

FORAGES FOR NORTH CAROLINA: GENERAL GUIDELINES AND CONCEPTS

An overview of forage species and their use in livestock production systems

Forage is defined as the edible parts of plants, other than separated grain, that can provide feed for grazing animals or that can be harvested for feeding. There are a variety of herbaceous forage plants that can be grown in North Carolina. Adapted species range from cool-season to warm-season grasses and legumes (Table 1). The diversity in forage species that can be grown in NC is, in part, due to the state’s geographical location (between 33.5° and 37° N) in what is recognized as the *transition zone*, an area between the cool, humid climate of the North and the warm, humid climate of the South. Cool-season species thrive when temperatures range from 65°F to 75°F, and warm-season species are best adapted to temperatures between 80°F and 95°F. Cool- and warm-season forages can be either annuals (live for one season) or perennials (live for multiple seasons).

In addition to climate, differences in soil characteristics determine where some species are better adapted than others. The combination of geology (composition) and geomorphology (soil formation processes) has resulted in four major NC soil regions: coastal plain, sandhills, piedmont, and mountains (Fig. 1). Soil chemical and physical characteristics can vary considerably within a soil region. Nevertheless, in general, soils across the NC coastal plain and sandhills are sandy to sandy-loam, in the NC piedmont they are clayey to clay-loams, and soils in the NC mountains are fine loamy to sandy-clay loams. Agronomically, the NC coastal plain and sandhills have been the major row and vegetable crops producing regions, whereas the NC piedmont has been a mixture of cropping systems with a strong dairy and beef presence and the NC mountains have been dominated by beef cattle production with some cropping present.

Table 1. Main forage species grown for livestock production in North Carolina

	GRASSES		LEGUMES	
	PERENNIAL	ANNUAL	PERENNIAL	ANNUAL
COOL-SEASON	Tall fescue Orchardgrass Kentucky bluegrass Redtop Timothy Perennial ryegrass Rescuegrass	Ryegrass Small grains	White clover Alfalfa Red clover Birdsfoot trefoil Crown vetch	Crimson clover Hairy vetch Arrowleaf clover Hop clovers Subterranean clover Berseem clover
WARM-SEASON	Bermudagrass Switchgrass Flaccidgrass Dallisgrass Bahagrass Carpetgrass Gamagrass Caucasian bluestem Big bluestem	Pearl millet Sorghum Sudangrass Sorghum-sudan hybrids Crabgrass	Sericia lespedeza	Kobe lespedeza

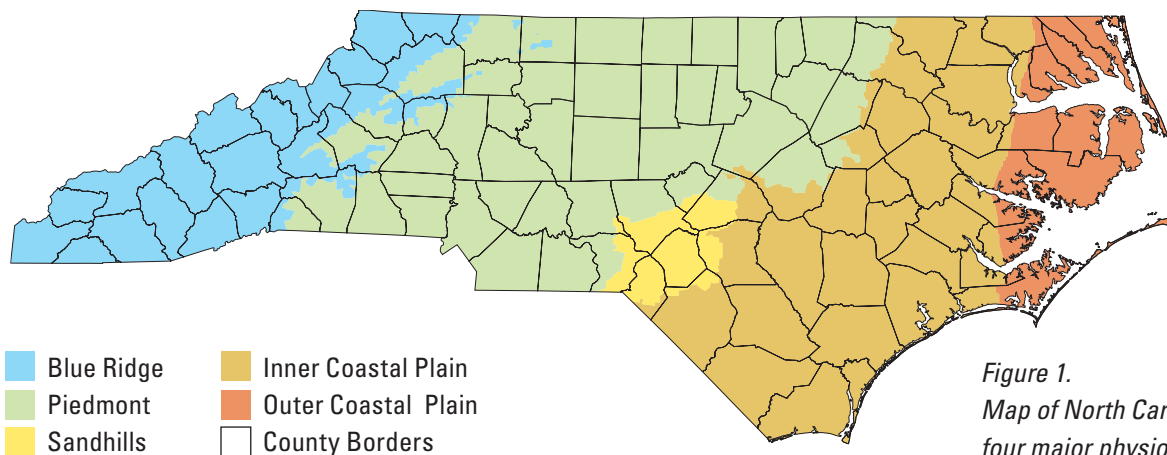


Figure 1.
Map of North Carolina that identifies four major physiographic regions.

Weather conditions (including rainfall and temperature), soil conditions (including moisture and temperature), and management practices (establishment, fertilization, and frequency and intensity of forage defoliation) determine not only the short-term productivity of forage species, but most importantly its *persistence*—its presence or absence and stand longevity. The traditional perennial forage species grown in the NC coastal plain have been tall fescue (where adapted), bermudagrass, bahiagrass, and dallisgrass (Table 1). In the NC piedmont, tall fescue and bermudagrass have dominated, whereas in the NC mountains, Kentucky bluegrass and white clover pastures have dominated, although orchardgrass is also well-adapted. Alfalfa can be grown in all three zones and where adapted has generally been harvested and conserved as hay.

Establishing large acreages to forages can be costly and time-consuming. Thus, deciding which species to plant must involve consideration of several issues, including (1) the system’s main objectives, (2) which forages most closely match those objectives, and (3) what management decisions have the greatest impact on success.

FORAGE PRODUCTION SYSTEMS

Forage plants can provide feed for animals through grazing or be stored and shipped as hay, silage, or haylage for subsequent feeding to livestock during periods of short supply. Further, forages can be included as part of crop rotation systems (i.e., as cover crops, to break the cycle of agricultural pests), as well as recycling of animal wastes (i.e., land-application of waste from concentrated animal feeding operations), biomass production for bioenergy purposes, and to prevent contamination of water resources (i.e., riparian vegetation), among other uses. Each specific theme has its own inherent challenges and opportunities.

The implication of defining specific objectives for a forage-based system should include efforts to identify not only the most productive plant species, but in fact, the focus should be on identifying the species that remain productive with the level of inputs and management that land managers are able to provide (such as high versus low inputs and intensive versus extensive management). Consequently, it is impossible to make a single forage recommendation for all conditions. Controlled experimentation provides the foundation for understanding the mechanisms that drive responses, and in conjunction with careful observation and applied research-based information should aid on decision-making processes to generate specific recommendations for a given set of conditions.

CHOICE OF FORAGE SPECIES

Legumes versus Grasses

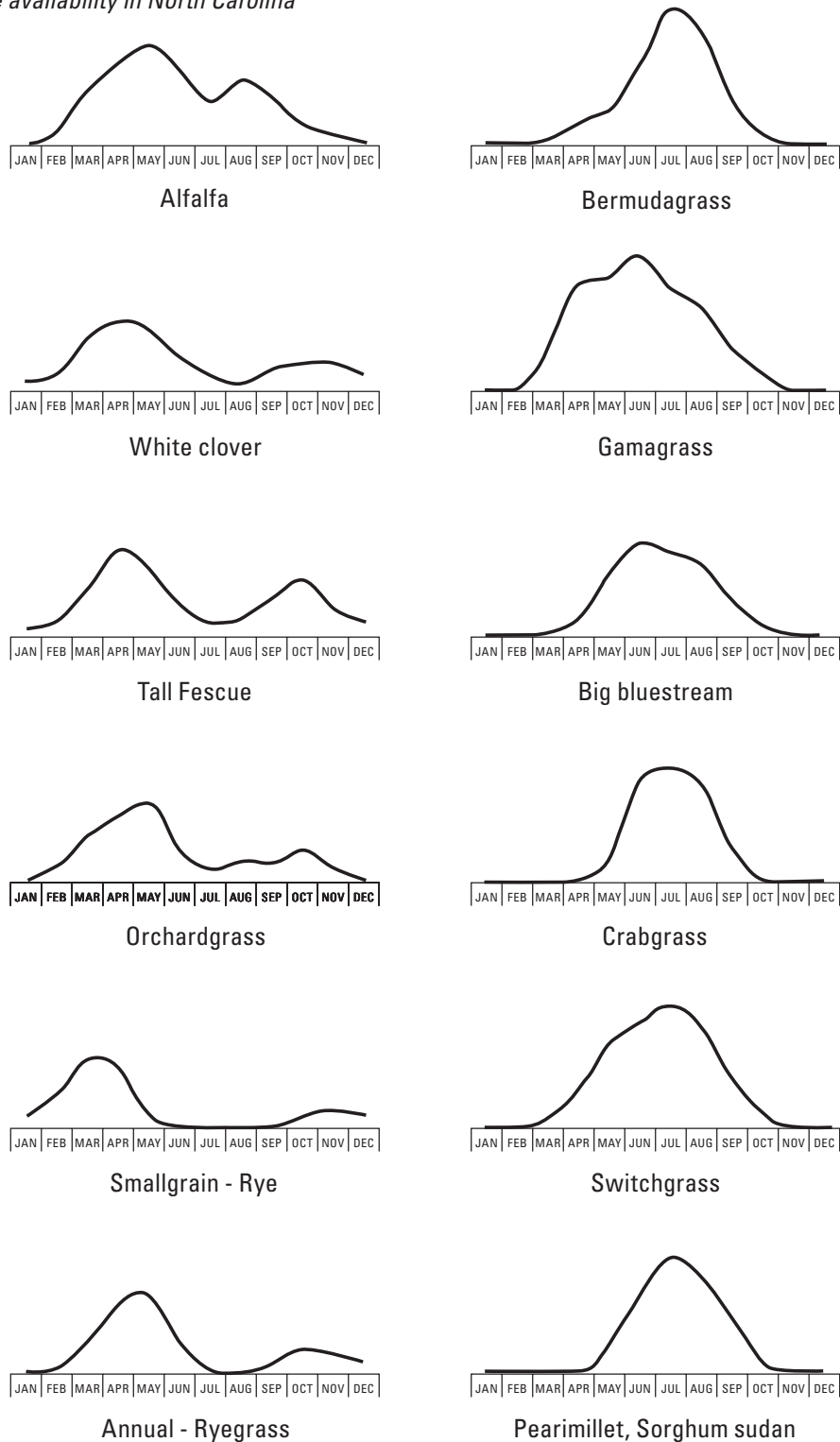
Legumes differ from grasses in several ways, including size and shape of leaves, stems, roots, and flowers. One of the most remarkable differences between legumes and grasses is that most legumes can form a symbiotic (mutually beneficial) relationship with certain bacteria that live in the soil. These bacteria (*Rhizobia* species) form nodules on plant roots in which atmospheric nitrogen is changed to forms of nitrogen that are of nutritional value to the plants. This process, referred to as *nitrogen fixation by legumes*, plays a key role in low-input production systems where there is limited application of nitrogen fertilizer. In addition, legumes are generally recognized as being of greater nutritive value than grass species when fed to ruminant animals.

Seasonal Forage Availability

The time of the year that forage is needed as well as its intended use are two critical points to consider when deciding which forages to grow. It would be optimal to have a forage species that grows year-round and meets the nutritional demands of livestock. Nevertheless, due to variations in weather (temperature being the main driver), we have no single year-round forage species in North Carolina. Our best approach is to design forage systems that match periods when specific

forages actively grow (Fig. 2). This approach will consequently describe periods of forage mass abundance and shortage. It is possible to achieve year-round forage supply from standing forages using a combination of management practices that include growing a mix of warm-season and cool-season annual and perennial species (Table 1, Fig. 2) and forage conservation practices (such as stockpiling).

Figure 2. Seasonal forage availability in North Carolina



CHOICES AFFECTING SUCCESS OF A PRODUCTION SYSTEM

Relationship Between Quantity and Nutritive Value

For this publication, *quantity* is defined as the amount of forage mass (lb) produced after a period of regrowth (days) per unit area (acre). The longer the regrowth period, the greater the amount of total herbage that accumulates, at least up to a point (Fig. 3). Early in the growing season and right after a defoliation event, leaves (the photosynthetic machinery of the plant) are just starting to grow. During these times, there is a limited amount of foliage and consequently plant regrowth is slow (Phase 1, Fig. 3). As regrowth continues, leaf mass accumulates, which translates into greater photosynthetic machinery and more rapid plant growth (linear phase, Phase 2, Fig. 3). This rate of growth continues until maturation, when plants start shading themselves and leaf senescence occurs (Phase 3, Fig. 3). Herbage accumulation is ultimately the balance between regrowth and senescence of plant tissue. *Nutritive value* is defined as the chemical composition, digestibility, and nature of digested products of forage. Measurements of nutritive value include crude protein, in vitro dry matter disappearance, neutral detergent fiber, acid detergent fiber, and/or lignin concentrations.

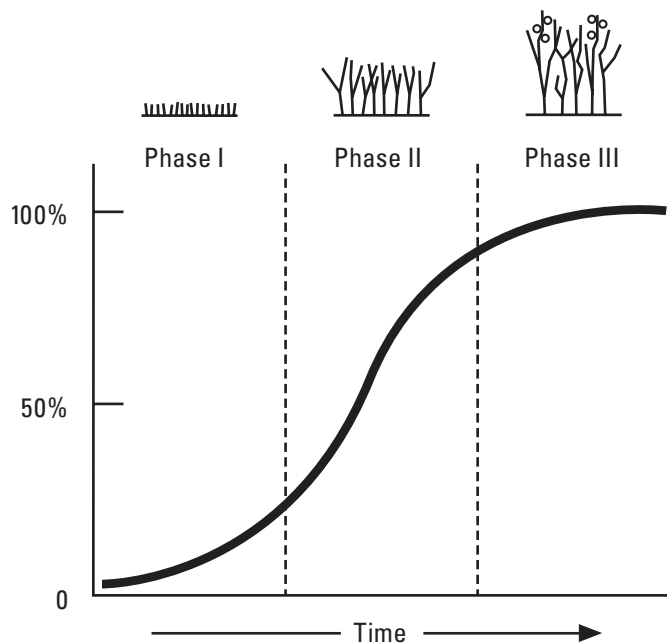


Figure 3. Accumulation of forage mass (lb per acre) during a period of recovery growth. Phase 1: low accumulation rate, Phase 2: high accumulation rate, and Phase 3: little or no net accumulation rate due to balance between new growth and senescence of plant tissue. (Adapted from Hodgson, 1990; Saul and Chapman, 2002.)

The general trend for the relationship between forage quantity and nutritive value is that the longer the regrowth period, the greater is the herbage accumulation and the lower the nutritive value (Fig. 4). As plants mature, there is greater accumulation of the cell wall components (i.e., lignin, cellulose, and hemicellulose, represented by acid detergent fiber, ADF, and neutral detergent fiber, NDF, in Fig. 4) compared with cell contents (i.e., protein, sugar). The rate at which the relationship between forage quantity and nutritive value changes, although following the described general trend, varies among forage species, and consequently, should be one of the factors considered when defining defoliation strategies (such as how often and how close to the ground the forage should be grazed or cut).

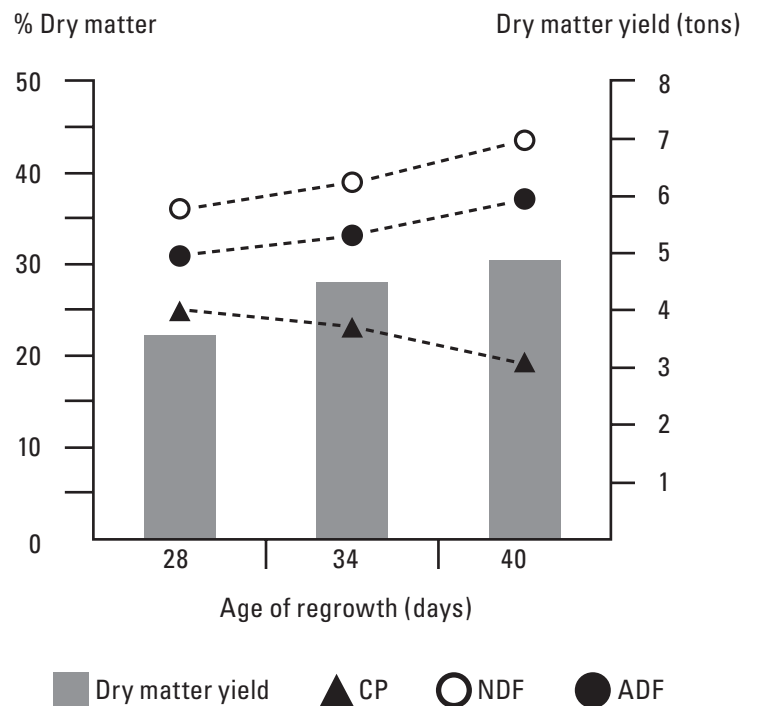


Figure 4. Dry matter yield, crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) of alfalfa (*Medicago sativa*) harvested for hay as a function of length of regrowth interval. (Adapted from Kallenbach et al., 2002.)

Grazing Systems

Grazing systems integrate the combination of soil, plant, animal, social, and economic features, using stocking (or grazing) methods and management objectives designed to achieve specific goals. There can be a variety of desired outcomes, but for most producers economic goals are of primary importance (i.e., return on investment). Grazing management practices can be defined as the manipulation of livestock grazing to accomplish a desired result. Choice of grazing management strategies (i.e., number of animals per acre, also known as *stocking rate*; continuous versus rotational stocking, also known as *stocking method*; and time of defoliation) affects pasture yield, nutritive value, stand longevity, weight gain, and milk production of an individual animal as well as the amount of milk and meat produced per acre (Fig. 5).

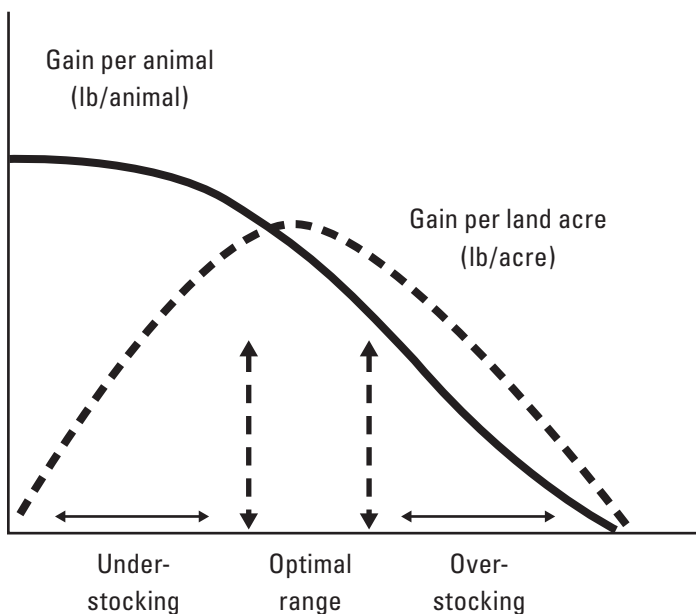


Figure 5. Effect of stocking rate on gain per animal and gain per acre. (Adapted from Mott, 1973.)

In understocked pastures, individual animal responses are greatest as a function of forage in excess and animals being allowed to pick and choose (select) the forage that constitutes their daily diet. Nevertheless, in understocked conditions, gains per unit of land area are not at their maximum and the relative utilization of forage is very low (more forage is left in the field and not consumed by the animals). Increasing the stocking rate may decrease individual animal responses, but increases animal weight gains per acre to a point as a function of increasing the relative forage utilization from the pasture (Fig. 5). In contrast, in overstocked conditions, there is simply not enough forage to feed the animals. Thus, gain per animal and gain per acre are lower, but also the persistence (presence versus absence) of the forage species planted is compromised. The use of grazing management strategies provides land managers the opportunity to manage their operations so that such use maximizes the desirable defined outcomes in a sustainable approach.

If an animal has the genetic potential, animal products from livestock grazing are the result of a combination of (1) the nutritive value of forages to meet the daily energy requirements of the animal, and (2) the amount of forage offered or available to be grazed. Differences in nutritive value (i.e., digestibility) determine the upper limit for an individual animal response when quantity of forage offered is not a limiting factor. In contrast, quantity of forage explains the proportion of the potential animal response (i.e., average daily gain) that will actually be achieved. The amount of forage consumed by the animals is termed *intake*. Animal intake can be influenced by a variety of factors that include environmental factors (temperature and humidity), management factors (stocking rate, stress), and interaction with inherent plant characteristics (i.e., ergot alkaloid, nitrates, prussic acid, and nutritive value).

Conservation of Forages

Forages can be conserved and stored for feeding livestock in periods when pastures are inadequate and/or there is a shortage in forage supply. Nevertheless, at best, conserved forages can rarely match the nutritive value of fresh forage. For harvested forages, nutrient losses start immediately after cutting, and some biochemical losses are unavoidable. In addition, handling operations can reduce the overall nutritive value of the forage due to leaf shattering (leaves are in general of greater nutritive value compared to stems), leaching, or molding. In general, the removal of water as quickly as possible after cutting results in minimization of losses. Typically, fresh forages have between 75% and 85% moisture.

Hay

Hay production requires that the forage be dried to 16% or less moisture (a process called *hay curing*). The goal is to dry the forage as soon as possible to minimize losses due to plant respiration. Depending on weather conditions, reaching 20% moisture could be achieved in one or three to five days. Thus, a cutting schedule for hay should target sunny, hot, rain-free days, so that transpiration rates are high and accelerate the drying process. Production practices such as conditioning, tedding, and raking can increase the efficiency of hay production. *Mechanical conditioning* involves bending and crushing the forage to create physical openings and hasten loss of moisture. In *chemical conditioning*, drying agents such as potassium carbonate are applied. *Tedding and raking* disperse the forage to be dried uniformly in the field and subsequently gathered in windrows for baling.

It is critical that hay bales have $\leq 16\%$ moisture and be stored under dry conditions. Re-wetting events encourage growth of fungi and microbes that due to respiration processes have the potential to increase the temperature of the moist plant tissue. Temperature increases have the potential to reduce the nutritive value of the hay (due to Maillard reactions) as well as to the point where spontaneous combustion can cause fire.

Haylage and silage

Forage is conserved as haylage and silage by anaerobic (oxygen-free) storage, under conditions that encourage fermentation of sugars to organic acids (lactic, acetic, and propionic). Production of haylage and silage is generally the choice for regions where weather conditions (high moisture and frequent rainfall) are not conducive for hay production or where the forages of choice (such as corn and sorghum) are poorly suited for hay, especially because they are more difficult to dry.

The main difference between haylage and silage is the moisture level at which the forage is packed to achieve optimum anaerobic and fermentation conditions. Based on the starting moisture level of the material to be ensiled, it can be classified as: high-moisture silage ($\geq 70\%$ moisture), wilted-silage (60 – 70%), and low-moisture (40 – 60%). Low-moisture silage is referred to as *haylage*, or when baled and sealed with plastic wrap it is referred to as *baleage*. Nevertheless, in general, it should be avoided to try to ensile forages with high moisture to prevent spoilage.

Successful silage production requires fast fermentation. The main objective of the fermentation phase is to reduce the pH of ensiled forage from an initial value of around 6 to between 3.8 and 5.0 so that growth of undesirable microorganisms will

be restricted and the silage is stable. The resistance to pH change is termed *buffering capacity*. The buffering capacity varies widely among silage crops. In general, legumes have higher buffering capacity (and therefore are more difficult to appropriately ensile) compared to grasses.

Stockpiling

Stockpiling is the practice of allowing forage to accumulate in the field until it is needed for grazing. Some people have referred to stockpiled forage as *standing hay*. The foundation for this practice is to identify forages whose nutritive values do not decrease rapidly due to maturation and consequently can be utilized in periods where active vegetation growth is limited (i.e., during winter when temperatures can easily fall below 32°F). Once forage accumulation has been achieved, land managers can allocate animals to graze the stockpiled pasture using the same general concepts as when feeding fresh standing forage. One of the most studied and suitable species to be stockpiled in the transition zone is tall fescue, because it retains live leaves and high carbohydrates into the winter better than most species. Other plants, including bermudagrass, may be stockpiled, but they generally do not remain of high nutritive value as long as tall fescue does.

SUMMARY

There are a variety of herbaceous forage plants that can be grown in the state of North Carolina. Species adapted range from cool-season to warm-season grasses and legumes. Cool- and warm-season forages can be either annuals (live for one season) or perennials (live for multiple seasons). Forage plants do not only provide forage for grazing animals, but can be produced for storage and/or shipped for subsequent feeding of livestock during periods of short-supply. Forages can also be included as part of crop rotation systems (i.e., as cover crops, to break the cycle of agricultural pests); to recycle animal wastes (i.e., land-application of waste from concentrated animal feeding operations); to produce biomass for bioenergy purposes; and to prevent contamination of water resources (i.e., as plantings in riparian zones), among other uses. Each specific theme has its own inherent challenges and opportunities. Consequently, it is important to understand the factors and management practices that can have the greatest impact on the success of a production system that incorporates the use of forages.

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