

ID-143

Rotational Grazing

Ray Smith, Garry Lacefield, Roy Burris, David Ditsch, Bob Coleman, Jeff Lehmkuhler, and Jimmy Henning





Much of Kentucky's land resource has rolling topography and would be best used by implementing sound rotational grazing systems for cattle.

Ray Smith, Garry Lacefield, David Ditsch, and Jimmy Henning are faculty members in the Department of Plant and Soil Sciences.

Roy Burris, Bob Coleman, and Jeff Lehmkuhler are faculty members in the Department of Animal and Food Sciences.

Rotational grazing can help Kentucky farmers increase forage productivity, which can increase yield of animal products per acre and may increase profit margins for forage-based farming systems. At the same time, rotational grazing has the potential to

- reduce cost of machinery, fuel, and facilities
- reduce supplemental feeding and pasture waste
- improve monthly pasture distribution and yield
- improve animal waste distribution and nutrient use
- improve pastures' botanical composition
- minimize daily fluctuations in intake and quality
- allocate pasture to animals more efficiently, based on nutritional needs

Farmers and ranchers who have adopted improved grazing practices may call these practices *controlled grazing*, *intensive grazing*, *management intensive grazing*, *rotational grazing*, or *intensive rotational grazing*.

A rotational grazing program can generally be defined as use of several pastures, one of which is grazed while the others are rested before being regrazed. Continuous grazing is the use of one pasture for the entire grazing season.

Kentucky's land and climate offer farmers the opportunity to grow large quantities of high-quality pasture from cool- and warm-season grasses and legumes. However, only about one-third of the pasture forages produced are actually used by grazing animals. In addition, much of the forage consumed is not as high in quality as it should be, resulting in low animal output per acre of forage grazed. This low-quality forage occurs particularly in late spring and summer pastures and in much of the hay that is produced.

Kentucky pastures are generally too large to ensure the even grazing that would result in greater forage utilization. With large pastures, the animal decides when, where, what, and how frequently a plant is defoliated. Use of low-cost, versatile fencing to reduce pasture size can transfer decision making from the animal to the manager, which often results in improved utilization of available forage and greater control over pasture allocation.

Kentucky has great opportunity and potential in animal-based agriculture, and better utilization of forage is the key to realizing this potential. If pastures are managed for better productivity, captured in a higher-quality stage, and converted more efficiently to animal products, animal-based agriculture will without question increase Kentucky's agricultural income.



Rotational grazing allows the manager to make the best possible match between animal needs and forage production, as on this reclaimed mine site in Perry County.

Key Principles of Rotational Grazing

A sound rotational grazing system is a worthy goal for Kentucky producers. Such a system involves three principles:

Principle 1: Rotational Grazing Maximizes Forage Yield and Availability

Rotational grazing helps managers make the best possible match of quantity and quality between forage and the livestock's nutritional needs, which will vary with age, body size, livestock class, and especially the production level to be supported. Growing animals, lactating livestock, and livestock under stress (cold temperatures, wet weather, etc.) need more nutrition than mature, non-lactating stock.

Pasture that is leafy and green and free from anti-quality factors (such as the endophyte of tall fescue and undesirable weed species) will provide both high protein and high energy for grazing livestock. Pasture must also be made available in quantities that permit grazing animals to achieve their nutritional requirements.

Yield: Moving to an improved grazing system will increase yield per acre beyond that of continuous grazing. Improved grazing systems allow for quick defoliation of the forage to a target residual height followed by enough rest time to

allow the forage to regrow to a grazable height. An improved grazing system will also allow alteration of the stocking rate to adjust to the forage's changing growth rates.

Continuous grazing does not allow for adjustment of changing forage growth rate or for rest periods to allow for forage regrowth. Continuous grazing leads to overgrazing during slow-growth periods. Overgrazed pastures will not reach their yield potential.

Continuous grazing has been compared to planting a field of soybeans and then running a combine over the field all year long. Such a comparison makes it easy to see the negative effects of continuous grazing on pasture yield. In contrast, the graze per rest cycles of an improved grazing system allow for maximum regrowth of the forage, given limitations resulting from factors such as weather and soil fertility.

Availability: Meeting the nutritional needs of grazing livestock is not only a function of forage quality, but animal intake as well. Every day, grazing stock need to consume forage dry matter equal to 2 to 5% of their body weight. For example, a 1,100-lb cow can require 22 to 33 lb of dry matter from pasture daily. A 100-lb doe can require 3 to 5 lb of dry matter from pasture daily. Pastures should contain 1,000 to 1,500 lb of usable forage dry matter per acre so that meeting live-

stock nutritional needs (which can vary from animal to animal) is not limited by pasture quantity. The amount of forage in 1,000 to 1,500 lb can vary, too. It may represent only 4 inches of dense grass, or it may represent 8 inches or more forage if the stand is thin and open.

Keeping an adequate supply of forage before grazing livestock across the full grazing season is challenging for all managers. A rotational grazing system will require the use of a mix of forages to meet the seasonal fluctuations in plant growth and livestock requirements. An almost infinite combination of forages can be used successfully.

Principle 2: Maintain Forage Quality to Meet Animal Nutrient Needs

Rotational grazing allows the manager to regulate the frequency and intensity of grazing to control quality, yield, utilization, and persistence of pastures. A sound rotational grazing system has benefits for forage production and utilization. These benefits fall into six main areas: quality, regrowth, persistence, utilization, and nutrient recycling.

Quality: Rotational grazing systems are more likely than continuous grazing to maintain pastures in an actively growing state. With continuous grazing, animals tend to return to the same area repeatedly and allow forages in non-grazed areas to become mature, resulting in reduced intake and digestibility. The net result is that overall quality of the pasture declines. With rotational grazing, selective grazing is limited, resulting in forage being more uniformly grazed and more uniformly regrown.

Within the pasture, forage quality varies greatly from the base of the plant to the uppermost leaves, especially with legumes and to a lesser extent with forage grasses. The upper half of an alfalfa or red clover canopy, for example, contains the majority of the leaf yield. Therefore, forage quality of legumes is higher in the top half of the pasture than in the lower half. The crude protein in the top 6 inches of an alfalfa canopy, for example, can be twice that of the lower 6 inches. (Energy content follows a similar pattern, although it doesn't decline as sharply toward the lower part of the plant.)

This layering of quality within the pasture canopy has practical implications. Grazing management that promotes the removal of the top half of the canopy to support maximum gains is a technique called *top grazing*. Stocker cattle are excellent as top grazers because they select the highest quality forage and maximize their average daily gains. Significant residual forage remains, however, when top grazing is used. This residual material, though lower in quality, is still valuable for dry cows or other animals with lower nutritional needs than stocker cattle. Following top grazers with dry cows or other livestock with lower nutritional requirements is known as *leader/follower grazing* or *first-and-second grazing*. This system allows for maximum forage utilization as well as high levels of animal output per acre.

The quick, nonselective grazing that occurs with rotational grazing is an advantage in grass-legume pastures (Figure 1) because it enables legume regrowth and grass regrowth to occur at about the same rate. If only top grazers are used so that grazing heights remain high, grass regrowth tends to be faster.

Regrowth: Rotational grazing and managing to maintain both adequate carbohydrate reserves from root or stubble and proper residual leaf area will result in maximum regrowth rates. The rate of regrowth by forage species after defoliation (mowing or grazing) is related to the amount of leaf area remaining and carbohydrate reserves in the root system, both of which supply energy needed for rapid regrowth.

The rest cycle in a rotational grazing system allows carbohydrate-cycling species (such as alfalfa, red clover, big bluestem, switchgrass, and indiangrass) to maintain proper energy reserves to fuel regrowth. Rotational grazing can also benefit forage species that rely more on residual leaf area for regrowth (orchardgrass and tall fescue), because grazing pressure can be managed to leave enough green leaf tissue to power that regrowth (Figure 2).

Grazing that removes most of the available top growth of grasses leads to death and sloughing of large portions of grasses' fibrous root systems. Small root



Figure 1. Effect of grazing height on legume and grass regrowth in a grazed pasture. From Blaser, et al., 1986. Virginia Polytechnic Institute Bulletin 86-7.

systems lead to slow top growth and lower water infiltration into the soil and uptake by the plant.

Persistence: Rotational grazing will result in greater persistence of forage species that regrow from stored carbohydrates and are sensitive to overgrazing or repeated defoliation. It also helps species persist during periods of drought stress. In University of Missouri research,

changing the method of grazing from continuous to weekly or daily rotations increased the persistence of big bluestem. University of Georgia researchers reported that repeated close grazing of endophyte-free tall fescue caused a weakened stand. However, the fescue survived in those endophyte-free pastures that had 4 inches of residual growth maintained across the season.

Figure 2. The orchardgrass plant on the left was clipped weekly to 1 inch for one month to simulate continuous grazing. The orchardgrass plant on the right was clipped at the beginning and end of the month to simulate rotational grazing. For the plant on the right, the value of rotational grazing is apparent after six days of regrowth.





Rotational grazing keeps pastures higher in quality than does continuous grazing and favors the growth and persistence of legumes.

Utilization: Most pastures contain a great deal of forage that is never consumed and eventually decays. Traditional continuous grazing systems may use only 30 to 50% of the available forage. The rest of the forage is either trampled, soiled, or of little value because it overmatures or dies. Most of this loss occurs with underutilized fall stockpiles and during periods of rapid growth where there is surplus beyond what is needed for livestock. When the appropriate stocking density is used, shortening grazing periods to three to seven days increases utilization 50-65%; to two days, 55-70%; and to one day, 60-75%.

Nutrient Recycling: Pasture fertility represents a real opportunity for Kentucky livestock producers. Kentucky surveys show that soil testing is done on only about 10 percent of pastures. Of the pastures that are soil tested, 40% are below pH of 6.0, 45% are low in phosphorus, and 35% are low in potassium. These low rates should be a concern to managers for all types of pastures, but are especially critical for fields where legumes are to be established and grown. Ideally, plant nutrients should be applied according to soil test recommendations to achieve desired levels of pasture production.

A ton of grass-legume forage harvested as hay removes 35 to 45 pounds of nitrogen (N), 10 to 15 pounds of phosphorus (P_2O_5), and 40 to 50 pounds of potas-

sium (K_2O). Grazing animals excrete, in their feces and urine, between 70 and 90 percent of the N, P, and K they consume from forage. Since a mature cow (1,200 lb) on pasture or consuming hay eats approximately 5½ tons of forage per year, a significant amount of nutrients moves through their digestive system. Manure can be a valuable resource in maintaining pasture soil fertility.

Rotational grazing provides better manure (fertility) distribution than typical continuous grazing, in which most of the manure and urine is distributed close to shade and water. Research has shown that soil-test P and K values are often three to five times higher within 50 ft of shade than are average levels in the general pasture. The smaller paddocks and shorter distance to water in rotational grazing systems improve manure distribution.

Manure is also more evenly distributed at higher stocking densities. When the travel area of the animal is restricted, grazing and manure distribution are enhanced.

Maintaining pasture fertility solely with plant nutrients supplied in manure and urine may be easy on some pastures but more difficult on others. Realistic monitoring of pasture fertility through soil testing (in general, every three years) and grazing practices that encourage more uniform distribution are essential.

Guidelines for Designing Rotational Grazing Systems

The whole farm should be planned, followed by development of the rotational grazing system as time and money allow. This approach will limit the number of times fences will need to be moved.

Lanes can be a positive in the system. They are necessary if there is a dairy, and they also

- make separating sick cattle easier
- make AI breeding much easier
- allow cattle to be put where they need to be

Two lanes side by side and rotated back and forth will help control erosion.

Lanes can also be a negative force:

- 15 percent of manure is left in the alleyway.
- Cows will drink less if they have to travel too far to water.

Long, round corners make it easier to mow or crop when fencing around the better soils on the farm; fence for the most soils benefit.

The squarer the paddock, the better. However, the smaller the paddock, the less critical the shape.

Every paddock should have water.

Make sure you have a good mix of warm- and cool-season forages and a plan to use them to balance forage availability throughout the year.

Fencing should not be put up all at once; it should be a learn-as-you-go process. Make sure good-quality permanent fencing is used where needed, but also use temporary fencing.

Integrate the fencing system with livestock handling facilities so cattle can be treated or moved to a handling facility easily from any paddock on the farm.

Use as much of the usable forage as possible to meet the nutritional needs of livestock but still allow forages to regrow.

A manager should not reseed with all new varieties until learning how to manage what is already there.

Current resources should be used. It is not necessary to spend a lot of money in order to have water and fence.

Fertilizing should be done where it will do the most good following soil test recommendations.

To make rotational grazing successful, managers must gather information, make a plan, put a system in place, and then look to see which parts are working.



A good rotational grazing system allows the use of high-quality forages such as alfalfa, which requires rest periods after grazing and in the fall.

University of Missouri researchers have conducted several studies over the past five years on fertility and manure management in pastures. Their work resulted in the following conclusions, summarized here:

- Alleyway paths to water often become areas of significant manure and urine deposition, which can result in a loss of plant nutrients from manure best utilized on pasture. These high-traffic pathways can also be the primary sources of parasitic larva that hatch from feces of small ruminants. (According to the UK Veterinary Disease Laboratory, parasitism is the leading cause of small ruminant death in Kentucky.)
- Shade trees in pastures are major sites of manure accumulation; however, the availability of shade is important in hot weather and is desired in most systems.
- Grazing systems with more frequent rotations will result in more uniform distribution of manure and plant nutrients across a pasture. Frequent rotations can also serve to interrupt life cycles of some livestock parasites and may reduce parasitic pressure.
- Fencing paddocks to minimize landscape variation will encourage more uniform grazing and manure distribution. For example, managers should fence slopes separately from bottoms and ridge tops.

- Square paddocks generally result in more even manure distribution than paddocks of other shapes.
- When setting up a grazing system, keep in mind that any landscape position that looks cool and comfortable to people (north- and east-facing slopes) will also appeal to livestock. Setting up paddocks and rotations to minimize the number of days that livestock can camp at these sites will more uniformly distribute manure over the entire pasture.

Principle 3:
Economic profit can be realized through improved livestock efficiency and productivity.

Rotational grazing produces economic profit by allowing the manager to optimize animal performance and forage utilization. By switching from continuous grazing to rotational grazing, animal gain per acre generally can be increased significantly, though individual animal performance actually may decrease slightly. Farmers often increase stock numbers to capitalize on all of rotational grazing's benefits for quality and quantity of pasture growth.

Good management of pastures, paddocks, and rotation schedules can lead to increased gain per acre. For example, workers in several states have found that rotational grazing will increase pounds of beef per acre from 35 to 61% (Table 1).

How to Know When to Move to Fresh Pastures

The right time to rotate pastures depends on many factors. Making the following six observations can help with the decision:

Look down. Has the present paddock been used as much as desired, or is there too much forage left? In general, most new rotational grazing managers tend to allow livestock to overgraze pastures. A good rule when starting out is to leave a little more forage than seems necessary, which means livestock will need to be moved often.

Look ahead. Is the next paddock ready for grazing? How fast is pasture growth? Fast growth may indicate the need to speed up rotation or harvest some paddocks for hay. Slow growth signals the need to lighten stocking rate, add acres, or feed hay.

Look at the animals. Do the animals appear hungry, and are they in good condition? Livestock can let a manager know when they want to move, but their desire to move may be too soon for optimum pasture utilization. High-performing animals should be moved more often, however.

Look behind. How fast is the last paddock regrowing? Periods of slow growth may signal the need to slow the rotation, reduce stocking rate (by adding grazing acres or by selling or moving stock), or feed hay. Slowing the rotation (more days per paddock) makes animals graze closer and gain less, and future regrowth from these "overgrazed" paddocks will be slower.

Look at the weather. Approaching rain can signal the need to move from pure legume to grass-based pastures to prevent pugging of the soil and damage to the legume stand. Animals should be removed from johnsongrass and sorghum-sudan type pastures before frost.

Finally, look at the calendar. During the active growing season (April to October), residual forage height should be managed to allow fast regrowth. On fall and winter stockpiled pasture, graze longer and closer on each paddock to use forage that would otherwise be lost during the winter.

Increasing beef yield per acre can result in a reduced forage cost per pound of gain. More beef per acre at a lower cost of gain potentially leads to greater profit.

Dairy net profit for rotational grazing in Pennsylvania was 72% greater than for continuous grazing (\$129 vs. \$75, Table 2). Rotational grazing as a dairy farm enterprise was more profitable per acre than either hay or corn silage, based on Pennsylvania budgets.

Finally, a study from the University of Georgia (Table 3) showed several benefits from rotational grazing compared to continuous grazing. These benefits included an increase in stocking rate and total calf gain per acre, with a reduction in hay fed per cow. These results were realized without significantly reducing calf weaning weight or pregnancy rate.

Layout and Design

Developing grazing systems involves subdividing large pastures into smaller pastures or paddocks (cells) that give the manager control over how long cattle are allowed to graze a particular area (paddock) before they are moved. No single blueprint or model exists for setting up a grazing system that will provide maximum control. Every Kentucky farm is unique; many different solutions are possible and workable. The most important factor in developing a rotational grazing system is to develop one that is right for the farmer, the farm's resources, and the land's capabilities.

Laying out or designing a pasture system involves many decisions, including how many paddocks the system will have and their size, location of water sources, lane placement, and livestock flow around working facilities.

Table 1. Increase in beef gain per acre in rotational grazing compared to continuous grazing.

State	% Increase
Arkansas	44
Georgia	37
Oklahoma	35
Virginia	61



Rotational grazing enables managers to use high stocking densities and short grazing periods to increase utilization and decrease animal selectivity in grazing.

In most situations, the best way to start is to make a few simple or basic improvements in the current grazing system, which will begin the learning curve and allow the manager to develop the rotational system at a comfortable pace. It will also minimize "improvements" that later prove to be less than optimal. A lot of progress can be made by simply closing

the gate between two pastures—dividing an existing pasture in half is the start of a rotational grazing system.

Being flexible is fundamental to putting rotational grazing systems together. The farmer should do what he or she thinks best, but should be open to change—and continual planning—before driving the first post.

Table 2. Dairy enterprise budgets per acre for pasture and forage crops.

	Intensive Pasture	Continuous Pasture	Hay	Corn Silage
Gross return in field	\$193	\$112	\$196	\$313
Average storage loss	0%	0%	12%	13%
Gross return after storage	\$193	\$112	\$172	\$273
Total cost	\$64	\$35	\$156	201
Profit	\$129	\$75	\$20	\$58

Source: Farmer Profitability with Intensive Rotational Grazing. L. Cunningham and G. Hanson, Penn State University. 1995. *Note: Feeding loss was not measured. Pasture was valued based on dry matter nutrient value compared to the nutrient value and market price of dry hay.*

Table 3. Effect of year-round continuous vs. rotational stocking of endophyte-free tall fescue and common bermudagrass mixed grass pastures at Central Georgia Branch Station, Eatonton, Ga., 3-year average.

	Continuous	Rotational	Difference, %
Stocking rate, cow-calf units per acre	0.50	0.68	+36
Calf weaning weight, lb	502	502	0
Total calf gain per acre, lb	251	342	+36
Cow pregnancy rate, %	94	93	0
Hay fed per cow, lb	2,390	1,690	-29

Source: Dr. Carl Hoveland, University of Georgia.



Both cool- and warm-season forages are needed for a sound grazing system. This field of switchgrass in Owen County provides summer pasture for these stockers and complements tall fescue, which is used in spring and fall.



A leafy, high-quality mix of grasses and legumes can be achieved through well-managed rotational grazing.

Physical Components of Rotational Grazing Systems

A good rotational grazing plan will include four main physical components: forage supply, fencing system, water supply, and shade.

Forage Supply

A good rotational grazing system begins with a forage system that allows the maximum number of grazing days per year with forages that are suited to the land, livestock, and the manager's abilities and objectives.

Forage can be divided into two categories: cool-season and warm-season species, which differ in their seasonal ability to produce grazable yield. Cool-

season species (tall fescue, orchardgrass, timothy, white clover, and red clover) perform best in spring and after the weather cools down in the fall. Warm-season species (bermudagrass, eastern gamagrass, alfalfa, and annual lespedeza) perform better in midsummer.

Forage species should be matched to soils that will maximize their yield and growth. For example, tall fescue and white clover are well adapted to thin soils

Steps in Setting Up a Grazing Program

1. Start with a good aerial photograph of your pastures—the larger the scale, the better. These photographs are available at the local office of the Farm Service Agency office and USDA National Resources Conservation Service (NCRS) online sources. Just be sure you have a scale map. A soils map is also a valuable tool. A soils map, a list of descriptions, and some professional guidance are available through the NCRS. A grid for counting acres is also handy. It will help you even up the odd-size fields in total acres.
2. On your aerial photo, mark the property line, all roads, buildings, livestock-working areas, milk parlors, other permanent facilities, and existing water and shade.
3. Using the soils map, mark the major soils changes, considering both slope and quality of the soils. Then adjust these lines to make them workable as markers for your first permanent fences.
4. Draw around any crop fields if their soils are different from the soil breaks. You may also want to identify areas with different forages, such as alfalfa or warm-season grasses. Divide the farm along existing water sources.
Your completed map should
 - be a basic grazing system with water in each field
 - be divided based on productivity
 - have enough fields to begin rotational grazing
5. The next step is more difficult and requires patience. Subdivide the permanent fields in near-equal sizes, keeping the paddocks as square as possible. Plan and plan again. Draw lines, think, erase, and try again. Even when you start to fence, use temporary fencing so it will be easy to change. Try to use existing water if possible.
6. At this point you are already doing a good job of grazing, and it is time to refine the process. You should have enough paddocks so that your livestock will be moving every seven days or less. Place water in every paddock. This practice will allow you to make the paddocks as square as possible. You should also have shade in as many paddocks as possible, especially those that will be grazed in the summertime.
7. At some point you will want a system that will allow you to move your livestock to any part of the farm as needed, which will require a system of alleyways or lanes. All lanes should allow you to take an animal anywhere you need to if she has trouble birthing, is sick, or is scheduled for deworming and vaccination. This system will also allow you to graze more than one herd at a time. You may also want to build some sorting squares to separate livestock as needed without moving them to the barn. This system of alleyways/lanes will let you be in control of the grazing on your farm and make it easy to move cattle to your handling facilities, chutes, or scales.

or steeply sloping sites that hold water for growth in spring but often become droughty in summer. Because they hold little moisture for summer growth, these fields would be poor choices for maximizing productivity of warm-season forages. In another example, highly productive forages such as alfalfa should be planted on the deepest, best drained soils.

Most forage systems in Kentucky are based on cool-season forages such as tall fescue, orchardgrass, white clover, and red clover, which produce an abundance of forage in the spring and most falls but are not productive in mid-to-late summer.

The two biggest challenges in developing a balanced forage system are maintaining supplies of quality forage in midsummer and extending the grazing season as long as possible into the fall and early winter. Many forage species are capable of midsummer production, but they all have disadvantages that prevent their use for some producers. Alfalfa, as noted above, requires deep, well-drained soils, and it also requires a high level of management for best performance. Eastern gamagrass and other native warm-season perennial grasses are slow to establish, and seed is expensive compared to other cool-season forages. Summer annuals such as sorghum sudangrass and the millets must be seeded each year and require inputs of fertilizer nitrogen to maximize yield. However, a balanced and well-planned grazing system will include some acreage of warm-season forages that can be used as rescue crops in midsummer or in short periods of heat and drought stress when cool-season species are less productive.

An efficient grazing management plan should attempt to match pasture growth to animal needs and offer the potential for minimum pasture to be harvested and stored as hay or silage. Livestock systems managed for reproduction will have the greatest forage needs in the birthing and breeding season; forage needs will drop off after weaning. Spring-calving/kidding herds need the quality and quantity of spring and early summer pasture but must rely on stored forage in late winter. Fall-calving/kidding herds rely more on hay or silage and forage crops



High-tensile electrified wire is a viable and economic alternative to conventional fencing materials such as woven wire, and it enables a fencing system to be built more quickly.



Temporary fencing materials such as tread-in posts and electrified polytape allow for quick subdivision of existing pastures.

that provide pasture in fall and winter. Fall pasture options include stockpiled tall fescue, small grains, turnips or other brassicas, and annual ryegrass.

Stocker operations are usually one of two types:

- buying in the spring and selling in the fall
- buying in the winter, overwintering on hay or stockpiled pasture, and turning out on spring pasture

Both systems provide freedom to sell all or part of the stockers as forage growth slows. Stocker operations are much more sensitive to forage quality and quantity

for growth than reproductive operations, in which the mother's milk helps support calf/kid/foal performance.

Fencing System

Use of low-cost, versatile fencing to reduce pasture size can transfer decision making from the animal to the manager.

Rotational grazing usually relies on an electrified fencing system to subdivide larger pastures into smaller grazing units. Development of high-voltage, low-impedance electric chargers allows fencing of large acreages without losing voltage due to fence-line vegetation. These energizers send high-voltage, short-duration

pulses down the fence. Although 2,000 volts is considered adequate to control most stock, most fence chargers and systems should start with around 7,000 volts.

There is no standard system for comparison of energizers, and every manufacturer has a different scale. Joules are the most common measure of power in energizers. The joule rating is calculated using a combination of voltage, amperage, and pulse duration. Changing any of them affects the rating. Generally speaking, fencing system needs will grow, so obtain enough energizer capacity to cover future needs. Energizers come in mains, or plug-in units, as well as battery and solar units. It is best to use a plug-in energizer if possible because it delivers more charge (joules) per dollar spent.

A good ground is essential for the effectiveness of any electric fence system. The energizer's ground is like a radio antennae. A large radio collecting waves from a long distance needs large antennae, and a large energizer powering a lot of fence needs a large ground system with a minimum of three 6-foot galvanized ground rods. These rods may be placed in the ground at an angle if there is less than 6 ft of soil. Ground rods should be driven in a damp place, if possible, such as under the drip of the barn roof or in a low area.

An electric fence can be built in either of two ways. With the all-live system, every wire in the fence is energized, and the conduction of electrons back to the energizer depends on the soil. This system is generally effective in the southeastern United States because soils in this region have high mineral content and adequate rainfall. Also, in an all-live system, a limb or branch can fall across the wires and the fence will remain energized.

The other system is the hot ground system, which has one or more fence wires connected to the positive terminal of the energizer and the rest of the wires connected to the ground terminal. This system works well in sandy, arid areas—moist soil is not necessary to deliver a charge. The main disadvantage of the hot ground system is that it is high maintenance. If any charged wire touches a ground wire, the whole system shorts out. Rarely is a hot ground system needed in the eastern United States.



Electrified polytape (available in widths up to 1½ inches) is very visible and can be used for subdivision fencing for horse pasture. The twist in the polytape makes it flutter in the wind, resulting in greater visibility.

In Kentucky, the most economical controlled grazing fencing system is often one that includes a combination of permanent, electric, smooth, high-tensile wire fencing and temporary portable polywire (available on reels). An advantage of the reel is that it allows rapid setup and takedown of fence for temporary arrangements or strip grazing. Portable fiberglass fence posts are often used with the portable braided wire, with one strand of wire used for grazing of large animals and two strands for calves. Since it is electrified, high-tensile wire for the permanent fence often can be installed using low-tension techniques.

Types of Fencing

Following is an overview of several types of fencing and their appropriate place in a controlled grazing system:

For permanent boundary fence installations, New Zealand-type high-tensile wire is suggested. This is 12½-gauge high tensile smooth wire that is heavily

galvanized (Class III). Smaller diameter high-tensile wire is also now being used, particularly on interior division or paddock fences. This type of wire includes 14½-gauge and 16-gauge thicknesses. The use of such wire has implications for energizer selection (since smaller wire has a greater resistance to current flow) and in the length of fencing that can be energized.

For interior and temporary fences, a more flexible, low-tension wire is popular. Small-diameter, high-tensile wire can be used, but many producers prefer a slightly softer grade of wire since it is somewhat easier to work with when moving and handling the fence. An excellent alternative for temporary installations is braided wire, which contains fine-gauge steel wires braided with polyethylene strands into a wire, ribbon, or tape. These wires work quite well for installations of up to 1,200 ft. Because of the lower cross-sectional area of steel, energizer requirements differ from those of smooth high-tensile

Table 4. Sample water requirements for cattle, gallons per head per day.

Temp, F	Gal per lb DM	500-lb Calf, 12 lb DMI	750-lb Calf, 16.6 lb DMI	1,100-lb Dry Cow	1,100-lb Nursing Cow
40	0.37	4.4	6.1	7.4	8.1
60	0.46	5.5	7.6	9.2	10.1
80	0.62	7.4	10.3	12.4	13.6
90	0.88	10.6	14.6	17.6	19.4

Source: Winchester and Morris, 1956.



An effective water distribution system is essential to the grazing system. This permanent water tank was developed from a spring and provides an inexpensive source of water on a Metcalfe County farm.

wire. Some newer braided wires have more steel (thus less resistance), so they can be used in longer runs.

Water Supply

Water is possibly the most important, but least considered, nutrient for livestock. It is needed for virtually every body function. Many factors influence water intake. As air temperature increases above 40° F, water intake increases per lb of dry matter consumed (Table 4).

Lactating livestock require more water than dry animals, and at a constant temperature, livestock consuming more feed need greater water intake. Similarly, if water intake becomes limited, feed intake will decrease, and performance will be limited. Lush pasture can be 70% or more water and can decrease the amount of water that must be supplied in the water system, at least on a short-term basis.

Water intake restrictions can result from inadequate access of livestock to the water source, water temperature, and water quality. Quality is determined by total dissolved solids (TDS). High TDS levels may not pose serious health risks but may decrease total water intake. Water exposed to direct sunlight (tanks, ponds) can become quite warm in the hot days of summer, resulting in lower intakes.

Regardless of why decreased water intake occurs, performance will suffer.

Cooling water has been shown to reduce heat load and allow increased feed intake. Studies with dairy cattle have shown the most acceptable water temperature to be in the 60° to 80°F range. Using insulated drinking receptacles or building shades over the water tank can reduce heating from the summer sun. Insulated or heated waterers will be needed for pasturing stockpiled forage in late fall and winter.

Location of water in the grazing site will greatly influence grazing distribution. During hot weather, livestock congregate nearer the water source, resulting in less use of pasture farther from it. Research has shown that the maximum distance cattle will travel to water without decreasing grazing uniformity is 800 ft. As travel distance increases above that amount, pasture use decreases.

Developing Water Sources: Each situation is different, and flexibility is rewarded when it comes to developing water sources.

Although there is a monthly cost, public water supplies are often the best solution to livestock water needs when development, maintenance, and reliability are considered. At some point in developing a management system, a pressurized water system will become a necessity. It will provide water where it is needed instead of forcing the manager to work with a few water sites.

Consider using the raw water source of springs. They are an excellent source of water but are as different as grazing systems. A stream of water the size of a pencil and a large collection tank could water up to 70 to 100 beef cows. Also consider ponds as a water source. Watering from tanks below ponds is strongly preferred to watering directly out of the pond. The pipe should be installed under the dam when building the pond. The pipe then can go directly to a tank or to a collection basin. Water can then be pumped anywhere on the farm.

Shade

Shade is necessary to maximize livestock performance. Heat stress in the absence of shade can have several effects. Black-hided cattle, for example, can suffer from heat stress on bright sunny days in late summer when air temperature is comfortable.

Cows with natural shade spend more time grazing and less time standing than cows without shade. Natural shade from large, well-canopied trees is the most effective. This type of shade intercepts radiation from the sun and provides some air cooling through evaporation of moisture from leaves.

Artificial shade also will reduce heat stress, but attention must be paid to the type, orientation, and square footage per head. Hay or straw on wire are the best types of artificial shade because they have high insulation value, low bottom surface reflectance, and loss of absorbed heat to the air by convection. Aluminum panels painted white on top and black on the bottom are also effective. Direct heat from the sun is well reflected by the white paint, and the black bottom absorbs the heat from the ground and animals. Snow fence or shade cloth may also be used, but they are less effective than the other materials mentioned here. Both let through some sun, so they don't provide complete shading. For maximum shading, the long axis of the artificial shade should be oriented on an east-west line. Most research shows that 45 to 60 sq ft per cow is desirable.



Temporary or seasonal water systems can reduce distance traveled to drink and increase pasture utilization. Small to medium-sized tanks can easily be moved from paddock to paddock.

Pasture Number and Size

One of the most frequently asked questions by producers who want to start a rotational grazing program is “How many paddocks should I have?” Answers appear contradictory:

- One pasture can be grazed just as efficiently as many.
- or
- Regardless of how many paddocks there are, divide them again, and more money can be made.

The truth lies somewhere between these extremes.

In general, one should consider starting with five to 10 paddocks, which will allow a paddock to be grazed in three to seven days and rested for 25 to 30 days. In most cases, four paddocks should be considered a minimum. Table 5 contains several formulas that can help determine paddock number and size.

Some systems in the United States and New Zealand have as many as 30 to 60 or even more paddocks. Many of these are dairy farms where pastures are changed after each milking. Several studies have been conducted in the United States, and they generally show that for most beef operations, the added benefit above 8 to 12 paddocks may not be worth the additional cost of fencing, water, labor, and management.

University of Kentucky modeling studies compared continuous grazing with rotational grazing (four paddocks and eight paddocks) for beef production on endophyte-free tall fescue. Production ranged from 683 lb per acre for continuous grazing to 810 lb per acre for eight paddocks. The most striking difference was the four-paddock system, which showed an increase of 112 lb of beef per acre over the continuous system. The eight-paddock system showed a 127-pound increase in beef per acre over the continuous system. The rotational system increased returns by \$77 to \$103 per acre.

University of Missouri researchers compared the effect of 3-, 12-, and 24-paddock systems on the performance of beef cow-calf and stockers grazing cool-season grass and clover. When all costs and returns were compared, the three-paddock system resulted in \$84.36 increase above pasture, animal, and interest cost, the 12-paddock system showed a \$115.43 increase, and the 24-paddock system showed a \$117.74 increase. These results suggest that going to 12 paddocks yielded a profit of \$31. Going from 12 to 24 paddocks resulted in only a \$2.31 per acre increase.



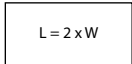
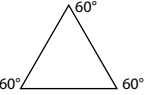
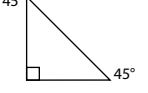
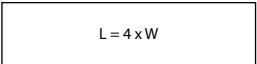
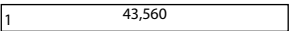
Shape of individual paddocks is important. Within practical limits, square paddocks are the most efficient compared with other shapes (rectangle,

triangle, pie, etc.). Square paddocks allow animals to obtain their daily ration of forages with a minimum of grazing time, effort, and trampling damage. Studies have shown that square paddocks are more economical to construct than other shapes (Figure 3). Having exactly square paddocks is not absolutely necessary, but avoid long, narrow paddocks. Whenever possible, fence across slopes rather than up and down slopes.

Horses and Rotational Grazing

As a spot grazer, horses are selective in which parts of the plant they will graze. Typically, horses select the more immature plant material, even when adequate forage is available. Horses also show preferences for particular forage types. UK research has shown distinct grazing preferences in which horses select one species of grass over another to the point that they overgraze that species while virtually ignoring other available forages. This preferential grazing behavior can result in some pasture areas being grazed to bare ground.

Figure 3. Effect of pasture shape on amount of fencing needed around 1 acre.

Shapes	Length
	744'
	836'
	888'
	951'
	1,007'
	1,040'
	87,122'

Source: Garry Lacefield, University of Kentucky.

Table 5. Grazing mathematics.

$$\text{Number of paddocks} = \frac{\text{days of rest}}{\text{days of grazing}} + 1$$

Example:
Number of paddocks = $\frac{28 \text{ days rest}}{4 \text{ days grazing}} + 1 = \mathbf{8 \text{ paddocks}}$

- Days of rest: Values range from 10 or less for grasses during periods of rapid growth to 30 for legumes and even more for periods of slow growth.
- Days of grazing: Varies from 1 to 7 and up. Shorter times on a paddock yield greater season-long utilization and less waste, selectivity, and regrowth grazing.

Acres required per paddock =

$$\frac{\text{weight} \times \% \text{ DMI} \times \text{number} \times \text{days per paddock}}{\text{DM per acre} \times \% \text{ utilization}}$$

Example:

Acres required per paddock =

$$\frac{500 \text{ lb} \times 3\% \times 100 \text{ head} \times 4 \text{ days}}{2,000 \text{ lb per acre} \times 60\%} = \mathbf{5 \text{ acres}}$$

- Weight: Weight per head, in pounds.
- Percent DMI: Percent dry matter intake, ranging from 2% to 4%.
- Number: Number of head to be grazed.
- Days per paddock: Amount of time that animals are to be allowed to graze in a given paddock. Values can range from 1 to 7 and up. To keep animals from grazing regrowth, keep days per paddock to 7 or less.
- DM per acre: Estimate of total forage dry matter available per acre as the animals enter a paddock.
- Percent utilization: Portion of the available forage per acre that animals will consume during a grazing period. Improved grazing systems can result in utilization of 60% for grasses and 75% for legumes.

Total acres required per grazing cycle =

$$\text{number of paddocks} \times \text{acres required per paddock}$$

Example:

Total acres required per grazing cycle =

$$8 \text{ paddocks} \times 5 \text{ acres per paddock} = \mathbf{40 \text{ acres}}$$

- Number of paddocks will be determined by the length of the rest and grazing periods.
- Acres required per paddock are determined by amount of forage needed each day by the grazing herd divided by the grazable forage dry matter per acre.
- The number of acres needed per grazing cycle will vary with the growth rate of the forage. As the growth rate slows, the number of acres required to supply 3% DMI and maintain 4 days on and 28 days off a paddock will increase.

$$\text{Stocking rate} = \frac{\text{number of animals to be grazed}}{\text{total acres grazed}}$$

Example:
Stocking rate = $\frac{100 \text{ head}}{40 \text{ acres}} = \mathbf{2.5 \text{ head per acre}}$

- Stocking rate and stocking density are often confused. Stocking rate applies to an entire grazing period (in this example, 32 days) or can be thought of as a season-long or whole-farm statistic.

$$\text{Stocking density} = \frac{\text{number of animals grazing on a paddock}}{\text{paddock size}}$$

Example:
Stocking density = $\frac{100 \text{ head}}{5 \text{ acres}} = \mathbf{20 \text{ head per acre}}$

- Stocking density is the stocking rate at a given point in time. In this example, 100 steers are grazing in a 5-acre paddock, which is a stocking density of 20 head per acre. Stocking density can be expressed as the number of pounds of grazing animals per acre at a given point in time (in this case, 10,000 lb per acre).

When rotational grazing is practiced, horse owners can, to some degree, control spot-grazing behavior. Horses can be put into a paddock when the average height of the forage is 6 to 8 inches and removed when the average height of the forage across the paddock is 3 to 4 inches. Because of a horse's grazing behavior, portions of the paddock may be grazed to below the 3-inch level, while other areas may still be at 6 to 8 inches, which can result in preferred areas being extensively overgrazed and taller forage not grazed at all. If overgrazing or spot grazing begins to occur, it is important to rotate horses to the next paddock. Mowing may be required in the first paddock to even pasture height so that spot grazing is reduced in the next grazing cycle.

With a well-managed rotational system, mature horses at maintenance will generally maintain body weight. Grazing projects at UK with mature horses on a cool-season pasture maintained body weights over a number of summer grazing periods. In addition, grazing projects at UK with bermudagrass have shown that mature horses can maintain body weight throughout the summer. In 2009, a group of 2- and 3-year-old horses had acceptable growth rates, with minimal supplementation, while on pasture.

Horse owners should consider the following management practices when they are rotationally grazing their pastures:

Mow the paddock to a 4-inch height after moving the horses from the paddock to help control spot grazing.

Drag the paddock to disturb and scatter the manure to help it break down and reduce its buildup. Ideally, horse owners should drag the paddock during the

warmer summer days, because summer heat and exposure to sunlight helps control parasites. Horse owners should allow 21 to 28 days between rotations for forage regrowth. Amount of regrowth will be affected by environmental conditions and the amount of forage material left in the paddock.

Pay attention to how much forage is available, and let forage height dictate when horses are moved to a new pasture. It is better to move a day early than a day late. If regrowth of the pasture is slow, horse owners may need to consider holding horses in an area and feeding hay to allow pastures to regrow to prevent serious overgrazing. Well-managed pastures with an effective rotational system can reduce feed costs, maintain a good forage base, and increase forage produced.

Goats and Rotational Grazing

Goats are known as top-down grazers, meaning that they prefer to graze vegetation above their shoulders and work their way down the plant. Other livestock species, including cattle, sheep and horses, prefer to graze much shorter vegetation than goats. Goats also tend to prefer browse (shrubs and small trees), while cattle and horses prefer grasses. Grazing systems that allow all types of pasture plants time to recover are more likely to meet the grazing preference of goats.

In theory, goats managed in a rotational system should realize greater average daily gains or at least maintain their weight compared to those grazed in a continual system. Rotational grazing should also allow goats to graze higher in the forage canopy, reducing their expo-

sure to larva of gastrointestinal parasites. Unfortunately, few studies have been conducted in Kentucky to measure the benefits of managing goats in a rotational grazing system.

In 2006 and 2007, a study was conducted in Greenup County, Kentucky, to compare rotational grazing vs. continuous grazing in a meat goat production system. Based on the results of this study, rotational grazing did not result in improved animal weight gain or a significant reduction in pressure from internal parasites (based on FAMACHA scores) compared to continuous grazing. These results were probably affected by the extreme dry weather conditions both years and the need for feed supplementation. However, does showed lower final fecal parasite egg counts on the rotational vs. continuous grazing, which suggests that barber pole worm egg production may be affected by the grazing system. In general, forage availability was greater in the rotationally grazed paddocks than in the continuously grazed pasture throughout the grazing season. Care should be taken when designing rotational grazing systems for goats, because systems with common water, shade, or alleyways will allow frequent close grazing in areas that have high parasitic pressure.

Fencing costs may be higher for goat vs. cattle production. Woven wire fencing for predator control on perimeters and multi-strand fencing for interior fencing may be necessary for keeping goats in designated paddocks. Other benefits of rotational grazing for goats include maintaining a sustainable forage base, increased forage production, and a more even distribution of manure.

Good Grazing Management

Good grazing management achieves the right balance between standing forage availability, forage utilization, and animal performance. The good manager stocks pastures heavily enough to graze available forage down to a target height that will allow rapid and maximum regrowth (during the growing season) without compromising nutritional needs of livestock. A good manager will observe pastures frequently for overgrazing and undergrazing and will periodically adjust the stocking rate or movement of cattle as needed. Guidelines for beginning and ending grazing heights and usual days of rest for several pasture crops are contained in Table 6.

A sound rotational grazing system is a worthy goal for Kentucky producers for three main reasons. Such a system

- helps managers efficiently use forage to meet the nutritional needs of livestock
- helps managers optimize forage yield, quality, and persistence
- increases profit by improving grazing livestock efficiency and productivity

The components of a good rotational grazing system are a balanced forage system, an electric fencing system, distributed water supply, and adequate shade for livestock. These components can be designed and customized to fit the needs of each farm. High-quality pasture is essential for Kentucky's livestock industry, but most fields are too big to be managed efficiently, so smaller, easier-to-manage pastures in a rotational system should be considered.

Table 6. Guidelines for rotational stocking of selected forage crops.

Crop	Target Height (inches)		Usual Days of Rest
	Begin Grazing	End Grazing ^a	
Alfalfa (hay types)	10-16	2-4	35-40
Alfalfa (grazing types)	10-16	2-4	15-30
Bahiagrass	6-10	1-2	10-20
Bermudagrass	4-8	1-2	7-15
Big bluestem	15-20	10-12	30-45
Caucasian bluestem (and other Old World bluestems)	10-20	4-6	14-21
Clover, white, and subterranean ^b	6-8	1-3	7-15
Clovers, all others ^b	8-10	3-5	10-20
Eastern gamagrass	18-22	10-12	30-45
Fescue, tall	4-8	2-3	15-30
Indiangrass	12-16	6-10	30-40
Johnsongrass	16-20	8-12	30-40
Kentucky bluegrass	8-10	1-3	7-15
Orchardgrass	8-12	3-6	15-30
Pearl millet	20-24	8-12	10-20
Ryegrass, annual	6-12	3-4	7-15
Sericea lespedeza	8-15	4-6	20-30
Small grains	8-12	4	7-15
Smooth bromegrass	8-12	3-4	20-30
Sorghum, forage	20-24	8-12	10-20
Sorghum/sudan hybrids	20-24	8-12	10-20
Switchgrass	18-22	8-12	30-45

Source: Excerpted from *Forage Pocket Guide*, developed by Don Ball, Garry Lacefield, and Carl Hoveland. 1999.

Note: These are merely guidelines. Stocking rates and growing conditions greatly affect forage growth. Also, the more closely pastures are grazed, the longer the rest period generally needs to be for species that are sensitive to defoliation.

^a The nutritional requirements of the livestock being grazed should be considered when deciding when to end grazing. The closer a pasture is grazed, the lower forage quality will be toward the end of that particular grazing cycle. Greater residual heights may be desired for animals with higher nutritional requirements (for example, stocker cattle vs. cows and calves).

^b Clovers are typically grown in pastures in mixtures with grasses. White clover and subterranean clover are quite tolerant of close defoliation; most other clovers are not.

Grazing Terminology

Aftermath: Forage grown following a harvest.

Animal unit day: The amount of dry forage consumed by one animal unit per 24-hour period.

Carrying capacity: The maximum stocking rate that will achieve a target level of animal performance in a specified grazing method that can be applied over a defined time period without deterioration of the ecosystem.

Continuous stocking: A method of grazing livestock on a specific unit of land in which animals have unrestricted and uninterrupted access throughout the time period when grazing is allowed.

Creep grazing: The practice of allowing juvenile animals to graze areas that their dams cannot access at the same time.

Deferred grazing: The delaying of grazing in a nonsystematic rotation with other land units.

Extensive grazing management: Grazing management that uses relatively large land areas per animal and a relatively low level of labor, resources, or capital.

First-last grazing: A method of using two or more groups of animals, usually with different nutritional requirements, to graze sequentially on the same land area.

Forage allowance: The relationship between the weight of forage dry matter per unit area and the number of animal units or forage intake units at any one point in time; a forage-to-animal relationship. The opposite of *grazing pressure*.

Forage crop: A crop of cultivated plants or plant parts (other than separated grain) produced to be grazed or harvested for use as animal feed.

Forward creep: A method of creep grazing in which dams and offspring rotate through a series of paddocks with offspring as first grazers and dams as last grazers. A specific form of *first-last grazing*.

Grazing land: Any vegetated land that is grazed or has the potential to be grazed by animals.

Grazing management unit: The grazing land area used to support a group of grazing animals for a grazing season. It may be a single area, or it may have a number of subdivisions.

Grazing pressure: The relationship between the number of animal units or forage intake units and the weight of forage dry matter per unit area at any one point in time; an animal-to-forage relationship. The opposite of *forage allowance*.

Intensive grazing management: Grazing management that attempts to increase production or utilization per unit area or production per animal through a relative increase in stocking rates, forage utilization, labor, resources, or capital.

Mixed or co-species grazing: Grazing by two or more animal species on the same land unit, not necessarily at the same time but within the same grazing season.

Mob grazing: In the management of a grazing unit, grazing by a relatively large number of animals at a high stocking density for a short time period.

Nonselective grazing: Utilization of forage by grazing animals so all forage species and/or all plants within a species are grazed.

Paddock: A grazing area that is a subdivision of a grazing management unit and is enclosed and separated from other areas by a fence or barrier.

Pasture: A type of grazing management unit enclosed and separated from other areas by fencing or other barriers and devoted, primarily by grazing, to the production of forage for harvest.

Put-and-take stocking: The use of variable animal numbers during a grazing period or grazing season with a periodic adjustment in animal numbers in an attempt to maintain desired sward management criteria—a desired quantity of forage, degree of defoliation, or grazing pressure.

Rotational stocking: A grazing method that uses recurring periods of grazing and rest between two or more paddocks in a grazing management unit throughout the period when grazing is allowed.

Short-duration grazing: Not an acceptable term.

Stocking density: The relationship between the number of animals and the specific unit of land being grazed at any single point in time.

Stocking rate: The relationship between the number of animals and the grazing management unit used over a specified time period.

Stockpiling forage: To allow forage to accumulate for grazing at a later period.

Sward: A population of herbaceous plants characterized by a relatively short growth habit and relatively continuous ground-cover, including both aboveground and belowground parts.

Vegetative: Involving nonreproductive plant parts (leaf and stem), the nonreproductive stage in plant development.

Excerpted from *Terminology for Grazing Lands and Grazing Animals*, Forage and Grazing Terminology Committee, Dr. V. Allen, Chair, Pocahontas Press Inc., Blacksburg, Virginia.