear in the upper-right quadrant, where both economics and birds have a positive MRR. The worst options would fall in the lower-left quadrant where neither MRR values are positive. In this specific example the indiangrass option falls in the upper-right quadrant suggesting the producer should choose that option given their objectives. The NWSG option is in the upper-left quadrant, indicating positive gains for dickcissels but economically less profitable than the existing introduced-grasses pasture.

Using a marginal rate of return analysis alone can lead to sound decision making, but it does have limitations especially when the objectives are measured on very different scales. In the previous example, $MRR_{Economic}$ was measured on the scale of percent change in dollars while MRR_{Birds} was measured as the change in the number of dickcissels. This makes it hard to choose an optimal strategy when there are trade-offs involved. The NWSG option, as you recall, did increase MRR_{Birds} but not

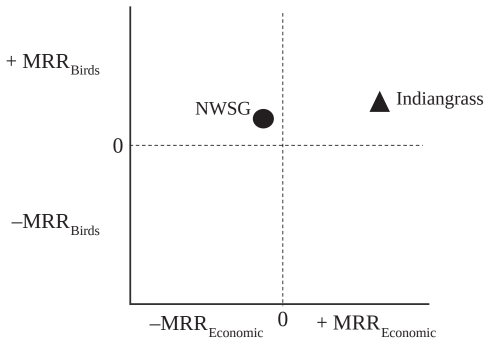

Figure 12.13 The marginal rate of return for two factors, economics and birds, as determined for two different strategies: native warm season grass mixture (*solid oval*) and Indiangrass (*solid triangle*) compared to the current strategy of introduced pasture. Positive values represent a gain in returns whereas negative values represent a loss in returns. Dotted lines represent the "break even" values.

$MRR_{Economic}$. Thus the decision of the landowner between those two objectives depends on how much they value one over the other. Given the objectives occur on different scales, the landowner is left to compare a bird to a dollar, which may not be the most intuitive comparison.

Instead of using attributes on different scales, we can use multiattribute utility theory (MAUT) to improve decision making [42]. To demonstrate the effectiveness of this approach, we will use an example involving the determination of stocking rate for a rangeland pasture (Fig. 12.14). As in the previous example, the landowner has an economic objective (maximizing profit) and a wildlife objective (hunting bobwhites). We will use bobwhite density (birds/acre) to measure the performance of a series of grazing options for the objective of bobwhite hunting. The key to this approach is defining the utility or preference the landowner has for each attribute on a scale from 0 to 100, with the 100 being the most preferred condition (i.e., a landowner is fully satisfied). For this example, $MRR_{Economic}$ follows a nonlinear pattern, where utility is very low, <0 MRR, and increases linearly thereafter (Fig. 12.15, top). The utility for bobwhite density follows a simple increasing linear function within a range of possible density (Fig. 12.15, bottom). Again, take note that both *y*-axis are on the same scale. The landowner wants to consider two different stocking rate strategies that will affect both the economic return and bobwhite density (Fig. 12.14). Strategy 1 (S1) has a utility value of 60 for bobwhite density and 5 for $MRR_{Economic}$; whereas Strategy 2 (S2) has a utility of 40 for bobwhite density and 40 for $MRR_{Economic.}$ Thus the overall utility for S1 is calculated as follows:

$$\text{Utility}_{S1} = \text{Utility}_{\text{Bobwhite}} \times W_{\text{Bobwhite}} + \text{Utility}_{\text{MRR}} \times W_{\text{MRR}}$$

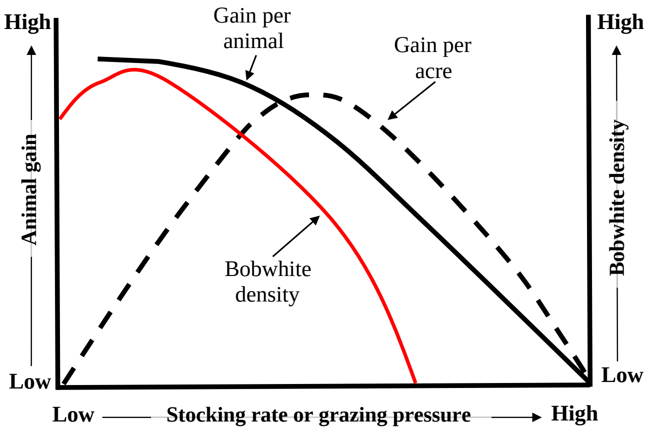

Figure 12.14 The relationship of gain per animal and gain per acre with stocking rate or grazing pressure on primary *y*-axis. The relationship of bobwhite density with stocking rate or grazing on secondary *y*-axis. *Adapted from Chapter 5: Managing grazing in forage—livestock systems.*

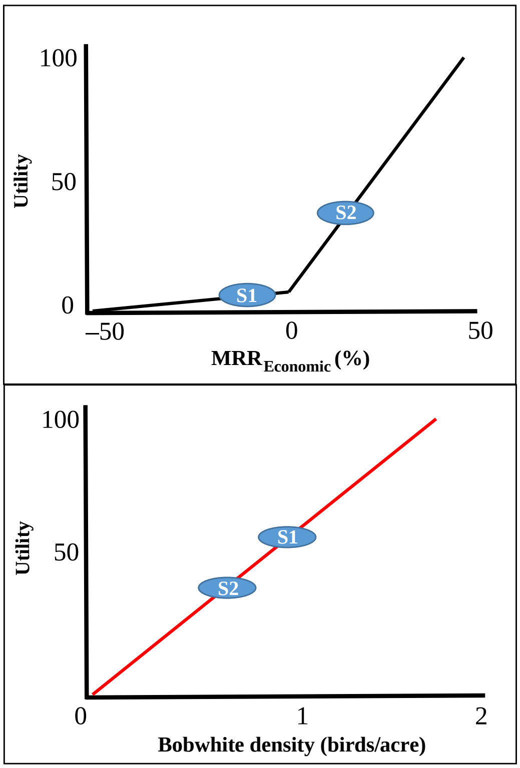

Figure 12.15 (Top) The relationship between marginal rate of return and utility for the objective of maximizing economic return from grazing cattle. (Bottom) The relationship of bobwhite density and utility for the objective of maximizing bobwhite hunting opportunities.

where W is the relative weight or importance of each objective (must sum to 1). Assuming equal weights, the utility of S1 is

$$32.50 = 60 \times 0.5 + 5 \times 0.5$$

Using the same equation, the utility for S2 is 40, suggesting it is the strategy that is the most optimal for both objectives ($40 > 32.50$). There is an explicit loss in bobwhite density by choosing S2, as S1 produced more bobwhites, but the difference was not great enough to overcome the loss in income with S1. This approach is flexible to each landowner's objectives, how much they value each objective (i.e., the weights can be changed), and the strategies they want to consider. Landowners and managers may be reluctant to explicitly quantify values and outcomes from strategies, but data- and value-based decision-making approaches will more often lead to successful choices for the objectives of their land.

Summary and conclusion

Finding the best strategy for meeting a wildlife objective, while also remaining economically solvent on a property consisting mostly of cattle production, is a challenging but not impossible task. The toolbox at managers' disposal is diverse, including prehistoric tools (e.g., fire), modern chemistry (e.g., herbicides), and analytical approaches (e.g., MAUT). No matter the wildlife objective, rules-of-thumb can help generalize the possible outcomes of management such as wildlife diversity which is (usually) proportional to the diversity of vegetation within the pasture and among patches. For specific species, like bobwhites, the greater the diversity in structure and composition across large areas, the greater their abundance. Managers need to start with clearly defined objectives and the understanding that tradeoffs will exist in almost any scenario. Science and technology tools are available to identify the best strategies to meet these objectives. These tools are often buried in scientific literature and not readily accessible to practitioners; thus managers should engage with appropriate areas of expertise (e.g., county extension, consulting biologists) for their particular problem.

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Index

Note: Page numbers followed by "*f*", "*t*", and "*b*" refer to figures, tables, and boxes, respectively.

C

G

H

I

K

L

M

Y

Z

Management Strategies for **Sustainable Cattle Production** in Southern Pastures

Edited by **Monte Rouquette, Jr. PAS** and **Glen E. Aiken**

Provides strategies to optimize cattle welfare and to help improve the sustainability of pastures and profitable cattle production.

Monte Rouquette, Jr. PAS
Regents Fellow and Professor of Forage Physiology, Texas A&M AgriLife Research Center – Overton, TX, United States

Glen E. Aiken
Center Director, UF-IFAS North Florida Research and Education Center – Quincy, FL, United States

Management Strategies for Sustainable Cattle Production in Southern Pastures is a practical resource for scientists, students, and stakeholders who want to understand the relationships between soil-plant interactions and pasture management strategies, and the resultant performance of cow-calf and stocker cattle. This book illustrates the importance of matching cattle breed types and plant hardiness zones to optimize cattle production from forages and pastures. It explains the biological and economic implications of grazing management decisions made to improve sustainability of pastures and cattle production while being compliant with present and future environmental concerns and cattle welfare programs.

- Documents the effects of cattle grazing on greenhouse gas emissions and carbon footprints
- Discusses strategies to enhance soil fertility, soil health, and nutrient cycling in pastures
- Provides information on the use of stocking rates, stocking strategies and grazing systems to optimize cow-calf production of weaned calves and stockers.
- Presents innovations in cattle supplementation and watering systems to minimize negative impacts on water and soil health
- Includes methods for weed control to maintain pasture condition and ecosystem stability
- Describes management strategies to integrate cattle operations with wildlife sustainability

Monte Rouquette, Jr. PAS has served at Texas A&M AgriLife Research and Extension Center, Overton, since 1970. His research program combines the soil–plant interface and environmentally compatible impacts of nutrient cycling under grazing and stocking conditions with the plant–animal interface that assesses biological components of efficiency for forage utilization by cows, calves and stocker cattle. His program also includes a birth-to-harvest database, BeefSys, used for modeling and economic aspects.

Glen E. Aiken has an h-index of 14 and is the research leader of the Forage-Animal Production Research Unit, Lexington, Kentucky. Dr. Aiken is a major contributor to forage-animal production in the United States to improve productivity, profitability, competitiveness, and sustainability of forage-based enterprises for the enhancement of food animal production. Currently, he is the Director of the University of Florida's North Florida Research and Education Center.

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